Methods of Diagnosis and Treatment in Endodontics

A Systematic Review

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Swedish Council on Health Technology Assessment
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Methods of Diagnosis and Treatment in Endodontics

A Systematic Review

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SBU's summary and conclusions

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SBU has evaluated the methods used by dentists to diagnose, prevent and treat inflammation and infection of the dental pulp. Root canal therapy (endodontics) is conducted to ensure healthy conditions in and around teeth, which have been damaged by caries, external trauma or other causes. Despite the overall high standard of dental health in Sweden, root fillings are still common and are expensive items of treatment for both the individual and the society.

The report forms the basis of national guidelines for dental care by the National Board of Health and Welfare.

SBU's conclusions

- ❑ Because of the lack of studies it is not possible to determine which diagnostic methods can disclose whether a vital but injured pulp can be maintained or whether it should be removed and replaced with a root filling. The available research provides limited direction as to what distinguishes a treatable from a non-treatable pulpal inflammation (pulpitis).

- ❑ The effects of different methods used for instrumentation, disinfection and root filling associated with root canal therapy are insufficiently investigated.

- ❑ An investigation of common practice among Swedish dentists shows that great variations exist in treatment strategies and choice of materials. This applies, for example, to the management of the exposed pulp or when a root filling is retreated. An exception is the use of engine driven instrumentation, which to a varying degree is used by almost two-thirds of the dentists.

- ❑ There is a need for prospective studies of root canal therapy, which show how teeth can be preserved in the long-term, without risk of recurrence of symptoms, periradicular inflammation or tooth fracture. The lack of good research in this field clearly indicates that priority should be given to well-planned and carefully conducted clinical studies of methods for diagnosis and treatment of the disease conditions of the pulp.

❑ There is a need for a national registry with quality indicators to be applied for follow-up evaluations of pulpal and root canal treatments.

Background and aims

For many people, toothache resulting from infection of the dental pulp is a cause of severe suffering. The infection often occurs as a result of dental caries. Pulpal infections can also occur in non-carious teeth by cracks or fractures, due to external trauma or in heavily restored teeth. The purpose of root canal treatment by root filling of teeth (endodontics) is to prevent and treat pulpal infections and thereby symptoms such as toothache and swelling because of suppuration. The aim of endodontic treatment is a functional and asymptomatic tooth, without signs of residual root canal infection, including loss of bone at the root apex.

The following specific questions were addressed:

- How well can different diagnostic methods determine the condition of the pulp in teeth with different types of injury (caries, trauma, restorative interventions and other causes)?

- How well can different radiographic methods demonstrate loss of bone at the root apex?

- Are there effective methods for treating pulpal inflammation so that the pulp can be preserved when it has been subjected to caries, trauma or other injury?

- How effective are different treatment measures when the pulp is necrotic (dead)?

- How effective are orthograde (root filling through the crown) and retrograde (surgical intervention at the root apex) treatments of root filled teeth showing signs of periapical inflammation (apical periodontitis)?

- How effective are different methods for treatment of acute toothache?
- Can the root filled tooth be restored effectively, with long-term survival of the tooth and the restoration?
- Is there a risk that cases of acute and chronic infection originating in the dental pulp may cause pathological conditions in other organs?
- What serious side-effects are associated with root canal therapy?
- Which are the most cost-effective methods for diagnosis and treatment of diseases of the dental pulp?

Method

SBU has developed a thorough and systematic methodology in which all literature relevant to the question under investigation is sought in available databases. Every study included has been scrutinized for quality and tabulated. The scrutiny comprised evaluation of the study relevance with regard to the subject matter and the methodological qualities – study design, internal validity (reasonable protection from systematic errors), statistical power and generalisability.

Quality evaluation of the articles on health economics was undertaken as a joint effort between an endodontist and a health economist. The results were subsequently graded on the basis of the quality of the scientific evidence.

The conclusions of the report are based solely on human studies. Experimental studies in laboratory animals and in-vitro studies were not included. Study selection was restricted to randomised controlled studies (RCT), controlled clinical studies (CCT) and prospective cohort studies. For assessment of the reliability of different radiographic methods for diagnosis of periapical bone lesions, post-mortem studies were accepted. In the section on serious side-effects and complications associated with root canal therapy, case reports were included.

Facts 1 Study Quality and Strength of the Evidence.

Study quality refers to the scientific quality of an individual study and its ability to provide a valid answer to a specific question.

Strength of the evidence refers to a judgment of the total strength of all scientific evidence and its ability to provide a valid answer to a specific question. SBU uses GRADE, an international grading system for scientific evidence. Study design is a key element in the overall judgment of each outcome measure. Other factors that can weaken or strengthen the power of the evidence are study quality, relevance, consistency, transferability, effect size, data precision, risk of publication bias, and other aspects, eg, the dose-response relationship.

Grading the strength of the evidence – four levels:

Strong scientific evidence (⊕⊕⊕⊕). Based on high-quality studies containing no factors that weaken the overall judgment.

Moderately strong scientific evidence (⊕⊕⊕○). Based on high-quality studies containing isolated factors that weaken the overall judgment.

Limited scientific evidence (⊕⊕○○). Based on high- or medium-quality studies containing factors that weaken the overall judgment.

Insufficient scientific evidence (⊕○○○). The evidence base is insufficient when scientific evidence is lacking, quality of available studies is poor, or studies of similar quality are contradictory.

The stronger the evidence, the less likely it is that the results presented will be affected by new research findings within the foreseeable future.

Conclusions
SBU's conclusions represent our overall judgment of benefits, risks, and cost-effectiveness.

Evidence-graded results

How well can different diagnostic methods determine the condition of the pulp in teeth with different types of injury (caries, trauma, restorative interventions and other causes)?

The aim of diagnosing the condition of the pulp is to determine whether an injured pulp can be treated and preserved, or should be removed and replaced with a root filling. The diagnosis is founded on any presenting symptoms, and the findings made by the dentist during examination. To determine whether the pulp is vital or dead is another important aspect of diagnosis. This is usually done by some form of vitality test. If the radiographic examination shows bone destruction around the root apex then the pulp is probably dead and infected.

Symptoms and clinical signs

- The scientific basis is insufficient to allow determination of whether sensitivity to heat, cold, electrical stimulation or percussion gives reliable information about the condition of the pulp in asymptomatic teeth with deep carious lesions (⊕○○○).

- There is no scientific basis on which to determine whether the presence, nature and duration of toothache offer accurate information about the condition of the pulp.

- There is no scientific basis on which to assess the value of inflammatory markers intended to determine the condition of the pulp in terms of reversible and irreversible pulpitis.

- There is no scientific basis on which to determine the value of markers of inflammation, infection and tissue damage in predicting the outcome of treatment intended to maintain an exposed pulp vital and asymptomatic.

Sensibility and determination of vitality

- The scientific basis is insufficient to allow assessment of the accuracy of electrical pulp testing to determine whether the pulp is vital or nonvital (⊕○○○).
- The scientific basis is insufficient to allow assessment of the accuracy of thermal testing to determine whether the pulp is vital or nonvital (⊕○○○).
- The scientific basis is insufficient to allow assessment of the accuracy of methods for measuring pulpal blood circulation to determine whether the pulp is vital or nonvital (⊕○○○).

Toothache and hypersensitivity to cold or heat stimulation and tenderness to percussion do not provide reliable information on the condition of the pulp. In general, there are major shortcomings in the design, the conduct and the reporting of studies on diagnosis. There is also an insufficient basis to allow assessment of the reliability of different tests for determining whether the pulp is vital or not. This applies to both electrical and thermal tests as well as methods used to determine the existence of pulpal blood circulation.

How well can different radiographic techniques reveal loss of periapical bone?

In assessing pulpal condition, radiographic examination is often an important supplement to clinical examination. It is particularly important to detect changes in the bone tissue around the root apex indicative of a severely inflamed or infected pulp. Radiographic examination is also used to evaluate the result of root canal therapy.

In recent years conventional film radiography has been superseded by digital radiography. A new method called CBCT (cone beam computed tomography) or volume tomography has been developed.

Radiographic methods and their accuracy in identifying the presence or absence of changes in the periapical tissues

- There is insufficient scientific support, from in-vitro studies, to determine whether the diagnostic accuracy of digital radiography is as high as conventional film radiography in detecting experimental periapical bone destruction (⊕○○○).

- There is insufficient scientific support, based on in-vitro studies, to determine whether volume tomography (CBCT) has greater diagnostic accuracy than intra-oral radiographic techniques in detecting experimental bone destruction (⊕○○○).

Radiographic methods for determining whether changes have occurred over time in the status of the periapical bone tissue

- There is insufficient scientific evidence, based on in-vitro studies, to answer the question of whether the subtraction technique has greater diagnostic accuracy than conventional techniques in detecting small areas of experimental bone destruction (⊕○○○).

The accuracy of radiographic examination for identifying different lesions in the periapical bone tissue (variants of apical periodontitis, periapical cyst, scar tissue healing)

- There is no scientific support, hence no conclusions can be drawn as to the accuracy of radiographic examination in identifying various forms of changes in the periapical bone tissue, including cyst formation and healing with scar tissue.

Periapical bone changes and pulpal status

- There is no scientific support, hence no conclusions can be drawn as to the accuracy of radiographic examination in providing information about the status of the pulp.

We have insufficient clinical knowledge on the diagnostic reliability of various radiographic methods. Both digital and film radiography have limited ability to demonstrate small experimental areas of bone destruction but good ability to identify normal conditions. The new method CBCT is more sensitive and discloses more small areas of bone loss in comparison with conventional radiographic techniques. Meanwhile there is insufficient documentation with respect to the diagnostic accuracy of this method. A difficulty encountered in evaluating radiographic methods is that the reference method, histological validation, in reality requires post-mortem studies or biopsy using surgical procedures.

Are there effective methods for treating the inflamed pulp so that it can survive following caries, trauma or other injuries?

Depending on the condition of the pulp, and whether it is directly exposed or not, there are two treatment choices. If the pulp is exposed then pulp capping or partial pulpotomy can be considered. Such treatment is relatively uncomplicated as the wound can be covered with an appropriate dressing and sealed and protected by a surface filling. The outcome is then monitored to ensure that no complications such as pulpitis or pulpal necrosis develop. If the pulp is deemed to be irreversibly inflamed, then the alternative is pulpectomy. This procedure is more extensive and means that the pulp is removed and replaced by a root filling.

Treatment of deep carious lesions

- There is limited scientific support for the claim that pulpal exposure occurs twice as frequently during direct, complete caries excavation than during stepwise excavation (⊕⊕○○).

- The scientific basis is insufficient to allow an evaluation of whether there are differences in pulpal survival rates following immediate complete caries excavation and stepwise excavation (⊕○○○).

- The scientific basis is contradictory with respect to healing rates following direct pulp capping when the pulp is exposed during excavation of deep caries. In two studies, the short-term (1–3 years) healing rate was 80–85% in asymptomatic teeth. Another study on adults with extensive caries lesions, including patients presenting with toothache, reports a much lower healing rate after a year (33%) (⊕○○○).

- There is limited scientific support that preoperative toothache increases the risk of failure of direct pulp capping (⊕⊕○○).

- There is no scientific basis on which to assess the effect of indirect pulp capping, ie when the deepest layer of carious dentine is permanently left in situ.

- There is no scientific basis for assessment of which method, indirect pulp capping, ie stepwise excavation, direct pulp capping, partial pulpal amputation or pulpal amputation gives the most favourable conditions for maintaining the pulp in a vital and asymptomatic condition.

- There is limited scientific evidence that there is no difference between "mineral trioxide aggregate" (MTA) and calcium hydroxide as dressings on exposed vital pulps (⊕⊕○○). There is no scientific evidence on which to assess the effect of other dressings.

- The scientific evidence is insufficient to allow assessment of the significance of age and tooth type on pulpal survival after direct pulp capping (⊕○○○).

- There is no scientific basis on which to assess whether it is more advantageous to preserve the vitality of some or all of the pulp tissue in teeth with deep caries than to undertake a pulpectomy and root filling.

- There is no scientific basis on which to assess the treatment outcome after pulpectomy and root filling.

- The scientific evidence is insufficient to allow assessment of whether the number of treatment sessions is of importance for the outcome of pulpectomy and root filling procedures (⊕○○○).

- There is no scientific basis on which to assess which other factors might be of importance for treatment outcome after pulpectomy and root filling.

Treatment of the traumatically exposed pulp (crown-fracture, crown-root-fracture)

- The scientific basis is insufficient for assessing the effectiveness of direct pulp capping, partial pulpotomy (partial pulp amputation) and pulpotomy (pulp amputation) in maintaining the vitality and function of some or all of the pulp (⊕○○○).

- The scientific basis is insufficient for assessing the prognosis for pulpal survival in teeth with completed root development compared with teeth with incomplete root development, different intervals elapsing between the occurrence of trauma and treatment, crown-fracture compared with crown-root-fracture (⊕○○○).

There are substantial gaps in our knowledge base and the report is unable to offer a clear answer to the question of which method is best for the management of deep carious lesions. Stepwise excavation results in fewer pulpal exposures than direct, complete caries excavation. Whether this results in higher survival rates for the pulp has not been adequately investigated. Still to be answered is the important question of which of the methods – indirect pulp capping, direct pulp capping/partial pulpotomy is the most effective treatment for a tooth with deep caries and an inflamed, vital pulp.

In teeth with traumatically exposed pulps, a study shows that the degree of root development and the time elapsing between sustaining the injury and receiving treatment does not influence the outcome of partial pulpotomy. It is uncertain whether the results can be generalised to routine clinical practice. There is a need for prospective studies. There are few studies which investigate the effects of pulpectomy and root filling.

How effective are different treatment measures when the pulp is necrotic (dead)?

Root canal treatment of a tooth with a necrotic pulp is in essence treatment of an infection. The aim of the procedures is to achieve an asymptomatic status and regain normal bone structure at the root apex in cases of apical periodontitis. Any symptoms usually subside directly or within a few days. Healing of apical periodontitis, however takes a relatively long time, in some cases several years. This leads to uncertainty in assessing the outcome of treatment.

Instrumentation

- There is no scientific basis on which to assess the influence of different root canal instruments and instrumentation techniques on the outcome of root canal treatment.

Disinfection

- There is no scientific basis on which to assess the influence of various intracanal irrigants and medicaments on the outcome of root canal treatment.

- There is no scientific evidence on which to assess whether calcium hydroxide has any therapeutic effect in root canal treatment.

Root filling material and root filling methods

- There is no scientific basis on which to assess whether any material or any method for root filling gives a better treatment outcome than any other.

Prognostic factors

- There is no scientific basis on which to assess to what extent the microbiological status of the root canal at the time of root filling influences the outcome of root canal treatment.

- There is no scientific basis on which to determine to what extent preoperative status (pulpal necrosis with or without apical periodontitis) influences the outcome of root canal treatment.

- There is no scientific basis on which to determine to what extent the quality of the root filling (length and density) influences the outcome of root canal treatment.

Number of treatment sessions

- There is limited scientific evidence to show that there is no clinically important difference in outcomes for teeth with necrotic pulps and apical periodontitis, when endodontic treatment is carried out in one, two or more treatment sessions (⊕⊕○○).

Post treatment complications

- There is limited scientific evidence that the risk of severe pain and swelling after root canal treatment is 1–15% (⊕⊕○○).

- There is no scientific basis for treatment protocols intended to prevent and treat pain and swelling after root canal treatment.

- There are contradictory results on the influence of the number of treatment sessions on the occurrence of post operative complications after root canal treatment of teeth with necrotic pulps (⊕○○○).

The review of the literature shows that there is no scientific basis on which to draw definite conclusions about the effectiveness of different methods and materials for root canal treatment. Nor is it possible to determine which factors determine the occurrence of post treatment discomfort, such as pain and swelling.

How effective are different methods of treating acute toothache?

Toothache and facial swelling are common reasons for seeking emergency dental care. Relatively simple measures are then needed to relieve the condition.

- In cases of symptomatic pulpitis or symptomatic apical periodontitis there is no scientific basis on which to assess whether debridement of the pulp chamber is as effective as conventional root canal therapy to achieve relief of symptoms.

- There is no scientific basis on which to assess whether additional treatment such as apical trepanation, analgesics and antibiotics, in combination with or without partial or complete treatment of the root canal system, can relieve the symptoms of acute toothache.

Reviewed studies answer different questions and give no basis for evidence-based conclusions. Thus there is no scientific basis on which to assess the effectiveness of various interventions intended to relieve acute toothache caused by pulpitis or apical periodontitis. There is also little information available about the effect of different intracanal dressings or other supportive measures intended to relieve or cure acute toothache.

How effective are orthograde (root filling through the dental crown) and retrograde (surgical intervention at the tip of the tooth root) treatments of root filled teeth showing signs of periradicular inflammation (periapical periodontitis)?

In cases of an emerging or persisting periapical lesion there are two methods for retreatment of a root filling. In orthograde revisions, the root canal system is accessed through the tooth crown whereby the old root filling is removed. Following disinfection procedures, a new root filling is inserted. Retrograde retreatment involves surgical intervention to access the root apex.

- There is no scientific basis on which to assess differences in outcome between orthograde and retrograde retreatment.

- There is little or no scientific basis for assessing differences in outcome after using various methods for orthograde or retrograde retreatment (⊕○○○).

- There is no scientific basis on which to assess the effectiveness of various methods for preventing or treating post operative discomfort after retreatment.

There is no scientific basis on which to assess how effective either treatment form is. Nor is there a basis for assessment of whether any method or material used for instrumentation, disinfection and root filling gives a better outcome than others for orthograde retreatment. The same applies to retrograde retreatment.

Can the root filled tooth be restored effectively, with long-term survival of the tooth and the restoration?

As well as achieving infection-free and asymptomatic teeth, a further aim of root treatment is the preservation of function of the treated tooth. Thus some form of restoration is necessary. The choice is between crown therapy (with or without post retention) and a less complex restoration which only replaces the lost tooth substance.

- There is no scientific basis on which to assess whether a crown is better than a filling in achieving long-term preservation of the tooth.

- There is limited scientific evidence to show that in a short-term perspective of 2–3 years, premolars with little remaining tooth substance, restored with post retained crowns, have a higher rate of survival, for both the restoration and the tooth, than premolars restored with crowns without post retention (⊕⊕○○).

- There is no scientific basis on which to assess whether post retention itself achieves long-term survival of a root filled tooth.

- There is limited scientific evidence to show that in the short term, premolars with extensive loss of tooth substance and restored with crowns without post retention, run a greater risk of loss of the restoration than teeth with a larger amount of preserved tooth substance (⊕⊕○○).

- There is no scientific basis on which to assess what type of temporary restoration best protects the tooth during or after endodontic treatment.

Is there a risk that cases of acute and chronic infection originating in the dental pulp may give rise to patholog-ical conditions in other organs?

The potential association between periodontitis and cardiovascular disease is recognised in numerous reports. Less attention has been given to a corresponding association with disease processes originating in the dental pulp. Case reports in the literature describe the occurrence of more or less serious complications in nearby organs (respiratory tract, brain), due to spread of bacterial infection from the root canals of teeth.

- The scientific basis is insufficient to assess the association between infections of endodontic origin and disease conditions of other organs (⊕○○○).

What serious side-effects are associated with root canal therapy?

Although root canal treatment and subsequent root canal filling are intended to be restricted to the root canal system of teeth, adjacent tissues and structures may be injured. While some injuries result in relatively insignificant consequences for the patient, others can lead to more extensive tissue damage and systemic effects.

- Side-effects and complications are reported in the form of allergic reactions, nerve damage, inflammatory changes with tissue necrosis and serious infectious conditions as direct sequelae to endodontic treatment, eg in conjunction with disinfection and root filling. There is no scientific basis on which to assess the risk and risk factors for the development of such complications.

Ethical aspects

The review by the project group discloses that in all areas there is a lack of reliability and insufficient scientific support to allow firm conclusions to be drawn with respect to a number of issues. In general, reliable support seems to be lacking on the relative value of different methods for diagnosis and treatment. In isolated cases it is not possible even to determine whether the established interventions are better than no intervention at all. This does not mean that there are absolutely no grounds for preferring a certain method to another in everyday clinical practice. For example, methods which expose the patient to great risk should be avoided. Methods which are particularly expensive, should also be avoided until such time as they are confirmed in scientific studies. Moreover, in the absence of empirical support, diagnostic and treatment methods which are supported by relevant established theoretical assumptions, should be given preference over methods which lack a theoretical basis.

Aspects on health economics

Which are the most cost-effective methods for diagnosis and treatment of diseases of the dental pulp?

- There is no scientific basis for assessing cost-effectiveness of various methods of treating diseases of the dental pulp.

It has been possible to include empirical health economics studies only in the form of a systematic overview with two empirical studies. The conclusion of this overview is that at present, there is no support in published empirical studies on the cost-effectiveness of different methods of endodontic treatment. This does not exclude the likelihood that different methods have a good effect and are cost-effective. However, to date this has not been demonstrated in empirical studies of health economics.

Survey of current practice routines

Within the field of endodontics many different methods and treatment philosophies subsist. In recent years there have been important technological advances, including the introduction of engine driven instrumentation of root canals. In this context, a survey was conducted to explore how Swedish dentists perceive treatment options in various clinical cases and which materials and methods they use. A questionnaire was posted to a random selection of 2 012 dentists out of 8 705 dentists practicing in Sweden. The response rate was 80%.

The responses to the questionnaire showed the following:

Mechanical instrumentation is used, at least to some extent, by two-thirds of the respondents.

- To treat a carious exposure of the pulp in a mandibular molar in a 22 year-old patient, a clear majority (>80%) choose pulp capping or partial pulpotomy. For a 50 year-old patient with the same condition in a maxillary premolar, about half of the respondents recommend pulpectomy and root filling.

- With respect to the number of treatment sessions usually required for pulpectomy and root filling, more employ two or more treatment sessions than immediate root filling.

- For restoration of a recently root-filled molar with four of the five tooth surfaces missing, the great majority prefers a crown fabricated in the laboratory rather than a composite crown.

- In treating acute pulpitis in a carious mandibular molar, three out of four dentists debride the pulp chamber.

- In a case with an incomplete filling in the apical portion of the root canal and with obvious radiographic indication of apical periodontitis in an otherwise asymptomatic maxillary incisor (root filling five years old) about 60% suggest revision of the root filling. The rest propose re-examination and follow-up after a year. A few respondents consider no action necessary.

- In a similar case, the difference being that the tooth has a post retained crown and signs of acute apical periodontitis, half propose an apicoectomy. A third would refer the case to an endodontist for assessment and possible treatment. Only a few would remove the post retained crown and undertake orthograde retreatment. A very small minority reported that they would put the patient on antibiotics with a checkup 3–6 months later.

- By far the most commonly used method for root filling is sealer with guttapercha as the core material, while rosin chloroform and gutta-percha is used by fewer than a quarter. Of the available sealers, the most frequently used are AH+, Tubli-Seal and Sealapex.

Need for research

The systematic review of the literature shows that there are many knowledge gaps within this branch of dentistry. There is therefore a need for both randomised studies and prospective observational studies with follow-up, in order to

- evaluate diagnostic methods which with reasonably good certainty can determine the condition of the pulp in teeth afflicted by deep caries, trauma, or other forms of injury

- determine the reliability of digital volume tomography (CBCT) for diagnosis of changes in the periapical bone tissue

- investigate whether a pulp exposed by caries or other causes is best treated by measures intended to preserve the pulp, such as pulp capping/partial pulpotomy or pulpectomy and root filling

- improve our knowledge of the importance of specific treatment factors which explain why many endodontic treatments do not achieve an optimal outcome, ie develop or have persistent apical periodontitis

- investigate whether modern techniques for instrumentation improve the outcome of root canal therapy

- study whether root filled teeth survive long-term and what factors influence the loss of endodontically treated teeth

- investigate the risk that teeth with persistent but asymptomatic periapical inflammation will result in pain and swelling or that the area of periapical bone destruction will increase in size

- study the risk to general health when teeth with periapical inflammatory processes remain untreated.

Concluding discussion and consequence analysis

This systematic overview discloses extensive shortcomings in the scientific basis underlying methods applied for diagnosis and treatment in endodontics.

It is acknowledged that practitioners have lengthy clinical experience of several of the methods and considerable knowledge from in-vitro studies which have tested material and techniques for instrumentation and root filling. Moreover, animal studies have provided a basis for understanding how the pulp and the periapical tissues respond to therapeutic interventions.

There are, however, few clinical studies of high scientific quality. This means that there is only weak scientific support for those measures aimed at restoring healthy conditions in and around teeth with infected pulps.

At the same time it should be noted that there are important parameters which can influence treatment results but which cannot easily be controlled in clinical studies, such as the clinician's experience and skill. It is seldom possible to assess to what extent such factors influence the results of treatment studies or clinical evaluations. It is however, reasonable to assume that in a discipline such as endodontics, these factors are most important, because of the technically complicated nature of many endodontic treatments. This is probably a contributing factor to the great variations in outcomes of endodontic treatment reported in cross-sectional studies. Future research should therefore test treatment protocols which can be standardised as far as possible. Moreover, today there are tools available which can facilitate the technical procedures. Priority should therefore be given to an investigation of the influence on treatment outcomes of increased use of such techniques in everyday general practice.

Because there are no evidence-based conclusions for many of the questions addressed by this systematic review, it is not meaningful to propose changes to conventional clinical routines. Until studies of high quality become available, it would be desirable to reach consensus on guidelines to support endodontic diagnosis and treatment procedures.

1. Introduction

"Comparative observations are an essential prerequisite for experimental and scientific medicine; otherwise the physician will wander around without direction and fall prey to thousands of illusions". Claude Bernard 1866.

This systematic review of the literature forms the basis of national guidelines for dentists, issued by The Swedish National Board of Health and Welfare, for treatment of diseases of the dental pulp and the periapical tissues [1]. The report is therefore relevant to dentists involved in the diagnosis, prevention and treatment of disease conditions originating in the dental pulp, ie general dental practitioners, specialists in endodontics (root canal therapy), maxillofacial surgery and paedodontics (children's dentistry). It is also of relevance to dentists who are specialists in radiologic diagnosis and other dental specialties, as well as dental hygienists and third party purchasers of dental care.

The dental pulp and diseases of the pulp

Within every tooth there is a hollow channel which extends from the crown to the root tip. This space, or canal, is normally filled with soft tissue, known as the dental pulp. The main opening of the root canal, at the tip of the root, is called the apical foramen, through which the pulp is in communication with the surrounding tissues (the periodontal membrane and the jaw bone). The pulp tissue also receives its blood and nerve supply (Figure 1.1a) through the apical foramen. The pulp has a key role in dental development and function. Because it is so richly supplied with nervous tissue, it is also an important sensory organ. Under normal conditions, the pulp is completely encased and protected by the attachment apparatus of the tooth and the hard tissues (enamel and dentine) (Figure 1.1a). When the hard tissue barrier is breached, most commonly due to dental caries, bacteria and bacterial metabolites penetrate the pulpal space through the narrow tubules in the dentine and the pulp becomes inflamed. Pulpal inflammation can also arise if a tooth is damaged through trauma, or after extensive dental restoration. When direct exposure of the pulp occurs (Figure 1.1b), there is a risk for subsequent pulpal death. A dead pulp allows infection to establish within the tooth. This infection leads in turn to inflammation in the tissues around the root apex (Figure 1.1c).

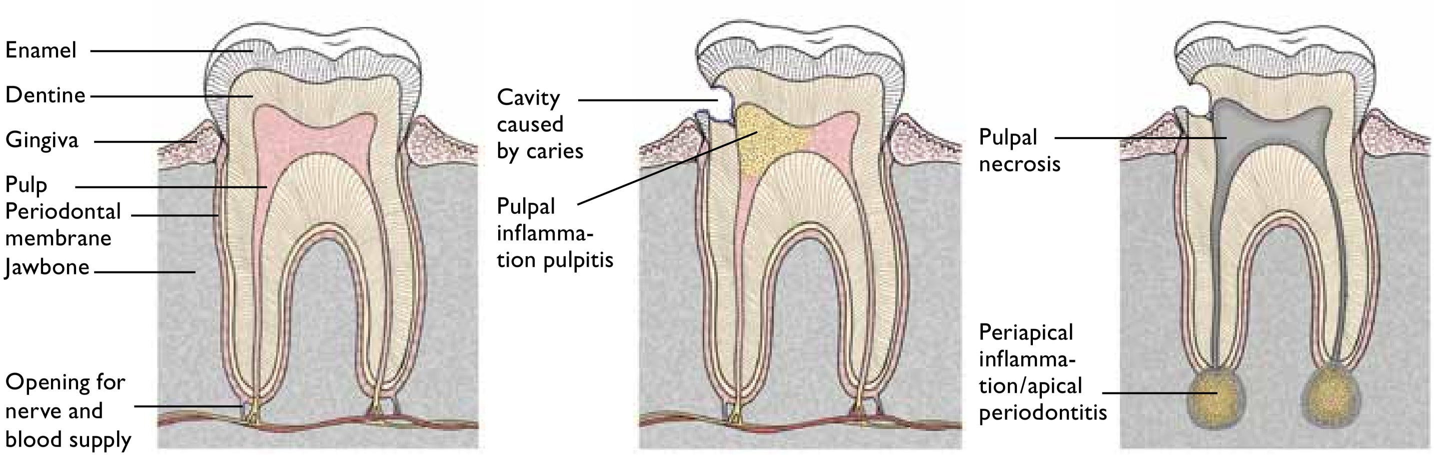

***Figure 1.1a–c** Cross-section of a molar tooth and the surrounding tissues. The pulp is in the centre of the tooth. In Figure 1.1a the crown is encased in intact hard tissue (enamel and dentine) and the root is protected by the attachment apparatus (jawbone and periodontal membrane); the tooth is in sound condition. Blood vessels and nerves supply the tissue primarily through the open-ings (foramina) at the tips of the roots (root apices). Figure 1.1b shows a partially inflamed pulp. The cause is often damage to the hard tissue barriers, eg by caries, allowing bacteria to access the pulp. In Figure 1.1c the pulp is dead (necrotic). At the root apices, inflammation develops when bacteria colonise the area normally occupied by the pulp (the pulp chamber and pulp canals).*

Initially pulpal inflammation progresses without symptoms. Early discomfort can however occur; external irritation usually elicits a response of varying intensity. Typically the tooth becomes sensitive to hot or cold beverages, or sweet foods, or reacts with sharp pain if touched by a toothbrush. Toothache can develop and persist for varying periods of time, ease off and then recur. These are the symptoms of pulpitis (inflammation of the pulp).

If bacteria gain direct access, eg though a carious cavity (Figure 1.1b) the pulp becomes inflamed and may die. Death of the pulp (necrosis) can occur rapidly, but may also be more gradual. Pulpal necrosis can also develop in the absence of infection, for example following a blow to the tooth which loosens its attachment to the jawbone: this may damage the nerve and blood supply through the apex of the tooth, leading to death of the pulp.

The tissue of a necrotic pulp is susceptible to infection. There are several pathways by which oral bacteria can gain access. In the case of dental caries, access is through the damaged hard tissues. As the body's protection against infection is no longer functioning in a dead pulp, the bacteria will become established in the necrotic tissue within the tooth.

Once the infection is manifest, bacteria and their metabolites diffuse out of the root canal and elicit an inflammatory response in the attachment apparatus of the tooth, usually at the root tip (Figure 1.1c). This condition is usually referred to as an apical periodontitis, but terms such as apical granuloma or periapical osteitis are also common. It is important to distinguish between apical periodontitis and marginal periodontitis, which is caused by bacterial deposits in the dento-gingival region, the gum margin.

Clinical observations and animal studies confirm that apical periodontitis is caused by root canal infection. It has also been shown that the condition is not attributable to single strains of highly pathogenic bacteria, but by a combination of various infecting organisms. These eventually become organised into a microbiological community within the root canal space, where bacteria attach to the walls of the root canal and also penetrate the narrow tubules in the dentine. This type of bacterial colonisation is referred to as a biofilm.

A biofilm offers a protected environment for the bacteria. Various forms of cooperative interaction between the bacterial cells further strengthen their potential to survive and multiply. In the root canal, the bacteria in the biofilm community live under highly favourable conditions. With the death of the pulp there is nothing to prevent colonisation as the body's defence mechanisms cannot work when no blood supply exists. In principle this means that because of the abundance of nutrients in root canals, the bacteria can survive and even multiply relatively unrestricted.

In the tissues surrounding the root apex, infection causes destruction of the periodontal membrane and the alveolar bone (Figure 1.1c). The extent can vary, but the entire attachment of the tooth to the alveolar bone is seldom destroyed. The damaged tissues are replaced by the inflammatory process, which is intended to prevent and/or restrict the spread of the infectious elements to other parts of the body. However, the infection within the tooth remains. If left untreated, it will persist as a chronic condition.

Apical periodontitis associated with a tooth with an infected necrotic pulp can progress without symptoms. Acute toothache with painful teeth, pus formation in the alveolar bone and fever can nevertheless, occur at any time. In healthy people, such infections are usually not serious. However, if the body's resistance to infection is impaired, there is a risk that the infection may spread to other organs, with the development of potentially fatal complications.

Diagnosis

The principles for diagnosis of the condition of the dental pulp are no different from those applying to management of other disease conditions. In many cases, it is important for the dentist to determine whether the damage to the pulp is so severe that it is irreversible; if so, root canal treatment and a root filling are required or extraction. Under these circumstances the diagnosis is based on the symptoms described by the patient and the signs disclosed by clinical examination (Facts 1.1). A major determinant is whether the pulp is alive or dead. This can readily be assessed if the pulp chamber is open and can be inspected directly. However, this is not usually the case, and the dentist must apply indirect methods to assess the condition of the pulp by for example testing the sensitivity of the tooth to painful stimuli (cold, heat, electricity). Such tests can however, give false readings. This means for example that a negative response (no reaction) cannot immediately be interpreted as a sign of a dead pulp.

Another important aspect of diagnosis of the condition of the pulp is to determine whether a vital pulp, after being exposed by caries (Figure 1.1b), will respond to treatment. The present systematic review of the literature will evaluate the availability and accuracy of such methods.

Radiographic examination of changes in the periapical bone, which can indicate infection of the root canal, is an important aid to diagnosis. Generally radiographic examination discloses destruction of bone around the apices of the roots, but an increase in bone density can also signify pathological change. There are a number of radiographic methods available. In recent years, conventional film radiography has been superseded by digital radiography. Volumetric tomography (CBCT: cone beam computer tomography) has recently been introduced. It is important to be aware that the different radiographic methods vary in their potential to depict minor alterations in bone tissue, which can be of diagnostic importance.

Treatment principles and methods

The conditions to be considered for endodontic treatment are pulpitis and pulpal necrosis, in the presence or absence of apical periodontitis. In principle there are two approaches to treatment. One is to extract the tooth. For many years this was the usual treatment, particularly for teeth, which were badly damaged by caries. Today endodontic treatment (root canal therapy) is the primary approach to treatment.

Root canal treatment is causally directed. Briefly, this means that damaged and infected pulp tissue is removed, the root canal is disinfected and the cavity is filled with a root filling material. It is not unusual for patients to dread having root canal therapy because it is associated with pain, largely as a result of media misinformation. In reality, the use of modern local anaesthetics allows most treatment to be carried out without pain.

Before a decision to recommend root canal treatment, the dentist must develop an accurate diagnosis of the extent of the disease. One is whether the pulp is still vital. If not, root canal treatment is necessary, because an untreated necrotic pulp always poses a risk for infection and pain. In teeth where the pulp is still vital, there are other treatment options, depending on the extent of the infection and inflammation. An example is shown in Figure 1.1b, where it is possible to limit treatment to relatively simple wound treatment. The current status of this type of treatment is, however, inconclusive and failures do occur. If the intervention succeeds, the patient is spared time-consuming and expensive root canal treatment. In the present systematic review we investigate the evidence with respect to outcomes of this type of treatment and their cost effectiveness, in comparison with conventional root canal therapy.

The alternative to treatment, which attempts to preserve the pulp, is to remove it and root-fill the tooth. Removal of the pulp is called pulpectomy or pulp extirpation and is a type of root canal treatment. It is undertaken as a preventive measure, to prevent ongoing pulpal infection and subsequent necrosis.

In cases of pulpal necrosis and apical periodontitis, the focus of root canal treatment is on bacterial elimination. Usually the treatment comprises meticulous debridement and disinfection of the pulp spaces.

In most dental practices, root canal treatment is routine. However, the procedure is often technically demanding: for example, molar teeth can have multiple roots, which may curve sharply and in older people it is not uncommon for narrowing of the root canals to complicate treatment by restricting access.

Treatment aims

The aim of pulp and root canal treatment is to prevent and treat pulpal infection. If the dentist recommends treatment intended to preserve the pulp, the aim is that the tooth should be restored to a healthy and functional state, and be free of symptoms such as shooting pain or toothache. If the dentist recommends root canal treatment, the aim is also to restore health and function, ie after treatment the tooth should be asymptomatic and show no signs of active root canal infection in the form of persistent apical periodontitis. Thus, the steps involved in treatment should be meticulously carried out and the root filling should completely fill the prepared root canal space (Figure 1.2).

The quality of the root filling is considered to be most important, because its role is to prevent new infection of the tooth.

***Figure 1.2** Radiograph showing a lower molar tooth, with a recent root canal filling of high quality.*

Root fillings in Sweden

Today, the standard of dental health in Sweden is high. It might therefore be assumed that the need for root canal treatment is low. However, the older members of the population have numerous, extensive fillings and crowns. There is a risk that over time such teeth will develop pulpal necrosis and infected root canals. There are no reliable statistics on how many people and which groups in the population undergo root canal therapy in Sweden each year. The oral health of the population has been documented in many cross-sectional studies over the years and these include information on the number of root-filled teeth [2–11]. One example is the Jönköping series of studies, comprising repeated cross-sectional studies of people aged from 15 to 80 years. In the latest investigation, conducted in the year 2003, 5.4% of the teeth were root-filled [7]: an average of 1.4 root-filled teeth per individual. The corresponding values for 1973, 1983 and 1993 were 2.6, 2.3 and 1.9 respect-ively. If these figures are representative for the population of Sweden, it would appear that the number of root filled teeth in the population is decreasing. However, this trend is not reflected in the Gothenburg studies of women's oral health [6]. In a recent doctoral thesis, Ridell observed that of almost 2000 19 year-olds examined in Malmö, 9% had at least one root-filled tooth [10]. Thus, the evidence from these studies suggests that many root fillings are still being undertaken in Sweden.

The quality of root canal treatments has been investigated in several Swedish cross-sectional studies [2–11]. The studies have assessed not only the technical quality of the root fillings, but also the periapical health of the treated teeth. While many root canal treatments are successful, around 30% of teeth have inflammation at the root apices. Moreover, the technical quality of the root fillings is far from optimal. A higher frequency of periapical inflammation has been noted in teeth with root fillings of substandard quality (Figure 1.3).

***Figure 1.3** A root filling of poor quality in a premolar tooth, showing extensive bone destruction around the root apex caused by a persisting apical periodontitis.*

Many root fillings may therefore require revision. There are two approaches to this so-called retreatment. The pulp chamber may be reopened to remove the original root filling material, disinfect and refill the root canal. However, where there is an obstruction such as an intracanal post, or if it is considered appropriate for other reasons, surgical retreatment may be undertaken, ie the apex of the root is exposed, and a few mm of the root is resected in order to access the most apical part of the canal for cleaning and filling.

What is the long-term survival rate of root-filled teeth?

Are root-filled teeth more fragile than non-root-filled teeth? The question is highly relevant: apart from the fact that much of the tooth structure may already have been damaged by caries or fracture, the root canal treatment procedures involve the removal of even more hard tissue: not only to gain access to the root canals, but also during root canal treatment itself. The dentist uses instruments to mechanically remove the inner layer of the root canal walls, in order to clean the walls, to make room for disinfectant and to shape the canal in preparation for the root filling. It is clear that this further weakens the tooth. However, it is of interest to note that root-filled teeth seem to survive well. In a follow-up study in the USA of almost one and a half million root filled teeth in patients with health insurance, the survival rate after eight years was 97% [12]. Yet, it is uncertain whether these figures can be extrapolated to Swedish conditions. Of the teeth, which had been lost in the US study, 85% had not been restored with crowns. This implies that a major determinant of long-term survival of the root-filled tooth is how well the tooth is subsequently restored, to enable it to withstand chewing forces. There are well-established techniques for restoration of root-filled teeth; an important question, not least from a health economic perspec-tive, is whether these techniques result in root-filled teeth with the potential for long-term survival.

Other aspects addressed by the report

The methods used for pulp and root canal treatment are based largely on preventing or eliminating bacterial infection in the pulp cavity. In the early 20th century, strong antibacterial agents such as compounds containing phenol and formaldehyde were used. Such chemicals are still used today as components of disinfectants and root filling materials. Because of their strong antibacterial effect, if they are not confined to the root canal, there is a risk of damage, both locally and in peripheral organs. In sensitive individuals they can cause an allergic reaction. Undesirable side-effects can also occur with more commonly used chemicals. This systematic review therefore includes an evaluation of the risk of serious side-effects associated with disinfectants and root filling materials used by dentists in root canal therapy. We also evaluate reports in the literature of other treatment complications associated with pulp and root canal treatment, such as nerve damage, which may be caused by root filling procedures.

Survey of established practice

Under the auspices of the report, a survey of established endodontic practice was undertaken. Around 2 000 dentists practising in Sweden were selected statistically and requested to answer a number of questions about their endodontic practice routines. The aim of the survey was to determine to what extent new treatment technologies for root canal instrumentation and root filling have been adopted in general practice, how they manage various endodontic conditions and which materials and methods they use.

Ethics

Assessments conducted by SBU are to be made on the basis of a combined evaluation of medical, economic, social and ethical aspects. This is discussed in Chapter 4 of the report.

Questions addressed

The questions to be addressed are related to various pulpal conditions, which can give rise to the need for some form of pulpal or root canal treatment, including inflamed, necrotic pulps or a root-filled canal. For all these conditions, we evaluate the scientific evidence underlying the methods used for diagnosis and treatment. We evaluate the scientific evidence supporting options available to the dentist in cases where treatment has failed to restore healthy status. We also evaluate methods for restoring root-filled teeth and whether these methods result in acceptable long-term preservation of the restored tooth. Other questions to be addressed are health economic aspects and the risk of complications and serious side-effects associated with acute and chronic infections of the pulp.

Facts 1.1 Various symptoms and clinical observations form the basis of endodontic diagnosis. Examples are given of some common symptoms and observations (marked with +), which may be present when a pulp is inflamed or non-vital.

	Condition of the pulp			
Symptom/ observation	**Sound**	**Inflamed (pulpitis)**	**Dead (necrotic)**	**Root-filled**
Shooting pain	+/–	+/–	–	–
Toothache	–	+/–	+/–	+/–
Tenderness on chewing	–	+/–	+/–	+/–
Swelling/ pusformation	–	–	+/–	+/–
Periapical bone changes (radiographic)	–	+/–	+/–	+/–

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2. Description of methods

Literature search

The literature search included the databases PubMed, CINAHL, PsycInfo, the Cochrane Central Register of Controlled Trials, Cochrane Reviews, HTA, DARE, HEED and NHSEED. The search strategies were constructed in accordance with the overall questions to be addressed. The literature search was undertaken in collaboration with a specialist in informatics at SBU. Further studies were then sought manually through the reference lists of the scientific papers and in review articles. The search covered publications from January 1950 to April 2010 (Appendix 1).

The review process

The abstracts of the identified studies were examined independently by two assessors. The objective was to identify studies which were relevant to the questions being addressed. The results of the independent assessors were compared; full-text versions were ordered of all articles judged as relevant or "possibly relevant" by one or both of the assessors. Full-text versions were then examined independently by the same two assessors. In order to determine whether a study warranted inclusion in the third phase of the review process, predetermined inclusion and exclusion criteria were applied. The reasons for exclusion of a study were noted. Studies judged by at least one of the assessors to fulfill, or possibly fulfill the inclusion criteria were selected for inclusion in the final review (Figure 2.1).

The review comprised evaluation of the relevance of the studies to the questions to be addressed by the report and methodological quality – study design, internal validity (reasonable guarantee against systematic errors), analysis of the results, statistical power and generalisability. In order to ensure uniform, transparent and reproducible assessment with limited subjectivity, appraisal sheets were used, specifically structured for various study designs and research questions (Appendix 2). After appraisal, each study was awarded a grading for methodological quality (high, moderate, or low). When there was lack of consensus about the quality of a study, the articles were appraised by the entire project group. In cases where the appraisal concerned a paper in which a member of the project group was an author, or had any other kind of association with the content of the study, the entire expert committee participated in the final evaluation. Finally, important facts from the included studies were summarised and tabulated.

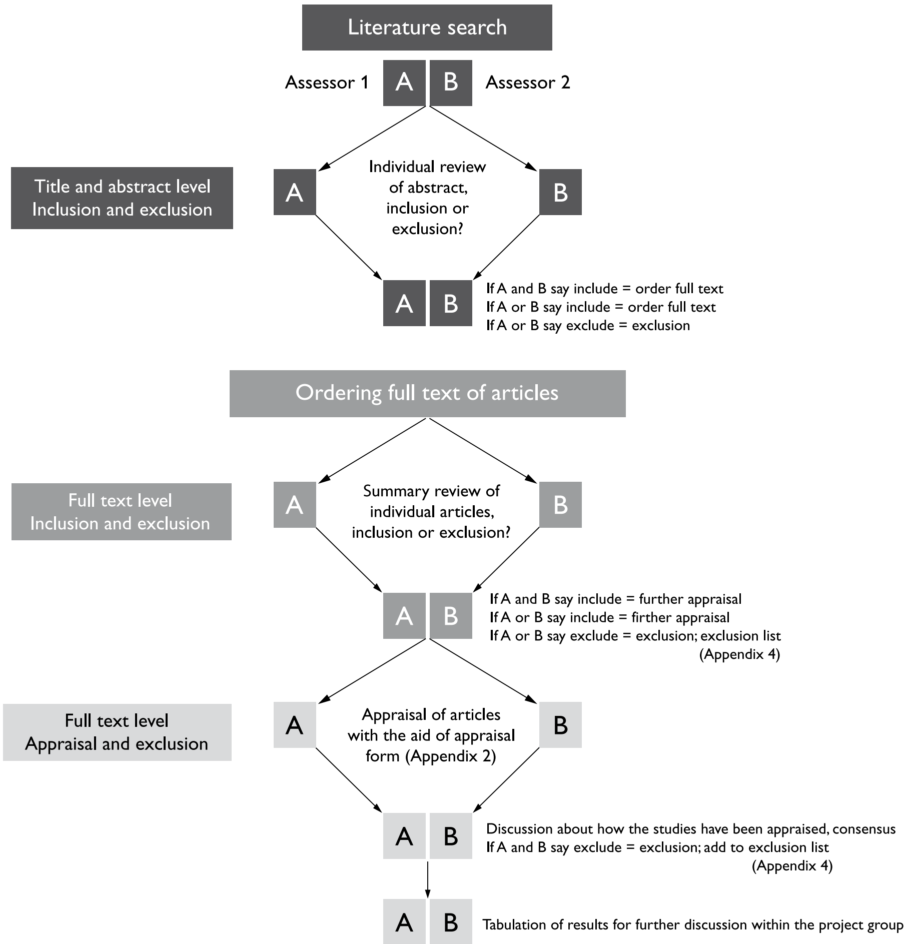

***Figure 2.1** Flow diagram showing the literature search and appraisal procedures.*

Evaluation of the scientific basis of the studies

Study quality refers to the scientific quality of an individual study and its potential to reliably address a specific research question.

The strength of the evidence is an assessment of the overall strength of the scientific basis for reliably addressing a specific research question. SBU applies the internationally developed system for grading evidence GRADE [1]. Each outcome is based on the study design assessed in the overall appraisal. The strength of the evidence may thereafter be positively or negatively affected by such factors as study quality, relevance, consistency of results, transferability, magnitude of effect, imprecision of the data and risk for publication bias.

There are four grades for strength of the evidence:
Strong scientific evidence (⊕⊕⊕⊕)
Based on high or medium quality studies with no factors that weaken the overall assessment.

Moderately strong scientific evidence (⊕⊕⊕○)
Based on high or medium quality studies with isolated factors that weaken the overall assessment.

Limited scientific evidence (⊕⊕○○)
Based on high or medium quality studies having factors that weaken the overall assessment..

Insufficient scientific evidence (⊕○○○)
Scientific evidence is deemed insufficient when scientific findings are absent, the quality of available studies is low, or studies of similar quality present conflicting findings.

The stronger the evidence, the lower the likelihood that new research findings would affect the documented results within the foreseeable future.

Conclusions

SBU's conclusions present an overall assessment of benefits, risks, and cost effectiveness.

Quality of Evidence	Study Design	Lower if	Higher if
Strong ⊕⊕⊕⊕	RCT	Risk of bias due to limitations of study quality (max –2)	Large effect size and no likely confounders (max +2)
Moderately strong ⊕⊕⊕○		Inconsistency between studies (max –2)	Clear dose-response relationship (max +1)
Limited ⊕⊕○○	Observational study	Indirectness (max –2)	Confounders should result in better treatment result in the control group (max +1)
Insufficient ⊕○○○		Poor precision (max –1)	
		High likelihood of publication bias (max –1)	

Finally, an overall weighted judgment is made based on all included factors.

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3. Systematic review of the literature

3.1 Diagnosis of the condition of the pulp

Background

Establishment of a diagnosis involves the collection and collation of information about a condition (the patient's description and clinical observations), which together with other data, will form the basis for a treatment decision. Diagnosis involves not only differentiating factors related to disease from those related to health, but also grading the degree of severity of a disease and distinguishing between different diseases (differential diagnosis). Accurate diagnostic assessment is the initial, essential stage in the process of clinical decision-making.

The objective of endodontic diagnosis is to identify teeth with unhealthy (inflamed or necrotic) pulps. As an infected root canal often causes pathological changes in the tissues surrounding the teeth, the endodontic diagnosis also includes an evaluation of the condition of these tissues. A diagnosis is seldom based on single observations, but is arrived at by collective analysis and evaluation of the patient's description of the condition, clinical observations and the results of examinations. The dentist finds clues in the patient's description of possible symptoms, such as pain, and a history of events such as trauma or dental restorative work. This information is complemented by clinical examination, clinical tests and radiographic examination of the teeth and surrounding alveolar bone. The clinical situation can be complex and the diagnostic process often involves a number of steps before a conclusion can be reached; for example, in cases of suspected pulpal necrosis in comprehensively restored teeth, the diagnosis must be based on radiographic examination and sensibility testing and the response of the tooth to application of cold and electrical stimuli.

Methods

Symptoms and clinical indications of pulpal inflammation/pulpal necrosis

Toothache, swelling or a tender tooth are common symptoms; for example the patient may report toothache which comes and goes, and persists for a varying time after ingestion of warm and cold beverages or sweet and sour food products, or when air is breathed in, indicating pulpitis (inflammation of the pulp). More pronounced and persistent toothache is considered to be an indication of an irreversible pulpal condition, which sooner or later will progress to death of the pulp. Dull pain which occurs in the absence of external stimuli, combined with tenderness on chewing or a feeling that the tooth is longer than the adjacent teeth, indicates pulpal necrosis, with spread of inflammation to the tissues surrounding the root apex (apical periodontitis). These various symptoms may form a basis for assessing the condition of the pulp, ie whether the pulp is reversibly or irreversibly damaged, or if it is vital or non-vital. However, the value of these symptoms is debatable and controversial.

Investigation of the condition of the pulp is often undertaken during routine dental examination, ie not because the patient is experiencing any symptoms. For example, during clinical examination the dentist may detect the presence of a fistula or a deepened periodontal pocket, or radiographic examination may disclose bone destruction periradicularly. Assessment of the condition of the pulp may also be undertaken in cases of extensive destruction of tooth substance due to dental caries, which is the most common cause of infection and inflammation of the pulp. If the pulp is exposed because of caries and is vital and bleeding, it might be possible to limit treatment to simple care of the wound. A prerequisite for successful outcome, however, is that the damage to the pulp tissue is not so serious that it cannot survive and becomes necrotic. In this chapter we evaluate the validity of methods for determining the condition of the pulp.

Assessment of the vitality of the pulp

Routine methods include eliciting a pain reaction by application of thermal and electrical stimuli, by percussion testing, drilling a test cavity, blasting with air or probing. However, these tests disclose only whether there is sensory nerve function (sensation in the pulp) or not. Such techniques can therefore not determine with certainty whether the pulp is vital, ie with functional blood circulation. Particularly in teeth, which have been loosened from their attachment apparatus (luxated) following an accident/external violence, sensory function may be temporarily damaged, but the blood circulation may still be functioning. A study showed that electric pulp testing and provocation by drilling were inadequate for determining the vitality of the pulp in luxated teeth [1]. Nor does an immature tooth with an open apex always give a reliable response to electric pulp testing [2]. It is therefore important to scrutinize the accuracy of methods, which measure vascular function in the pulp. Examples of such methods are Laser Doppler Flowmetry (LDF), pulse oximetry and measurement of the surface temperature of the tooth [3,4].

Assessment of the condition of the bone tissue (radiographic examination)

Radiographic examination is an essential and important complement to the clinical examination. The purpose is to provide information about the presence and severity of caries, deep restorations and fractures and bone changes. The validity of various methods of radiographic examination is assessed in Chapter 3.2.

Terms and measurements for describing the accuracy of diagnostic tests

In order to determine the accuracy of clinical observations and test results, ie how well they reflect healthy or diseased conditions, the clinical observation/test result (so-called index test) must be tested (validated) against a standard reference (reference test), also sometimes called the gold standard (Facts 3.1.3, Figure 3.1.4). The classical reference test for determining the condition of the pulp is histological examination. This is an example of an invasive reference test, because it requires extraction of the tooth or extirpation (removal) of the pulp tissue.

Validity of diagnostic tests

The validity depends on how well the reference test (validity criteria) agrees with the "true" condition. When there are unambiguous criteria for the "true" condition it is referred to as "criterion validity". An example is histological information or inspection/probing of the pulp to determine whether the pulp is vital or necrotic. Although histological examination gives a good picture of the condition of the pulp, it is not without shortcomings. The histological appearance leaves room for interpretation. Moreover it gives just a momentary impression and does not reflect a dynamic process. Thus for differential diagnosis between reversible and irreversible pulpitis, there is no appropriate reference standard to determine whether the pulp is reversibly or irreversibly inflamed. One means of overcoming this is to use a prospective study design, in which the outcome of pulp capping is related to pre-treatment symptoms, clinical finds and tests. By this means it would be possible to study the diagnostic validity of the extent of and character of bleeding of an exposed pulp after excavation of a deep carious lesion (index test). The reference test is the outcome of pulp capping, which can be directly related to reversible/irreversible pulpitis.

If an unambiguous reference test is unavailable or cannot be observed, the problem can be solved indirectly by constructing a reference test, so-called construct validity. It can be based on a combination of results of various tests and other results or clinical characteristics and prognostic indications. Altogether this gives a pragmatic validation of the disease. Validation is based on large amounts of empirical data and is often determined by international consensus proceedings with panels of experts, or by so-called Delphi-procedures [5]. Figure 3.1.4 illustrates various strategies for validating diagnostic tests.

Measures of accuracy

The relationship between test results and disease status can be expressed by means of various measures. The following are the classical measures for calculating the accuracy of a diagnostic test:

Sensitivity (SE), the likelihood that someone with the disease
has a positive test result.

Specificity (SP), the likelihood that someone who is healthy has a negative result.

Positive predictive value (PPV), the likelihood that those with positive results do in fact have the disease.

Negative predictive value (NPV), the likelihood that those with negative test results are in fact healthy.

The combination of the presence of the disease and the test results can be presented in a table form (Facts 3.1.3).

The level considered to provide "good accuracy" for a diagnostic test depends on the context in which it is applied. We decided that for a test of the condition of the pulp, "good accuracy" required a sensitivity of ≥75% and a specificity of ≥85%.

PPV and NPV describe the characteristics of a test from a clinical perspective. The predictive values are however, dependent on the prevalence of the disease in the population. When the prevalence is low, the PPV decreases for a given sensitivity and specificity, whereas NPV is not affected to the same extent. The predictive value in a study cannot therefore be directly extrapolated to another population unless the disease prevalence in the two populations is comparable.

In theory, sensitivity and specificity are independent of the disease prevalence in a population. In practice, however, they are influenced by patient characteristics, ie the spectrum of patients to whom the test is applied. This means that sensitivity and specificity of a test applied to patients referred to a specialist clinic cannot be expected to be the same as for patients attending a general practice. The former comprise a selected population, often with symptoms of a (as yet undiagnosed) disease, while the latter are primarily less selected and have a greater proportion of patients without the disease. Thus sensitivity and specificity are also influenced by the prevalence of the disease, which is lower in unselected populations [6]. As a rule, sensitivity is lower and specificity is higher in an unselected population [6,7].

Likelihood ratio (LR), summarises sensitivity and specificity in one measure. A positive likelihood ratio (LR+) describes the proportion of sick subjects with a positive test result divided by the proportion of healthy subjects with a positive test result (sensitivity/1 – specificity). A negative likelihood ratio (LR–) describes the proportion of diseased subjects with a negative test result divided by the proportion of healthy subjects with a negative test result (1 – sensitivity /specificity), see Facts 3.1.3 and Figure 3.1.3. In other words, LR+ expresses the odds that someone with the disease has a positive test result and LR– expresses the odds that someone with the disease has a negative test result.

Odds ratio, OR, expresses the odds of disease being present in patients with a positive test result in relation to the odds of disease being present in a patient with a negative test result. If OR = 1, the test is of no value. The higher the OR the better the test is at differentiating between diseased/not diseased. For calculation of the odds ratio and the likelihood ratio, see Facts 3.1.3.

Meta-analysis of diagnostic studies is appropriate if the studies are sufficiently homogeneous. The so-called I^2-value, which is based on Chi^2-analysis, is an expression of the degree of heterogeneity. If the I^2-value is greater than 40%, the heterogeneity is considered to be too great to justify a meta-analysis.

Evidence-graded results

Symptoms and clinical signs

- The scientific basis is insufficient to determine whether a heightened response to thermal/electric stimulation or percussion gives valid information about the condition of the pulp in asymptomatic teeth with deep carious lesions (⊕○○○).

- There is no scientific basis on which to determine whether the presence, characteristics and persistence of toothache provide valid information about the condition of the pulp.

- There is no scientific basis on which to assess the value of markers of inflammation intended to differentiate between reversible and irreversible pulpitis.

- There is no scientific basis on which to determine the predictive value of markers of inflammation, infection and tissue damage with respect to the outcome of treatment intended to maintain an exposed pulp, vital and asymptomatic.

Sensibility and determination of vitality

- The scientific basis is insufficient to allow assessment of the accuracy of electric tests in determining whether a pulp is vital or non-vital (⊕○○○).

- The scientific basis is insufficient to allow assessment of the accuracy of thermal testing for determining whether the pulp is vital or non-vital (⊕○○○).

- The scientific basis is insufficient to allow assessment of the accuracy of methods which measure pulpal blood circulation to determine whether a pulp is vital or non-vital (⊕○○○).

Questions addressed

This chapter assesses the accuracy of methods applied to determine the condition of the pulp in teeth damaged by caries, trauma, restorative procedures or other causes. We scrutinize methods, which investigate and determine whether a pulp is healthy, inflamed or dead (necrotic). The specific questions addressed are:

- How accurately can any patient symptoms, together with other clinical information, reveal the condition of the pulp?

- Are there clinical or biological markers, which can accurately determine the degree and extent of inflammation of an exposed vital pulp?

- Are there methods, clinical or biological markers, which can accurately predict the outcome of measures intended to maintain the pulp in a vital state and free of symptoms?

- How accurate are methods used to determine sensibility/vitality of dental pulp, based on the response of the tooth to pain, for determining whether a pulp is vital or non-vital?

- How accurate are non-invasive methods investigating blood flow for determining whether a pulp is vital or nonvital?

Inclusion and exclusion criteria

Articles published between 1950 and 2010. Articles in any language with summaries in English or Swedish. Systematic review articles dealing with the questions being addressed.

Facts 3.1.1 Inclusion criteria.

Population	Patients who can be expected to undergo the examination or test as part of routine clinical practice
Index test	Clinical symptoms, other clinical information, clinical tests or biological markers tested against a reference standard
Reference test (validity-criteria)	For pulp status of vital tissue: histological investigation of extracted tooth or extirpated pulp tissue, alternatively symptoms and clinical/radiographic information in a prospective study design. For vitality assessment of a pulp: as above or inspection/probing of the pulp tissue, alternatively radiographic examination in combination with continued root development in teeth with incompletely developed roots
Outcome	Sensitivity, specificity, likelihood ratio, odds ratio, multivariate analyses or ROC with or without Az (area under curve). Alternatively that the data are reported, so that sensitivity and specificity can be calculated

Facts 3.1.2 Exclusion criteria.

Population	In-vitro studies, animal studies Retrospective studies Experimental studies Studies with small samples
Index test	Tooth-whitening/bleaching methods Comparison of products
Reference test (validity–criteria)	Not defined/not acceptable as specified by the inclusion criteria
Outcome	Relevant data not presented, lack of measurement specified by the inclusion criteria

Result of literature search and selection of studies

The literature search identified 2 002 articles in the databases. In addition, reference lists from review articles, text books and articles published in journals were manually searched. Systematic reviews were included. Finally 155 articles were read in the full-text versions. When the 155 full-text articles were assessed according to the predetermined inclusion and exclusion criteria, 18 were found to meet the inclusion criteria. These were appraised and assessed according to an appraisal form (Appendix 2) with somewhat modified QUADAS-criteria, as being of high, moderate or low quality [8]. See flow diagram, Figure 3.1.1. A list was compiled of excluded studies, along with the main reasons for exclusion (Appendix 4).

Description of studies and results

The 18 studies selected for inclusion are described in Table 3.1.1 [9–26]. The presentation differentiates between studies, which investigate the accuracy of different symptoms and markers intended to assess the degree of inflammation of the vital pulp, and studies, which investigate methods for determining the vitality of the pulp. Figure 3.1.2. presents an analysis of the included studies in terms of the 14 quality criteria.

Of the included studies, none was assessed as having high quality, two were of moderate quality [14,16] and the remaining studies were of low quality. Of the two studies of moderate quality, one compared the accuracy of pulse oximetry with various standard methods of vitality testing [14]; the other investigated the accuracy of clinical markers for determining the degree of pulpal inflammation associated with deep carious lesions in asymptomatic teeth [16].

Symptoms and clinical markers as indicators of the inflammatory status of the pulp

Of eleven included studies, ten were assessed as being of low quality [9,10,15,17–21,24,25]. The study of moderate quality compared normal and abnormal responses to thermal and electrical stimuli and sensitivity to percussion and correlated the findings with the histological evidence in the pulp of 47 teeth, which had severe caries, but were asymptomatic [16]. The results disclosed no clear association between the test result and the inflammatory status of the pulp. Most of the teeth (80%) were tender to percussion regardless of the pulpal status; all the teeth with minimal or no pulpal inflammation exhibited hypersensitivity to either cold or heat stimulus. There was pronounced variation in the tissue reaction; the histological examination disclosed moderate/severe pulpal inflammation in 28% (13/47) of teeth. Thus the absence of pain did not rule out extensive inflammatory changes. Histological examination showed that 30% of the teeth had exposed pulps (loss of den-tine forming the roof of the pulp chamber). Moderate to severe pulpal inflammation occurred considerably more frequently (71%) in such teeth than in teeth where the dentine forming the roof of the pulp chamber remained intact (28%). The size of the sample is however, relatively small and the results have wide confidence intervals (Table 3.1.1).

A study of low quality investigated the accuracy of isolated and combined clinical symptoms for differential diagnosis of acute toothache in 74 patients [19]. Probing the pulp after exposure was used as the reference test to distinguish between vital and non-vital pulps. Bursts of pain in re-sponse to changes in temperature (cold/heat) were associated with pulp-itis (>75%), while persistent pain and a feeling that the tooth was elongated were associated with pulpal necrosis in >80% of cases. Tenderness to percussion was not of diagnostic value in assessing the condition of the pulp.

One study investigated the status of the pulp of 166 teeth extracted because of caries or for other reasons [24]. Histological status was correlated with the presence of toothache and the results of different clinical tests (percussion, responses to thermal and electrical stimuli). None of these markers was accurate in determining the status of the pulp. The study has methodological shortcomings and the quality was graded as low.

A study of low quality investigated the importance of various preoperative clinical markers for the outcome of pulp capping in 44 permanent teeth with carious exposures [21]. This is the only prospective study included. The successful outcome rate was significantly less for teeth with profusely and persistently bleeding pulps than for those in which bleeding from the pulp was less profuse and not persistent. The presence of mild preoperative toothache was not associated with poorer outcome. The study has methodological shortcomings and the material is small, with wide confidence intervals. Thus there is a lack of scientific support necessary to determine whether the presence, character and duration of toothache offer accurate information about the severity of the inflammatory response in the pulp. Nor is there sufficient scientific support to determine the value of other clinical signs of pulpal inflammation.

Biological markers as indicators of the inflammatory status of the pulp

Several studies have investigated different markers of inflammation as indicators of the inflammatory status of the pulp. Only one study, from the 1960's, met the inclusion criteria [15]. In this study of low quality, blood samples were taken from pulps exposed by caries or other causes. The number of white blood cells was measured (index test). After extraction of the tooth, the degree of pulpal inflammation was assessed histologically. The correlation between the cellular characteristics and the degree of pulpal inflammation was poor (sensitivity = 36%, specificity = 64%).

There is a lack of scientific support necessary to determine whether inflammatory markers can provide accurate information about the inflammatory status of the pulp and whether the inflammation is reversible or irreversible.

Determining the vitality

Electric test

In one study of moderate quality [14], the test group comprised 80 patients with the same number of single-rooted teeth in need of endodontic treatment, because of deep caries or for some other reason. With direct visual inspection as the reference test, the electric test had a sensitivity (for pulpal necrosis) of 71% and a specificity (for a vital pulp) of 92%. With one exception [13], other studies of low quality [9,11,13,17,18,23,24,26] reported high specificity (≥90%), while sensitivity, with one exception, was lower and showed considerably greater variation (21–87%).

Cold test

Only one study (the same as above) with moderate quality [14]. The cold test with tetrafluorethane had a sensitivity (negative response, indicating a non-vital pulp) of 81% and a specificity (positive response, indicating a vital pulp) of 92%. In other studies of low quality there was pronounced variation in specificity (10–98%) [9,11,12,18,23–26]. With the exception of one study, the sensitivity was ≥75% [9].

Heat test

Six studies, all of low quality, investigated the accuracy of heat test [9,12,13,23–25]. There were pronounced variations in both sensitivity and specificity.

Combinations of tests

Two studies of low quality investigated the accuracy of two tests, separately and in combination [24,26]. One investigated heat and cold tests [24]; combinations of tests gave higher specificity while sensitivity decreased. The other study compared cold and electric tests [26]; combinations of tests gave more accurate results than when they were applied independently. When the tests were combined, sensitivity (for a necrotic pulp) was 96% and specificity (for a vital pulp) was 92%.

Determination of blood flow

Two studies of low quality showed that Laser Doppler Flowmetry could differentiate between teeth with non-vital and vital pulps; sensitivity and specificity were high (88–100% and 100%, respectively) [11,22]. The reference test comprised direct inspection of the pulp chamber during root treatment and conventional sensibility/vitality assessment.

One study of moderate quality investigated the accuracy of pulse oximetry [14]. The reference test comprised direct visual inspection of the pulp tissue. Pulse oximetry had 100% sensitivity and 95% specificity.

Discussion

The literature within the field in focus for this systematic review is extensive. A considerable proportion however, comprises review articles or method descriptions. There are relatively few studies in which the accuracy of investigated procedures and test methods have been appraised according to well-defined criteria. No systematic review was identified. Most of the original papers included are out of date; few studies have tested new methods or attempted to improve the available methods.

One possible explanation for the lack of studies in recent years is the difficulty in establishing a relevant reference standard. Dental pulp tissue is normally not available for direct inspection or for microscopic or other examinations, especially if the tooth is healthy and in no need of endodontic treatment or extraction. Formerly, such teeth were frequently accessible as they were extracted if decayed by caries rather than being treated endodontically. In order to provide patients with removable dentures, healthy teeth were also often extracted. Nowadays, access to such teeth is limited in most of the industrialised countries. Another explanation for the lack of studies of good quality may be that cross-sectional data have traditionally been regarded as the only means, while the benefit of a prospective study design has not been considered. Only one of the included studies used this design [21].

Inflammatory mediator substances, such as prostaglandin [27,28], superoxide dismutase [29], TNF-alpha [30] or substance P [31] could indicate pulp status and have the potential to predict the outcome of treatment intended to maintain an exposed pulp vital and asymptomatic, eg pulp capping or pulpotomy. Although markers of this nature have been correlated with clinical signs and symptoms, no study met the inclusion criteria.

The impact of inflammation and tissue damage on the ability of the pulp to survive has yet to be clarified. Considering that infection is often the cause of inflammation any inflamed pulp should be able to heal if the source of infection is eliminated. Thus, a caries-induced pulpitis ought to be reversible and the pulp able to heal if caries is removed. An important prerequisite is, however, that infectious elements have not established themselves permanently in the pulp chamber. The review process failed to identify any clinical study of adequate quality, which investigated the relationship between markers of pulp infection and the outcome of conservative treatment. In summary, there is a dearth of knowledge about the importance of different symptoms and clinical findings to the outcomes of treatment aimed at preserving pulp exposed by caries or other forms of injury.

A large number of studies investigated the accuracy of various methods for testing pulp vitality. Most attention has been paid to methods based on eliciting pain response to the application of electrical and thermal stimuli. All except one of these studies were assessed as being of low quality. Many used healthy teeth as reference teeth. With such a study design, there is a risk that the accuracy of the diagnostic test being investigated will be overestimated [32]. When selection of material is based solely on teeth, which are to be extracted or to be root-filled there is a high risk of so-called spectrum bias. This means that the results cannot be generalised, because such a study sample is not representative of the spectrum of patients likely to undergo such testing in general dental practice. Thus there is a need for well-designed and well-conducted studies, which evaluate methods (electricity, thermal) to determine the vitality of the pulp.

An alternative means of determining pulpal vitality is measurement of blood flow. During the past 20 years, Laser Doppler Flowmetry has been investigated in a large number of studies, but to date the clinical applicability has not been confirmed. The method requires expensive and technically complicated equipment. One study, which investigated the use of the method in clinical practice, reported uncertain results unless the conditions for the examination were standardised [33]. A further limitation of the method is that it is not appropriate for tooth types other than anterior teeth in which the pulp cavity has not been reduced to a level below the marginal gingival level. Pulse oximetry is based on a less expensive and simpler technique than Laser Doppler Flowmetry. The method seems promising, but it is also limited to teeth with pulp tissue well within the crown portion of the tooth.

In most of the studies investigating the accuracy of methods for pulpal vitality testing the prevalence of teeth with extensive pulpal inflammation or pulpal necrosis is relatively high (often >40%). The reason is that the sample is primarily often selected, eg "teeth requiring endodontic treatment" or "teeth with subjective symptoms in the form of toothache". This means that the first diagnostic step has been taken, before the actual test is applied. The effect of such patient selection is sometimes referred to as "work-up bias" [34,35]. This means that both sensitivity and specificity change when the test is applied to a spectrum of patients who have not undergone such primary selection. It is important that this is kept in mind when a test is applied to a population of different composition.

There is a great need for studies, which show how clinical symptoms and tests are interlinked and together influence the accuracy of the diagnosis.

In general we found serious shortcomings in both study design and in the execution and reporting. Figure 3.1.2 shows the extent to which the included studies met important quality criteria. In almost all the studies the patient population is inadequately described. Only one study states whether the patients were chosen consecutively. This is a shortcoming because studies with patients who are not consecutively selected tend to overvalue the accuracy of diagnostic tests [5]. Inadequate description of the patient population also makes it impossible to determine the generalisability of the results to routine clinical practice. The index- and reference tests are inadequately described in half the studies. With respect to the reference test, few studies have at least two independent observers. This implies a risk for subjective evaluation of pulpal status. A further serious shortcoming is that it is not usually stated whether the reference test has been interpreted independently of the index text. In several studies the observers were not blinded. Both these shortcomings increase the risk of overvaluing the method's accuracy [32]. None of the studies reported precision (eg confidence intervals) and reliability of the test results.

In summary, there is a great need for improvement in terms of design, conduct and reporting of diagnostic studies. An excellent aid is STARD (Standards of Reporting of Diagnostic Accuracy) [36] which corresponds to the Consort Statement for randomised studies [37].

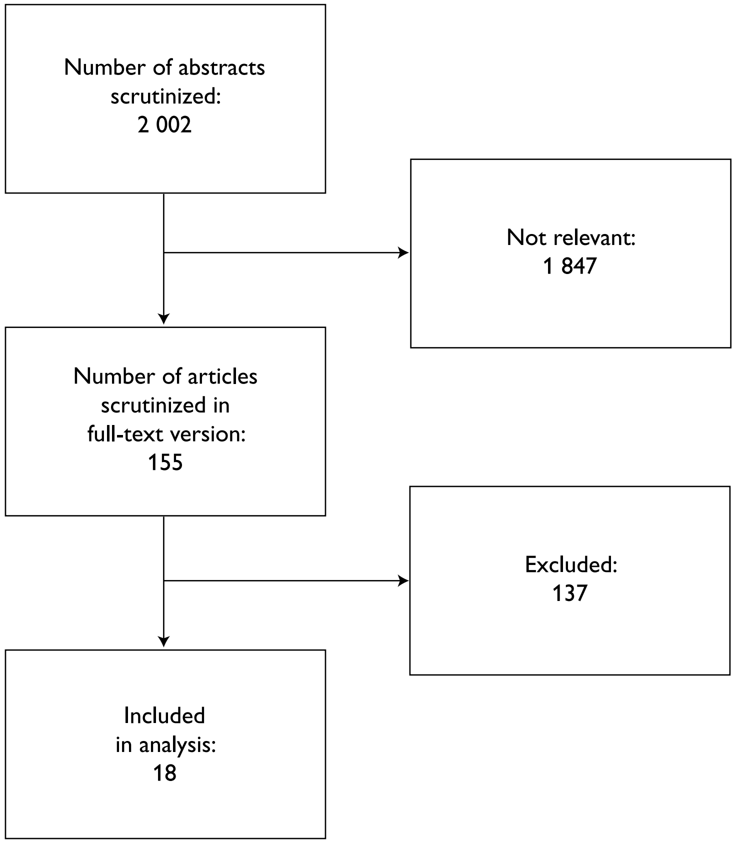

***Figure 3.1.1** Flow diagram of literature search.*

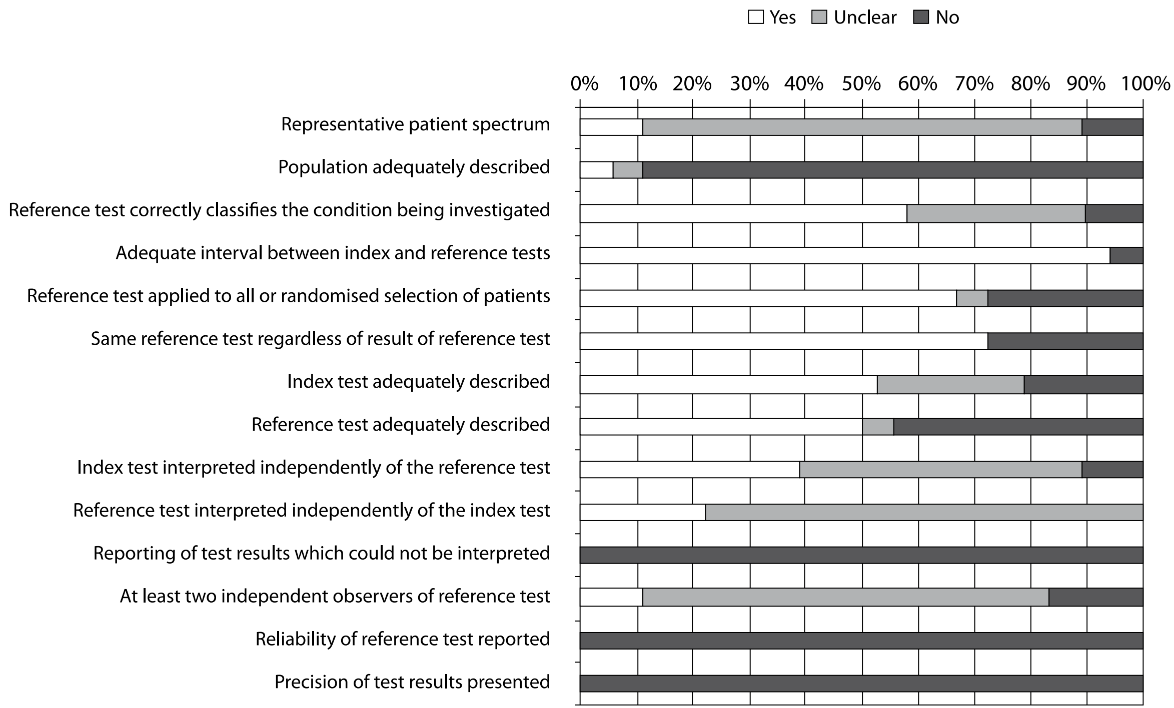

Figure 3.1.2 *Analysis of compliance with 14 quality criteria, modified after QADAS criteria, in the 18 included studies of pulpal diagnosis [8]. Percentage distribution of yes/unclear/no for the respective criterion.*

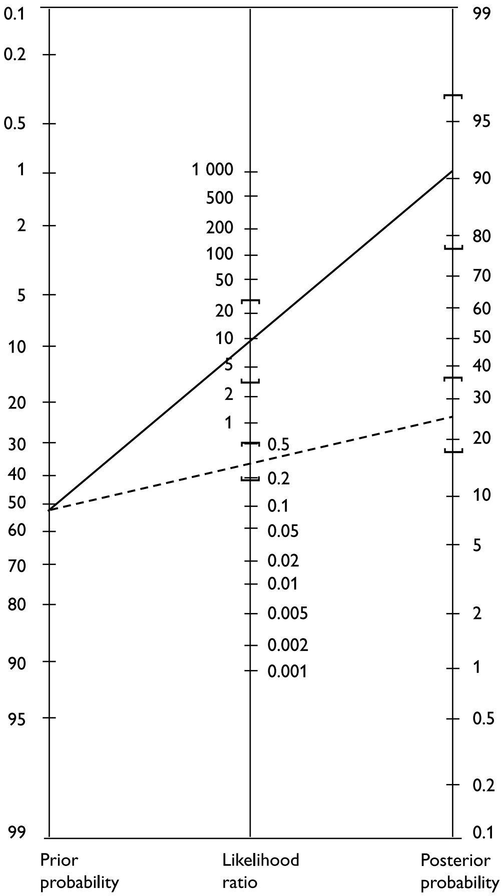

Figure 3.1.3 *With the aid of a so-called nomogram the theoretical probability of the disease after the test (posterior probability) can be calculated using LR (likelihood ratio), provided the disease prevalence is known. The data in the above example are the same as in Facts 3.1.3, where the prevalence of non-vital teeth before the test ("prior probability") was 52% and LR+ = 9 and LR– = 0.31. The middle vertical line in the nomogram indicates the values for LR+ and LR– respectively. The right vertical line presents the probability of the outcome after the test. The continuous line shows that the probability that a tooth with a negative response to electric testing is non-vital after the test is 91% and the dotted line shows that the probability that a tooth with a positive response to electric testing is non-vital is 26% (the square brackets show the 95% confidence intervals).*

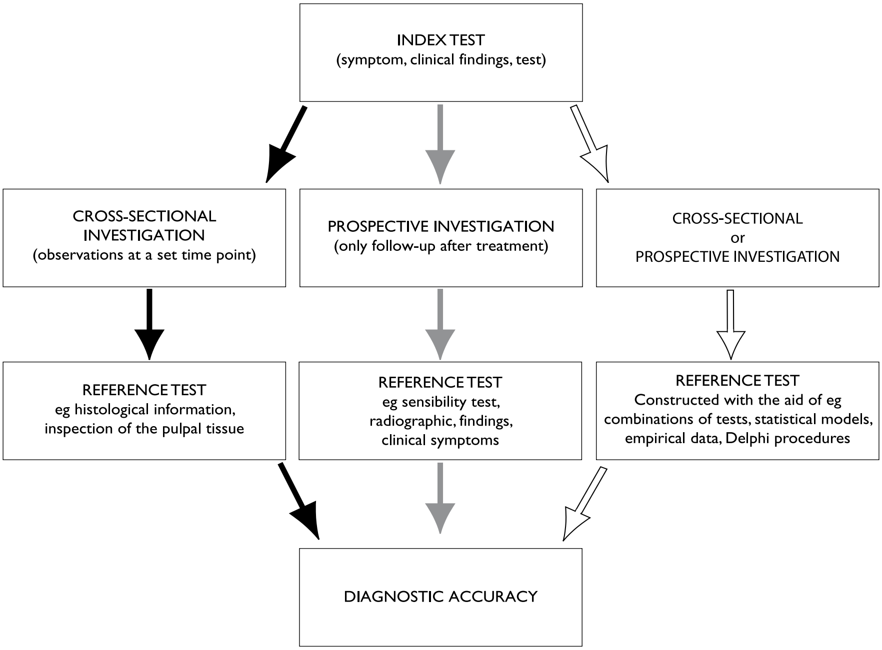

Figure 3.1.4 *Various strategies for determining diagnostic accuracy.*

The black arrows show a strategy in which cross-sectional data are used to investigate the accuracy of a diagnostic method. A cross-sectional study means that both an index test and a reference test are investigated and studied at the same time. A prerequisite is that an observed reference test is available (also called validity criteria). The grey arrows illustrate a prospective strategy, investigating how symptoms, clinical findings or test results are related only to observation of the natural progression of a condition or are related to treatment outcome. Both these strategies require an observable reference test ("criterion validity"). The third strategy is illustrated by the white arrows. This is applied when there are no observable criteria for the condition being investigated. The reference test is instead constructed with the aid of other methods ("construct validity"). Examples of conditions in which this strategy is applied are diagnosis of renal function or psychiatric conditions.

Facts 3.1.3 Calculation of sensitivity, specificity, positive predictive value, negative predictive value, odds ratio and likelihood ratio, in an example where the results of electric testing (index test) for 80 single-rooted teeth were compared with the status observed by direct inspection: vital (bleeding)/non-vital (non-bleeding) pulp (reference test) [14].

Reaction to electric testing	**Direct inspection**		
	Non-vital	**Vital**	**Total**
Negative (diseased)	a=30	b=3	33
Positive (healthy)	c=12	d=35	47
Total	42	38	80

Sensitivity = 30/42 = 0.71 (a/a+c)
Specificity = 35/38 = 0.92 (d/b+d)
Positive predictive value (PPV) = 30/33 = 0.91 (a/a+b)
Negative predictive value (NPV) = 35/47 = 0.74 (d/c+d)
Prevalence of non-vital teeth in the population = 42/80 = 52%

Positive likelihood ratio (LR+) = sensitivity/1–specificity
In the example: 0.7/1–0.92 = 9, ie the likelihood that the pulp is non-vital when there is a negative response to electric testing is 9.
Negative likelihood ratio (LR–) = 1–sensitivity/specificity
In the example: 1–0.71/0.92, ie the likelihood that the pulp is non-vital when there is a positive response to electric testing is 0.31.

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Facts 3.1.3 continued

Calculation of change in prevalence of non-vital teeth after testing:
Probability (p) that the tooth is non-vital (N) = p(N)
Odds that the pulp is non-vital = p(N)/1–p(N)
From the above example with a prevalence of non-vital teeth of 0.52:
Pre-test odds = prevalence/1–prevalence = 0.52/1–0.52 = 1.1
Post test odds = pretest odds* LR, ie 1.1 *9 =9.9
Post test p(N) = post test odds/(post test odds + 1)
Post test p(N) (prevalence of non-vital teeth) will then be = 9.9/1 + 9.9 +0.91, ie in theory, teeth with a negative response to electric pulp testing are non-vital in 91% of cases.
With the aid of the so-called nomogram it is possible to find the post test prevalence directly if LR and the pre-test prevalence are known. This is illustrated in Figure 3.1.3.

How should LR be interpreted?
Positive LR is >0, negative LR is <0.
Change in likelihood of disease after test:

>10 or <0.1	High or very high
5–10 or 0.1–0.2	Moderate
2–5 or 0.2–0.5	Minor, can be important
1–2 or 0.5–1	Minor, seldom important

Table 3.1.1 *Pulp diagnosis.*

Author **Year** **Reference** **Country**	**Aim**	**Study design** **Population characteristics** **Setting** **Disease prevalence**	**Index test**	**Reference test**	**Main findings (CI=95%)**	**Study quality** **Comments**
Dummer et al 1980 [9] United Kingdom	To differentiate between saveable and non-saveable pulps and vital and non-vital pulps	Cross-sectional 75 permanent teeth to be extracted mainly due to pain (72%) in an undefined number of patients Dental school clinic Non-saveable pulps: 50/75=67%; Non-vital pulps: 19/75=25%	<u>*Clinical markers of pulp status*</u> Presence/absence of pain. Character of pain. Tenderness at apex. Intra-oral swelling. Tenderness to percussion. Hypersensitivity to cold and heat <u>*Vitality tests*</u> Electric (Scoone´s unipolar), cold (ethyl chloride), heat (heated gutta-percha) One observer for history taking and clinical examination. Vitality tests by independent observer	<u>*Histology following extraction*</u> 1. Classification in 7 categories according to criteria by Seltzer [24] 2. Dichotomised classification: Saveable pulp = chronic partial pulpitis (n=50) Non-saveable pulp = more severe inflammation/ necrosis (n=25) Blinded to index tests Number of observers not reported <u>*Outcome measures*</u> Proportions	Most clinical signs correlated poorly with the separate histological categories Loss of sleep due to pain: *SE (non-saveable)= 0.74 (CI 0.60; 0.84), SP=0.74 (CI 0.17; 0.85) Any presence of pain: *SE (non-saveable pulp)= 0.88 (CI 0.76; 0.94), SP=0.60 (CI 0.41; 0.77) Tenderness to percussion: *SE (non-saveable)= 0.66 (CI 0.52; 0.78), SP=0.88 (CI 0.70; 0.96) Hypersensitivity to heat: *SE (non-saveable)= 0.18 (CI 0.07; 0.30), SP=0.92 (CI 0.81; 1.0) Hypersensitivity to cold: *SE (non-saveable)= 0.40 (CI 0.28; 0.54), SP=0.84 (CI 0.65; 0.94) Electric pulp test: *SE (necrotic)= 0.21(CI 0.09; 0.43), SP=1.0 (CI 0.94; 0.0) Cold test: *SE (necrotic)= 0.68 (CI 0.46; 0.85), SP=0.70 (CI 0.57; 0.80) Heat test: *SE (necrotic)= 0.95 (CI 0.75; 0.99), SP=0.41 (CI 0.29; 0.54)	Low Population characteristics poorly described Reference test not described in sufficient detail to permit replication Threshold of reference test (saveable/ non-saveable pulp) arbitrary, surrogate measure

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Table 3.1.1 continued

Author Year Reference Country	Aim	Study design Population characteristics Setting Disease prevalence	Index test	Reference test	Main findings (CI=95%)	Study quality Comments
Eidelman et al 1968 [10] Israel	To differentiate between treatable and non-treatable pulps	Cross-sectional 32 primary teeth with extensive caries, unspecified with regard to tooth type in children aged 6–12 years. Teeth with obvious periapical lesion excluded Dental school clinic Non-treatable pulps=22/32=69%	*Clinical markers of pulp status* Presence/ absence of pain. Nature, duration and quality of pain. Pulp exposed during excavation. Tenderness to percussion. Hypersensitivity to heat, cold, and whether pain continued after removal of stimulus. Radiographic findings *Vitality tests* Electric, cold, heat	*Histology following extraction* 1. Classification according to criteria by Seltzer [24] 2. Dichotomised classification: Treatable pulp: chronic partial pulpitis (n=10) Non-treatable pulp: more severe inflammation/necrosis (n=22) One observer blinded to index tests *Outcome measures* Proportions	Correct classification of histological diagnoses from clinical findings: 18/32=56% Adding clinical symptoms (dull pain, pain upon percussion, pulp exposure, radiographic evidence of deep caries, widened periodontal membrane): *SE (non-treatable pulp)= 0.91 (CI 72; 98), SP=0.40 (CI 17; 69)	Low Population characteristics poorly described Small sample with questionable internal validity No information on the accuracy of separate clinical findings Threshold of reference test (treatable/ non-treatable pulp) arbitrary, surrogate measure

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Table 3.1.1 *continued*

Author Year Reference Country	**Aim**	**Study design Population characteristics Setting Disease prevalence**	**Index test**	**Reference test**	**Main findings (CI=95%)**	**Study quality Comments**
Evans et al 1999 [11] United Kingdom	To differentiate between vital and necrotic puls	Cross-sectional Sample 1: 67 teeth in 55 patients aged 8–35 years with anterior teeth subjected to dental trauma with at least 2 signs of pulp necrosis (loss of pulp sensitivity, discolouration, radiographic signs of pathology) Sample 2: 77 non-injured intact teeth from same or other patients Dental hospital (According to LDF): 1. All necrotic coronal pulp 2. All vital	<u>*Clinical markers of pulp status to assess pulp vitality*</u> History of pain. Presence of alveolar sinus tract. Tenderness to percussion. Coronal discolouration (direct light, transillumination). Radiography (apical radiolucency, inflammatory external root resorption). History-taking by one observer <u>*Vitality tests*</u> 1. Laser Doppler flowmetry (LDF). 2. Electric (Analytical Technology), cold (ethyl chloride)	<u>*Visual examination after pulp exposure*</u> Classification: Whole pulp necrotic (n=60) Coronal pulp necrotic (n=7) Number of observers of radiography not reported: Blinding to index tests <u>*Outcome measures*</u> SE, SP	LDF more accurate than electric and cold test to determine pulp vitality. Sample 1: 60 teeth had total and 7 partially necrotic pulp. Sample 2: 2 teeth negative to electric test and 4 teeth negative to cold test had incomplete root development <u>*Sample 1 and 2:*</u> LDF: Flux values set at <7.0 and amplitude values at <1.6 SE (necrotic)=1.0, SP=1.0 Cold test: SE (necrotic)= 0.92, SP=0.89 Electric test: SE (necrotic)=0.87, SP=0.96 Discolouration (transillumination): SE (necrotic)=0.49, SP=0.97	Low Work-up bias in sample 1 Accuracy of LDF depends on the method used to classify the LDF signal

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***Table 3.1.1** continued*

Author Year Reference Country	Aim	Study design Population characteristics Setting Disease prevalence	Index test	Reference test	Main findings (CI=95%)	Study quality Comments
Garfunkel et al 1973 [12] Israel	To study the correlation between clinical and histological findings	Cross-sectional 132 teeth with painful pulp conditions considered in need of endodontic treatment from an undefined number of patients Exclusion criteria: Teeth with radiographic signs of apical periodontitis, incomplete case history and technical difficulties (n=23) Dental school clinic Pulpitis: 62/109=57%, partial or total pulp necrosis: 47/109=43%	*Clinical markers of pulp status* Four clinical categories according to: Character of pain Hypersensitivity to percussion Cold test Heat test Bleeding characteristics from exposed pulp *Vitality tests* Cold (ethyl chloride) Heat (heated gutta-percha)	*Histology following pulp extirpation* Classification: 4 categories: 1. Acute pulpitis (n=35) 2. Chronic pulpitis (n=27) 3. Chronic pulpitis with partial necrosis (n=39) 4. Total necrosis (n=8) Two observers blinded to index tests *Outcome measures* Proportions	Absolute agreement between clinical and histological diagnoses: 54/109=50% *Vitality tests* Cold: *SE (totally necrotic pulp)=0.75 (CI 0.41–0.93), SP=0.57 (CI 0.48–0.67) Heat: *SE (totally necrotic pulp)=0.63 (CI 0.31–0.86), SP=0.61 (CI 0.52–0.70)	Low Population characteristics poorly described Small sample Work-up bias Extent of pulp inflammation histologically not reported Validity of reference test questionable

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Table 3.1.1 continued

Author Year Reference Country	Aim	Study design Population characteristics Setting Disease prevalence	Index test	Reference test	Main findings (CI=95%)	Study quality Comments
Georgopoulou et al 1989 [13] Greece	To differentiate between vital and necrotic pulp	Cross-sectional Patients scheduled for endodontic treatment. 168 teeth/168 individuals aged 11–78 years (mean 38.5); (75 males, 93 females). Maxilla/mandible: incisors 37/13, canines 21/9, premolars 16/26, molars 19/27 Inclusion criteria: University hospital clinic At least half of the crown intact, no crown or extensive restoration 68/168=40% necrotic	<u>*Vitality tests*</u> Electric (unipolar testing device), cold (ice), heat (heated gutta-percha) Teeth double tested at 3–4 min time intervals always by varying test method	<u>*Visual examination following pulp exposure*</u> Classification: Vital (n=100) Necrotic (n=68) Number of observers not reported. Blinding to index tests <u>*Outcome measures*</u> Proportions	Electric test: SE (necrotic)= 0.94 *(CI 0.86; 0.98), SP=0.73 *(CI 0.64; 0.81) Cold test: SE (necrotic)= 1.0 *(CI 0.95; 1.0), SP=0.62 *(CI 0.52; 0.71) Heat test: SE (necrotic)= 1.0 *(CI 0.95; 1.0), SP=0.66 *(CI 0.56; 0.75)	Low Work-up bias External validity limited to teeth with no or minor restorations

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Table 3.1.1 continued

Author Year Reference Country	Aim	Study design Population characteristics Setting Disease prevalence	Index test	Reference test	Main findings (CI=95%)	Study quality Comments
Gopikrishna et al 2007 [14] India	To differentiate between vital and necrotic pulp	Cross-sectional 80 patients/ 80 single rooted incisors, canines or premolars requiring endodontic therapy. Reasons: deep caries with clinical and radiographic signs indicating irreversible pulp inflammation or prosthodontic therapy. Contra-lateral sound control tooth Not stated 42/80=52.5% non-vital (experimental sample)	*Vitality tests* 1. Blood oxygen saturation level by pulse oximeter monitor. A value of <75% taken as negative 2. Electric (Parkell pulp vitality tester) 3. Cold (tetrafluroethane)	*Visual examination following pulp exposure (test group only)* Classification: No bleeding (necrotic) n=42 Bleeding (vital) n=38 Control group: electric test, cold test Three observers blinded to index tests *Outcome measures* SE, SP, PPV, NPV	The pulse oximeter dental probe was effective, accurate and objective to evaluate pulp vitality. Accuracy was superior to electric and cold tests Pulse oximetry: SE (non-vital)= 1.0 *(CI 0.91; 1.0), SP=0.95 *(CI 0.79; 0.97) PPV=0.95, NPV=1.0 Cold test: SE (non-vital)= 0.81 *(CI 0.67; 0.90), SP=0.92 *(CI 0.79; 0.97) PPV=0.92, NPV=0.81 Electric test: SE (non-vital)= 0.71 *(CI 0.56; 0.83), SP=0.92 *(CI 0.79; 0.97) PPV=0.91, NPV=0.74	Moderate Work-up bias likely Limited external validity Pulse oximetry device not commercially available

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Table 3.1.1 continued

Author Year Reference Country	Aim	Study design Population characteristics Setting Disease prevalence	Index test	Reference test	Main findings (CI=95%)	Study quality Comments
Guthrie et al 1965 [15] USA	To differentiate between coronal and total pulp inflammation	Cross-sectional Population characteristics: 44 primary, 9 permanent teeth/27 children aged 4–11 years with carious pulp exposure and bleeding pulp upon caries excavation. Controls: 14 primary and permanent teeth with normal pulps Not stated Total pulpitis: 24/53=46%	<u>*Biological markers of pulp status*</u> White blood cell count (hemogram): peripheral blood from patient's finger as reference. Rise in neutrophils or lymphocytes ≥10% compared with peripheral counts considered as elevated count. Size of pulp exposure. Character of bleeding at exposure site <u>*Clinical markers of pulp status*</u> History of pain Electric test Hypersensitivity to cold (ice), heat (warm gutta-percha) Percussion test Abnormal tooth mobility	<u>*Histology following extraction*</u> Dichotomised classification: 1. Coronal: inflammatory changes restricted to pulp chamber (n=29) 2. Total: pulp inflammation extending into one or more root canals (n=24) Number of observers, blinding not reported <u>*Outcome measures*</u> Proportions	No clear association between white blood cell count, pulp testing by heat, cold or electricity with extent of pulp inflammation Hemogram: *SE (total pulp inflammation) = 0.36 (CI 0.20; 0.56), SP=0.64 (CI 0.46; 0.79) Profuse bleeding: *SE=0.40 (CI 0.23; 0.59), SP=0.89 (CI 0.73; 0.96) History of spontaneous pain: *SE=0.63 (CI 0.42; 0.79), SP=0.79 (CI 0.61; 0.90)	Low Population characteristics poorly described Small sample Threshold of reference test arbitrary, surrogate measure

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Table 3.1.1 continued

Author Year Reference Country	**Aim**	**Study design Population characteristics Setting Disease prevalence**	**Index test**	**Reference test**	**Main findings (CI=95%)**	**Study quality Comments**
Hasler et al 1970 [16] USA	To differentiate between no/minimal and moderate/severe pulp inflammation in asymptomatic teeth with suspected pulpitis	Cross-sectional 47 painless vital teeth/47 patients age 13–56 years (mean 28 years) Teeth with extensive caries registered at routine examination University clinic Moderate/severe pulpitis: 13/47=28%	<u>*Clinical markers of pulp status*</u> Electric, cold (ethyl chloride, ice), heat (heated gutta-percha) Percussion Radiographic findings Comparison with adjacent or contra lateral sound tooth	<u>*Histology following tooth extraction*</u> Dichotomised classification: 1. No or minimal pulpitis (n=34) 2. Moderate/severe pulpitis (n=13) One examiner of clinical status Two examiners of histological findings Blinding to index tests likely Repeated clinical tests and histological examination <u>*Outcome measures*</u> Proportions	Asymptomatic teeth with extensive caries had moderate to severe pulp inflammation in 28% Pulp exposed (discontinuity of dentin floor): 30% *SE (moderate/severe inflammation)=0.71 (CI 0.50; 0.92), SP 0.88 (CI 0.73; 0.95) Test teeth. Radiography: 6/47 teeth showed apical pathosis Control teeth. All tested positive to electric pulp test and responded normally to heat, cold, percussion Abnormal reaction to tests: Heat: *SE (moderate to severe pulpitis)=0.54 (CI 0.29; 0.77), SP=0.21(CI 0.10; 0.37) Cold: *SE (moderate to severe pulpitis)=0.85 (CI 0.58; 0.96), SP=0.12 (CI 0.05; 0.27) Percussion: *SE (moderate to severe pulpitis)=0.77 (CI 0.50; 0.92), SP=0.21 (CI 0.10; 0.37)	Moderate Threshold of reference test arbitrary, surrogate measure Limited external validity

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Table 3.1.1 continued

Author Year Reference Country	Aim	Study design Population characteristics Setting Disease prevalence	Index test	Reference test	Main findings (CI=95%)	Study quality Comments
Johnson et al 1970 [17] USA	To differentiate between pulp hyperaemia, pulp inflammation and necrosis	Cross-sectional 706 teeth/94 consecutive patients. Full mouth extractions or single tooth extractions because of caries (1/3), toothache, marginal periodontitis, prosthodontics. 361 teeth subjected to pulp vitality testing Private dental hospital Hyperaemia: 198/634=31% Severe inflammation: 70/706=10% Necrosis: 50/706=7%	*Clinical markers of pulp status* Hypersensitivity to heat (heated gutta-percha) and cold (ethyl chloride) *Vitality test* Electric (Burton vitalometer)	*Histology following extraction* Classification: 1. Hyperaemia (n=198) 2. Inflammation (no cellular or cellular infiltration) (n=70) 3. Necrosis (n=50) Dichotomised classification: 1. Early hyperaemic stage, no inflammatory cellular infiltration 2. "Irreversible" cellular inflammation or necrosis Number of observers not reported. Blinding to index tests *Outcome measures* Proportions	Hyperaemia is an entity distinct from pulpitis. A significant correlation was found between hyperaemia and sensitivity to heat Electric test: *SE (pulp necrosis)= 0.57 (CI 0.41; 0.72), SP=0.99 (CI 0.97; 0.995) Cold test: *SE (irreversible inflammation)= 0.35 (CI 0.22; 0.52), SP=0.49 (CI 0.43; 0.55) Heat test: *SE (irreversible inflammation)= 0.59 (CI 0.53; 0.64), SP=0.39 (CI 0.25; 0.55)	Low Status of included teeth poorly described Small samples in subgroups Threshold of reference test arbitrary, surrogate measure

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Table 3.1.1 continued

Author Year Reference Country	Aim	Study design Population characteristics Setting Disease prevalence	Index test	Reference test	Main findings (CI=95%)	Study quality Comments
Kamburoglu et al 2005 [18] Turkey	To differentiate between vital and necrotic pulp	Cross-sectional 93 teeth/97 patients aged 15–65 years (mean 33 years) in need of endodontic care because of caries: 41 molars, 43 premolars, 58 incisors. Exclusion criteria: teeth with periodontal disease, restoration, previous history of injury, anomalies, hypertension or cardiac pacemakers, routinely receiving analgesics and anti-depressants University clinic 43/93=necrotic 46%	_Clinical markers_ History of pain Caries removal without anaesthesia Sensitivity to probing Percussion Radiographic examination _Vitality tests_ Electric (Digitest Digital Vitality Tester, Parker Electronics) Cold (butan-propan gas) Repeated measurements of electric test Comparison with adja-cent or contra lateral sound tooth (n=49)	_Visual inspection of exposed pulp_ Dichotomised classification: Bleeding=vital (n=50) No bleeding=non-vital (n=43) One observer and one evaluator No reliability test of radiographic assessment Blinding not reported _Outcome measures_ Proportions. SE, SP, PPV, NPV	Cold test was more reliable than electric test. The ability of electric and cold tests to identify vital teeth was higher than the ability to identify non-vital teeth Sensibility to probing: *SE (non-vital)= 1.0 (CI 0.92; 1.0), SP=0.76 (CI 0.63; 0.86) Sensibility on caries removal: SE (non-vital)= 1.0 *(CI 0.92; 1.0), SP=1.0 *(CI 0.93; 1.0) Electric test: SE (non-vital)= 0.84 *(CI 0.70; 0.92), SP=0.96 *(CI 0.87; 0.99) Cold test: SE (non-vital)= 0.93 *(CI 0.81; 0.98), SP=0.98 *(CI 0.87; 0.99) Percussion: SE (non-vital)= 0.19 (CI 0.11; 0.33), SP=0.81 (CI 0.67; 0.90) Widened lamina dura: SE (non-vital)= 1.0 *(CI 0.92; 1.0), SP=0.80 *(CI 0.67; 0.89)	Low Population characte-ristics poorly descri-bed One examiner, no reliability test of radio-graphic findings Pain reported as an index test but poorly described

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Table 3.1.1 continued

Author Year Reference Country	Aim	Study design Population characteristics Setting Disease prevalence	Index test	Reference test	Main findings (CI=95%)	Study quality Comments
Klausen et al 1985 [19] Denmark	To evaluate acute dental pain to differentiate between pulpitis, apical periodontitis (AP) and marginal periodontitis (MP)	Cross-sectional 74 patients with acute dental pain diagnosed with pulpitis, acute apical periodontitis (AP) associated with pulp necrosis or marginal periodontitis (MP) Exclusion criteria: Patients with dubious or mixed diagnosis excluded Emergency clinic Not applicable	<u>*Clinical markers*</u> Ability to point out the exact tooth Interference of pain with sleep Constant pain Tenderness to temperature changes, to chewing Tooth feels extruded Impaired mouth opening Reddening of the oral mucosa in the apical region Tenderness to palpation in apical region, to percussion, to digital pressure Tooth mobility Swelling of regional lymph nodes	<u>*Visual examination and probing of exposed pulp*</u> Classification: Vital or necrotic. Radiographic findings (normal, apical rarefaction, marginal bone loss) Condition of marginal periodontium: normal, deep pocket. Four diagnoses: 1. Apical periodontitis, (n=30) 2. Pulpitis (n=28) 3. MP (n=9) 4. Pulpo-periodontitis (n=7) excluded from analysis In cases of obvious diagnosis of MP no pulp vitality test Two examiners. One collected clinical data, the other established the diagnoses Blinding to index tests not reported <u>*Outcome measures*</u> SE, SP, odds ratio (OR), discriminant analysis to analyse the value of combined symptoms No contingency tables	A combination of the signs and symptoms constant pain, tenderness to temperature changes, the tooth feels extruded, impaired mouth opening, tenderness to palpation in apical region, and mobility were good indicators to discriminate between the three diagnoses; 82% of the cases were correctly diagnosed No or limited differential diagnostic value of tenderness to sweet and sour, character of pain, duration of pain, fever, colour of tooth, tenderness to percussion, swelling of regional lymph node, patient ability to point out exact tooth Single signs/symptoms: Apical periodontitis: Constant pain: SE=0.82; SP=0.64 Tooth feels extruded: SE=0.65; SP=0.75 Reddening of the oral mucosa in apical region: SE=0.67; SP=0.74 Pulpitis: Tenderness to temperature changes: SE=0.76; SP=0.72 Interference of pain with sleep: SE=0.65, SP=0.52 Odds ratio of apical periodontitis vs pulpitis: Constant pain: 10.6 Reddening of mucosa in the apical region: 23.6	Low Population characteristics poorly described Number and age of patients with the different symptoms not stated

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Table 3.1.1 continued

Author Year Reference Country	Aim	Study design Population characteristics Setting Disease prevalence	Index test	Reference test	Main findings (CI=95%)	Study quality Comments
Koch et al 1970 [20] Sweden	To differentiate between coronal and total pulpitis	Cross-sectional Population characteristics: 48 painful primary lower molars in an undefined number of patients. 46 molars with pain and pulp exposure, 2 with pulps covered by a layer of non-carious dentin Dental school clinic Total pulpitis: 20/48=42%	*Clinical markers of pulp status* Frequency, duration of tooth ache Character of bleeding at pulp exposure Thermal sensitivity Tenderness to percussion and pressure Gingival swelling and fistula Radiographic findings: widened periodontal membrane or more pronounced changes	*Histology following extraction* Dichotomised classification: 1. Cellular infiltration of the coronal pulp only 2. Cellular infiltration in one or more radicular pulps Number of observers, blinding to index tests not reported *Outcome measures* Proportions	Decision for or against pulpotomy on the basis of clinical findings correlated with the histological classification in terms of pulpotomy indicated in 88% of the cases *SE=0.90, SP=0.86	Low Population characteristics poorly described Work-up bias Unclear how results of index test related to reference test Threshold of reference test arbitrary, surrogate measures

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Table 3.1.1 continued

Author Year Reference Country	Aim	Study design Population characteristics Setting Disease prevalence	Index test	Reference test	Main findings (CI=95%)	Study quality Comments
Matsuo et al 1996 [21] Japan	To investigate preoperative clinical findings indicative of prognosis of pulp capping	Prospective study 44 teeth/38 patients (age 20–69 years) with carious exposure and without extensive pain Exclusion criteria: Severe damage to the pulp during excavation (n=3) University clinic No of operators not reported Not applicable	<u>*Clinical markers of pulp status*</u> History of pain (pain/no pain) Heat, cold test Percussion test Colour of dentine Hardness of dentine surrounding exposed pulp Diameter of pulp exposure Character of bleeding: 1. Slight=slight or overflowing, arrested within 30 seconds 2. Conspicuous=overflowing, not arrested within 30 seconds <u>*Vitality tests*</u> Electric (Dentotest) Cold (ethyl chloride) Heat (temporary stopping) Percussion	<u>*Success of treatment (pulp capping)*</u> Criteria of success: No clinical signs or symptoms of irreversible pulpitis, sensitive to electric test Follow-up: 3 months (n=44) 12 months (n=25) >12 months (n=19) Number of examiners, blinding to index test not reported <u>*Outcome measure*</u> Proportions	Character of bleeding was the only clinical marker that resulted in a statistically significant difference in success Successful outcome: Slight bleeding: 31/35=88.6% Conspicuous bleeding: 5/9=55.6% ($p<0.04$) *SE (conspicuous bleeding)=0.50 (CI 0.22; 0.79), SP=0.86 (CI 0.71; 0.94) Successful outcome: Hardness of dentin: Hard/medium: 35/42=83% Soft: 1/2=50% (NS) Diameter of pulp exposure: ≤0.5 mm: 16/19=86.7% 0.5–1 mm: 13/15=84.2% >1–2 mm: 7/9=77.8% (NS) Overall successful treatment after 3–18 months follow-up: 80–83%	Low Population characteristics poorly described Possible bias from surgical procedure Possible interactions between various preoperative symptoms/clinical findings not analysed Small sample Short follow-up in half of the sample

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Table 3.1.1 continued

Author Year Reference Country	**Aim**	**Study design Population characteristics Setting Disease prevalence**	**Index test**	**Reference test**	**Main findings (CI=95%)**	**Study quality Comments**
Olgart et al 1988 [22] Sweden	To differentiate between vital and non-vital pulp in traumatized young permanent anterior teeth	Cross-sectional/ longitudinal Sample I: 33 teeth/ 25 patients aged 7–20 years with a 1 year history of injury from trauma scheduled for endodontic treatment because of suspected pulp necrosis Electric pulp testing at two consecutive examinations 6–9 weeks apart Controls: 33 non-injured teeth Sample 2: 20 teeth/ 18 patients aged 7–16 years subjected to moderate trauma initially non-sensitive to electric pulp test with reasonable chance for pulp recovery These patients tested 3 and 6 weeks and every 3 months after trauma Non-vital: 37/53=70% (controls excluded)	*Vitality test* Laser Doppler Flowmetry (LDF)	*Visual examination and probing after pulp exposure* Classification: Necrotic (no bleeding) n=37 Vital (response to electric test and normal LDF-values) n=16 Blinding to index test, number of observers not reported *Outcome measures* Mean differences in LDF values between vital and necrotic pulps	LDF indicated recovering blood circulation in luxated teeth before they regained response to electric test Sample 1 (pulp necrosis): Low or zero flowmetric signal in 32/33 teeth with pulp necrosis; less than 10% in controls LDP signal synchronous with heartbeat in normal teeth but absent or weaker in necrotic teeth *SE (necrotic)= 0.88 (CI 0.73; 0.95), SP=1.0 (CI 0.90; 0.95) Sample 2 (non-sensitive teeth): 16/20 had normal LDF-values. All showed positive reaction to electric test 3 weeks–28 months after trauma Four teeth did not recover (necrotic and tested negative to electric pulp testing) 28 months after trauma	Low Potential work-up bias 11 of 20 teeth in sample 2 not subjected to reference test

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Table 3.1.1 continued

Author Year Reference Country	Aim	Study design Population characteristics Setting Disease prevalence	Index test	Reference test	Main findings (CI=95%)	Study quality Comments
Petersson et al 1999 [23] Sweden	To differentiate between vital and necrotic pulp	Cross-sectional Population charac-teristics: patients (21–79 years) scheduled for endo-dontic treatment and students with intact teeth Molars (n=28), premolars (n=36) and incisors (n=11) Sample 1: 59 teeth/56 patients. Sample 2 (controls): 16 teeth/9 students Dental school clinic Non-vital: 29/75=39% (Students' intact teeth excluded)	*Vitality tests* Electric (Analytic Technology) Cold (ethyl chloride) Heat (heated gutta-percha)	*Visual inspection after pulp exposure. No reference test for intact control teeth* Classification: Bleeding pulp=vital (n=46) No bleeding, pulp tissue destruction=non-vital (n=29) Number of examiners, blinding to index tests not reported *Outcome measures* Proportions, SE, SP, PPV, NPV	The probability of a non-sensitive reaction rep-resenting a non-vital pulp was similar for cold and electric tests (88–89%) but lower for heat tests (48%) The probability of a sensitive reaction representing a vital pulp was highest for cold tests (90%) and similar for electric and heat tests (83–84%) Calculations including sample 1 only (n=59) Electric test: SE (non-vital)= 0.72 *(CI 0.54; 0.85), SP=0.90 *(CI 0.74; 0.97) Cold test: SE (non-vital)= 0.83 *(CI 0.66; 0.92), SP=0.90 *(CI: 0.74; 0.97) Heat test: SE (non-vital)= 0.86 *(CI 0.69; 0.95), SP=0.57 *(CI 0.39; 0.73) Accuracy: Electric tests=81%, cold tests=86%, heat tests=71%	Low Population characte-ristics poorly descri-bed Work-up bias

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Table 3.1.1 continued

Author **Year** **Reference** **Country**	**Aim**	**Study design** **Population characteristics** **Setting** **Disease prevalence**	**Index test**	**Reference test**	**Main findings (CI=95%)**	**Study quality** **Comments**
Seltzer et al 1963 [24] USA	To study the correlation between clinical signs, tests and symptoms and the pathologic status of the pulp	Cross-sectional 166 teeth in an undefined number of patients scheduled for extraction because of tooth ache, orthodontic, periodontal, prosthetic reasons and full mouth extraction Not reported Irreversible pulpitis: 60/166=36% Necrotic: 24/166=14%	*Clinical markers of pulp status* Pain (presence and character) Percussion Radiographic signs Abnormal reaction to heat Abnormal reaction to cold *Vitality tests* Pain Percussion Electric (Burton vitalometer) Cold (ice or ethyl chloride) Heat (heated gutta-percha or ball burnisher) Heat and cold tests combined	*Histology following tooth extraction* Classification in 7 categories: A=Intact-non-inflamed (n=23) B=Atrophic (n=40) C=Intact pulp with scattered inflammatory cells (n=19) D=Chronic partial pulpitis with partial necrosis (n=24) E=Chronic total pulpitis with partial necrosis (n=14) F=Chronic total pulpitis (n=22) G=Total necrosis (n=22) Dichotomisation: A–D=Non-suppurative (n=106) E–G=Suppurative (n=60) Number of observers, blinding to index tests not reported *Outcome measures* Proportions	Pain severity reported or provoked by stimulus only partially related with inflammatory response Poor relationship between other indicators including response to pulp testing and pulp status Localized pulpitis (A–D) vs total pulpitis or necrosis (E–G): Presence/absence of pain: *SE (total pulpitis)= 0.65 (CI 0.53; 0.77), SP=0.76 CI 0.68; 0.85) Sensibility to percussion: *SE (total pulpitis)= 0.38 (CI 0.27; 0.0.5), SP=0.92 (CI 0.85; 0.96) Abnormal reaction to heat: *SE (total pulpitis)= 0.31 (CI 0.22; 0.40), SP (E–G)=0.84 (CI 0.71; 0.92) Abnormal reaction to cold: *SE (total pulpitis)= 0.23 (CI 0.16; 0.33), SP (E–G)=0.80 (CI 0.66; 0.89) Vital vs necrotic pulp: Presence/absence of pain: *SE (necrotic)= 0.36 (CI 0.28; 0.44), SP=0.46 (CI 0.28; 0.65)	Low Population characteristics poorly described Threshold of reference tests arbitrary, surrogate measure

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Table 3.1.1 continued

Author Year Reference Country	Aim	Study design Population characteristics Setting Disease prevalence	Index test	Reference test	Main findings (CI=95%)	Study quality Comments
Seltzer et al 1963 [24] USA					Sensibility to percussion: *SE (necrotic)= 0.38 (CI 0.21; 0.57), SP=0.84 (CI 0.77; 0.89) Electric pulp test: *SE (necrotic)= 0.72 (CI 0.49; 0.88), SP=0.92 (CI 0.85; 0.96) Response to cold: *SE (necrotic)= 0.89 (CI 0.67; 0.97), SP=0.24 (CI 0.17; 0.32) Response to heat: *SE (necrotic)= 0.94 (CI 0.74; 0.99), SP=0.29 (CI 0.22; 0.38) Response to heat and cold: *SE (necrotic)= 0.78 (CI 0.55; 0.91), SP=0.86 (CI 0.79; 0.91)	

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Table 3.1.1 continued

Author Year Reference Country	Aim	Study design Population characteristics Setting Disease prevalence	Index test	Reference test	Main findings (CI=95%)	Study quality Comments
Tyldesley et al 1970 [25] United Kingdom	To study the relationship between the pathological condition of the pulp and pain	Cross-sectional 142 teeth scheduled for extraction in an undefined number of patients presenting with toothache Not reported Generalised pulpitis: 101/142=71% Necrotic: 18/142=13%	*Clinical markers of pulp status* Character of pain Heat and cold tests Percussion tests *Vitality tests* Cold Heat Percussion	*Histology following extraction* Classification: A. Normal (n=12) B. Hyperaemic (n=4) C. Acute localised pulpitis (n=25) D. Acute generalised pulpitis (n=35) E. Acute with chronic pulpitis (n=15) F. Chronic pulpitis (n=19) G. Degeneration (n=14) H. Necrosis (n=18) Number of examiners not reported. Blinding to index tests *Outcome measures* Proportions	No clear association between clinical symptoms and histological findings Localised pulpitis (A–C) vs generalised pulpitis/necrosis (D–H): Pain: Mild/severe: *SE (generalised pulpitis)= 0.68 (CI 0.59; 0.77), SP=0.41 (CI 0.28; 0.57) Intermittent/constant: *SE (generalised pulpitis)= 0.37 (CI 0.28; 0.46), SP=0.61(CI 0.46; 0.74) Cold: *SE (generalised pulpitis)= 0.92 (CI 0.85; 0.96), SP=0.12 (CI 0.05; 0.26) Heat: *SE (generalised pulpitis)= 0.92 (CI 0.86; 0.97), SP=0.02 (CI 0.04; 0.13) Percussion: *SE (generalised pulpitis)=0.16 (CI 0.10; 0.24), SP=0.93 (CI 0.81; 0.98) Vital vs necrotic: Cold: *SE (necrotic)= 0.94 (CI 0.72; 0.99), SP=0.10 (CI 0.06; 0.16) Heat: *SE (necrotic)= 0.89 (CI 0.67; 0.97), SP=0.05 (CI 0.02; 0.05) Percussion: *SE (necrotic)= 0.28 (CI 0.13; 0.51), SP=0.89 (CI 0.82; 0.93)	Low Population characteristics poorly described Work-up bias

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Table 3.1.1 continued

Author Year Reference Country	Aim	Study design Population characteristics Setting Disease prevalence	Index test	Reference test	Main findings (CI=95%)	Study quality Comments
Weisleder et al 2009 [26] USA	To assess the validity of two cold tests and electric pulp tests separate and combined by using direct visual inspection as reference standard	Cross-sectional 150 teeth/150 individuals (18–76 years) undergoing endodontic treatment University clinic Necrotic: 64/150=43%	*Vitality tests* Electric (Analytic Technology) Cold (carbon dioxide or Endo-ice)	*Visual inspection after pulp exposure* Classification: Bleeding pulp=vital (n=64) No bleeding, bleeding in apical part only= necrotic (n=86) Number of examiners, blinding to index tests not reported *Outcome measures* Proportions, SE, SP, PPV, NPV	The three tests combined gave the best accuracy: 97% of teeth responding to all three tests contained vital pulps, whereas 90% of teeth that failed to respond contained necrotic pulps All three tests combined: SE (necrotic)= 0.96 *(CI 0.86; 0.99), SP=0.92 (CI 0.84; 0.96) Electric test: SE (necrotic)= 0.75 *(CI 0.63; 0.84), SP=0. 92 (CI 0.84; 0.96) Cold test (Endo-ice): SE (necrotic)= 0.92 *(CI 0.83; 0.97), SP=0.76 (CI 0.66; 0.83) Cold test (carbon dioxide): SE (necrotic)= 0.89 *(CI 0.79; 0.95), SP=0.76 (CI 0.66; 0.83)	Low Population characteristics poorly described Work-up bias

* = Calculations not reported by the author(s).

CI = Confidence interval; LDF = Laser Doppler Flowmetry; n = Number; NS = Not statistically significant; NPV = Negative predictive value; PPV = Positive predictive value; SE = Sensitivity; SP = Specificity

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3.2 Radiologic diagnosis of the periapical tissues

Background

Radiographic examination is an essential complement to clinical examination for diagnosis of endodontic conditions. The altered appearance of the bone tissue around the root apex is a particularly important indicator of an extensively inflamed or necrotic infected pulp. Radiographic examination is also used as an aid during endodontic treatment and to evaluate the treatment result.

Changes to the bone tissue around the root apex (periapical changes) may appear on a radiograph as increased bone density (sclerosis) or as destruction of bone tissue (periapical bone destruction). Both conditions can represent inflammatory changes in response to an infected pulp. Apical periodontitis is diagnosed by radiographic evidence of periapical bone loss, in combination with clinical symptoms from periradicular tissue and/or the absence of a positive response by the pulp to sensibility testing.

Figure 3.2.1 *Intra-oral radiograph of an maxillary right anterior tooth. The tooth is a bridge abutment. The arrow indicates a radiolucent (dark) area signifying bone destruction as a consequence of apical periodontitis.*

The potential of a radiograph to disclose periapical bone destruction depends on several factors. The size and location of the bone destruction are important characteristics and in fact determine whether the lesion will be detectable by radiography at all. Conventional intra-oral radiographic examination is the most common technique (Figure 3.2.1). While film radiography has been used for many years, digital techniques are becom-ing increasingly common in dental practice. Another technique, called cone beam computed tomography (CBCT), was developed during the 1990's (Figure 3.2.2) [1,2]. A project called SEDENTEXCT is currently underway within EU, to evaluate, among other factors, the accuracy of CBCT [3].

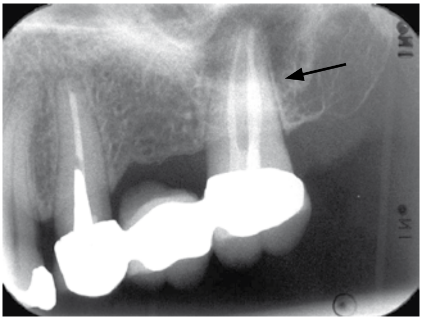
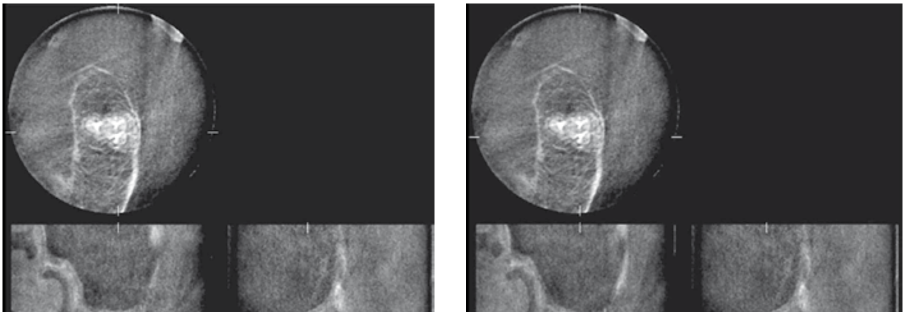


Figure 3.2.2 *Intra-oral radiograph of the left side of the upper jaw. A radiolucent (dark) area can be seen around the root tips of the root-filled molar tooth. The question is whether the area depicted is a normal extension of the maxillary sinus or periapical bone destruction. CBCT images (below) show normal bone structure at the root apices. The radiolucent area is a normal extension of the maxillary sinus.*



Conditions other than endodontic conditions can also give rise to destruction of perapical bone, e.g. various cysts and tumours. Periapical biopsies reveal however, that inflammatory processes of endodontic origin (granulomas and radicular cysts) predominate (>90 per cent) [4]. A controversial issue of long standing is to what extent the characteristic features of the bone destruction can provide information about the type of inflammatory change. The potential to determine cystic formation from the radiographic appearance of the lesion has long been in focus because under certain conditions, surgical treatment of a radicular cyst is preferable to conventional endodontic treatment. Another uncertainty for the clinician is interpretation of changes in the periapical bone tissue around root-filled teeth: whether the area is healing, or whether the endodontic treatment has failed. Repeated radiographic examination can provide information about whether the periapical bone destruction has increased or decreased in size and thus provide some guidance. In other cases the healing process is slow and a long follow-up period is necessary to determine whether the treatment has had the desired effect. There are also cases in which an apical periodontitis heals by formation of fibrous connective tissue instead of bone. Such scar tissue formation has however, a characteristic appearance and occurs mostly following surgery in the periapical region [6].

Methods for analysis of radiographs

Intra-oral radiographic examination is used as a diagnostic aid to study healing of bone or the development of bone destruction after endodontic treatment. For more accurate assessment, the pre- and post treatment radiographs should be taken with identical projections. It is also important that factors which influence darkness and contrast are kept constant. Treatment studies in which the radiographic technique has shortcomings are of doubtful scientific value. Subtraction radiography is a technique which can facilitate assessment of changes in the periapical bone tissue. In a few studies the technique has been applied to assess bone healing after endodontic treatment [7].

As with all diagnostic procedures, assessments vary among different examiners and within the same examiner on different occasions. These differences therefore have a pronounced influence on conclusions about the success or otherwise of endodontic treatment [8]. A method frequently used to reduce variation in radiographic diagnosis is to have several examiners, who are calibrated according to unambiguous criteria and reference illustrations [9]. However, one study found that a calibration programme for assessment of periradicular bone destruction was of limited benefit [10].

Strindberg's criteria have often been applied for assessment of outcome [11]. The criteria are based mainly on a description of changes in the radiographic appearance, with the outer limits being healed or not healed. In recent years, another system, "the periapical index" (PAI), has been used increasingly [12]. PAI also includes a description of the radiographic appearance on a 5-point scale, reference pictures and a calibration test comprising 100 radiographs. Observers who use PAI must exhibit a high level of agreement after calibration against the reference radiographs. Both the Strindberg criteria and PAI are based on intra-oral radiographs. It has been suggested that conventional intra-oral radiographs should be replaced with CBCT and PAI has been modified accordingly [13].

In the Consort Statement it is stated that for assessment of outcome in randomised controlled studies, an important aspect should be methods to improve the quality of effect measures; these methods should be well described [14]. Examples of factors intended to improve the quality are the use of multiple observations and training of the examiners [14]. In scientific studies it is therefore unacceptable for only a single observer to assess pre- and post treatment radiographs. Two or three experienced, calibrated observers are required and the level of agreement both between and within observers should be presented. The observers should not be aware which treatment the radiographs represent (blinded), nor should they be the same practitioners who carried out the treatment (independent observers).

Evidence-graded results

Accuracy of radiographic methods for identifying the presence or absence of changes in the periapical tissues

- There is insufficient scientific evidence from *in-vitro* studies to determine whether the diagnostic accuracy of digital radiography is as high as conventional film radiography in disclosing experimental periapical bone destruction (⊕○○○).

- The scientific evidence from *in-vitro* studies is insufficient to determine whether cone beam computed tomography (CBCT) has greater diagnostic accuracy than intra-oral radiography in disclosing experimental bone destruction (⊕○○○).

Radiographic methods for determining possible changes over time in the status of the periapical bone tissue

- The scientific evidence from *in-vitro* studies is insufficient to determine whether the subtraction technique has greater diagnostic accuracy than conventional radiography for disclosing minor areas of experimental periapical bone destruction (⊕○○○).

The accuracy of radiographic examination in differentially identifying various forms of periapical bone changes (various forms of apical periodontitis, cysts, healing with scar tissue formation)

- There is a lack of scientific evidence and therefore no conclusions can be drawn as to whether radiographic examination can differentiate various forms of inflammatory changes in the periapical bone tissue, including cyst formation and healing with scar tissue formation.

Periapical bone destruction and status of the pulp

- There is a lack of scientific evidence and therefore no conclusions can be drawn as to whether radiographic examination can provide information about the status of the pulp.

Questions addressed

This section addresses the accuracy of radiographic methods used for diagnosis of periapical bone changes. We also evaluate whether the radiographic appearance can provide information about the kind of condition. The specific questions to be addressed are:

- Which radiographic methods are available and how accurate are they for identifying the presence or absence respectively, of changes in the periapical tissues?
- Which of the radiographic methods is most accurate in determining whether changes have occurred in the status of the periapical bone tissues over time?
- Can the appearance of the periapical bone destruction provide accurate information on the type of condition (eg severity of inflammation, cyst or healing with scar tissue formation)?
- How well does an area of periapical bone destruction reflect the condition of the pulp in a tooth which has not been endodontically treated?

Inclusion criteria

Twenty-five articles met the inclusion criteria. These articles were then appraised with reference to conduct of the study and selection of subjects, size of sample, observer variables and outcome measure; study quality was graded as high, moderate or low (Appendix 2). The excluded articles, with the main reason for exclusion, are presented in Appendix 4.

Facts 3.2.1 Inclusion criteria.

Population	Patients who can be expected to undergo examination in a clinical setting Post-mortem studies
Index test	Various radiographic methods tested against a reference standard Method should be in clinical use in Sweden
Reference test	Histological investigation Bony cavity in skeletal material
Outcome	Sensitivity, specificity, likelihood ratio, odds ratio or ROC with or without Az (area under curve). Alternatively data to be reported so that sensitivity and specificity can be calculated

Results of literature search and selection of studies

In all, the searches yielded 493 articles, of which 109 were ordered in full-text versions. The basis of the selection was that the studies concerned methods which were relevant to the questions being addressed, ie studies or assessments of the value of radiographic methods applied for assessment of changes in periapical bone. Animal studies were excluded. A manual search of the reference lists of published articles yielded a further 60 articles to be read in full-text. Searches were also made of the reference lists of review articles. Systematic review articles have been included. The final scrutiny comprised a total of 169 full-text articles. See flow diagram in Figure 3.2.1.

Description of studies and results

The 25 articles which were included are presented in Table 3.2.5 [15–39]. Of these, none was assessed as high quality, 10 are of moderate quality [15,19,20,24,26–28,32,35,36] and 15 are of low quality [16–18,21–23, 25,29–31,33,34,37–39].

Which radiographic methods are available and how accurate are these methods for identifying the presence or absence respectively, of changes in the periapical tissues?

The question was addressed in 19 articles, of which ten were of moderate quality and nine of low quality [15,16,19–22,24,26–29,31,32,34–39]. In seven of the articles of moderate quality the material was obtained from the lower jaws of skeletal material or cadavers [15,19,26–28,32,35]. Generally, the reference method comprised drilling a hole of varying size into the bone tissue at the root tips, mostly in the premolar and molar regions [15,26–28]. In one article of moderate quality material was obtained from cadavers (upper and lower jaws) [24] and two were clinical studies [20,36].

Four articles of moderate quality compared the diagnostic accuracy of conventional intra-oral film radiography and digital radiography with either storage phosphor plates (Table 3.2.1) [15,24] or sensors (Table 3.2.2) [27,28].

Table 3.2.1 *Accuracy of conventional film radiography and digital radiography with storage phosphor plate, for diagnosis of small periapical bone lesions.*

Material/ reference test Index test	**Number of jaws/ type of lesion**	**Number of obser-vations/ observers**	**Sensi-tivity/ PPV**	**Speci-ficity/ NPV**	**ROC-technique P(A), Az or other analysis**
Lower jaw, molars, autopsy [15]/ storage phosphor plate and film	8/19 roots/ drilled holes of 4 different depths	116 images/ 8 observers	–	–	ANOVA Storage phosphor plate and film comparable
Lower jaw, Upper jaw, autopsy histology [24]/ storage phosphor plate and film	100/ 50 teeth upper jaw, 50 lower jaw, histology	300 images/ 3 observers	–	–	Az Storage phosphor plate: 0.74–0.88 D-film: 0.80–0.91 E-film: 0.75–0.88

Az = Area under curve; NPV = Negative predictive value; P(A) = Area under ROC; PPV = Positive predictive value; ROC = Receiver operating carachteristics

Table 3.2.2 *Accuracy of conventional film technique and digital technique with a sensor, for diagnosis of minor periapical bone lesions.*

Material/ reference test Index test	**Number of jaws/ type of lesion**	**Number of observations/ observers**	**Sensitivity/ PPV**	**Specificity/ NPV**	**ROC-technique P(A), Az or other analysis**
Lower jaw skeleton, premolars, molars [28]/CCD sensor and film	6/drilled lesions 1 mm, 3 mm, 5 mm	20 images with lesions, 16 images without lesions/ 7 observers	–	–	<u>*Mean value P(A)*</u> Film: 0.79 Sensor: 0.75 <u>*Az*</u> Film: 0.84 Sensor: 0.79
Lower jaw skeleton, premolars, molars [27]/CCD sensor image processing	6/drilled lesions 1 to 5 mm	293 observations/ 7 observers	–	–	<u>*Mean value P(A)*</u> Sensor original: 0.75 Image processing: 0.75 <u>*Az*</u> Sensor original: 0.79 Image processing: 0.79

Az = Area under curve; CCD = Charge coupled device; NPV = Negative predictive value; P(A) = Area under ROC; PPV = Positive predictive value; ROC = Receiver operating carachteristics

All the studies showed that digital radiography had the same diagnostic accuracy as film radiography regardless of which digital technique was applied. Two of the studies also showed that digital image processing did not improve the diagnostic accuracy [15,28]. In a clinical study, periapical and panoramic radiographs were compared using CBCT as the reference method (Table 3.2.3) [20].

Table 3.2.3 *Accuracy of conventional film technique, digital technique and CBCT, for diagnosis of periapical bone lesions.*

Material/ Reference test Index test	**Number of jaws/ type of lesion**	**Number of observations/ observers**	**Sensi-tivity/ PPV**	**Speci-ficity/ NPV**	**ROC-technique P(A), Az or other analysis**
Clinical study [36]/CBCT cf periapical radiographs storage phosphor plates	50 patients/ teeth which had under-gone apico-ectomy	50 patients/ teeth which had undergone apicoectomy			After 1 week a bone defect was detect-able by both methods. After *12 months 28% more bone defects were detected by CBCT than on periapical radiographs, but in 5% of cases a bone defect was detected only on the periapical radiographs
Clinical study [20]/CBCT cf panoramic and periapical film	888 patients/ PAI	1 508 teeth 3 observers	Periapical mean value: 0.55/0.98 Panora-mic mean value: 0.28/0.99	Periapical mean value: 1/0.38 CBCT mean value: 1/1	–
Lower jaw skeleton Molars [32]/ CBCT, CCD-sensor	6 lesions drilled 2 mm and 4 mm	10 first molars/ 6 observers	Periapical mean value 0.25/1 CBCT mean value 1/1	Periapical Mean value: 1/0.38 CBCT Mean value: 1/1	–

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Table 3.2.3 continued

Material/ Reference test Index test	Number of jaws/ type of lesion	Number of observations/ observers	Sensitivity/ PPV	Specificity/ NPV	ROC-technique P(A), Az or other analysis
Lower jaw skeleton, premolars [35]/CBCT, intra-oral film and storage phosphor plate	12 acid-etched lesions 0.1, 1.5 and 2 hr	924 images/252 periapical area/ 6 observers	1 hr Film 0.68 LR+ 1.41 Storage phosphor plate 0.73 LR+ 2.19 CBCT 0.83 LR+ 2.54	1 hr Film 0.52 LR– 0.62 Storage phosphor plate 0.67 LR– 0.40 CBCT 0.71 LR– 0.25	1 hr Film mean value Az 0.65 Storage phosphor plate mean value Az 0.71 CBCT mean value Az 0.83

Az = Area under curve; CBCT = Cone beam computed tomography; CCD = Charge coupled device; LR = Likelihood ratio; NPV = Negative predictive value; PPV = Positive predictive value; ROC = Receiver operating carachteristics

The mean sensitivity for all tooth groups was 0.55 for periapical radiographs and 0.28 for panoramic radiographs, while the corresponding mean specificities were 0.98 and 1.00, respectively. The positive predictive value for periapical radiographs was 0.98 and for panoramic radiographs 0.99. The corresponding negative predictive values were 0.55 and 0.44, respectively. In one study there was substantial inter-observer variation, of similar magnitude with respect to both film technique and digital imaging [15].

The diagnostic accuracy of CBCT and intra-oral radiographs has been compared in two in-vitro studies of moderate quality (Table 3.2.3) [32,35]. Both studies used lower jaws from skeletons. Compared to intra-oral radiographs, CBCT had higher sensitivity, specificity and Az values for ROC-analysis. These findings are supported by the results of clinical studies in which more periapical bone destruction was detected by CBCT than by intra-oral radiography [31,36] (low respectively moderate quality). Inter-observer variation was also lower for CBCT than for conventional radiography [32,35,36].

Which radiographic method is most accurate in detecting changes in periapical bone status over time?

Two in-vitro studies of moderate quality compared conventional radiography with subtraction radiography for detecting periapical lesions between two examinations (Table 3.2.4) [19,26]. In both studies, the diagnostic accuracy was improved when the subtraction technique was applied to small bone lesions. There was also less interobserver variation with the subtraction technique [26].

Table 3.2.4 *Accuracy of subtraction radiography for diagnosis of minor periapical bone lesions, in-vitro studies.*

Material/ Reference test Index test	Number of jaws/ type of lesion	Number of observa-tions/ observers	Sensitivity	Specificity	ROC-technique P(A)
Lower jaws from skeleton [19]; cf conventional and subtraction techniques	1/6/22 "bone chips" of varying weight	79 images with 234 sites/4	Conventional mean value: 57.4 Subtraction mean value: 88.1	Conventional mean value: 98.0 Subtraction mean value: 88.8	
Lower jaws from skeleton [26]; cf conventional and subtraction techniques	6/26/drilled holes of varying depths	26 pairs of images/10	–	–	At depths <1 mm mean value: Conventional: 0.601 Subtraction: 0.819 Depths <2 mm Conventional: 0.767 Subtraction: 0.955

Can the radiographic appearance of periapical bone destruction provide accurate diagnostic information about different conditions (eg severity of inflammation, cyst or healing with scar tissue formation)?

In a doctoral dissertation (low quality), the radiographic appearance of periapical tissue was compared with biopsies [17]. The results indicated that using radiographs, it was possible to differentiate between normal states and inflammation of varying severity. The likelihood of a correct diagnosis improved if more than one radiograph was taken [18]. However, the studies were based on a limited patient spectrum and the material was restricted to upper anterior teeth. A similar study of root-filled teeth found that if periapical bone destruction could be detected radiographically, histological examination always confirmed the presence of inflammation (low quality) [23]. Two other studies of low quality showed that the radiographic appearance did not provide reliable guidance in differentiating the histological diagnoses of granuloma or cyst [30,33].

How well does periapical bone destruction reflect the status of the pulp in a non-root-treated tooth?

An article of low quality investigated this question [25]. The results showed that radiographic anomalies such as changes in the shape and width of the periodontal space, and disruption of continuity of the lamina dura were associated with a pathologically altered dental pulp.

Discussion

A complicating factor in studies of the diagnostic accuracy of radiographic techniques to demonstrate periapical bone destruction is the difficulty of finding a relevant reference method. To circumvent this problem various in-vitro methods have been developed. Skeletal material has usually been used and defects created by drilling holes into the bone, or by applying acid to the bone for varying periods of time. When a hole is drilled, the size of the bone defect is known. However, the method does not reproduce the relatively diffuse borders seen in biological bone destruction. Acid etching results in an appearance more closely resembling the appearance of natural bone destruction, but the size of the defect achieved by etching is difficult to estimate. Thus, studies based on the acid-etch method usually report the duration of application of the acid as a measure of the effect of etching.

Biopsies from patients and tissue samples prepared from cadavers have been used to study the severity of inflammation and various pathological changes in relation to the radiographic appearance. All these studies are of low quality, because interpretation of the histological sections has been limited to one observer and moreover the material has not been representative. Conventional radiography is probably not sensitive enough to provide information about different conditions and the status of the pulp of a non-root-filled tooth. Four excluded articles evaluated ultrasound as a method for differential diagnosis of granulomas and cysts [40–43]. The results are promising but the scientific support is insufficient for evaluation of the diagnostic accuracy of this method. The method is not available to dentists in Sweden.

It is important to note that all studies of moderate quality in this review were conducted in-vitro and the evidence is therefore of limited value. Moreover the studies have generally been limited to the lower jaws of human skeletons. With respect to diagnostic accuracy, the results cannot be applied directly to the clinical setting. The low values on sensitivity probably reflect the difficulty in detecting small periapical bone lesions. If, however, an area of bone destruction can be detected, this is a finding with high positive predictive value.

The high values for specificity show that the radiographic methods evaluated accurately disclose teeth with normal periapical conditions. The low negative predictive values indicate however, that there is a risk of underdiagnosis. The prevalence of periapical bone destruction in the cited studies is higher than in the general population. It should be noted that in populations with low prevalence, the negative predictive value increases (lower risk of underdiagnosis) while the positive predictive value decreases (greater risk of overdiagnosis).

Early inflammation in the bone tissue is clearly difficult to diagnose on intra-oral radiographs. In studies conducted in the 1960's it was shown that it is also difficult to detect bone lesions which are limited to the trabecular bone in the mandibular molar region [44,45]. It is only once the cortical bone has been eroded that the bone destruction is obvious [45]. Whether this is in fact the case has been questioned in more recent literature and it is likely that the results have been influenced by the region which was examined [46].

Radiographically detectable bone destruction is usually more extensive in reality than it appears on the radiograph [46]. Radiographic projection is also important. Taking several radiographs with different projections improves the potential for a correct diagnosis compared with taking only one radiograph [18]. For follow-up of endodontic treatment, subtraction radiography has a greater potential to disclose changes in the size of areas of bone destruction between two examinations than conventional visual assessment of the radiograph [19,26]. However, subtraction radiography has been applied in only a limited number of treatment studies because the technique is time-consuming and complicated.

CBCT has attracted much attention in recent years. Our review of the literature shows shortcomings in documentation of the diagnostic accuracy of this method. Detailed *in-vitro* studies on skeletal material indicate that the method has higher sensitivity and specificity than intra-oral peria-pical radiography. The higher sensitivity is confirmed in clinical studies, but because it has not been measured against a reliable reference method it is difficult to estimate the risks of both false positive and false negative responses. The advantage of the method is that it is relatively easy to apply. Moreover it provides a three-dimensional image of the area of interest, which can be an advantage when assessing the condition of multi-rooted teeth. A literature review conducted by SEDENTEXCT recommends that CBCT should not be used routinely for endodontic diagnosis because the diagnostic accuracy for examination of periapical bone destruction has yet to be established [3]. A recently published article addressed the uncertainty of assessing an endodontic treatment in follow-up studies where conventional intra-oral radiographic technique has been used [47]. It is suggested that CBCT should be used instead, because of the risk that conventional radiography has overestimated the success rate of endodontic treatment in previous studies. Meanwhile there is also a risk that CBCT overestimates the frequency of unsuccessful treatment because healing of periapical bone destruction may take longer than previously assumed. For example, at one-year post endodontic treatment follow-up, CBCT can show persisting bone destruction, while a conventional intra-oral radiograph shows healing [36]. This question is highly topical and should be addressed, in order to provide guidelines for the direction of future research. The major disadvantages of CBCT are greater cost and a potentially higher radiation dose, depending on the size of the radiation field being used.

Risks associated with radiographic examination

During endodontic treatment the dentist needs to take several radiographs, both prior to treatment, for diagnosis, and during root treatment, to evaluate the treatment steps. A radiograph is also taken after completion of the root filling, to check that the instrumented canal has been well obturated. Moreover at follow-up appointments, radiographs are taken to determine whether periapical bone destruction has healed, or if a lesion has developed. When the treatment results are doubtful, follow-up radiographs may be necessary for several years [48]. Thus endodontic treatment can require five to seven radiographs. The radiation dose is however small. Depending on the technique, it is estimated that intra-oral radiographic examination gives around 0.01–0.02 mSv (milliSievert) per film. For digital radiography using sensors the dose is 50% less and with an optimal technique is 0.005 mSv per image [49]. The risk of developing cancer following exposure to radiation associated with endodontic treatment of a tooth must be regarded as almost negligible, particularly as it is no greater than the risk associated with ten days' exposure to natural background radiation [50].

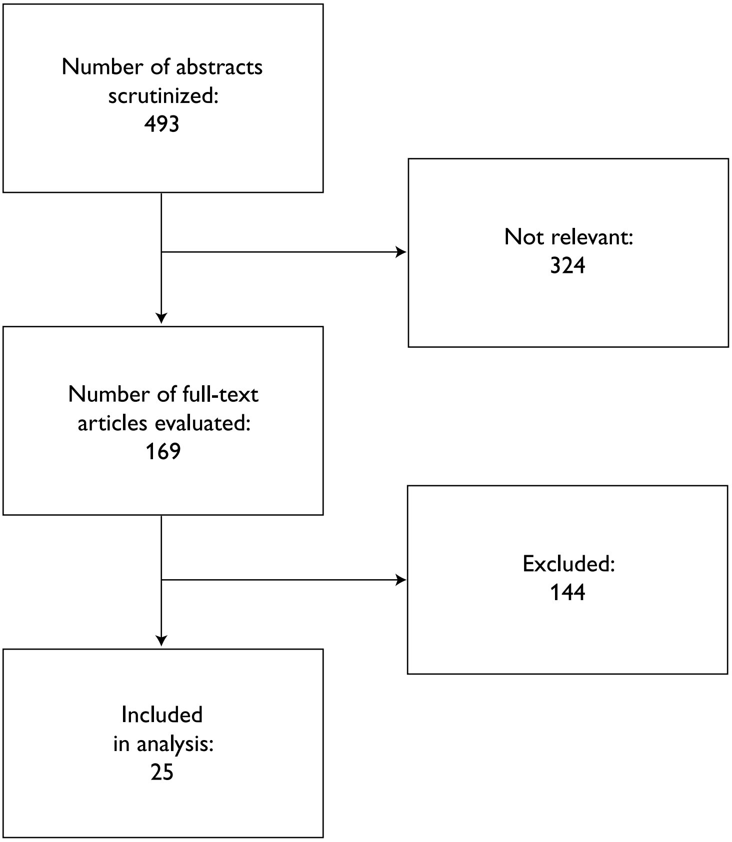

Figure 3.2.1 *Flow diagram of literature search.*

Table 3.2.5 *Radiographic studies.*

Author Year Reference Country	Aim	Study design Population characteristics	Index test	Reference test	Main findings	Study quality Comments
Barbat et al 1998 [15] Australia	Compare film with storage phosphor plates in detecting simulated apical radiolucencies	Post-mortem mandibles 8 mandibular segments, 19 roots from molars, 4 normal controls and 15 roots bone removal 116 images	1. Film, Kodak Ultraspeed 2. Storage phosphor plates (Digora, dose reduction 62%) with 3 digital image configurations (greyscale, inverse, colour intensity mapping) Plexiglass device 6 endodontists and 2 endodontic graduate students, 2 readings Darkened room	Artificial lesions in mandibles Radiographs taken: 1. Preoperatively 2. After artificial removal of lamina dura 3. 5 mm lesion in cancellous bone 4. As 3 and 1 mm lesion cortical bone involvement 5-point confidence scale that lesion was present or not 3-way ANOVA	Film radiographs and greyscale digital images were comparable Digital imaging did not enhance detectability of lesions Lesions were readily detectable after removal of lamina dura only Substantial interobserver variation Intraobserver agreement around 90%	Moderate Difficult to analyse the results
Holtzmann et al 1998 [24] USA	Compare D- and E-speed films and storage phosphor plates in detection of periradicular bone loss in cadaver jaws	Post-mortem 28 cadavers, 100 teeth, 50 maxillary and 50 mandibular, 48 molars, 39 premolars, 13 anterior teeth. 4 samples lost. 19 of 96 samples had pathosis	1. Film, D- and E-speed 2. Storage phosphor plates (Digora) Soft tissue filter 4 endodontists in a dimly lit room 1 observer was discarded (degenerated data)	Histologic examination. Gold standard determined by Delphi panel. True pathosis or normality unanimously determined by two panel members 5-graded scale for periradicular radiolucency ROC-analysis	No significant differences between D- and E-speed films and storage phosphor plates (Az values between 0.74–0.91, SD 0.05–0.08) The accurate histologic condition could not be predicted by the diagnostic tests	Moderate Histological diagnosis not described in detail Relatively few roots with inflammation
Kullendorff et al 1996 [28] Sweden	Compare CCD-images with film in detection of artificial periapical bone lesions; and high- and low-contrast resolution of the systems	Six dry mandibles 20 images of roots with lesions of different sizes and 16 images of roots without a lesion	1. E-speed film 2. CCD-sensor (Visualix/VIXA) Soft tissue filter 7 observers Subdued light	1. Line-pair plate – MTF. 2. Contrast detail phantom – low-contrast resolution 3. Dry mandibles Artificial lesions 1 mm, 3 mm and 5 mm 5-point rating scale for lesion present or not ROC-analysis	1. Film superior high-contrast resolution 2. CCD and film comparable low-contrast resolution, except for smallest objects 3. No significant difference in diagnostic accuracy between film and CCD in detecting periapical lesions. Mean P(A) and Az 0.79 and 0.75, respectively and mean Az 0.84 and 0.79 Range P(A): 0.72–0.92 film and 0.69–0.87 CCD	Moderate Findings applicable to mandibular teeth only

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***Table 3.2.5** continued*

Author Year Reference Country	Aim	Study design Population characteristics	Index test	Reference test	Main findings	Study quality Comments
Kullendorff et al 1996 [27] Sweden	Compare CCD-images with and without image processing for detection of artificial periapical bone lesions How did dentists use image-processing, was the performance influenced?	Six dry mandibles 20 images of roots with lesions of different sizes and 16 images of roots without a lesion	CCD-sensor (Visualix/VIXA) Soft tissue filter 1. High quality original greyscale images 2. The dentists were allowed to individually use image-processing functions. Changes noted 7 observers Subdued light	Dry mandibles. Artificial lesions made stepwise 1 mm to 5 mm at the apex of one molar and one premolar 5-point rating scale for lesion present or not. Improvements using the image processing functions were noted ROC-analysis	No difference in diagnostic accuracy between original digital images of high quality and image processed image Mean P(A) and Az 0.75 (SD 0.068) and 0.79, respectively for both original and processed images Contrast and brightness changes were preferred Observers reached different results of diagnostic accuracy, range P(A) 0.64–0.87	Moderate Findings applicable to mandibular teeth only
Kullendorff et al 1997 [29] Sweden	Clinically compare CCD-images (with and without image processing) with film, for detection of periapical bone lesions	Clinical study 40 recall patients after endodontic treatment and 10 patients referred for radiographs 59 roots, 14 with lesion and 45 without	1. E-speed film 2. CCD-sensor (Visualix/VIXA) with original images and image processed images 7 observers Subdued light	Reference standard decided by two observers. 5-point rating scale for lesion present or not ROC-analysis	Film radiography performed slightly better than CCD imaging for detection of periapical lesions Mean P(A) and Az for film 0.88 and 0.89, respectively, and for CCD 0.82 and 0.84 The observers' performance varied. Range P(A) film 0.78–0.95 and CCD 0.77–0.87. Image processing did not improve observer performance	Low Reference test questionable
Farman et al 1998 [21] USA	Compare film and CCD-sensor regarding observer accuracy in the estimation of the size of periapical radiolucencies	Clinical and radiological evaluation of size of periapical lesions 28 consecutive patients requiring periradicular surgery, 28 teeth diagnosed with periapical radiolucency	1. E-speed film 2. CCD-sensor (Visualix-2/Gendex) CCD-images unenhanced, contrast enhanced, or equalized 14 observers. 10 randomly selected images from each modality measured twice	Impression was taken of the periapical cavity after surgical removal of the soft tissue. The size of the impression was measured to 0.1 mm ANOVA	CCD-images with image equalization closest to "gold standard" and best observer agreement. Contrast-stretched and unenhanced images were less accurate; film consistently least accurate ($p<0.002$)	Low Patient spectrum not representative

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Table 3.2.5 continued

Author Year Reference Country	Aim	Study design Population characteristics	Index test	Reference test	Main findings	Study quality Comments
Christiansen et al 2009 [36] Denmark	Compare periapical radiography and CBCT for assessment of periapical bone defects	50 patients receiving periapical surgery (58 teeth, incisor, canine or premolar) Radiographs taken 1 week and 12 months post-operatively	1. Periapical radiographs, storage phosphor plates (Digora) 2. CBCT (NewTom 3G) 3. Observers assessed and measured the bone defects	Presence of bone defect 1 week and 12 months after periapical surgery Area of bone defect measured 1 week post-operatively	1 week post-operatively, all bone defects were detected with periapicals and CBCT 12 months post-operatively, CBCT detected 28% more defects than periapical radiographs, in 5% periapical radiographs showed defects, but CBCT not. The area of the defects was 10% smaller in periapical radiographs	Moderate No reference test to observations after 12 months
Estrela et al 2008 [20] Brazil	Determine accuracy of digital panoramic and periapical film radiographs compared to CBCT on detection of apical periodontitis clinically	Consecutive patients in one radiologic clinic, at least one tooth with history of endodontic infection 888 patients, 1 508 teeth in all regions, 94.5% endodontically treated. Lesion prevalence not known (CBCT apical periodontitis 964, normal 544)	1. Digital panoramic (Veraviewepocs, Morita) 2. Periapical film radiographs (F-speed) 3. Calibrated observers PAI-score (5 degrees) Inter-observer agreement by Kappa statistics in 10% of the sample. Kappa PAI for all methods range 0.89–1.00	Cone beam computed tomography (CBCT, Accuitomo MCT-1) 3 calibrated observers PAI-score (5 degrees) SE, SP, NPV, PPV, accuracy, ROC-analysis	Conventional methods underrate apical periodontitis. Overall SE 0.55 for periapical and 0.28 for panoramic radiography, SP range 0.96–1.00. Lowest SE for incisors (0.16) in panoramic radiography. PPV 0.96–1.00, NPV 0.35 panoramic incisors/molars to 0.65 periapicals canines Accuracy 0.70 for periapicals and 0.54 for panoramic radiography. CBCT gave higher PAI-scores than other methods	Moderate No reference test for CBCT
Patel et al 2009 [32] United Kingdom	Compare diagnostic accuracy of CBCT with periapical radiography (CCD-sensor) for the detection of artificial periapical bone defects	Dry mandibles 10 first molars on 6 partially dentate intact human dry mandibles. 4 teeth were not used. 6 molar teeth in human mandibles	1. CCD-sensor (Schick) intra-oral periapicals 2. CBCT scanner (Veraviewpocs) Soft tissue substitute 6 examiners Dimmed room Kappa: Inter-examiner reliability 0.35 intra-oral and 0.64 CBCT; Intra-examiner 0.51 intra-oral and 0.72 CBCT	Artificial lesions. 2 mm and 4 mm in cancellous bone at the base of the extraction sockets at the distal roots of the first molars 5-point confidence scale, lesion present, not present. SE, SP, PPV, NPV, ROC-analysis. Kappa observer agreement	CBCT superior to intra-oral radiography. Overall SE CCD-sensor 0.25 (SD 0.10) and CBCT 1.0 (p=0.026), regardless of lesion size. SP 1.0 both techniques. PPV 1 both techniques. NPV 0.384 (SD 0.02) CCD and 1 CBCT. ROC CCD radiographs Az 0.791 (SD 0.087), significantly lower than CBCT Az 1.000 (SD 0)	Moderate Findings applicable to mandibular teeth only

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***Table 3.2.5** continued*

Author Year Reference Country	Aim	Study design Population characteristics	Index test	Reference test	Main findings	Study quality Comments
Sogur et al 2009 [35] Turkey	Compare diagnostic accuracy of CBCT, storage phosphor plates and film for the detection of chemically created periapical lesions in dry skulls	Dry mandibles 12 dry human mandibles 924 images, 84 image plate/film periapical radiographs and 756 CBCT. Number of scored periapical areas was 252; 84 for each image modality	1. CBCT (Accuitomo 3DX, Morita) 2. Storage phosphor plates (Digora Optime, Soredex) 3. F-speed film (Insight, Kodak) Soft tissue filter 6 observers. Kappa ranged between slight and fair for phosphor plates and film, between fair and moderate for CBCT	Chemically created lesions in periapical areas of the first and/or second premolars. Radiographed after 0.1, 1.5 and 2 hours 5-graded scale presence/absence of lesions. SE, SP, PPV, NPV, ROC-analysis and Kappa. ANOVA statistics	Az values larger for CBCT than for intra-oral radiographs for all acid durations For 1 hour of acid duration a significant difference was found between CBCT (Az 0.83 SD 0.10) and film (Az 0.65 SD 0.08) (p=0.02) and between CBCT and phosphor plate (Az 0.71 SD 0.06) (p=0.043). For 1.5 hour a significant difference (p=0.006) between CBCT and phosphor plates For 2 hours acid duration no significant difference between the techniques (p>0.05). No difference was found between phosphor plates and film	Moderate Reference test not proven
Lofthag-Hansen et al 2007 [31] Sweden	Compare information obtained from CBCT and periapical film radiography	Clinical study 36 patients with a tooth presenting clinical or radiographic findings of a periapical lesion. Maxillary premolars or maxillary-mandibular first or second molars	1. Periapical film radiography (F-speed) 2. CBCT (3D Accuitomo) 3 specialists in oral radiology analysed all radiographs together. Consensus	None. Additional information from CBCT compared to intra-oral periapical radiographs was noted	Among 46 teeth, periapical radiographs and CBCT demonstrated lesions in 32 teeth; CBCT showed an additional 10 teeth with lesions On root level, 53 lesions were found with both techniques, and 33 more roots with lesions were found in CBCT	Low No reference test
Briseno Marroquin et al 1995 [16] Germany	Study how the visibility of artificial lesions was affected on film radiographs by size, region and projection	Post-mortem mandibles 6 macerated mandibles with incisors, premolars and molars 70 images. All teeth/roots had lesion preparation	Film radiographs taken ortho-radial, 25 degrees mesial- and distal-eccentric Soft tissue filter 10 dentists, 2 readings Observer crossed out if failed to reach a 90% agreement between 2 readings 6 observers	Stepwise enlargement of artificial lesions. No lesion, lesion limited to spongiosa, and with cortical erosion Lesion detectability. SE, SP	Overall SP 75%. Overall SE 59%. Region influenced detectability Lesions larger than 3 mm were usually detectable at mandibular incisors and premolars. Isolated spongiosa lesions at mandibular molars were generally not detectable. Angle projection not significant	Low Incomplete description of material

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***Table 3.2.5** continued*

Author Year Reference Country	Aim	Study design Population characteristics	Index test	Reference test	Main findings	Study quality Comments
Fuhrmann et al 1997 [22] Germany	Compare dental film radiographs with high resolution CT for identification of artificial bone defects between maxillary sinus and roots	Post-mortem study 21 dentate specimens of the posterior maxilla from 13 cadavers. 79 premolars and molars	1. Periapical film radiographs (E-speed) 2. CT scanner (Somatom Plus) 1 mm axial scans 2 observers. All registrations made twice	Artificial defects (n=40) of different sizes (1–2 mm) created in the cortex of the floor of the maxillary sinus above 23 premolars and molars. Histology. Soft tissue removed Identification of defects on a 3-point scale	None of the defects could be identified from the periapical film radiographs. CT revealed 30% clearly, 32.5% with difficulty and 37.5% could not be seen	Low No normal roots? No soft tissue
Rohlin et al 1989 [34] Sweden	Evaluate diagnostic accuracy of panoramic when compared with periapical radiography in the assessment of periapical bone tissue pathology	Clinical study 60 patients, 117 teeth with different periapical status in each anatomical region with 50% probability that a periapical lesion was present	1. Panoramic film radiography (OP5, Palomex) 2. Periapical film radiographs (E-speed) 5 oral radiologists reported twice about sclerotic and osteolytic lesions. 83% same diagnosis	"True pathology" based on the results of the simultaneous interpretation of both techniques and 5 observers. Follow-up examination of teeth with varying scores 5-point scale. ROC-analysis	No overall difference between panoramic and periapical radiography Mean P(A) periapicals 0.979 and panoramic 0.934. However, periapical radiography was superior for sclerotic lesions and for all lesions on maxillary premolars and mandibular molars; it was also superior for osteolytic lesions in premolars	Low Patient material not described and not representative Reference test doubtful
Dove et al 2000 [19] USA	Determine SE and SP of digital subtraction radiography (DSR) for detection of periapical and periodontal bone lesions with 2 different methods	One dry mandible with molars and premolars. 234 anatomical sites	1. Conventional film (E-speed) 2. Subtraction radiography (Electro Medical Systems DSR) Soft tissue filter X-ray source and film positions were varied. Digitized images 4 radiologists	Bone chips placed in 6 different locations Presence or absence of bone lesion. SE and SP. Paired student t-test	Mean SE and SP for digital subtraction radiography was 88% (SD 8) and 89% (SD 9), corresponding figures for conventional detection was 57% (SD 15) and 98% (SD 4). Significant difference in SE. DSR good even at disparate projection geometries	Moderate Findings applicable to mandibular teeth only

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Table 3.2.5 continued

Author Year Reference Country	Aim	Study design Population characteristics	Index test	Reference test	Main findings	Study quality Comments
Kullendorff et al 1988 [26] Sweden	Compare diagnostic performance of film radiographs and computer-assisted subtraction technique for detection of small periapical lesions	6 dry human mandibles 6 blocks containing a canine, 2 premolars and 2 molars. 13 lesions in cancellous bone and 13 included cortical bone	1. Periapical films exposed in a reproducible way 2. Radiographs were digitised and subtraction images produced 10 observers	Artificial periapical defects produced with 1 mm diameter. The depths were gradually increased by 0.5 mm. Bone loss measured with 125 I absorptiometry. 5-point rating scale for lesion present or not ROC-analysis	Subtraction technique good accuracy even for shallow lesions. Conventional radiography significantly inferior for lesions <2 mm (p<0.001) and for lesions confined to the cancellous bone (p<0.05) Wide range of diagnostic accuracy for the individual observer for lesions depths <1 mm, P(A) 0.477–0.932 for conventional technique, for subtraction less variation 0.786–0.918	Moderate Findings generalizable to posterior mandible region only
Tammisalo et al 1993 [37] Finland	Compare periapical film radiographs and detailed narrow-beam (DNB) radiography for detecting periapical bone lesions	Clinical study Panoramic radiographs of 282 consecutive patients assessed for periapical pathology, 155 had signs of periapical pathology and examined with periapical and DNB radiography 262 sites from 145 pairs of radiographs evaluated	1. Periapical film radiographs (E-speed) 2. DNB examinations (Scanora, Soredex) 4 sets of radiographs with different projections Stereoscopic viewing 5 observers. 2 readings. Significant interobserver variation	Two radiologists read all images simultaneously. In 7 cases with no agreement, additional tomography was made for final judgement Osteolysis, sclerosis and apical widening of the periodontal space were recorded. 5-point scale for lesion. ROC- and Kappa-analysis. SE, SP	No significant difference between the overall performance of DNB and periapical radiography for detection of periapical lesions All lesions/whole dentition: Periapical P(A) 0.872, DNB P(A) 0.942. No difference between regions. No difference in sensitivity or specificity	Low Reference test questionable Population not representative
Tammisalo et al 1995 [38] Finland	Compare diagnostic accuracy between perapical film radiography and detailed zonography for detection of periapical pathology	Clinical study 302 consecutive dentate patients with panoramic radiography. 170 dental areas in 167 patients with clinical or radiological signs of periapical pathology were selected from the panoramic radiographs by 5 radiologists. 259 periapical sites selected for comparison. Half healthy	1. Periapical film radiographs (E-speed) 2. Detailed zonography (Scanora, Soredex) 25 mm layer thickness 4 images with slightly different projections Stereoscopic viewing 5 observers. Half of the series was evaluated twice Interobserver variations similar for the techniques	Two radiologists reread all images contemporaneously. The result was the reference standard Osteolytic and sclerosis lesions of the periapical bone and apical widening of periodontal ligament space were recorded ROC- and Kappa-analysis. SE, SP	No significant difference in overall or regional performance of periapical radiography, multiview and stereoscopic zonograms in the detection of periapical lesions using ROC SE for periapicals was 72%, multiview zonography 88% and stereoscopic zonography 85%. SP were 93%, 84% and 89%, respectively	Low Reference test questionable Population not representative

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Table 3.2.5 continued

Author Year Reference Country	Aim	Study design Population characteristics	Index test	Reference test	Main findings	Study quality Comments
Tammisalo et al 1996 [39] Finland	Evaluate the ability of detailed tomography and periapical film radiography to reveal periapical lesions	Clinical study 263 consecutive dentate patients with panoramic radiography. 182 dental areas in 177 patients with signs of pathology were selected for tomography and periapical radiography. 6 areas were excluded 171 pairs of radiographs with 243 periapical sites	1. Periapical film radiographs (E-speed) 2. Tomography (Scanora, Soredex) resulting in four 8 mm thick cuts 5 observers Half of the tomograms reassessed 2 months later. Significant inter-observer variation. Intra-observer Kappa values for 5-category rating varied between 0.51–0.70	Two radiologists reread all images simultaneously to establish a reference standard. Presence or absence of osteolysis or sclerosis of periapical bone, apical widening of the periodontal ligament space 5-category confidence rating. ROC and Kappa-analysis. SE, SP	Overall and regional ROC values revealed no significant differences between detailed tomography P(A) 0.925 and periapical radiography P(A) 0.889. SE for tomography was higher, especially in posterior regions	Low Reference test questionable Population not representative
Brynolf et al 1967 (thesis) [17] Sweden	Can intact and damaged periapical areas be distinguished from each other roentgenologically? Is it possible to distinguish types and stages of lesions in damaged periapical areas?	Post-mortem histology and radiology 142 subjects, 320 periapical biopsy specimens upper incisors, 292 teeth radiographed. 93 normal	Periapical film (Radia-Tized) radiographs, short cone bisecting angle technique and tubular diaphragm Radiology 1 or 2 observers Darkened room	Histology of periapical tissue specimens. One observer (same for histology and radiography) Per cent agreement histologic and roentgenological features	Possible to radiographically distinguish histologically normal from pathological, and to classify different periapical lesions Parameters: 1. Trabecular pattern 2. Shape and width of increased radiopacity and/or periapical radiolucency 3. Differentiation in shape of the periodontal space or periapical radiolucency	Low Index test and reference test not independent Patient spectrum not representative One observer of reference test

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***Table 3.2.5** continued*

Author Year Reference Country	Aim	Study design Population characteristics	Index test	Reference test	Main findings	Study quality Comments
Brynolf 1970 [18] Sweden	How reliable is information obtained from one, two or more roentgenograms?	Post-mortem histology and radiology 212 maxillary incisors, 101 normal and 111 pathologic	Periapical film (Radia-Tized) radiographs, short cone bisecting angle technique, ortho-radial, eccentric views; and tubular diaphragm 1. Ortho-radial 2. Ortho-radial + eccentric 3. Ortho-radial + tubular diaphragm 4. 2+3 5. Repeated 1 6. Repeated 4 1 observer	Histology of periapical tissue specimens. One observer (same for histology and radiography) Per cent agreement histological and roentgenological features	Number of correct diagnoses correlated with the number of roentgenograms Calculated SP for one radiograph 0.69, for two 0.76, corresponding SE 0.56 and 0.64, P+ 0.67 and 0.75, P– 0.59 and 0.66 95% CI for one radiograph, SP 0.60–0.78, SE 0.47–0.65 For two radiographs, SP 0.55–0.73, SE 0.68–0.85	Low One non-independent observer Unclear if index- and reference tests were independent
Green et al 1997 [23] USA	Compare radiographic and histologic appearance of periapical tissue lesions	Post-mortem study Maxillary and mandibular specimens. Teeth with root canal treatment were identified. For comparison teeth with normal radiographic appearance were used. 29 root canal treated teeth, 10 normal	Periapical radiographs Two trained observers who agreed on the observation Presence or absence of periapical radiolucency in radiographs	Histologic examination uninflamed or inflamed One observer	10 specimens with periapical radiolucency all inflamed. 19 without periapical radiolucency, 5 inflamed and 14 uninflamed. 10 normal controls uninflamed Calculated SE 0.67, SP 1.00, PPV 1.00, NPV 0.74	Low Not representative material Incomplete description of radiographic technique
Linenberg et al 1964 [30] USA	Compare clinical/ radiographic diagnosis with the microscopic diagnosis	Biopsies 110 periapical biopsy specimens from 68 healthy male basic recruits. Specimens from apices of non-restorable teeth. All teeth had areas of radiographic rarefaction	Complete mouth roentgenograms and clinical impression at surgery of periapical lesion 1 observer for clinical and radiographic diagnosis	Histology of periapical biopsies, interpretation by several pathologists Diagnosis of cyst, granuloma or chronic periapical abscess	The surgeon was in agreement of the pathologists' findings in 66 of the 110 cases (60%)	Low Not representative material 1 observer

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Table 3.2.5 continued

Author Year Reference Country	Aim	Study design Population characteristics	Index test	Reference test	Main findings	Study quality Comments
Ricucci et al 2006 [33] United Kingdom	Compare the presence or absence of a radiopaque lamina of periapical lesions with histological findings	Clinical material 60 teeth with periapical radiolucencies	Paralleling film radiographs scanned and digitised 2 trained observers recorded the presence or absence of a radiopaque lamina on periapical lesions	Histologic examination. Diagnosis of periapical abscess, granuloma or cyst	The diagnosis of periapical lesions cannot be made on the basis of the presence or absence of a radiopaque lamina. Agreement between radiographs and histology: 10 lesions with radiopaque lamina/3 cysts and 7 granulomas or abscess; 47 lesions without radiopaque lamina/7 cysts and 40 granulomas or abscess	Low Not representative material
Kaffe et al 1988 [25] USA	Evaluate radiographic features correlated to pulp diagnosis	28 patients/teeth with toothache and 28 "healthy"	Intra-oral periapical radiographs taken with paralleling technique and film 10 experienced dentists	Pulp sensitivity, inspection of root canal and pulp at root canal treatment. Healthy teeth followed 1.5–2 years Crowns masked 5-category confidence rating of existence of 18 radiographic features ROC. Correlation analysis	Lamina dura's continuity and shape and periodontal ligament's width and shape consistent features for diagnosis of teeth with nonvital pulps Healthy teeth were identified by pattern, size, and density of bone trabeculae	Low Uncertain reference test Patient material not described in detail

ANOVA = Analysis of variance; Az = Area under ROC-curve; CBCT = Cone beam computed tomography; CCD = Charge coupled device; CT = Computed tomography; DNB = Detailed narrow beam; DSR = Digital subtraction radiography; MTF = Modulation transfer function; P(A) = Area under ROC; NPV = Negative predictive value; PAI = Periapical index; PPV = Positive predictive value; ROC = Receiver operating characteristic; SD = Standard deviation; SE = Sensitivity; SP = Specificity

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3.3 Treatment of teeth with inflamed pulps

Background

Causes of pulpal inflammation

Caries is the most common cause of an inflammatory condition of the dental pulp. Various symptoms and clinical findings may indicate that the pulp is irreversibly inflamed, including persistent toothache, radiographic changes in the periapical region, abnormal pain reactions to thermal stimuli, and/or abnormal bleeding from an exposed pulp. The significance of these symptoms and signs for the prognosis of a treatment aimed to preserve the pulp has not been studied.

The pulp can also be damaged by injury from trauma. If it is exposed by crown fracture, the wound is often superficial and any infection will in the short-term be limited to the area nearest the exposure. The potential for preserving the health of the pulp and maintaining the tooth in an asymptomatic state should therefore be good in these cases.

What are the advantages of preserving the vitality of the pulp? Why not root-fill the tooth instead?

A tooth with an inflamed vital pulp, caused either by a deep carious lesion or by a crown fracture due to trauma, can be treated in one of two ways: attempt to preserve the pulp, or remove it and root-fill the tooth. The advantage of preserving the pulp tissue is most obvious in the case of a young permanent tooth with large pulp chamber and undeveloped root, because pulpectomy arrests root development. The dentinal walls in the root will then be thin, increasing the risk of root fracture. A root-filled tooth in an adult also carries with it the risk for fracture. From a cost aspect as well, the alternative of retaining all or some of the pulp is preferable.

Types of treatment

Surgical methods

There are several treatment options for preserving the vitality of the pulp and the functionality of a tooth with deep caries. With indirect pulp capping the deepest layer of carious dentine is left undisturbed. The aim of this method is to avoid exposure of the pulp and thus enhance the potential for healing. In Sweden this method is not common. More often carious tissue is completely removed, either at the same appointment (immediate complete caries excavation) or in several treatment steps (stepwise excavation). In the latter case the aim is to allow the pulp an opportunity to recover, at the same time avoiding a potentially unnecessary pulpal exposure. If the pulp happens to be exposed, the wound can be covered with a dressing (direct pulp capping). Another approach is to remove the outermost layer of pulpal tissue and apply a dressing to the wound (partial pulpotomy). Yet another option is to remove the contents of the pulp chamber and locate the surface of the wound at the opening of the root canal (pulpotomy). A most radical approach is to remove all the pulp tissue, from the pulp chamber and the root canals (pulpectomy), and replace it with a root filling. In this section we examine the scientific support underlying the effect of these methods, ie that the pulp chamber remains uninfected and does not give rise to toothache and/or periapical inflammatory lesions.

If the pulp is exposed by trauma, direct pulp capping or partial pulpotomy are the usual treatment methods, but pulpotomy and pulpectomy may also be used.

The result of treatment (the effect measure) is ascertained by examination to determine that healing has occurred. For stepwise excavation and pulp capping or partial pulpotomy, the following criteria apply to healing:

- Asymptomatic tooth
- Positive response to sensitivity testing
- Radiographically normal periapical conditions
- Continued root development in immature teeth

Criteria for lack of healing:

- Pain and tenderness in the tooth

- Necrotic pulp as indicated by clinical and radiographic observations. For teeth that have been treated by pulpotomy or pulpectomy, the outcome is evaluated primarily by radiographic examination. Subjective symptoms are also noted, as well as other clinical findings, which indicate the development of a root canal infection.

Wound dressings

If the pulp tissue is directly exposed, some type of wound dressing is usually applied. Sometimes restorative material (eg resin composite) is applied to cover the wound. Calcium hydroxide is the most common wound dressing. Despite its high pH, it creates conditions conducive to healing of the pulp tissue. Other wound dressings contain steroids, with or without antibiotics, but these agents are not routinely used in Sweden. In recent years promising results have been reported for "mineral trioxide aggregate", MTA. Calcium hydroxide is also considered to have a beneficial effect as a wound dressing after pulpectomy. The material is then used as an intermediate dressing in the instrumented canal between appointments. Whether this measure improves the treatment result is the subject of debate.

Other factors which influence pulpal healing

The outcome of treatment of a deep carious lesion, with or without pulpal exposure, depends largely on how extensively the pulp is infected at the time of treatment. The outcome can also depend on the age of the patient, the treatment approach (indirect pulp capping, direct pulp capping, etc) and the choice of material applied to the exposed pulp tissue. The capacity of the restorative material to prevent leakage of bacteria is another factor. When a pulp is exposed due to trauma the treatment result can depend on the location of the fracture, the degree of root development of the tooth and the time elapsed between the accident and treatment.

Factors which influence healing after pulpectomy

The aim of pulpectomy is to prevent infection of the pulp cavity, to maintain the health of the periapical tissues and to ensure asymptomatic conditions. In order to achieve this result, proper asepsis during treatment, effective removal of the pulp tissue and dense fill of the instrumented root canal are critical measures, to prevent root canal infection. Complicated root canal anatomy and the skill of the operator can influence the outcome. The impact of these and other treatment variables on the outcome is not satisfactorily explained and are investigated in this systematic review.

Evidence-graded results

Treatment of deep carious lesions

- There is limited scientific support for the claim that pulpal exposure occurs twice as frequently during direct complete caries excavation as in stepwise excavation (⊕⊕○○).

Table 3.3.1 *Risk of pulpal exposure during direct complete caries excavation compared with stepwise excavation.*

Effect measure	No of patients (no of studies)	Mean risk in standard group (min–max)	Relative risk (95% CI)	Absolute effect per 1 000 patients	Scientific support	Remarks
Exposed pulp	529 (3)	Standard = direct excavation 0.37 (0.31–0.42)	2.16 (1.85; 2.48)	196 fewer	⊕⊕○○	Quality: –1 Surrogate measure: –1

CI = Confidence interval

- The scientific basis is insufficient to allow an evaluation of whether there are differences in pulpal survival rates following immediate complete caries excavation and stepwise excavation (⊕○○○).

- The scientific basis is contradictory with respect to healing rates following direct pulp capping when the pulp is exposed during excavation of deep caries. In two studies, the short-term (1–3 year) healing rate was 80–85% in asymptomatic teeth. Another study on adults with very deep carious lesions, including patients with preoperative toothache, reported a much lower healing rate after one year (33%) (⊕○○○).

- There is limited scientific support that preoperative toothache is associated with increased risk of failure after direct pulp capping (⊕⊕○○).

Table 3.3.2 *Risk of failure after pulp capping of permanent teeth with preoperative symptoms of pulpitis (toothache).*

Effect measure	**No of patients (no of studies)**	**Mean risk in standard group (min–max)**	**Relative risk (95% CI)**	**Absolute effect per 1 000 patients**	**Scientific support**	**Remarks**
Vital asymptomatic Pulp	411 (2)	Standard = no toothache 0.17 (0.13–0.21)	RR=2,07 (1.69; 2.45)	178 fewer	⊕⊕○○	Quality: –1 Imprecise data: –1
	51 (1)	Reference = no toothache	OR=0.48 (0.28; 0.82)	-		

CI = Confidence interval; OR = Odds ratio; RR = Relative risk

- There is no scientific basis on which to assess the effect of indirect pulp capping, ie when the innermost layer of carious dentine is permanently left in situ.

- There is no scientific basis for assessment of whether indirect pulp capping, stepwise excavation, direct pulp capping, partial pulpotomy or pulpotomy offers the best potential for maintaining the pulp in a vital and asymptomatic condition.

- There is limited scientific evidence that there is no difference in treatment effect between "mineral trioxide aggregate" (MTA) and calcium hydroxide as wound dressings on an exposed vital pulp (⊕⊕○○). There is no scientific evidence on which to assess the effect of other wound dressings.

Table 3.3.3 *Effect of two different dressings (MTA and calcium hydroxide) on direct pulp capping of an exposed vital pulp.*

Effect measure	**No of patients (no of studies)**	**Mean risk in standard group (min–max)**	**Relative risk (95% CI)**	**Absolute effect per 1 000 patients**	**Scientific support**	**Remarks**
Vital asymptomatic pulp	93 (2)	Standard = 5% calcium hydroxide (0–9%)	RR=0,86 (–1.06–2.78)	7 fewer (NS)	⊕⊕○○	Quality: –1 Imprecise data: –1

CI = Confidence interval; NS = Not statistically significant; RR = Relative risk

- There is insufficient scientific evidence to determine the influence of age and type of tooth on survival of the pulp following direct pulp capping (⊕○○○).

- There is scientific basis on which to assess whether it is more advantageous to preserve all or some of the pulp in teeth with deep caries than to undertake a pulpectomy and root filling.

- There is a no scientific basis on which to assess the treatment outcome after pulpectomy and root filling.

- There is insufficient scientific evidence to determine whether the number of treatment sessions is of importance for the outcome of pulpectomy and root filling (⊕○○○).

- There is no scientific basis on which to assess which other factors might be of importance for the treatment outcome after pulpectomy and root filling.

Treatment of the traumatically exposed pulp (fracture of the tooth crown, fractures of the crown and root)

- The scientific basis is insufficient to allow assessment of the effectiveness of direct pulp capping, partial pulpotomy and pulpotomy, in maintaining the vitality and function of some or all of the pulp (⊕○○○).

- There is insufficient scientific evidence to determine the prognosis for pulpal survival in teeth with
  – completed root development, compared with teeth with incomplete root development;
  – varying intervals between the occurrence of trauma and treatment;
  – crown fracture compared with combined crown and root fractures (⊕○○○).

Questions addressed

- How effective are different methods for preserving the pulp in a vital, asymptomatic condition in teeth with deep decay, or teeth with traumatically exposed pulps, respectively?

- How effective is pulpectomy?

- What factors influence healing after a pulpectomy?

Inclusion and exclusion criteria

Articles published between 1950 and 2010. Articles in all languages with at least a summary in English or Swedish and systematic reviews.

Facts 3.3.1 Inclusion criteria.

Population	Deciduous or permanent teeth. While the response of the pulp of a deciduous tooth might be different from that of the permanent tooth studies on deciduous teeth were accepted with respect to stepwise excavation and direct or indirect pulp capping to avoid losing important information. Studies calculating the cost effectiveness and cost benefit. Study type: randomised controlled studies (RCT) quasi-RCT, controlled clinical studies (CCT) or prospective cohort studies with reference groups. Observation time ≥1 year, attrition ≤30%
Intervention	Indirect pulp capping, direct pulp capping, partial pulpotomy, pulpotomy and pulpectomy. Pulp capping using various wound dressings. Pulp exposure after stepwise and immediate complete caries excavation, respectively
Control	RCT, quasi-RCT, (CCT) or prospective cohort with reference group. Acceptable reference groups are groups within the cohort, eg age, size of pulp exposure, degree of root closure
Outcome	Survival of the pulp, verified by absence of symptoms, sensibility testing, radiographic examination or closure of the roots in young teeth. With reference to studies on pulpectomy: the minimum allowable unit for effect measure is the individual tooth

Facts 3.3.2 Exclusion criteria.

Population	Animal studies. Human experimental studies employing teeth with healthy pulp. Retrospective studies, observational studies (cohorts without comparison groups) Studies with undefined populations or small samples
Intervention	Studies which investigate traumatic lesions, pulp amputations in deciduous teeth, pulp dressings which devitalise pulpal tissue, apexification (closure of the root)
Control	Retrospective studies, prospective observational studies without reference groups
Outcome	Studies with undefined outcome measures

Results of literature search and selection of studies

The search of the literature yielded 800 abstracts, of which 635 were considered irrelevant. In all 165 full-text articles were assessed according to the predetermined criteria for inclusion/exclusion. Articles, which met the inclusion criteria were scrutinized and assessed with the aid of an appraisal form (Appendix 2) and graded with respect to internal and external validity as high, moderate or low quality. Seventeen studies were finally included. The excluded studies, with the main reason for exclusion, are listed in Appendix 4. See also flow diagram in Figure 3.3.1.

Description of studies and results

Included studies

Stepwise excavation, indirect or direct pulp capping, partial pulpotomy, pulpotomy

Fifteen studies were included: a systematic review [1], a cost-analysis [2], eight randomised controlled studies [3–10] and five prospective cohort studies with comparison groups [12–16]. One of these studies investigated treatment of traumatised vital pulps [13]. The remaining studies investigated methods for treating vital pulps in teeth with deep carious lesions.

Pulpectomy

Two studies were included: a controlled clinical study following the treatment outcome in relation to bacterial status at the time of the root filling [17] and a randomised controlled study comparing the outcomes of pulpectomy carried out in one or two treatment sessions [11].

The included studies are presented in Table 3.3.4–3.3.6. The results with respect to type of injury (caries, trauma), treatment method and wound dressing are summarised below.

Deep carious lesions

Comparing pulp exposure in stepwise and immediate complete caries excavation

Three randomised controlled studies of moderate quality found that the risk of pulp exposure increases significantly with immediate complete excavation of caries compared with stepwise excavation (relative risk = 2.16) [3–5]. One of the studies of moderate quality found a significantly higher frequency of healing after stepwise excavation (74%) than after immediate complete excavation (62%) after an observation period of one year [3]. Another study, of low quality, found no such difference [12].

Indirect pulp capping

Two randomised controlled studies [6,7] and a controlled study [16], all of low quality, reported a healing rate (survival of the pulp or asymptomatic tooth, assessed clinically or radiographically) of 85 to 100%. The material was limited to teeth without preoperative signs of pulpitis and the follow-up period was short (1 to 1.5 years). One of the studies investigated deciduous teeth [6], one investigated both deciduous and young permanent teeth [16] while the average age of the patients in the third study was 27 years [7]. No studies investigating the longer-term survival of the pulp were identified. Due to lack of evidence, no conclusions can be drawn with respect to the effect of indirect pulp capping.

Direct pulp capping

Two randomised controlled studies [3,8] and a prospective cohort study [15], all of moderate quality, investigated healing in teeth with symptoms of pulpitis and asymptomatic teeth. In one of the studies, around a third of the teeth were extracted for histological examination [15]. The healing rate was then assessed as lower in this group, but not significantly different from the clinically/radiographically assessed group. No prospective studies of the long-term healing rate could be identified.

Two studies of moderate quality reported a lower frequency of successful pulp capping in permanent teeth with clinical and/or radiographic signs of pulpitis at the time of treatment compared with teeth without such signs [8,15]. Most of the patients with symptoms had persistent toothache. For permanent teeth without preoperative symptoms of pulpitis, the healing rate was around 80% and for symptomatic teeth, around 60% (relative risk = 2.07).

In one of the studies the failure rate for pulp capping in the group with preoperative symptoms of pulpitis was in fact greater than reported in Table 3.3.5, because 17.5% (24/137) of the teeth were assessed as failures only three days post treatment, on the grounds of persistent toothache [8]. Because of subsequent loss to follow-up, these teeth were not included in the analysis. The difference in healing rate between teeth with and without preoperative symptoms was thus greater than reported in the study.

Another randomised controlled study of moderate quality compared the outcomes of pulp capping and partial pulpotomy in adults after an observation period of one year. The healing rates were the same for both treatment approaches and much lower than in the two studies described above (33%) [3]. Only teeth with very deep carious lesions were included in the study. The study also found a higher risk of failure in cases of preoperative toothache. However, the number of patients with and without toothache respectively is not reported.

Partial pulpotomy

A randomised controlled study of moderate quality [9] and a cohort study of low quality [14] report healing rates of 91–94% for young permanent teeth without preoperative signs or symptoms. The follow-up period was two years. No studies that investigated long-term heal-ing frequency were identified. In contrast, the previously cited study [3] reported much lower (33%) pulpal survival after one year of follow-up. Because of the contradictory scientific support, it is not poss-ible to draw conclusions with respect to the effect of partial pulpotomy as a method of treating teeth with cariously exposed pulps.

Pulpotomy

No studies meeting the inclusion criteria could be identified.

Pulpectomy

A randomised controlled study of moderate quality compared the outcome of pulpectomy in one or two treatment sessions (calcium hydroxide was used as a root canal dressing between the appointments) [11]. A majority of the teeth in the study had pulpitis symptoms because of caries. The healing rate was high (93%) and of similar magnitude in both treatment groups. The follow-up time was up to three years. The treatment was carried out by a dentist specialised in endodontics, and this limits the generalisability of the results. A controlled clinical study of low quality found that at one year follow-up, teeth with positive bacterial samples at the time of root filling had a poorer, statistically non-significant treatment outcome than teeth with negative bacterial samples [17]. After observation periods of three and a half to four years, the analysis showed that the outcome for teeth with positive bacterial samples was significantly lower than for those with negative samples. The treatment was carried out by students under supervision and included control radiographs. In general, significantly more treatment failures were noted after three and a half to four years than after one year's observation.

Comparison of methods

We were unable to identify any randomised or non-randomised controlled studies of at least moderate quality, comparing different methods aimed at preserving the vitality and functional capacity of the whole or part of the pulp. This means that there is a lack of well-planned, well-conducted studies comparing the outcomes of indirect pulp capping, direct pulp capping, partial pulpotomy and pulpotomy. There is also a lack of studies comparing these methods with pulpectomy.

Comparison of immature and mature permanent teeth and between tooth types

One study of moderate quality observed no statistically significant difference in healing rate after direct pulp capping in permanent teeth of young (<15 years) and older individuals (≥15 years) [15]. Nor did the study find any statistically significant difference in healing rate with respect to tooth type: molars versus premolars versus incisors. There were however, numerical differences: incisors had the highest healing rate and premolars the lowest. Another study of low quality showed that teeth with unexposed pulps after stepwise excavation had a greater healing rate in individuals <50 years than in those >50 years of age [3]. Statistically the difference was of borderline significance. Because of the insufficient scientific support, it is not possible to draw any conclusions with respect to the influence of patient age or type of tooth on the outcome of direct pulp capping.

One study of low quality showed no differences in healing rates between deciduous and permanent teeth following direct or indirect pulp capping [16].

Trauma

Partial pulpotomy

One prospective cohort study of moderate quality was identified [13]. The material comprised 178 teeth with both complete and incomplete root development. Calcium hydroxide was used as a wound dressing. After an observation period of at least three years, the healing rate, assessed clinically and radiographically, was 95%. There was no difference in healing rate between teeth with complete or incomplete root development. No difference was disclosed between short (<72 hours) and longer intervals (>72 hours) between the traumatic episode and treatment. This single study cannot form basis for conclusion with respect to the outcome of partial pulpotomy in teeth with traumatic pulp exposures. Studies, which investigated other methods of treatment did not meet the inclusion criteria.

Wound dressings

The effect of different wound dressings was compared in six randomised controlled studies [6–10,16]. One study of moderate quality investigated the effect of Ledermix, an anti-inflammatory non-steroidal compound, calcium hydroxide and zinc oxide eugenol in direct pulp capping [8]. After an observation period of two years, there were no significant differences between the four dressings. Two studies of moderate quality compared calcium hydroxide paste with "mineral trioxide aggregate" (MTA) as dressings after direct pulp capping and partial pulpotomy, respectively [9,10]. After observation periods of two to three years, no differences were disclosed with respect to healing. Thus, there is limited scientific evidence that MTA has equal effect as calcium hydroxide paste.

Two studies of low quality compared different calcium hydroxide containing compounds for indirect pulp capping and found no differences after a one-year observation period [7,16]. A randomised controlled study of low quality compared adhesive resin with calcium hydroxide paste as a dressing for indirect pulp capping in deciduous teeth with deep carious lesions [6]. The observation period was one and a half years. The results disclosed no differences between the methods.

Systematic reviews

A systematic review of low quality compared the effect of various wound dressings [1]. The authors' conclusions were that the results did not support proposals to change currently accepted practice. Another systematic review [18] had included four studies, two of which investigated the survival of restorations after complete or incomplete removal of dentinal caries [19,20]. These studies did not specifically investigate teeth with deep carious lesions and did not meet our inclusion criteria. The review was excluded. The other two studies were included and are tabulated in the report [4,5].

Cost-analysis

A modelling study of moderate quality investigated the costs and benefits of direct pulp capping compared with pulpectomy [2]. With the support of the decision analysis, the authors concluded that if the healing rate for pulp capping is greater than 56 per cent, then this and not pulpectomy should be the method of choice. The analysis considered only direct costs for the procedures. The long-term effects of the treatment (eg risk of toothache) and the patients' preferences were not taken into account. See chapter on health economic aspects.

Discussion

The included studies differ with respect to patient selection, tooth type, indications for treatment and observation times. The patient populations are often poorly described and several studies omit information about the number and type of operator. This limits the potential for comparison of data and for generalising the results to general practice.

The results of this systematic review show that there are substantial gaps in our knowledge base with respect to treatment of the vital pulp. Hence, the report is unable to offer a clear answer to the question of whether indirect pulp capping, stepwise excavation, direct pulp capping/ partial pulpotomy is the most effective treatment for a tooth with deep caries and an inflamed pulp. Stepwise excavation certainly leads to fewer pulp exposures than direct complete caries excavation, but whether this results in a higher survival rate for the pulp has not been adequately investigated.

The report cannot draw conclusions about the most effective method of treating a pulp with a carious exposure. The studies reporting the outcomes of direct pulp capping have short follow-up times and thus the long-term survival of the pulp is uncertain. It is furthermore not known whether pulp capping or pulpectomy offers the greater potential to maintain non-infectious conditions and thus the health of the periapical tissues and asymptomatic teeth long-term. There are almost no studies at all of health economic aspects of different treatment options. Such studies should consider both patient satisfaction and direct and indirect costs.

The presence of preoperative pain (toothache), particularly over a long period and if it has caused sleep disturbance, should be regarded as a contraindication for pulp capping. Yet, it is difficult to assess pain. The experience is subjective and is modified by both physical and psychological factors. Thus, measurement of pain can easily be erroneous. The three studies, which evaluate the result of pulp capping in relation to preoperative toothache, have differing and in part imprecise definitions of toothache, which makes it difficult to compare the results. It has been proposed that dichotomising toothache/no toothache is the most relevant and this was the basis for presentation of the results [21]. It shows that the healing rate after pulp capping is lower in cases of preoperative toothache. The evidence is limited and more well-designed studies evaluating the importance of preoperative toothache are needed urgently. An important unanswered question is how data such as the patient's age, tooth type, a combination of preoperative symptoms and clinical observations (eg presence, persistence and character of toothache, the extent and depth of the carious lesion, the location of the pulp exposure, its size and the tendency of the pulp to bleed) can be applied to make a well-informed choice between pulp capping and pulpectomy.

Studies, which compare different types of dressings for the exposed pulp (calcium hydroxide paste, cement containing calcium hydroxide, MTA, Ledermix and zinc oxide eugenol), disclose no difference in treatment outcome. MTA and calcium hydroxide paste were comparable. The review found no support for other materials.

With reference to treatment of traumatised teeth with pulp exposure, only one study was of adequate quality [13]. None of the variables investigated influenced the treatment outcome of partial pulpotomy. Specialists carried out the treatments and generalisability to general practice can therefore not be assessed. There is a need for prospective studies addressing this question.

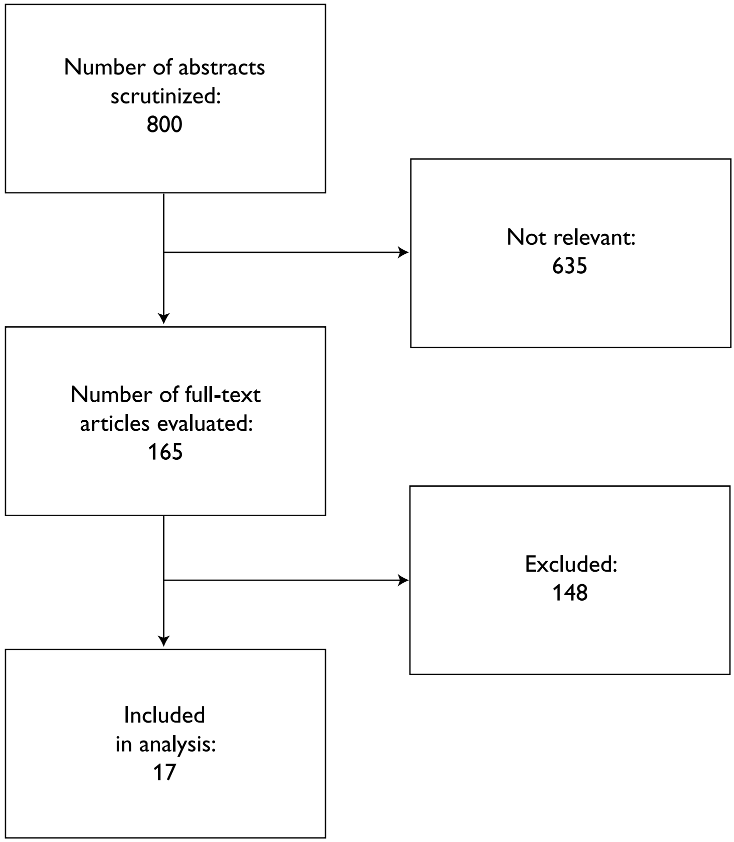

Figure 3.3.1 *Flow diagram of literature search.*

Table 3.3.4 *Vital pulp treatment. Stepwise excavation.*

Author Year Reference Country	Aim	Study design Sample characteristics Setting Inclusion and exclusion criteria	Intervention (I) Control (C)	Main findings (CI=95%)	Study quality Comments
Björndal et al 2010 [3] Denmark	To test the effect of stepwise excavation vs direct complete excavation of deep caries lesions in adults using pulp exposure, 1 year pulp vitality without apical radiolucency, and pain as the outcome measures	RCT 292 incisors, premolars and molars Eligible (n=440) Multicenter study (n=6). Number of operators and number of teeth treated by each operator not reported >18 years of age, a primary caries lesion radiographically involving 75% or more of the dentin, and the presence of a well-defined radiodense zone between the caries lesion and the pulp. Mild to moderate pre-treatment pain was accepted Unbearable pain and/or pain disturbing night sleep, no response to cold and electric pulp testing, attachment loss >5 mm, pregnancy, systemic disease, refused to participate (n=126)	I: Stepwise excavation/ 149 teeth C: Direct complete excavation/143 teeth Outcome measure 1: Pulp exposure/ no pulp exposure Outcome measure 2: Healing/no healing Criteria of healing: no pain, pulp vitality (thermal and electric) without apical radiolucency Follow-up: 1 year Drop-out rate: 22/314=7% Blinding: yes; 2 independent observers of radiographs blinded to treatment	Pulp exposure/ no pulp exposure: I: 25/143=17.5% C: 43/149=28.9% Difference: 11.4% (CI: 1.2; 21.3) Healing: I: 106/143=74.1% C: 93/149=62.4% Difference: 11.7% ($p<0.04$) Patients with pre-treatment pain had significantly less successful treatments than those without pre-treatment pain Borderline significance of higher success rate in age group <50 years compared with >50 years Difference in outcome between centres	Moderate Number of patients with and without preoperative pain not reported. Character of pre-treatment pain not described Differences in outcome between the six centres. Number of operators at each centre not reported Short follow-up time
Heinrich et al 1991 [12] Germany	To compare the frequency of pulp exposure after stepwise with that of direct complete excavation in primary molars with deep caries lesions	CCT 125 primary molars randomly sampled from 2 406 children aged 6–7 years Not stated Paired primary lower second molars with deep dentin caries matched according to age, gender and lesion depth. Comparability with respect to possible preoperative pain, and radiographic findings not stated Not stated	I: Stepwise excavation/ 52 teeth. Re-opening, complete excavation of caries after 6–8 weeks. Temporary dressing: calciumhydroxide, ZOE and phosphate cement. C: Direct complete excavation of caries/52 teeth Outcome measures: Pulp exposure/no pulp exposure	No difference in prevalence of pulp exposure I: Pulp exposure: 7/52=13.5% *(CI 7; 25) C: Pulp exposure: 12/52=23.1% *(CI 14; 36)	Low Randomisation procedure unclear Possible selection bias Outcome surrogate measure

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Table 3.3.4 continued

Author Year Reference Country	Aim	Study design Sample characteristics Setting Inclusion and exclusion criteria	Intervention (I) Control (C)	Main findings (CI=95%)	Study quality Comments
Leksell et al 1996 [4] Sweden	To compare the frequency of pulp exposure after stepwise with that of direct complete excavation in permanent posterior teeth with deep caries lesions	RCT 116 subjects/134 teeth aged 6–16 years (mean 10.2 years). Equal distribution of gender Specialist clinic, 6 operators Posterior permanent teeth with deep caries to the extent that pulp exposure could be expected if direct complete excavation was chosen. 14 teeth with provoked and transient pain shortly before treatment were included Persistent pain and/or radiographic periapical pathologic changes	I: Stepwise excavation/57 teeth. Re-opening and complete excavation of caries after 8–24 weeks. Temporary dressing: calciumhydroxide and ZOE cement C: Direct complete excavation of caries/ 70 teeth Outcome measures: Outcome 1: pulp exposure/no pulp exposure. Outcome 2: healing/ no healing Criteria of healing: normal clinical and radiographic findings, continued root development in immature teeth Follow-up: >1 year (mean 3.6 years) Drop-out rate: Outcome 1: 7/134=5% Outcome 2: 7/47=15%	Outcome 1 I: Pulp exposure: 10/57=17.5% *(CI 10; 29) C: Pulp exposure: 28/70=40% *(CI 29; 52) *Relative risk: C/I=2.3 (CI 1.65; 2.91) Outcome 2 Stepwise excavation with unexposed pulps: Healing: 40/40. Exposed pulps: not reported	Moderate Randomisation procedure not reported Outcome of group with pulp exposure not reported Main outcome surrogate measure

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Table 3.3.4 continued

Author Year Reference Country	Aim	Study design Sample characteristics Setting Inclusion and exclusion criteria	Intervention (I) Control (C)	Main findings (CI=95%)	Study quality Comments
Magnusson et al 1977 [5] Sweden	To compare the frequency of pulp exposure after stepwise with that of direct complete excavation in primary molars with deep caries lesions	RCT 55 teeth/55 children aged 5–10 years Equal distribution of gender University clinic Number of operators not reported Primary molars with a supposedly thin layer of softened carious dentin remaining on the pulpal floor of a deep lesion Episodes of persistent or shooting pain, tenderness to pressure or percussion Radiographically: periradicular or internal pulp changes	I: Stepwise excavation/ 55 teeth. Re-opening and complete excavation of caries after 4–6 weeks. Temporary dressing: calciumhydroxide and ZOE cement C: Direct complete excavation of caries/ 55 teeth Outcome measures: Pulp exposure/no pulp exposure	I: Pulp exposure: 8/55=15% *(CI 8; 26) C: Pulp exposure: 29/55=53% *(CI 40; 65) *Relative risk: C/I=3.6 (CI 2.9; 4.3)	Moderate Quasi-randomised No follow-up of the two interventions Outcome surrogate measure

* Calculations not reported by the author(s).

C = Control; CCT = Clinical controlled trial; CI = Confidence interval; I = Intervention;
RCT = Randomised controlled trial; ZOE = Zinc oxide eugenol

Table 3.3.5 *Vital pulp treatment. Pulp capping.*

Author **Year** **Reference** **Country**	**Aim**	**Study design** **Sample characteristics** **Setting** **Inclusion and exclusion criteria**	**Intervention (I)** **Control (C)**	**Main findings** **CI=95%**	**Study quality** **Comments**
Björndal et al 2010 [3] Denmark	To test direct pulp capping vs partial pulpotomy of pulps exposed as a result of caries, using 1-year pulp vitality without apical radiolucency and pain as the outcome measure	RCT 51 subjects/51 premolars/molars with exposed pulps as a result of stepwise or direct complete excavation. Adults (≥18 years; mean=30 years). Consecutively included patients Intention-to-treat: 68 teeth; 10 excluded (treatment elsewhere, visible pus or too large exposure) Multicenter study (n=6). Number of operators not stated Pulp exposed during either stepwise (n=25) or direct complete excavation (n=43) of a primary caries lesion involving ≥75% of the dentin and with the presence of a well-defined radiodense zone between lesion and pulp. "Mild to moderate" pre-treatment pain was accepted Prolonged unbearable pain or pain disturbing night sleep, pus draining from exposed pulp, not informed consent	I1: Direct pulp capping I2: Partial pulpotomy Outcome measures: Healing/no healing Criteria of healing: No pain, pulp vitality (thermal and electric) without apical radiolucency Follow-up: 1 year Drop-out rate: 7/58=12% Blinding: Yes; 2 observers of radiographs blinded to treatment Repeated measurements of preoperative lesion depth made by one observer	I1: 7/22=31.8% I2: 10/29=34.5% Difference: NS Presence of pre-treatment pain significantly associated with treatment failure	Moderate Small sample in relation to the number of independent variables (operator, patient's age, size of pulp exposure, type of tooth, presence and character of pain) Observations of pain difficult to interpret Short follow-up time

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Table 3.3.5 *continued*

Author Year Reference Country	Aim	Study design Sample characteristics Setting Inclusion and exclusion criteria	Intervention (I) Control (C)	Main findings CI=95%	Study quality Comments
Cvek 1993 [13] Sweden	To study the results of partial pulpotomy in crown-fractured incisors 3–15 years after treatment	CCT 178 teeth/162 subjects with crown-fractured permanent incisors treated between 1973 and 1988 Specialist clinic. Operators: 32 specialised dentists Traumatised permanent incisors with crown fracture and pulp exposure (vital pulp tissue, sensitive to electric tests) Follow-up <3 years (n=31), dislocated teeth with uncertain prognosis (n=3), concomitant intra-alveolar root fracture (n=1)	I: Partial pulpotomy Grouping: Mature (n=88), immature (n=90) teeth. Interval between accident and treatment: 1–72 hours (n=162) >72 hours (n=16) Crown fracture (n=159) Crown-root fracture (n=19) Outcome measures: Healing/no healing Criteria of healing: No clinical symptoms, no radiographic pathological changes, radiographically observed continued root development in immature teeth, and when available clinically verified hard tissue barrier and sensitivity to electric tests. Follow-up: 3–15 years Independent outcome examiner and blinding to investigated variables likely Drop-out rate: Not applicable (last available control used as final control)	No difference in the proportion of healed pulps between mature/immature teeth or between various intervals between accident and treatment. Crown-root fractures healed more often than crown fractures. No failures occurred later than 3 years after treatment Healing: All teeth: 169/178=95% *(CI 91; 97) Immature teeth: 84/90=93% *(CI 86; 97) Mature teeth: 85/88=97% *(CI 91; 99) Interval 1–72 hours: 155/162=96% *(CI 91; 98) >72 hours: 14/16=88% *(CI 64; 97) All 19 crown-root-fractured teeth healed	Moderate External validity cannot be determined Insufficient data to discover possible differences between some of the subgroups Sample from previous study included [22]

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Table 3.3.5 continued

Author Year Reference Country	Aim	Study design Sample characteristics Setting Inclusion and exclusion criteria	Intervention (I) Control (C)	Main findings CI=95%	Study quality Comments
Falster et al 2002 [6] Brazil	To compare the outcome of an adhesive resin system with a calcium hydroxide liner for protection of the dentin-pulp complex of primary molars treated with indirect pulp capping	RCT 48 primary molars (number of subjects not stated) in children aged 3–5 years. Equal distribution of gender Not reported Children with high caries activity, active caries lesion in deep dentin on occlusal surfaces of 1st or 2nd molars where complete caries removal would risk caries exposure Pulp exposure occurred, or complete caries removal was obtained without risking pulp exposure	I: Indirect pulp capping (no re-enter) I1: Total etch technique (Scotch Bond MultiPurpose)/ 25 molars/restored with composite I2: Calcium hydroxide liner (Dycal)/23 molars/ restored with composite *Outcome measures:* Healing/no healing *Criteria of healing:* No spontaneous pain and/ or sensitivity to pressure, no fistula, oedema, abnormal mobility, no interradicular and/ or periapical radiolucency, no internal/ external root resorption not related to exfoliation process Follow-up: 2 years Drop-out rates not reported Two calibrated outcome examiners, consensus on disagreements. Blinding not reported	No difference in outcome between the 2 methods Healing: Overall: 43/48=90% *(CI 78; 96) I1: Clinical: All cases Radiographic: 24/25=96% *(CI 81; 99) I2: Clinical: All cases Radiographic: 19/23=83% *(CI 63; 93)	Low Randomisation procedure not described Small sample Blinding not reported Only occlusal cavities included

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Table 3.3.5 continued

Author Year Reference Country	Aim	Study design Sample characteristics Setting Inclusion and exclusion criteria	Intervention (I) Control (C)	Main findings CI=95%	Study quality Comments
Fitzgerald et al 1991 [7] USA	To compare: 1. Two calciumhydroxide containing dressing materials for direct and indirect pulp capping 2. The clinical success of direct and indirect pulp capping 3. The effect of zinc oxide eugenol cement with calciumhydroxide containing materials after complete caries removal in moderately deep caries lesions	RCT Consecutive subjects, 151 teeth/ 55 subjects aged 20–60 years (mean 27 years). Equal distribution of gender University clinic. Number of operators not reported Large caries lesions: I1: Pulp exposure anticipated with complete caries removal I2: Pulp exposure not anticipated with complete caries removal Periodontally compromised teeth, history of spontaneous pain, teeth not responding to electric pulp testing	I1: Indirect pulp capping (no re-enter)/(n=46) Life or Dycal randomly assigned as dressing materials I2: Complete caries removal (n=46). Life, Dycal or Zinc oxide eugenol (ZOE) (Cavitec) randomly assigned as dressing material At pulp exposure: pulp capping (n=8). Life or Dycal randomly assigned as dressing material *Outcome measures:* Healing/no healing *Criteria of healing:* No clinical symptoms, positive reaction to electric pulp testing (radiographic criteria not stated) Follow-up: 1 year Drop-out rate: 51/151=34%, explained, not analysed Blinding not reported	No difference in outcome between dressing materials or between I1 and I2 Healing: I1: 39/46= 85% *(CI 72; 92) I2 (complete caries removal + direct pulp capping): 48/54= 89% *(CI 78; 95)	Low Randomisation procedure to dressing materials unclear No randomisation to surgical procedures (I1 and I2) Blinding not reported. High drop-out rate

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Table 3.3.5 continued

Author Year Reference Country	Aim	Study design Sample characteristics Setting Inclusion and exclusion criteria	Intervention (I) Control (C)	Main findings CI=95%	Study quality Comments
Maryniuk et al 1990 [2] USA	1. To evaluate the costs and benefits of performing a pulp capping procedure or endodontic therapy for a tooth that is to receive a cast restoration 2. To determine what level of success would be needed to claim pulp capping procedure as the optimal treatment	Cost-analysis Costs and benefits of direct pulp capping compared with endodontic treatment (pulpectomy) determined using decision analysis. It was assumed that the tooth needed cast restoration and that endodontic treatment would cost approximately $200 more than a pulp capping		A success rate of ≥56% was needed for pulp capping to be the preferred treatment	Moderate Long-term success, patient's time, costs, discomfort and preference not included in the model
Mejàre et al 1993 [14] Sweden	To evaluate the outcome of partial pulpotomy of pulps exposed during excavation of deep caries in posterior permanent teeth	CCT Consecutive subjects, 37 teeth/37 subjects aged 6–15 years (mean 9 years) Specialist clinic, 16 operators Permanent posterior teeth with vital pulp exposure due to caries. Intention to treat: 44 teeth Follow-up <1 year (n=7)	I: Partial pulpotomy/capping with calcium hydroxide I1: No preoperative pain or radiographic pathological findings (n=31) I2: Preoperative spontaneous pain or radiographic pathologic findings (n=6) *<u>Outcome measures:</u>* Healing/no healing No clinical symptoms, positive reaction to electric pulp testing, no radiographic pathology, continued root development in immature teeth Follow-up outcome 1: ≥2 years (mean 4.7 years) Follow-up outcome 2: ≥3 years Drop-out rate (3 years): 10/36=28%, not analysed	Outcome 1 Healing: I1: 29/31= 94% *(CI 79; 98) I2: 4/6= 67% *(CI 10; 70) *Relative risk: I2/I1 2 years: 5.17 (CI 3.41; 6.92) 3 years: 5.75 (CI 4.10; 7.40) Outcome 2 Healing: I1: 21/23= 91% *(CI 73; 98) I2:2/4= 50% *(CI 15; 85)	Low Small sample in one subgroup Blinding not reported Limited external validity

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Table 3.3.5 continued

Author Year Reference Country	Aim	Study design Sample characteristics Setting Inclusion and exclusion criteria	Intervention (I) Control (C)	Main findings CI=95%	Study quality Comments
Miyashita et al 2007 [1]	To examine the relative effectiveness of techniques/ materials aimed to maintain pulp vitality in adults with asymptomatic extensively decayed teeth	Systematic review RCT or quasi-RCT on permanent asymptomatic teeth with extensive caries. 4 studies included: Shovelton 1971 [8], Fitzgerald 1991 [7], Hodosh 2003 [23], Whitworth 2005 [24] Excluded: Traumatised teeth	In our review 2 of the studies are included: Fitzgerald 1991 [7] and Shovelton 1971 [8]. Hodosh 2003 excluded because tested experimental dressing materials are not available on the market [23]. Whitworth 2005 excluded because the study does not specifically investigate extensive caries lesions [24]	Main conclusion by review authors: "The findings do not suggest that there should be any significant change from accepted conventional practice procedures when the pulp of the carious teeth is considered"	Low Technically good quality. Some tested dressing materials are not available on the market One study does not specifically deal with extensive caries. In addition, only asymptomatic teeth included Traumatised teeth not included. Surgical techniques not analysed Conclusions unclear

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Table 3.3.5 continued

Author Year Reference Country	Aim	Study design Sample characteristics Setting Inclusion and exclusion criteria	Intervention (I) Control (C)	Main findings CI=95%	Study quality Comments
Nyborg 1958 [15] Sweden	1. To obtain a qualitative and quantitative evaluation of the outcome of pulp capping on the basis of histologic examination and with long follow-up periods 2. To find the value of an unsupported clinical and radiographic follow-up examination in the assessment of the results of pulp capping	CCT 225 permanent teeth/225 subjects aged <15 years (n=124), adults (n=101), consecutive subjects likely. Clinical study (n=144). Clinical and histologic study (n=81) Private practice, one operator Teeth with deep caries lesions. Incisors (n=48), premolars (n=61), molars (n=116). Intention-to-treat: 234 teeth Non-vital pulp, some teeth with severe signs of pulpitis (eg severe pain, pus); number not reported	I: Direct pulp capping/ capping with calcium hydroxide I1: No preoperative clinical/ radiographic signs of pulpitis (n=200). Clinical evaluation (n=124). Clinical and histologic evaluation (n=76) I2: Preoperative signs of pulpitis (eg prolonged pain, pain at night, radiographic changes) (n=25) Clinical evaluation (n=20) Clinical and histologic evaluation (n=5) *Outcome measures* Healing/no healing *Criteria of healing* Clinical/radiographic: no persistent pain or radiographic periradicular rarefaction or condensation, positive reaction to electric pulp testing. Histologic: healed pulp lesion with no or only slight cellular infiltration deep in the lesion area Follow-up: Clinical: >1 year: 88%; >3 years: 82% of the sample. Histologic: >1 year: 98%; >2 years: 72% of the sample Drop-out rates: Clinical examination: 9/234=4%. Histologic examination: 5/81=6% Blinding, independent outcome examiners for radiographs. For histologic examination not reported	No statistically significant difference between clinical and histologic findings in the assessment of healing/ no healing *Healing clinical/radiographic* I1 (no signs of pulpitis): 106/124= 86% *(CI 79; 91%). I2 (signs of pulpitis: prolonged pain, pain at night): 9/20= 45% *(CI 26; 66%) *RR: I2/I1=3.79 (CI 3.21; 4.37) *Healing histologic* I1 (n=76): 55/69=80% *(CI 69; 88%); no/uncertain assessment (n=7) I2 (n=5): none (uncertain assessment, n=1) No difference between adults and children: *RR=1.65 (CI 0.73; 2.56) No difference between molars and premolars: *RR=0.60 (CI 0.08; 1.12) No difference between molars and incisors: *RR=1.16 (CI 0.39; 1.92)	Moderate Small sample in one subgroup Unclear exclusion criteria for I2 Limited external validity (one operator)

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Table 3.3.5 continued

Author Year Reference Country	Aim	Study design Sample characteristics Setting Inclusion and exclusion criteria	Intervention (I) Control (C)	Main findings CI=95%	Study quality Comments
Sawusch 1982 [16] USA	To compare two calcium hydroxide-containing dressing materials when used for indirect (leaving the innermost layer of carious dentin without re-enter) or direct pulp capping (caries excavation produced a small pulp exposure) in primary and young permanent teeth	CCT 207 teeth (number of subjects not stated) in patients aged <14 years; primary and young permanent teeth with extensive caries University clinic or private practice. No of operators not reported Depth of caries lesion indicating need of pulp capping Clinical symptoms (pain from pressure, fistula or epulis, abnormal tooth mobility), radiographic pathology, patients not possible to recall	I1: Indirect pulp capping/ 184 teeth (136 primary, 48 permanent teeth). Two dressing materials (experimental Dycal, improved Dycal) randomly tested I2: Direct pulp capping/ 23 teeth (16 primary, 7 permanent teeth) *Outcome measures* Healing/no healing *Criteria of healing* No clinical symptoms, no radiographic pathologic findings Follow-up: 1–2 years (mean 1.3 years). Drop-out rate, blinding not reported	No difference in outcome between dressing materials or between primary and permanent teeth Healing: Overall: 199/207=96% *(CI 93; 98) I1: Primary teeth: 130/136=96% *(CI 91; 98), permanent teeth: 48/48=100% I2: Primary teeth: 14/16=88% (CI 64; 97), permanent teeth: 7/7=100%	Low Short follow-up Surgical procedures not randomised Blinding not reported Small samples in subgroups

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Table 3.3.5 continued

Author Year Reference Country	Aim	Study design Sample characteristics Setting Inclusion and exclusion criteria	Intervention (I) Control (C)	Main findings CI=95%	Study quality Comments
Shovelton et al 1971 [8] United Kingdom	To compare the efficacy of 4 dressing materials when used for direct pulp capping in permanent teeth with or without preoperative pain	RCT 412 subjects/412 premolars or molars in patients aged 15–24 (n=244), 25–34 (n=106), 35–44 (n=59), unknown (n=3) years. Equal distribution of gender. Trial A = no preoperative pain (n=275) Trial B = preoperative pain (n=137) Multicenter study (8 dental schools). No of operators not reported Premolars and molars with exposed vital pulps due to caries Patients younger than 15/older than 4 4 years, no bleeding (non-vital) teeth, illness/cortico steroid therapy	I: Direct pulp capping Trial A (non-symptomatic) One-step procedure (n=275) Capping with: I1: Ledermix (n=109) I2: Glycerrhetinic acid (non-steroid anti-inflammatory + neomycin (GLA) (n=103) I3: Calcium hydroxide (n=108) I4: Zinc oxide eugenol (ZOE) (n=68) Trial B (preoperative history of pain) Two-step procedure (n=137): The allocated medicament was applied temporarily and re-applied 3 days later. Teeth with unsuccessful temporary treatment (no pain relief) were considered unsuccessful (24/137=18% one week post-operatively). Same dressing materials as Trial A, but I4 was not used *Outcome measures* Healing/no healing Criteria of healing: No clinical symptoms, no radiographic pathological findings, positive reaction to electric pulp testing Follow-up: 1 year, 2 years Drop-out rates: 1 year: 31%, explained, analysed 2 years: 47%; explained, not analysed Independent, blinded outcome examiner	No difference in outcome between dressing materials Outcome 1 year follow-up Trial A. Healing: 164/200=82% *(CI 76; 87) Trial B. Healing: 48/67=72% *(CI 63; 84) *Relative risk: Trial B/ Trial A, 1 year outcome: 1.58 (CI 1.09; 2.06) Outcome 2 year follow-up Trial A. Healing: 115/154=75% *(CI 67; 81) Trial B. Healing: 33/51=65% *(CI 51; 71)	Moderate Possible confounding (age, type of pulp exposure: caries or accidental) High drop-out rate at 2 year follow-up

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Table 3.3.5 continued

Author Year Reference Country	Aim	Study design Sample characteristics Setting Inclusion and exclusion criteria	Intervention (I) Control (C)	Main findings CI=95%	Study quality Comments
Qudeimat et al 2007 [9] Jordan	To compare the clinical success rate of calcium hydroxide with that of MTA in partial pulpotomy of permanent molars with carious pulp exposures	RCT 43 healthy subjects/63 restorable permanent first molars in subjects aged 6.8–13.3 years (mean 10.3 years) University clinic. No of operators not reported Carious pulp exposures. Intention-to-treat: 92 patients/135 teeth Previous operative procedures, history of spontaneous or prolonged pain, swelling, tenderness to percussion or palpation, or pathological mobility, preoperative radiographic pathology, not responding within normal limits to sensitivity testing or haemorrhage control unsuccessful	I: Partial pulpotomy I1: Capping with MTA/ 17 subjects/28 teeth I2: Capping with calcium hydroxide/17 subjects/ 23 teeth *Outcome measures* Healing/no healing No subjective or clinical symptoms, no radiographic pathology, continued root development in immature teeth Follow-up: 25–46 months (mean 35 months) Drop-out rate: 9/43 subjects (12/63 teeth)= 19–21%; explained Calibrated, independent and blinded outcome examiners. Reliability reported	No difference in outcome between dressing materials Healing: I1: 26/28= 93% *(CI 77; 98) I2: 21/23= 91% *(CI 73; 98)	Moderate Limited external validity (one operator)

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Table 3.3.5 continued

Author Year Reference Country	Aim	Study design Sample characteristics Setting Inclusion and exclusion criteria	Intervention (I) Control (C)	Main findings CI=95%	Study quality Comments
Tuna et al 2008 [10] Turkey	To evaluate the long-term effectiveness of MTA compared with calcium hydroxide when used as pulp capping materials in primary teeth	RCT (quasi-randomised; split mouth model) Symmetrical pairs of primary molars in 50 consecutive healthy children aged 5–8 years Not stated. No of operators not reported Deep dentin caries with excavation resulting in pulp exposure, pulp exposure less than 1 mm, red colour, hemostasis evident in 2–3 min, no other clinical or radiographic signs of pathology One of the paired molars with no pulp exposure at excavation, spontaneous pain, sensitivity to percussion/palpation, swelling, pathological mobility, widening or loss of lamina dura, furcation radiolucency, internal or external root resorption	I: Direct pulp capping I1: Capping with MTA/22 molars/restored with amalgam I2: Capping with calcium hydroxide/20 molars/ restored with amalgam *Outcome measures* Healing/no healing *Criteria of healing* No clinical symptoms, no radiographic pathology Follow-up: 2 years Drop-out rate: 8/50=16% Outcome examiners blinded to materials	No difference between dressing materials Healing: I1: 22/22 I2: 20/20	Moderate Randomisation procedure not described Power analysis unclear External validity unclear

* Calculations not reported by the author.

C = Control; CCT = Clinical controlled trial; CI = Confidence interval; I = Intervention; MTA = Mineral trioxide aggregate; NS = Not statistically significant; RCT = Randomised controlled trial; RR = Relative risk; ZOE = Zinc oxide eugenol

Table 3.3.6 *Vital pulp treatment. Pulpectomy.*

Author **Year** **Reference** **Country**	**Aim**	**Study design** **Sample characteristics** **Setting** **Inclusion and exclusion criteria**	**Intervention (I)** **Control (C)**	**Main findings** **CI=95%**	**Study quality** **Comments**
Engström et al 1965 [17] Sweden	To compare the outcome of pulpectomy in teeth with positive or negative bacterial culture prior to root canal filling	CCT 156 patients/173 permanent teeth Dental school clinic. Operators: Dental students Not reported	I: Pulpectomy and root filling I1: Root canal filling with growth of bacteria (n=52 teeth) I2: Root canal filling with no growth of bacteria (n=78 teeth) Outcome measure: Successful/unsuccessful treatment Criteria of successful treatment: Distinct unbroken lamina dura Unsuccessful treatment: Widened periodontal space, marked bone destruction, condensation or severe apical root resorption Follow-up: 1 year and 3.5–4 years Drop-out (3.5–4 years): 40/156 patients=26%; 44/173 teeth=25% Number, independent or blinded examiners not reported Reliability test not reported	1 year follow-up: Tooth as unit of analysis: No significant difference between teeth with and without growth: I1: 39/52= 75% *(CI 62; 85) I2: 68/78= 87% *(CI 78; 93) Root as unit of analysis: Significant difference between roots with and without growth: 56/69=81% *(CI 71; 89) vs no growth: 98/108= 91% *(CI 84; 95) 3.5–4 years follow-up: Tooth as unit of analysis: Significant difference between teeth with and without growth: I1: 30/49= 61% *(CI 47; 74) I2: 68/80= 85% *(CI 76; 91) Overall lower success rates compared with 1 year follow-up The percentage of failures was significantly higher in teeth with a preoperative diagnosis of symptomatic pulpitis	Low Population poorly defined Potential imbalances between groups not examined

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Table 3.3.6 continued

Author Year Reference Country	**Aim**	**Study design Sample characteristics Setting Inclusion and exclusion criteria**	**Intervention (I) Control (C)**	**Main findings CI=95%**	**Study quality Comments**
Gesi et al 2006 [11] Italy	To compare the outcome of pulpectomy in two treatment sessions with calcium hydroxide as an intracanal dressing vs root filling in one session procedure	RCT 256 consecutive patients/256 teeth, mainly adults (95% >20 years). Equal distribution of gender Private practice, one operator specialised in endodontics Restorable tooth with painful (n=204/256=80%) or non-painful (52/256=20%) vital pulp. Major reason for treatment: caries (184/256=72%) Severe attachment loss, remarkable medical history, physical or mental disability, on pain or antibiotic medication or treatment for systemic disease. Intention-to-treat: n=295	I: Pulpectomy I: 1-step procedure (n=130 teeth) C: 2-step procedure (n=126 teeth) Outcome measures: Successful/not successful treatment Criteria of successful treatment: No subjective symptoms, normal or unclear (widened apical periodontal space or diffuse lamina dura) periapical condition Follow-up: 2–3 years Drop-out rate: 12/256=5% Two independent, blinded examiners. Reliability reported	No difference in outcome between 1-and 2-step procedure Successful treatment: I: 114/123= 92.6% *(CI 87; 96) C: 113/121= 93.4% *(CI 88; 97) Overall: 227/244= 93% *(CI 89; 96)	Moderate Limited external validity

* Calculations not reported by the author(s).

C = Control; CCT = Clinical controlled trial; CI = Confidence interval; I = Intervention;
RCT = Randomised controlled trial

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3.4 Treatment of teeth with necrotic pulps

Background

The aim of endodontic treatment (root canal treatment) of a tooth with a necrotic pulp is to eliminate root canal infection in cases of apical periodontitis and to prevent infection in cases of sterile necrosis. The goal of treatment is to achieve asymptomatic and infection free conditions and in teeth with apical periodontitis, to restore normal structure to the periapical tissues. The tooth usually becomes asymptomatic immediately after treatment, or within a few days. Persistence of symptoms may be an indication of failure to eliminate bacterial infection. Healing of apical periodontitis is however, a relatively slow process: an interval of 6–12 months is usually required before there is evidence of complete healing and in some cases it may take up to several years. Thus it can be difficult for the dentist to decide whether the bone is going to heal completely or not radiographically.

Treatment methods

The central steps in root canal treatment comprise debridement, irrigation and disinfection, followed by root filling. The aim of debridement is to remove all infected hard and soft tissue; the canal is then prepared and shaped so that it can be effectively disinfected and sealed with a root filling. Debridement and preparation of the root canals may be carried out by hand or machine-driven instrumentation. Over the years, various root canal irrigants with disinfectant properties have been tested. It is desirable that during instrumentation the irrigant aids in dissolving necrotic tissue and killing bacteria in the areas not accessible to instrumentation. To enhance the treatment effect, medicaments are often inserted (so-called intracanal dressings) for various periods of time. Techniques and materials vary and there is uncertainty as to which yield the best treatment results. The root filling is intended to prevent reinfection and re-growth of any remaining bacteria. The technical qualities of the filling, ie its ability to be adapted closely to the original anatomy of the root canal, the length and the density of the filling, are considered to be major determinants of treatment outcome [1–4].

Evidence-graded results

Instrumentation

- There is a lack of scientific support on which to determine the importance of different root canal instruments and instrumentation techniques for the treatment outcome.

Disinfection

- There is a lack of scientific support on which to determine the importance of different root canal irrigants and medicaments on the outcome of root treatment.

- There is a lack of scientific support on which to determine whether calcium hydroxide has any effect on the outcome root canal treatment.

Root filling materials and root filling methods

- There is a lack of scientific support on which to determine whether any particular material or method for root filling gives a better treatment result than any other.

Prognostic factors

- There is a lack of scientific support on which to determine to what extent the microbiological status of the root canal at the time of root filling influences the outcome of root treatment.

- There is a lack of scientific support on which to determine to what degree preoperative status (pulpal necrosis, with or without apical periodontitis) influences the outcome of root treatment.

- There is a lack of scientific support on which to determine the possible influence of the quality of the root filling (length and density) on the outcome of root treatment.

Number of treatment sessions

- There is limited scientific evidence to support the claim that the number of treatment sessions – one, two or more – has any clinically important influence on the outcome of endodontic treatment of teeth with necrotic pulps and associated apical periodontitis (⊕OOO).

Table 3.4.1 *Effect of one or two treatment sessions on healing of apical periodontitis.*

Effect measure	**No of patients (no of studies)**	**Mean risk in standard group (min–max)**	**Relative risk (95% CI)**	**Absolute effect per 1 000 patients**	**Scien-tific support**	**Comments**
Healing	150 (2)	Standard= 2 treatment sessions 22% (18–25%)	RR=1,31 (0,74–1,87)	67 fewer	⊕⊕○○	Quality: –1 Imprecise data: –1

Post treatment complications

- There is limited scientific support that the risk of severe pain and swelling after root treatment is 1–15% (⊕⊕○○).

- There is a lack of scientific support for treatment protocols intended to prevent and/or treat pain and swelling after root treatment.

- There are contradictory results with respect to the influence of the number of treatment sessions on the occurrence of post operative complications after root treatment of teeth with necrotic pulps (⊕○○○).

Questions addressed

- Is the choice of method and materials for instrumentation, disinfection (irrigants and medicaments) and root filling of importance for the outcome of root treatment?

- What other factors influence the outcome of root treatment (number of treatment sessions, preoperative periapical status, microbiological status, quality of root filling)?

- Are there effective methods for preventing or managing post-operative discomfort following root filling of teeth with necrotic pulps? What factors influence the incidence and severity?

Criteria for inclusion

Articles published 1950–2010. Articles published in any language, provided there is at least an abstract in English or Swedish. Systematic overviews in which the included studies meet the inclusion criteria for treatment studies as listed below. Prospective treatment studies addressing some of the specific questions; the study design to include control groups and/or comparisons for relevant factors within the cohort.

Facts 3.4.1 Inclusion criteria.

Population	Studies in vivo on humans. Permanent teeth. Only studies where it is clearly stated that preoperatively, the treated tooth had a necrotic pulp (with or without apical bone destruction) or where preoperative pulp and periapical status are presented separately in the results section of the study. At least 15 teeth in each group for randomised controlled trials (RCT) and clinical controlled trials (CCT) or at least 30 teeth in cohort studies
Intervention	Root canal instrumentation, disinfection and root filling. The methods to be appraised should be available or expected to become available in Sweden
Control	Root treatment completed in one or more sessions, disinfection and root filling, various instrumentation techniques, various root filling materials
Outcome	The minimal acceptable unit for evaluation of the effect measure "apical periodontitis" to be the individual tooth. The minimal acceptable unit for evaluation of the effect measure "post operative complications" to be the individual patient, (ie one treated tooth per patient). For studies of the effect measure "apical periodontitis", the results should be based on both clinical and radiographic examination. At least one years' follow-up. For studies evaluating post operative complications, the evaluation should be made at the time of a completed treatment step or completed treatment. Attrition of maximum 30%

Results of literature search and selection of studies

The literature search yielded 1 464 articles, of which the full-text version was ordered for 186. A further 77 articles were added after a manual search of reference lists. See flow diagram in Figure 3.4.1.

Description of studies and results

In all, 22 studies were included. None was assessed as high quality [5–26]. Nine studies were of moderate quality [6,8,11,12,14,18,21,22,25] and the remaining 13 were of low quality.

Methods and materials for instrumentation, disinfection and root filling

Two studies of low quality were included [5,9].

Instrumentation

The review failed to identify any study, which analysed the outcome of different instrumentation techniques in relation to relevant clinical criteria. Several studies compare different instrumentation techniques with each other, eg hand and mechanical instrumentation, with respect to how well they retain the original form of the root canal, how much infected tissue is removed and the potential to achieve a technically good root filling. There are no clinical studies assessing the effect of different instrumentation techniques in cases of apical periodontitis.

Disinfection

Several studies describe and test the effectiveness of different irrigants. However, there is no comparison with relevant clinical outcome measures. The same applies to root canal medicaments. In a study of low quality, 172 teeth with apical periodontitis were treated [5]. In a total of 58 teeth in the test group, calcium hydroxide was extruded into the periapical tissues. In the control teeth the medicament was inserted to be confined to the root canal. After follow-up times of two to three years, healing was recorded in 79.3% of the teeth in the test group and 81.6% of those in the control group. There were discrepancies between the groups with respect to the size of the preoperative periapical bone destruction. No statistical analysis was included.

Sodium hypochlorite in varying concentrations is a common root canal irrigant. The review failed to identify any study (meeting the inclusion criteria), which compared the effect of varying concentrations of sodium hypochlorite on the healing rate of apical periodontitis.
Calcium hydroxide is the most common interappointment disinfectant. Its antimicrobial properties have been documented in laboratory studies and in clinical case studies. There are studies comparing healing rates for apical periodontitis following endodontic treatment undertaken in one or two appointments (see below: The importance of the number of treatment sessions).

Root filling material

Gutta-percha as the core material for root filling has been used in many treatment studies. However, with reference to relevant outcome measures, there is a lack of comparative studies with other materials.

The effect of various root canal sealers has been compared with reference to healing rates for apical periodontitis [27,28]. However, none of the studies met the inclusion criteria.

Root filling methods

One study evaluated the healing of apical periodontitis in mandibular molars with apical periodontitis, after root filling with either the cold lateral condensation technique or Soft-Core [9]. After three years' follow-up, there was no difference between the two groups. The study was assessed as low quality because the population and the method of selection were inadequately described.

Other factors of importance for the treatment prognosis

Three studies were included, two of moderate quality [6,8] and one of low quality [7].

Number of treatment sessions

Two randomised control studies showed no difference in healing of apical periodontitis after treatment of teeth with infected pulpal necrosis in one or two sessions [6,8]. One of the studies was based on 94 individuals and 101 treated teeth [6]. The treatment outcomes after one and two years respectively were compared. In the group treated in one appointment, iodine potassium iodide was used as an intracanal disinfectant during the treatment session. In the group treated in two sessions, calcium hydroxide was used as a canal dressing between appointments. Another study disclosed no difference in the outcome for treatment carried out in two sessions, using calcium hydroxide as an interappointment root canal dressing, compared with instrumentation and root filling in one treatment session [8]. The study comprised 73 teeth, of which 67 were evaluated for up to five years.

Preoperative periapical status

None of the included studies specifically addresses the question of the importance of preoperative periapical status. One study found that the preoperative size of the lesion did not influence the treatment outcome [7]. This finding was not confirmed by another study, which reported that the preoperative size of the lesion was of importance to treatment outcome (hazard ratio 2.45 (1.21–4.58)) [8]. The follow-up times in both studies varied, the longest being five years. One of the studies was assessed as low quality because the population in the study was inadequately described [7].

Microbiological status at the time of root filling

Two studies investigated the association between microbiological status at the time of root filling and subsequent healing of apical periodontitis [6,7]. In one of the studies, teeth with a positive bacterial sample had a healing rate of 44%, compared with 80% for those with a negative bacterial sample [6]. The difference in healing rate was not statistically significant. The other study reported that the healing rate in teeth with negative bacterial samples at the time of root filling was 94% and 68% for those with positive bacterial samples [7]. The difference reached statistical significance.

These studies imply that the treatment prognosis is poorer when there is evidence of bacteria at the time of root filling. Because of methodological shortcomings however, one of the studies cannot be used to support conclusion [7].

Quality of root filling

Two of the included studies analysed the importance of the quality of the root filling [7,8]. In both studies the length of the root filling in relation to the root apex was the indicator. Both studies concluded that the length of the root filling was not important. However, the observations are based on limited material and very little variation in the length of the root fillings. In one of the studies, 67 teeth were treated in all and allotted to treatment in a single session or in two sessions [8]. Of these, the root fillings in 55 teeth extended to within 2 mm of the root apex. The root filling in one tooth extruded beyond the apex and the remaining 11 had root fillings, which were shorter, terminating more than 2 mm from the apex. In the other study, 10 teeth had extruded root fillings [7], all of which showed periapical healing. The remaining teeth were root-filled to within 2 mm from the apex.

Complications following endodontic treatment

Seventeen studies of post operative complications after endodontic treatment were included [10–26]. Of these, seven were assessed as being of moderate quality [11,12,14,18,21,22,25].

Incidence of swelling and pain

One study (moderate quality) investigated the frequency of post endodontic pain and/or swelling of such severity that the patient had to be seen by the dentist [22]. This occurred in 3% of 946 patient appointments. Pain and swelling were positively correlated with the severity of pain before treatment, teeth with pulpal necrosis and acute apical abscess. In another study of moderate quality, it was reported that prophylactic administration of penicillin V could prevent the occurrence of such conditions in completely asymptomatic teeth with apical periodontitis [18]. A study of low quality, comprising 170 symptomatic and 204 asymptomatic teeth with necrotic pulps, reported that none of the following factors influenced the incidence of post operative complications: the patient's age or gender, the size of the bone lesion, whether analgesics had been taken before treatment or the presence of symptoms before treatment [10].

The importance of the number of treatment sessions

Two studies compared the degree of pain after endodontic treatment completed in one or two treatment sessions and found that the patients developed little or no pain after treatment [13,14]. A study of moderate quality investigated patients with vital teeth [14]. Pain was experienced primarily in association with overfilling of the root canals. The other study, of low quality, included teeth with both vital and non-vital pulps [13]. The same low grade of post operative pain was observed in both cases. In a study of moderate quality, limited to teeth with necrotic pulps, 4% of patients treated in one session and 5% of those treated in two sessions experienced serious post operative pain after the root filling [12]. A study of low quality of teeth with necrotic pulps found that the number of patients who experienced pain after the first visit was significantly lower if the treatment was carried out in two sessions with an interappointment root canal dressing of calcium hydroxide (15%), than if the complete root canal treatment was carried out in a single treatment session (40%) [15]. The severity of the pain was comparable in the two groups. In a study of low quality, the incidence of post operative discomfort in 60 patients with asymptomatic single-rooted teeth with pulpal necrosis was the same, regardless of whether treatment was carried out in one or more treatment sessions [20]. How-ever, in a study of a group of 291 patients with pulpal and periapical bone diagnoses, the incidence of post operative discomfort was greater when treatment was carried out in several sessions than when the root filling was done in the same session as the instrumentation (moderate quality) [11]. Post operative discomfort was more frequently associated with teeth with pulpal necrosis than those with vital pulps. The incidence of pain after root canal treatment in one or more sessions was investigated in a study of low quality [17]. Both teeth with vital pulps and pulpal necrosis were included in the analysis. However, in the case of teeth with pulpal necrosis, no distinction was made between those with apical periodontitis and those without. Therefore only the teeth with vital pulps were considered; no differences were observed in the incidence of post operative discomfort in relation to the number of treatment sessions.

Preventive measures

A study of low quality investigated whether oral administration of dexamethasone could prevent discomfort after root canal instrumentation in 40 patients with asymptomatic vital teeth [16]. Patients administered dexamethasone had significantly less discomfort up to 48 hours post treatment. In another study of moderately high quality, comprising 760 patients with symptomatic and asymptomatic vital teeth, intra-canal dressings of two non-steroidal mild anti-inflammatory agents (ketoprofen or diclofenac) gave better pain relief than a placebo [21]. A study of moderate quality found that prior to treatment of asymptomatic teeth with vital pulps by root canal instrumentation and a temporary root canal filling of calcium hydroxide, a prophylactic dose of 4 mg dexamethasone gave significant symptom relief for 4 and 12 hours after treatment [25]. After 24 and 48 hours there was no difference in effect compared with a placebo. None of the patients in either test or placebo group developed severe toothache. In a study of low quality, the incidence of post operative discomfort was investigated, after complete instrumentation or instrumentation of two-thirds of the length of the root canal, respectively [26]. In all cases (n=157) camphorated parachlorphenol was used as an intra-canal dressing after instrumentation. There were no significant differences between the groups.

Two studies of low quality found no effect of penicillin and Amoxycillin respectively on the incidence of discomfort after endodontic treatment of teeth with necrotic pulps [23,24].

Other studies

One study (low quality) investigated which factors influenced post operative discomfort after endodontic treatment and retreatment [19]. The cohort with root filled teeth was not considered because the reasons for endodontic retreatment were not included. In the cohort with untreated teeth, there was a correlation between discomfort before treatment and the frequency of post treatment discomfort while the periapical diagnosis (with or without indications of apical periodontitis) was not of importance.

Discussion

The review of the literature reveals a lack of scientific support on which to draw definite conclusions as to which methods and materials are most effective for treatment of teeth with necrotic pulps. Nor is it possible to determine which measures should be taken in order to prevent post operative discomfort such as pain and swelling. This is despite the fact that the frequency of discomfort after endodontic treatment has been investigated in numerous studies, some of which are of moderate quality. The main reason is the pronounced difference in treatment methods investigated in the various studies. Yet, collectively the data shows that the incidence of severe toothache after endodontic treatment is low.

The best available effect measures in studies investigating the outcome of endodontic treatment are radiographic and clinical signs. However, comparative studies can only answer questions as to how effective various treatment protocols are in relation to each other and not how effective endodontic treatment is per se. Although further knowledge of this issue would be advantageous, placebo studies cannot be undertaken for justifiable ethical reasons.

The time required for repair of bone destruction in apical periodontitis varies from case to case and may take up to several years. We regarded the requirement of at least one year's follow-up for inclusion of studies in this report reasonable, because most lesions heal within this time period [29]. Yet it would be preferable to have access to studies with longer observation periods, but few such studies are available. Those, which do exist generally had methodological shortcomings related to selection of treated patients and teeth, and high rates of attrition.

Various root filling materials, both core materials and root canal sealers, have been investigated in laboratory and clinical follow-up studies. The outcome measures have varied. The clinical studies appraised have methodological shortcomings: patient selection is often inadequately described and many studies are retrospective in design, or do not have a control group [30]. In several studies there have been high rates of attrition [27]. Prospective studies with adequate controls have used the root as the minimal statistical unit [28].

Several root filling methods have been compared in different types of studies. Primarily, the studies have investigated different techniques for root filling with thermoplastic gutta-percha and the lateral condensation technique using gutta-percha. A meta-analysis found no difference between these two techniques with respect to periapical bone healing 1–5 years after treatment [31]. The studies on which the meta-analysis was based included teeth with both vital and necrotic pulps; however, the pulpal diagnosis was not taken into account in the presentation of results and the meta-analysis was therefore excluded.

In a number of clinical studies, it has been observed that the quality of the root filling, insofar as it can be assessed radiographically, is important for the outcome of endodontic treatment. Several of these studies have been excluded because of methodological shortcomings (retrospective studies, high attrition rate, analysis using the root as a unit, analysis not taking into account the preoperative diagnosis). It has long been considered that an optimal root filling should closely approach the tip of the root (2 mm from the apex), be well-sealed along its entire length and not have an unfilled space apical to the root filling. Clinical and epidemiological studies report a statistical relationship between inadequate quality of the root filling and apical periodontitis. It may be assumed that meticulous instrumentation and disinfection of the root canal is more important for the treatment outcome than the quality of the root filling itself.

There has been longstanding debate over whether root filling materials and irrigants with increased antibacterial properties should be used in order to enhance treatment outcome. An increased antibacterial effect may however cause undesirable side-effects (Chapter 3.9). The appraised literature does not support the concept that increasing the antibacterial potential of irrigants, medicaments or root filling materials will lead to improved outcomes with respect to healing of apical periodontitis.

In recent years, several new techniques have been introduced into clinical practice to improve the effectiveness of root canal treatment, such as mechanical instrumentation, different forms of plastic materials, heated gutta-percha and the surgical microscope. Adoption of the new techniques by Swedish dentists varies considerably (Chapter 6). We have been unable to identify any study in which such innovative techniques have been evaluated with reference to their potential to improve the outcome of endodontic treatment.

A number of randomised clinical studies comparing the outcomes of endodontic treatment carried out in one, two or more sessions have shown that the number of treatment sessions is not an important determinant of outcome. The two studies, which were included, were conducted in specialist clinics and consecutive enrolment of patients was applied in only one. This highlights the limited generalisability of the results and the need for further studies in this field. Apart from the quality of the root filling, epidemiological data and clinical follow-up studies indicate that the preoperative periapical status of the tooth and negative bacterial culture at the time of root filling are important parameters for the outcome of endodontic treatment [1–4,32–38]. In the review of the literature we were unable to find definite support for either of these predictors. One reason might be that in the included studies, these factors were often observed as secondary findings and were not addressed as primary issues. Another reason might be that the material studied was inadequate and that variations in the results were too small to disclose any differences.

In the included studies, treatment was usually conducted under well-controlled conditions at teaching institutions or specialist clinics. Swedish epidemiological studies report a high prevalence of apical periodontitis associated with root-filled teeth [32–37]. Around one in every three root-filled teeth shows signs of apical periodontitis. Moreover, in endodontic treatment there is always a risk of technical mishaps or complications, which can negatively effect the treatment prognosis. Among such undesirable events are an undetected root canal, instrument fracture, root perforation, jamming of an instrument and over-instrumentation. Little is known about how effective modern endodontic treatment is in everyday practice. This is an obvious shortcoming because the epidemiological data indicate that the results of endodontic treatment achieved in well-controlled clinical studies cannot be generalised to everyday general dental practice.

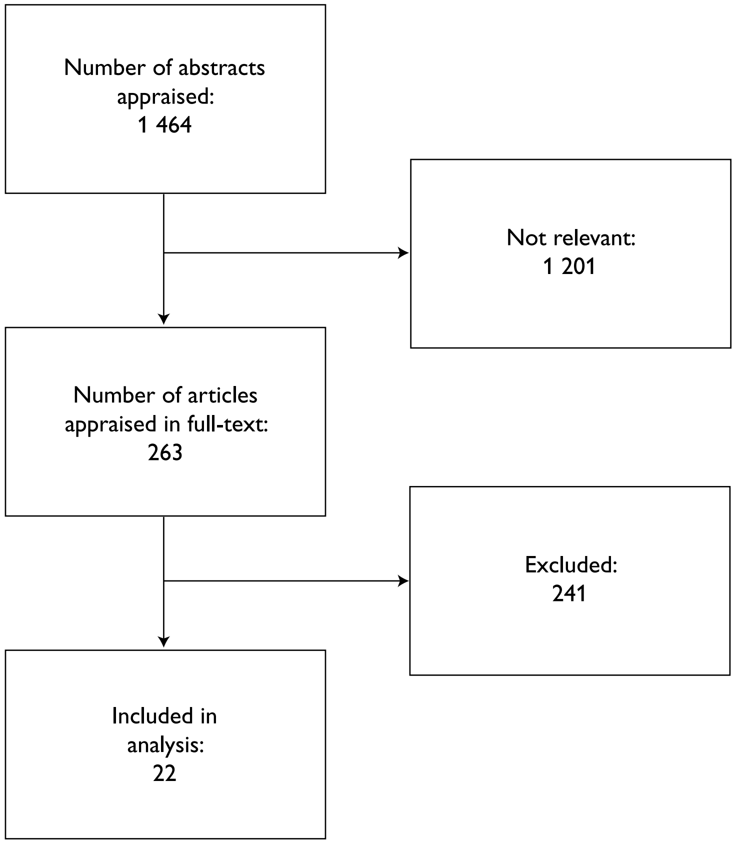

Figure 3.4.1 *Flow diagram of literature search.*

Table 3.4.2 Treatment of teeth with necrotic pulp.

Author Year Reference Country	Aim	Study design	Sample characteristics	Intervention Control	Main findings	Study quality Comments
Caliskan et al 1996 [5] Turkey	1. Long-term result of endodontic treatment on teeth with apical periodontitis 2. Comparison of outcome in teeth with and without extrusion of calcium hydroxide	CCT	Non-consecutive sample. 172 teeth with apical periodontitis in 115 patients. 65 teeth had symptomatic apical periodontitis and 107 were asymptomatic	Asymptomatic teeth were instrumented in 1 session and symptomatic teeth were partially instrumented in several sessions until symptoms subsided Group 1: Calcium hydroxide was confined to the root canal (n=114) Group 2: In 58 teeth of which 48 were randomly selected, calcium hydroxide was extruded periapically All teeth root-filled one week after final instrumentation. Teeth followed up for 2–5 years	Healing rate was 81.6% in group 1, and 79.3% in group 2 Complete dissolution of extruded calcium hydroxide occurred in 48% of overfilled teeth. Partial dissolution in 38%	Low Imbalanced at baseline with respect to lesion size
Molander et al 2007 [6] Sweden	1. 2-year clinical and radiographic outcome after root canal treatment in 1 vs 2 sessions 2. To study the significance of the microbiological status on outcome	RCT (minimisation method)	Consecutive sample. 101 teeth with asymptomatic apical periodontitis in 94 patients	Microbiological samples obtained before and after instrumentation but before root canal filling 1-visit group (n=53): Root canals medicated with Tubulicid Plus and 5% IPI solution prior to root filling. 2 visit group (n=48): Root canals filled with calcium hydroxide for 1 week prior to root filling All teeth were followed up for 2 years. 12 teeth were lost to follow-up (4 in the 1-visit group and 8 in the 2 visit group)	Healing rate 65% in the 1-visit group and 75% in the 2 visit group. Non-significant difference. In teeth with a negative microbiological sample before root filling, the healing rate was 80%, as compared to 44% in teeth with positive cultures. Non-significant difference	Moderate Number of eligible patients not reported Follow-up less than 4 years

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Table 3.4.2 *continued*

Author Year Reference Country	Aim	Study design	Sample characteristics	Intervention Control	Main findings	Study quality Comments
Sjögren et al 1997 [7] Sweden	To study differences in healing rate depending on microbiological status at time of root filling in teeth with apical periodontitis	Cohort	Non-consecutive sample. 55 single rooted teeth with apical periodontitis. Number of patients not stated	All teeth treated endodontically. Microbiological samples taken before root canal instrumentation and before obturation. All teeth followed for up to 5 years if not complete healing had taken place. Loss to follow-up 4%	Following instrumentation, 22 root canal cultures were positive. Overall, healing rate was 83%. In root canals with cultivable bacteria, healing rate was 68% and in root canals with negative samples healing rate was 94%. Difference statistically significant. 10 teeth with slight overfilling had no impact on outcome. All other teeth were root filled within 2 mm off the apex	Low Population not adequately described
Weiger et al 2000 [8] Germany	Influence of calcium hydroxide in teeth with apical periodontitis (1- vs 2 visit treatment)	RCT (minimisation method)	Non-consecutive sample. 73 teeth with apical periodontitis in 73 patients	All teeth treated by means of root canal instrumentation 1-visit group (n=36) Obturation following root canal instrumentation. 2 visit group (n=31). Obturation following 7–47 days with calcium hydroxide in the root canals between appointments All teeth followed up for 5 years if complete healing had not taken place earlier. Loss to follow-up 8.2%	Overall healing rate 77.6%. No significant difference between the two treatment groups	Moderate Number of eligible patients not reported Follow-up less than 4 years

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Table 3.4.2 continued

Author Year Reference Country	Aim	Study design	Sample characteristics	Intervention Control	Main findings	Study quality Comments
Özer et al 2009 [9] Turkey	To evaluate outcome of root canal treatment in teeth root filled with cold lateral compaction compared to Soft-Core	RCT	Non-consecutive sample of 98 patients with mandibular molars with apical periodontitis	All teeth instrumented with Quantec LX instruments and obturated with either cold lateral compaction gutta-percha or Soft Core. In both groups Diaket sealer was used 80 patients re-examined clinically and radiographically 3 years following treatment	Overall healing rate 82.5%. In the Soft-Core group 85% healed cases and in the cold lateral compaction group 80% (non-significant)	Low Population not adequately described Clinical and radiographic evaluation not adequately described

CCT = Controlled clinical trial; IPI = Iodine potassium iodine solution; n = Number;
RCT = Randomised clinical trial

Table 3.4.3 *Post treatment symptoms.*

Author Year Reference Country	Aim	Study design	Sample characteristics	Intervention Control	Main findings	Study quality Comments
Alacam et al 2002 [10] Turkey	To determine incidence of inter appointment flare-ups in teeth with necrotic pulps	RCT	Non-consecutive sample of 474 patients, 170 symptomatic and 304 asymptomatic teeth with necrotic pulps. 2 operators	All root canals filled with calcium hydroxide following root canal instrumentation. Patients were allocated in a double-blind manner to 1. 500 mg diflunisal (2 per day) 2. Placebo 3. No medication All patients evaluated by means of a flare-up index (FUI). No drop-outs	No difference between the groups of medication. Mandibular teeth more flare-ups than teeth in upper jaw (FUI 16.86 vs 12.96). No impact of gender, age, diameter of lesion, asymptomatic/symptomatic teeth	Low Population not adequately described Follow-up period not clearly stated
Albashaireh et al 1998 [11] Jordan	Difference in post obturation pain incidence after single- and multiple-visit endodontic treatment	CCT	Consecutive sample of 300 patients, free from symptoms, referred for endodontic treatment	Patients consecutively allocated single- or multiple visit for endodontics treatment. 9 patients were excluded or failed to attend follow-up Patients asked to categorize pain in a 4-graded scale. 1, 2, 3, 7 and 30 days after obturation	Incidence of pain greatest during the first 24 hours. 97% pain free after 7 days. Single-visit less pain than multiple-visit (27.5% vs 37.6%). Vital pulp lower pain (9%) than non-vital (41%) No significant difference between males and females, 32% and 33% respectively	Moderate Randomisation procedure not described

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Table 3.4.3 continued

Author Year Reference Country	Aim	Study design	Sample characteristics	Intervention Control	Main findings	Study quality Comments
Al-Negrish et al 2006 [12] Jordan	Difference in post obturation pain incidence after single- and multiple-visit endodontic treatment of non-symptomatic maxillary incisors with necrotic pulps	CCT	120 referred patients (66 female and 54 males), 15–45 years. Inclusion criteria: One asymptomatic necrotic central maxillary incisor without periapical lesion	Patients assigned consecutively to either 1- or 2 visit endodontic treatment. 60 patients in each group All patients received 20 500 mg tablets of paracetamol to be taken at discomfort Patients asked to report pain, partly based on use of analgesics: 1=no pain; 2=slight pain; 3=moderate pain; 4=severe pain (written criteria) 2 and 7 days after obturation	After 2 days 14.9% reported pain in the 1-visit group and 24.1% in the 2 visit. No statistical difference between groups or pain categories. After 7 days 3.7% of the patients had pain in the 1-visit group and 10.3% in the 2 visit group. No statistical difference The flare-up rate (moderate to severe pain) after 2 days was 9.2% for the one visit and 13.8% for the 2 visit group. After 7 days 1.8% and 5.2%, respectively, in the 2 groups	Moderate Randomisation procedure not described Number of eligible patients not reported
DiRenzo et al 2002 [13] USA	Post operative pain after 1- and 2 visit endodontic treatment	RCT	Non-consecutive sample of 80 patients requiring root canal therapy on mature permanent maxillary and mandibular molars	Patients randomly assigned by coin toss to 1-visit and 2 visits endodontic treatment. Each patient received tablets, 600 mg of ibuprofen to take as needed. Pain levels recorded using VAS on a scale 0–170 Preoperative pain, and pain 6, 12, 24 and 48 hours postoperatively were noted. 8 patients failed to return VAS form	No statistically significant difference in pain report between 1 and 2 visit at preoperative or any of the 4 postoperative intervals No difference between vital/non-vital and maxillary/mandibular molar groups. The majority of patients in both groups reported no pain or minimal pain. 20% of the patients took analgesic	Low Study seems under-powered, at least if analysis is stratified on preoperative diagnosis

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Table 3.4.3 continued

Author Year Reference Country	Aim	Study design	Sample characteristics	Intervention Control	Main findings	Study quality Comments
Gesi et al 2006 [14] Italy	To determine the incidence of clinical symptoms and periapical lesions following pulpectomy in teeth with vital pulps in 1 or 2 sessions	RCT	Consecutive sample of 295 patients (45% men and 55% women) with one tooth requiring pulpectomy	Patients treated with pulpectomy randomised in 2 groups: 1=2-step treatment with inter appointment calcium hydroxide dressing 2=1-step treatment Pain assessed by a verbal rating scale (VRS) graded 0–3. Percussion test Follow-up 1 week after completion of root filling and annually for 3 years. Clinical and radiographic follow-up. Drop-out rate 4.7%	Post operative pain (13.3%) recorded 1 week after permanent filling was significantly associated with overfilling, with no difference between the treatment groups	Moderate Number of eligible patients not reported
Ghoddusi et al 2006 [15] Iran	Incidence and severity of flare-ups after endodontic treatment of pulpless teeth in 1 or 2 sessions with and without calcium hydroxide as an intracanal dressing	RCT	Non-consecutive sample of 69 patients with pulpless teeth (39 females and 30 males)	All root canals were instrumented. According to random allocation teeth were: 1. Root filled at the same appointment (1 visit) 2. Root canals left empty between 2 appointments 3. Root canals filled with calcium hydroxide between 2 appointments Pain assessed on a 10-degree VAS scale. Swelling measured on a 4-degree scale. Data coding combining pain and swelling Patients given a form to register every 6 hours for 72 hours. Recalled after 72 hours. 9 patients excluded	Incidence of pain was significantly higher in group 2 than in group 3 (47.5% vs 15%). In group 1 incidence was 40% No difference in severity of pain Incidence of swelling significantly lower in group 3 than group 1 (10% vs 35%)	Low Distribution of relevant factors between trial groups following randomisation not stated. May have resulted in imbalances

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Table 3.4.3 continued

Author Year Reference Country	Aim	Study design	Sample characteristics	Intervention Control	Main findings	Study quality Comments
Glassman et al 1989 [16] USA	Effect of oral dexamethasone to manage inter-appointment pain	RCT	Consecutive sample of 40 patients with asymptomatic vital teeth requiring endodontic treatment	Root canals left empty following instrumentation. Patients randomly allocated to receive either dexamethasone or placebo (double-blind) Patients seen after 24 hours and 48 hours and rated pain on a visual analogue scale: None (0), mild (1–33), moderate (34–66) and severe (67–100). 3 patients excluded	Significant differences at 8, 24 and 48 hours in pain ratings between groups. Mean post treatment pain rating for dexamethasone 8.3 at 8 hours, 1.1 at 24 hours and 1.1 at 48 hours. At 8 hours 60.3% were free from pain For placebo 29.6 at 8 hours, 14.3 at 24 hours and 7.8 at 48 hours. At 8 hours 17.1% were free from pain	Low Distribution of relevant factors between trial groups following randomisation not stated. May have resulted in imbalances
Ince et al 2009 [17] Turkey	Differences in occurrence of pain after root canal treatment (1) between vital and non-vital teeth and (2) between single- and multiple-visit treatment	RCT	A sample of 306 patients in need of endodontic treatment for various reasons. In the context of this report, only vital cases are considered (n=153) since no discrimination was made for teeth with and without apical periodontitis in non-vital teeth	Endodontic treatment at a single visit (n=87) or multiple visits (n=66). Patients assigned randomly to either group following root canal instrumentation. All teeth root filled with gutta-percha and AH26 root canal sealer Pain evaluated 3 days after the initial appointment. Patients recorded their pain as none, mild, moderate or severe	No significant differences in post treatment pain levels between patients treated at a single visit or at multiple visits. Differences with regard to pre-treatment pain not reported specifically for vital cases	Low Population not adequately described with regard to vital cases

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Table 3.4.3 continued

Author Year Reference Country	Aim	Study design	Sample characteristics	Intervention Control	Main findings	Study quality Comments
Mata et al 1985 [18] USA	To determine incidence of flare-ups in necrotic teeth and to evaluate effect of penicillin in preventing flare-ups in conjunction with endodontic therapy	RCT	Consecutive sample of 100 patients with teeth with asymptomatic necrotic pulps and periapical radiolucencies	After root canal treatment alternate patients were given (double-blind) either placebo tablets or PenicillinV (250 mg) Self-reported pain or swelling during the first 2 days after treatment. Pain and swelling graded on a 5-point scale. Flare-up recorded when patient had an unscheduled emergency visit. No drop-outs	88% of the patients reported some degree of pain/swelling within the first 24 to 48 hours of primarily a mild nature. 15% of the patients developed flare-ups. Significant differences between groups regarding incidence of flare-ups with 24% in placebo group and 6% in penicillin group	Moderate Number of eligible patients not reported
Mattscheck et al 2001 [19] USA	Factors associated with post treatment pain after root canal treatment and orthograde retreatment	Cohort	Non-consecutive sample of 84 patients from a dental school clinic requiring endodontic treatment	Endodontic treatment according to routine procedures with respect to diagnosis. Patients asked to report post treatment pain during 4–120 hours on a VAS scale. Patients requiring analgesics were omitted from the study after the time of self-administration Pre-treatment factors were: patient demographics, tooth number, pulpal diagnosis, initial treatment, retreatment and periapical diagnosis	No difference between teeth with primary endodontic treatment and retreatment. Pain significantly increased after 4–12 hours compared to other times Patients with VAS >20 6 hours prior to treatment reported significantly higher post operative pain. No differences with respect to periapical diagnosis	Low Sub-groups imbalanced at baseline with respect to pre-treatment periapical diagnosis. Primary endodontic treatments included both vital and non-vital teeth
Mulhern et al 1982 [20] Canada	Incidence of post treatment pain following endodontic treatment of teeth with necrotic pulps at one or three sessions	RCT	Non-consecutive sample of 60 patients with 60 asymptomatic teeth with necrotic pulps	Patients randomly assigned to 1 or 3 visits with 30 teeth per group Pain and swelling registered at 48 hours post-operatively. Clinical examination after 1 week. No drop-outs	Overall incidence of post operative pain was 33%. No difference in post operative pain between single- and multiple-visit groups, 26.7% vs 40%	Low Number of eligible patients not reported Randomisation procedure not described

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Table 3.4.3 continued

Author Year Reference Country	Aim	Study design	Sample characteristics	Intervention Control	Main findings	Study quality Comments
Negm et al 1994 [21] Egypt	Effect of diclofenac and ketoprofen as intracanal dressings on post treatment pain as compared with placebo	RCT	760 subjects with vital pulp exposure, acute and chronic pulpitis in single tooth/one operator	Following root canal instrumentation patients were randomly assigned to intracanal dressing (double-blind allocation): 1 = Diclofenac (Voltaren) 2 = Ketoprofen (Profenid) 3 = Hyaluronidase 4 = Placebo 5 = 1+3 6 = 2+3 Asymptomatic teeth and symptomatic teeth divided each in 6 subgroups Pain recorded before 2, 4, 8, 12 hours and 2, 3 days. 4-graded scale. 3 patients dropped out	Diclofenac and ketoprofen significantly better than placebo in controlling post operative pain in both asymtomatisk and symptomatic patients. No significant differences between medication groups at any time	Moderate Number of eligible patients not reported Distribution of relevant factors between trial groups following randomisation not stated. May have resulted in imbalances Yet, sample was stratified with regard to symptomatic and asymptomatic cases
Walton et al 1992 [22] USA	Incidence of flare-ups and their association with various clinical and demographic factors in patients having teeth with apical periodontitis	Cohort	Consecutive sample of 926 patients undergoing endodontic treatment during a 4-month period	All patients endodontically treated according to routine procedure Flare-ups within a few hours to a few days after a root canal treatment defined as pain or swelling, or both in patients seeking active treatment No drop-outs	Flare-up rate 3.17%. Flare-ups correlated positively with more severe symptoms (severe pain 19.2% and swelling 15.2%), pulp necrosis (6.5%) and painful apical pathosis (13.1%) and patients on analgesics Fewer flare-ups in undergraduate patients (1.5%) and following obturation procedures (1.8%). Other investigated factors did not correlate eg number of visits, treatment procedure, taking antibiotics	Moderate Number of eligible patients not reported but seems to be the same as the included sample

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Table 3.4.3 continued

Author Year Reference Country	Aim	Study design	Sample characteristics	Intervention Control	Main findings	Study quality Comments
Walton et al 1993 [23] USA	Effect of prophylactic penicillin on posttreatment symptoms in patients with an asymptomatic necrotic tooth	RCT	Non-consecutive sample of 80 patients seeking dental care at a dental school. Age 17–78 years. 32 females and 48 males	Endodontic treatment according to routine procedure Random allocation to following groups (double-blind): A. 2 g of penicillin at start and 1 g after 6 hours post treatment B. Placebo C. No medication Symptoms of pain were self-reported according to VAS scale at 4, 8, 12, 24 and 48 hours, as well as signs of swelling	The incidence of pain and swelling, respectively, were: A. 69.2%, 3.8% B. 79.2%, 4.2% C. 70%, 0% No significant differences between groups	Low Distribution of relevant factors between trial groups following randomisation not stated. May have resulted in imbalances
Pickenpaugh et al 2001 [24] USA	Effect of prophylactic amoxicillin on occurrence of flare-ups in asymptomatic necrotic teeth	RCT	Non-consecutive sample of 70 adult patients with one asymptomatic, necrotic tooth per patient, in need of endodontic therapy	Random allocation to the following groups (double-blind) A. 3 g amoxicillin one hour before endodontic treatment B. Placebo Endodontic treatment according to routine procedure All patients received Ibumetin to take every 4 to 6 hours and Tylenol if ibumetin did not relieve pain All patients recorded pain (0–3), percussion pain (0–3), swelling (0–3) and number and type of pain medication each morning and evening for 5 days	Flare-ups among 4% in the placebo group and 6% in the amoxicillin group. A flare-up was defined as moderate to severe pain or swelling with an onset 12–48 hours after treatment and with a duration of at least 48 hours. No significant differences between amoxicillin and placebo groups. No impact of age, gender, lesion size, previous endodontic treatment or allergy	Low Distribution of relevant factors between trial groups following randomisation not stated. May have resulted in imbalances Retreatments included?

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Table 3.4.3 continued

Author Year Reference Country	Aim	Study design	Sample characteristics	Intervention Control	Main findings	Study quality Comments
Pochapski et al 2009 [25] Brazil	To study the effect of dexamethasone on post endodontic pain	RCT	Non-consecutive sample of 50 patients with teeth with asymptomatic inflamed vital pulps	Patients randomly allocated to: Group 1: Placebo Group 2: Dexamethasone 4 mg All medications were administered 1 hour prior to root canal treatment in a double blind fashion. All root canals filled with calcium hydroxide following complete root canal instrumentation Patients required to complete a pain diary at 4, 12, 24 and 48 hours post-operatively. 3 patients were lost to follow-up	No patient reported severe pain following endodontic treatment. Patients in the dexamethasone group reported significantly lower pain levels at 4 and 12 hours post-operatively No significant differences at 24 and 48 hours after treatment	Moderate Number of eligible patients not reported
Balaban et al 1984 [26] USA	Impact of premedication on exacerbations following endodontic treatment	CCT	157 consecutive cases with a necrotic tooth with a periapical destruction	Standardised endodontic procedure except for the treatment of the apical third of the canal A. In 77 cases root canals were instrumented in the coronal two thirds, and then sealed temporarily with a dressing of camphorated parachlorphenol B. In 80 cases root canals were instrumented to 1 mm short of the radiographic apex. Then sealed temporarily with a dressing of camphorated parachlorphenol Symptoms of pain and/or swelling were recorded at the second and third appointments	14.3% in group A had an exacerbation after the first visit corresponding to 10% in group B. The difference was not statistically significant There was a significant association between exacerbations and patients under the age of 50. No significant difference regarding gender	Low Randomisation procedure not described Population inadequately described

CCT = Controlled clinical trial; FUI = Flare-up index; n = Number; RCT = Randomised controlled trial; VAS = Visual analogue scale; VRS = Verbal rating scale

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3.5 Revision of endodontic treatment

Background

Endodontic treatment does not always fully achieve its goals, ie after treatment the tooth is asymptomatic, free of infection and shows no evidence of apical periodontitis. Pain, swelling and fistulae associated with the root-filled tooth are all indications of a persistent or a newly developed root canal infection or of some non-endodontic condition such as a split tooth. A common condition is that of a clinically asymptomatic root-filled tooth, with radiographic evidence of developing periapical bone destruction or persistence of earlier bone destruction. Such a situation can deteriorate to an acute condition with pain and swelling. Teeth, which were initially diagnosed with periapical bone destruction require time to heal; follow-up studies have shown that the time required can vary from a few months to several years. The diagnosis of apical periodontitis associated with a root-filled tooth is reasonably certain in cases where there are clinical symptoms and evidence of periapical bone destruction. Similarly, the diagnosis is reasonably certain when a radiograph discloses an increase in the size of an existing area of bone destruction, or the development of a new lesion. However, in cases where the only evidence is persistence of previously observed bone destruction, the diagnosis is less certain, but more likely with an increase in the length of time elapsing since the primary root filling.

Treatment options

Apart from extraction, there are two options: orthograde or retrograde retreatment. Orthograde re-treatment (revision of the root filling) means that the dentist recreates access to the root canals, in order to treat the root canal infection mechanically and chemically. For technical reasons, the infected area is often difficult to access. Moreover the microorganisms are more often resistant to treatment than is the case with primary root canal infection.

Retrograde retreatment (apical surgery, apicoectomy) means that the root canal system is accessed by means of a surgical procedure. A few mm of the root tip are amputated. This is usually followed by some form of root-end preparation and disinfection of the exposed root canal. The cavity which has been prepared is then sealed with a so-called retrograde root filling. The complexity varies depending on the accessibility of the root, the competence of the operator and the availability of various forms of special equipment.

In this section of the systematic review we have scrutinized methods used for both types of retreatment. The outcome measures have been the same as for primary endodontic treatment. When the treated tooth, after a healing period, is asymptomatic and without clinical or radiographic indications of apical periodontitis, the treatment outcome has been achieved. We have also sought evidence to support methods which can prevent or treat post operative complications associated with retreatment.

Evidence-graded results

- There is a lack of scientific evidence on which to determine differences in the outcomes of ortho- or retrograde retreatment.

- The scientific support is inadequate or unavailable to allow determination of differences in outcome following different methods of ortho- or retrograde retreatment (⊕○○○).

- There is a lack of scientific support on which to determine the effectiveness of different methods for preventing or treating post operative complications following retreatment.

Questions addressed

- Are there differences in outcome between orthograde and retrograde retreatment?

- Is the outcome of orthograde retreatment influenced by choice of method: the number of treatment sessions, instrumentation technique, disinfection protocol or root filling material?

- Is the outcome of retrograde retreatment influenced by choice of method: root tip amputation only, root tip amputation with retrograde filling, retrograde preparation technique or retrograde filling material?
- Are there effective methods for preventing or treating post operative complications after re-treatment?

Inclusion criteria

Articles published 1950–2010. Articles in all languages with at least an abstract in English or Swedish. Systematic reviews of treatment studies in which the included studies meet the inclusion criteria for treatment studies as specified below. Prospective treatment studies with a control group and/or comparisons for relevant factors within the cohort which answer some of the specific questions being addressed.

Facts 3.5.1 Inclusion criteria.

Population	Studies in vivo on humans. Permanent teeth. Root-filled teeth with symptoms or radiographic signs of apical periodontitis (persistent, newly developed or increasing area of bone destruction). In cases of persistent bone destruction only, at least a year should have elapsed since the primary root filling. At least 15 teeth in each group for randomised controlled trials (RCT) and controlled clinical trials (CCT) or at least 30 teeth in cohort studies
Intervention	Orthograde or retrograde retreatment of a root-filled tooth. The methods should be available or should be expected to become available in Sweden. (Studies using amalgam as the retrograde material are not included)
Control	Orthograde compared to retrograde retreatment of a root filling. Orthograde root filling retreatment: Treatment in one or more sessions. Treatment with various disinfectants. Treatment with various instrumentation techniques. Treatment using various root filling materials. Retrograde retreatment of a root filling: Root tip amputation only, compared with root tip amputation and retrograde filling Treatment using various retrograde preparation techniques. Treatment using various retrograde filling materials

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Facts 3.5.1 continues

Outcome	The minimum allowable unit for evaluation of the outcome measure 'apical periodontitis' to be the individual tooth. The minimum allowable unit for evaluation of the outcome measure 'post operative complications' to be the individual patient (ie one treated tooth per patient). For studies using apical periodontitis as the outcome measure the results should be based on both clinical and radiographic evaluations At least one year's follow-up. For studies evaluating post operative complications the evaluation should be made at the time of completion of treatment. Maximum allowable attrition 30%

Results of literature search and selection of studies

The literature search yielded 2 013 abstracts, of which full-text versions were ordered of 183. A manual search of reference lists yielded a further 30 articles, which were also ordered in full-text versions. See flow diagram in Figure 3.5.1.

Description of studies and results

Comparison of orthograde and retrograde retreatment

A randomised controlled study of low quality presented the results of orthograde and retrograde root filling retreatment [1]. After one year, the frequency of healing was higher in the group which had undergone retrograde retreatment. The difference was statistically significant. With further follow-up time (two and four years) however, no significant difference in healing was observed. In both groups the healing rate after four years was around 55%. The study comprised only single-rooted teeth, mainly in the maxilla, and this limits the generalisability of the results.

The study also had shortcomings with respect to evaluation of healing and presentation of the results.

Methods of orthograde retreatment

Appraisal of the literature disclosed no studies comparing the effect of different instrumentation techniques, disinfection protocols or root filling materials with reference to healing of apical periodontitis. In a prospective cohort study comprising 86 teeth (low quality) the magnitude of the bone lesion was investigated as a potential prognostic factor for the outcome of orthograde retreatment [2]. No significant difference could be shown for teeth with areas of bone destruction greater or less than 5 mm in diameter. However, in another prospective cohort study comprising 54 teeth (moderate quality) the authors reported that those teeth which healed within five years of retreatment had initially less bone destruction, mean 3.7 mm, while the mean for those which failed to heal was 5.6 mm [3]. In the same study, 35 of 44 teeth which healed had negative bacterial cultures from the root canal at the time of the root filling. Of teeth with positive bacterial cultures, only two out of six healed. The healing rate was 62% after two to eight years in the former study [2] and 74% after five years in the latter [3]. In both the included studies, the retreatment was carried out on selected patients and teeth, not recruited randomly or consecutively. Moreover, one of the studies included 11 teeth which had previously undergone retrograde retreatment [2]. The scientific support is somewhat contradictory and is insufficient to identify factors which influence the outcome of orthograde retreatment. Scrutiny of the literature failed to identify any studies (meeting the inclusion criteria), which addressed methods of preventing or treating post operative complications associated with orthograde retreatment.

Methods of retrograde retreatment

A study of moderate quality supported the hypothesis that a retrograde seal of the root canal system gives a better result than amputation of the root tip and condensation of the existing root filling [4]. In the experimental group, after amputation of the root tip, a root-end cavity was prepared and filled with Mineral Trioxide Aggregate (MTA). In this group 85% (22 teeth) exhibited complete healing. In the group in which the root tip was amputated only, 28% (seven teeth) exhibited complete healing after one year. The generalisability of the study was limited because only incisors, cuspids and bicuspids were included. Follow-up time was only one year. An earlier report of moderately high quality investigated the incidence of post operative complications after retrograde retreatment with and without retrograde filling with MTA [5]. The difference between the groups was not statistically significant. The pain culminated on the day of operation in both groups while swelling culminated during the first 24 hours post-operatively. The literature search failed to identify any other studies (meeting the inclusion criteria) which investigate methods for preventing or treating post operative complications associated with retrograde root fillings.

Discussion

In addition to the included effect study [1], a further study [6] of similar design was noted in the systematic review of the literature. There are shortcomings in the description of the population and the indications for treatment [6]. This study has therefore been excluded. However, the results after one year follow-up were in good agreement with the corresponding results in the included study [1].

There is insufficient scientific support on which to determine whether ortho- and retrograde retreatment give different outcomes, both short- and long-term, with respect to healing of apical periodontitis in root-filled teeth. In routine clinical practice, a number of factors influence the choice of treatment. For example, the magnitude of the bone destruction, accessibility, the technical quality of previous treatment, the cost of treatment, the preferences of the clinician and the patient, the availability of various types of special equipment, future restorative requirements of the tooth, etc. Although future comparative studies may provide valuable general information, clinical decisions in every individual case will still have to be made on the basis that the conditions applying to every case are unique.

Only two studies which met our inclusion criteria specifically investigated the result of orthograde retreatment [2,3]. Thus, there is a need for studies which investigate both the outcome of such treatment and the relative importance of different treatment protocols. Factors which influence the incidence and severity of post operative symptoms should also be investigated.

Root fillings are sometimes revised as a precautionary measure on so-called technical indications. This means that a root filling may be revised before inclusion in a prosthodontic construction, despite the absence of evidence of apical periodontitis. The effect of endodontic retreatment based on such indications requires investigation in prospective studies with control groups and an extended follow-up period.

A frequent shortcoming in published studies of retrograde retreatment is the lack of a clearly presented, unambiguous indication for treatment. Many studies do not state clearly that the teeth which were treated had been root-filled and had signs of persistent or newly developed apical periodontitis. In the absence of symptoms or evidence that the apical periodontitis is increasing, time must be allowed for healing after completed primary root treatment, before there is reason to consider further endodontic treatment. In this report we set a minimum follow-up time of at least one year. If a study has a follow-up time of less than one year after the primary root treatment, there is a risk that some of the included teeth with bone changes are in fact healing. If this is not taken into account, both healing frequency and comparison of different methods or materials can be misleading. Several of the scrutinized studies failed to state the follow-up time following primary endodontic treatment or previous revision. Such studies were therefore excluded.

Over the past 10–15 years, apical surgery has undergone significant technological advances. Today, specialists in this field routinely use operating microscopes or other advanced equipment to aid visibility. Ultrasound techniques are used to ensure the best possible accessibility in retrograde preparations. In a randomised controlled study comprising 399 patients, retrograde preparation with ultrasound gave a higher healing rate (80%) than preparation using a bur (71%) [7]. The difference was however not statistically significant. The study included teeth examined at an interval of only 6 months after primary endodontic treatment and attrition in the bur group was 30%. The study was therefore not included in the report.

Materials specifically for retrograde root fillings have been developed and are commercially available (Super-EBA, MTA, Retroplast). We have not identified any study (meeting the inclusion criteria) which compares the various materials.

In the literature review, no information has emerged contradicting the view that modern aids and material indeed facilitate and probably improve the healing potential of apical periodontitis after retrograde retreatment. In the scrutinized studies in which a new technique is applied, the reported healing rates are often very high (>85%) [8]. However, many of these studies have shortcomings in the description of indications for treatment and many teeth are excluded, sometimes without good reason. Thus, it is uncertain whether the results achieved apply in general to root-filled teeth with apical periodontitis. There is therefore a need for randomised studies where techniques and materials for retrograde retreatment are investigated on a representative selection of teeth, with clearly defined indications for revision.

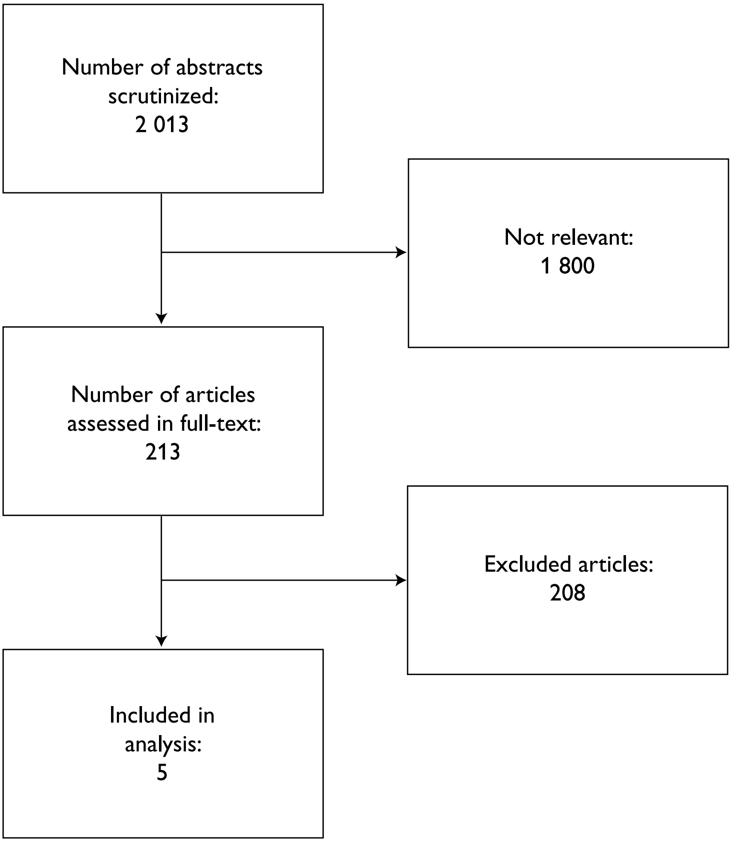

Figure 3.5.1 *Flow diagram of literature search.*

Table 3.5.1 *Retreatment.*

Author Year Reference Country	Aim	Study design	Sample characteristics	Intervention Control	Main findings	Study quality Comments
Caliskan et al 2005 [2] Turkey	To evaluate outcome of non-surgical retreatment and to identify factors influencing prognosis	Cohort study	71 patients/42 male and 29 female/age not stated/ 90 teeth referred/86 teeth included/all teeth with radiographic signs of AP. Previous endodontic treatment >2 years	Non-surgical retreatment with calcium hydroxide as an inter appointment dressing. Protocol individually adjusted. Cohort subdivided into groups according to lesion size and previous surgical treatment. Clinical and radiological evaluation after 6, 12, 24 up to 96 months. No drop-outs	62% cases healed completely, 14% showed incomplete healing, 24% failed to heal Root-filled teeth with lesion <5 mm completely healed in 68% and teeth with lesions >5 mm healed in 59% ($p=0.69$). Of 11 teeth, previously root filled and surgically treated 5 healed completely, 2 healed incompletely and 4 failed to heal ($p=0.49$)	Low Population not adequately recruited and described Inclusion and exclusion criteria not clearly described Follow-up period not clearly stated

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Table 3.5.1 continued

Author Year Reference Country	Aim	Study design	Sample characteristics	Intervention Control	Main findings	Study quality Comments
Christiansen et al 2008 [5] Denmark	To assess post operative discomfort following surgical retreatment with smoothening of the gutta-percha root filling or retrograde filling with MTA, and to evaluate effect of operating time on post operative pain	RCT	42 patients/19 male and 23 female/average age 54 years (range: 30–68 years)/42 teeth with radiographic signs of AP and previous endodontic treatment >2 years	Surgical retreatment with smoothening of gutta-percha or retrograde MTA filling. Post operative discomfort analyzed in relation to surgical method, sex, age, buccal fenestration, volume of periapical bone defect, operation time. Questionnaires, VAS and interview at suture removal on day 5–7. No drop-outs	Post operative pain peaked (VAS=29) after 3 hours. Swelling peaked on first post operative day (VAS=41) No statistically significant difference in post operative comfort depending on surgical retreatment method, operating time, size of buccal cortical bone cavity or the volume of periapical bone defect VAS scores for pain 3 hours post-operatively significantly higher ($p=0.018$) for women (VAS=37) compared to men (VAS=20). VAS score for swelling one day post-operatively significantly higher ($p=0.038$) for women (VAS=50) than men (VAS=33). Smoking habits not significant ($p>0.11$)	Moderate Number of eligible patients not accounted for Only incisors, canines and premolars Women and men not equally allocated to experimental and control group
Christiansen et al 2009 [4] Denmark	To compare healing after root-end resection with a MTA-retrograde filling with root resection and smoothing of the gutta-percha only	RCT	68 patients examined/ 44 patients included/ 20 male and 24 female/average age 55 years/52 incisors, canines and premolars with radiographic signs of AP and previous endodontic treatment >2 years	Surgical retreatment with smoothening of gutta-percha or retrograde MTA filling. Clinical and radiological examination after 6 and 12 months. Drop-out rate 2% (1 tooth)	In MTA group 22 teeth (85%) complete healing. In smoothening gutta-percha group complete healing in 7 teeth (28%). The difference was statistically significant ($p<0.001$)	Moderate 1 year follow-up Only incisors, canines and premolars

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Table 3.5.1 continued

Author Year Reference Country	Aim	Study design	Sample characteristics	Intervention Control	Main findings	Study quality Comments
Kvist et al 1999 [1] Sweden	To compare healing after surgical vs non surgical retreatment	RCT	92 patients included/ 38 male and 54 female/ average age 52 years (range: 17–75 years)/95 incisors and canines with radiographic signs of AP and clinical findings or endodontic treatment >4 years	Surgical retreatment using bur or files and gutta-percha as retrograde filling or non-surgical retreatment including a 2-week intra-canal dressing with calcium hydroxide Clinical and radiological examination after 6, 12, 24 and 48 months. Drop-out rate was 3% at 12 months control and 5% and 48 months control	At the 12-month recall 24 teeth (52%) showed complete healing in surgical retreatment group. In non-surgical retreatment group complete healing in 13 teeth (29%). The difference was statistically significant ($p<0.05$) At 48-month recall 26 teeth (58%) in the surgical retreatment group and 23 teeth (52%) in the non-surgical retreatment group showed complete healing. Difference not statistically significant ($p>0.05$)	Low Observers of radiographs not independent or blinded Absolute numbers of teeth showing healing not in original article Supplemental data provided by authors for this report
Sundqvist et al 1998 [3] Sweden	To investigate microbial flora in root-filled teeth with AP and to study the outcome of non-surgical retreatment	Cohort study	54 asymptomatic teeth with radiographic signs of AP and endodontic treatment >4 years	Non-surgical retreatment in three sessions with calcium hydroxide as an inter appointment dressing. Teeth with or without positive culture at time of root filling compared. The influence of initial size of the periapical lesion analyzed. Clinical and radiologic examination yearly for 5 years if complete healing not earlier. 4 teeth (8%) drop-out	37 (74%) showed complete healing. 13 teeth (26%) failed to heal. At time of root filling 6 teeth yielded positive culture and 44 teeth negative Teeth with positive culture healed 33%, teeth with negative culture healed 80% ($p=0.03$). The difference in initial mean size between the lesions that healed (3.7 mm) and those that did not heal (5.6 mm) was statistically significant ($p=0.03$)	Moderate Population not adequately recruited and described

AP = Apical periodontitis; MTA = Mineral trioxide aggregate; p = Probability;
RCT = Randomised controlled trial; VAS = Visual analogue scale

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3.6 Treatment of acute conditions

Background

Pain and swelling associated with infection of the pulp and periapical tissues are common complaints among patients seeking emergency dental care. The aim of emergency treatment is to provide effective relief of discomfort. The measures to be taken are determined by the nature and severity of the condition. In certain cases, treatment can be limited to prescription of pain-relieving medication and/or antibiotics, possibly in combination with surgical drainage. If the tooth in question is badly broken down by caries or extensively traumatised and is deemed unrestorable, the best treatment may be extraction of the tooth. If the aim is to retain the tooth, it is often necessary to open the pulp canal. In such cases, apart from relieving the patient's discomfort, it is important that the emergency treatment procedures does not endanger the prognosis for the subsequent treatment of the tooth

The principles for endodontic treatment in cases of toothache are the same as for asymptomatic conditions, ie complete debridement, shaping and disinfection of the root canal system of the tooth. For an emergency consultation, time is often the limiting factor as to what it is possible to achieve. This section therefore concerns treatment options, which can rapidly and effectively relieve or cure acute toothache caused by pulpitis or apical periodontitis.

Evidence-graded results

- There is a lack of scientific support on which to determine whether removing the contents of the pulp chamber in cases of symptomatic pulpitis or symptomatic apical periodontitis, respectively, is as effective in achieving relief of symptoms as complete treatment of the root canal system.

- There is a lack of scientific support on which to determine whether supplementary treatment such as apical trepanation, analgesics and antibiotics, in combination with, or without, partial or complete treatment of the root canal system, can provide relief of symptoms in cases of acute toothache.

Questions addressed

- Is removal of the contents of the pulp chamber in cases of symptomatic pulpitis or symptomatic apical periodontitis respectively, as effective for relief of symptoms as total removal of the contents of the root canal system?

- Are there supplementary treatments (eg incision, apical trepanation, analgesics, antibiotics, local anaesthesia) which in combination with, or without, limited or complete treatment of the root canal system can relieve the symptoms of acute toothache?

Inclusion criteria

Articles published 1950–2010. Articles in all languages with at least a summary in English or Swedish. Systematic reviews of treatment studies in which the included studies meet the inclusion criteria below. Prospective treatment studies with control groups and/or comparisons for relevant factors within the cohort.

Facts 3.6.1 Inclusion criteria.

Population	Studies in vivo on humans. Teeth in the permanent dentition treated for symptomatic pulpitis or symptomatic apical periodontitis. Clear statement of whether or not the teeth have previously been treated endodontically and separate presentation of these data in the results section. At least 25 teeth in each group. The discomfort experienced can be attributed to a specific tooth in each individual
Intervention	Removal of the contents of the pulp chamber. Incision, apical trepanation, analgesics and antibiotics, separately or in combination with complete instrumentation of the root canal. The methods appraised should be available or expected to become available in Sweden
Control	Complete instrumentation of the root canal. Placebo
Outcome	Relief of symptoms after treatment. Evaluation after completion of treatment step or completion of treatment. Results presented in relation to preoperative diagnosis. Maximum attrition 30%

Results of literature search and selection of studies

The search of the literature yielded 443 articles, of which 73 were selected for appraisal in the full-text version. A further 16 articles were added after a manual search of chapters in text books and review articles. See flow diagram in Figure 3.6.1.

Description of studies and results

In all, five studies were included, two of moderate and three of low quality. Two of the studies investigated the effect of anti-inflammatory agents for treatment of symptomatic pulpitis [1,2]. One study investigated the effect of oral penicillin [3]. With respect to emergency treatment of symptomatic apical periodontitis, two studies concerned the effect of anti-inflammatory agents [4] and one the effect of oral penicillin [5].

Debridement of the pulp chamber

None of the included studies compared the relative benefits of debridement of the pulp chamber and complete instrumentation of the root canal system in achieving relief of symptoms in cases of symptomatic pulpitis or apical periodontitis.

Supplementary treatment

Symptomatic pulpitis

In a study of low quality, a randomised controlled trial in 50 patients investigated the effect of a corticosteroid (Dexamethasone) intra-canal dressing after removal of the pulp [2]. Physiological saline served as a control. The results were assessed after 24, 48 and 72 hours. After 24 hours, the corticosteroid group experienced significantly less discomfort than the control group (physiological saline). At the subsequent assessments, 48 and 72 hours respectively, no significant differences were observed.

A randomised controlled study of moderate quality investigated the effect of long-acting cortisone (Depo-Medrol) administered by local intraosseous injection in 40 patients [2]. After local anaesthesia, the patients were randomly allocated to test or control group; the control group was injected with physiological saline. The effect of the treatment was rated by the patients on a scale of 0–3. Post-operatively, all patients had access to analgesics (ibuprophen and paracetamol with codeine) as required. One week after treatment, the Depo-Medrol group reported significantly better effects than the saline group. Moreover, the patients in the test group had required fewer analgesics for post treatment discomfort.

A placebo-controlled, randomised study of low quality investigated the effect of penicillin on 40 patients [3]. All participants also received ibuprophen and paracetamol with codeine to take as required. The level of pain relief was assessed daily on a three-point scale. The effect of treatment was evaluated after seven days. No difference in effect was observed between the groups.

Symptomatic apical periodontitis

In a randomised controlled study of moderate quality, 41 patients were treated for symptomatic apical periodontitis [5]. After instrumentation of the root canal, the patients were randomly allocated to receive a course of oral penicillin for seven days, or a placebo. All patients were also provided with ibuprophen and paracetamol with codeine to take as required. No differences were observed between the groups.

In a study of low quality the effect of a preparation containing corticosteroids and antibiotics (Ledermix) as a root canal dressing was compared with calcium hydroxide and a root canal without any dressing after instrumentation [4]. The study comprised 194 subjects, monitored for 4 days. The subjects with Ledermix dressings experienced significantly less discomfort than the other subject groups.

Discussion

There are no studies comparing the removal of the contents of the pulp chamber with complete removal of the pulp in cases of acute toothache caused by pulpitis or apical periodontitis. Nor is there sufficient knowledge about the effect of different intra-canal dressings or other auxiliary measures intended to ease or arrest acute toothache. There is a need for studies which assess the effects of limited measures, such as removal of the contents of the pulp chamber and the use of various pharmaceuticals.

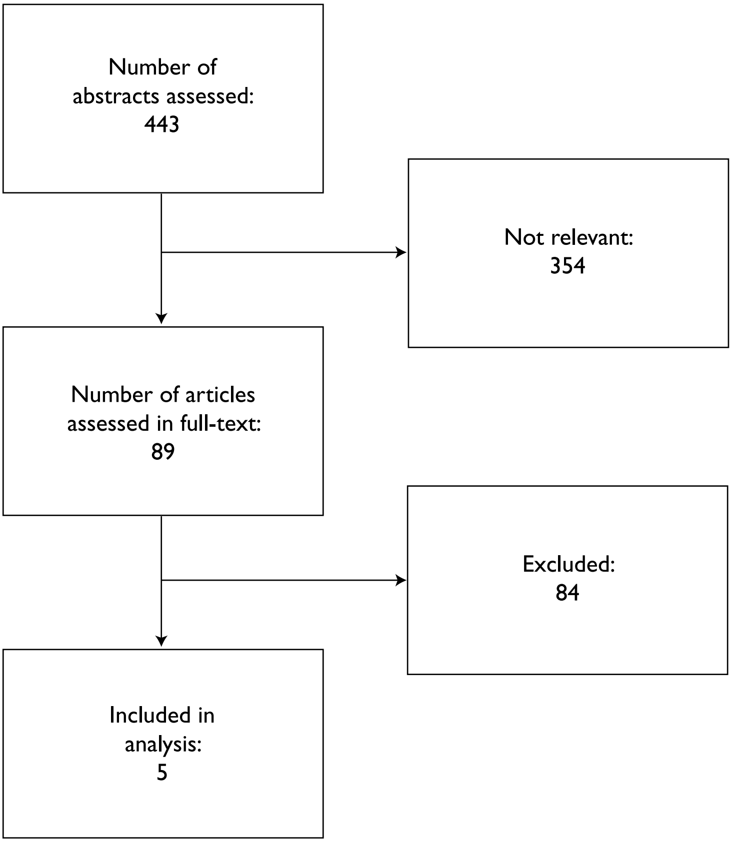

Figure 3.6.1 *Flow diagram of literature search.*

Table 3.6.1 *Emergency treatment.*

Author Year Reference Country	Aim	Study design	Sample characteristics	Intervention Control	Main findings	Study quality Comments
Ehrmann et al 2003 [4] Australia	To investigate post operative pain comparing 3 intracanal dressings applied following root canal instrumentation in teeth with symptomatic apical periodontitis	RCT	Non-consecutive sample of 221 patients with 223 teeth treated for symptomatic apical periodontitis in an emergency clinic	Root canal treatment and canals medicated with: 1. Ledermix paste (triamcinolone/tetracyclin mixture) 2. Calcium hydroxide paste 3. No dressing Pain evaluation initially, 4 hours after treatment, daily for 4 days by VAS: 0–25 no to mild pain; 25–50 moderate pain requiring analgesics for relief; 50–75 severe pain, pain not relieved by medicaments; 75–100 extreme pain, pain not relieved by any measures taken 29 teeth in 27 patients were excluded leaving 194 teeth in 194 patients for the analysis	All patients had pain prior to treatment with no difference between groups. Treatment in group 1 with Ledermix paste gave a significantly lower post operative pain score (p=0.04) than groups 2 (calcium hydroxide) and 3 (no dressing) No difference between groups 2 and 3	Low Teeth previously endodontically treated included?
Gallatin et al USA [2] 2000	To evaluate pain reduction in teeth with irreversible pulpitis using an intraosseous injection of methylprednisolone (Depo-Medrol)	RCT	Non-consecutive sample of 40 patients presenting for emergency treatment (1 tooth/patient with irreversible pulpitis)	All patients rated their pain and swelling on a scale 0–3 and were randomly allocated to intervention or control (double-blind) Intervention; Intraosseous injection of methylprednisolone (Depo-Medrol) Control; Intraosseous injection of saline Patients rated their pain daily during one week. No drop-outs	Depo-Medrol significantly reduced pain compared to saline. Patients receiving Depo-Medrol used fewer analgesics	Moderate External validity questionable

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***Table 3.6.1** continued*

Author Year Reference Country	Aim	Study design	Sample characteristics	Intervention Control	Main findings	Study quality Comments
Henry et al 2001 [5] USA	To study the effect of penicillin on post operative pain and swelling following endodontic treatment on teeth with symptomatic apical periodontitis	RCT	Non-consecutive sample of 41 patients presenting for emergency treatment (1 tooth/patient with symptomatic apical periodontitis)	All patients rated their pain on a scale 0–3. All teeth were endodontically treated. Patients were randomly allocated to intervention or control (double-blind) Intervention; 7-day oral dose of penicillin. Control; placebo (lactose) Patients rated their pain and swelling daily during one week. No drop-outs	Penicillin did not significantly reduce pain and swelling or number of analgesic medications taken	Moderate External validity questionable
Moskow et al 1984 [1] USA	To study the effect on post operative pain using a corticosteroid as intracanal medicament following root canal instrumentation in teeth with symptomatic pulpitis	RCT	Consecutive sample of 50 patients presenting for endodontic treatment of teeth with a vital pulp	All patients rated their pain on a scale 0–100. Following root canal instrumentation all patients were allocated to intervention or control in a double-blind manner with respect to type of tooth, pulpal diagnosis and pre-operative pain Intervention: Root canals filled with dexamethasone 4 mg/ml Control: Root canals filled with physiologic saline solution Patients rated their post-operative pain on a scale 0–100 at 24, 48 and 72 hours post-operatively	Patients receiving dexomethasone reported more often no pain 24 hours post-operatively ($p<0.05$)	Low Population not adequately described

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Table 3.6.1 continued

Author Year Reference Country	Aim	Study design	Sample characteristics	Intervention Control	Main findings	Study quality Comments
Nagle et al 2000 [3] USA	To determine the effect of penicillin on pain in patients with a tooth diagnosed with irreversible pulpitis	RCT	Non-consecutive sample of 40 adult patients presenting for emergency treatment (1 tooth/patient with irreversible pulpitis)	All patients rated their pain on a scale 0–3 and were randomly allocated to intervention or control (double-blind) Intervention: 7-day oral dose of penicillin Control: Placebo (lactose) Patients rated their pain daily during one week. No drop-outs	No reduction of pain or number of analgesic medication taken by penicillin	Low External validity questionable Potentially under powered study

p = Probability; RCT = Randomised controlled trial; VAS = Visual analogue scale

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3.7 Permanent and temporary restoration of root-filled teeth

Background

A further aim of root canal treatment, in addition to achieving an infection-free, healthy tooth, is that it can serve as a functional unit of the dentition. Thus, some form of restorative treatment is required after completion of the root filling. In general, the complexity of the restoration is determined by the severity of tooth structure loss as a result of earlier caries, trauma or prior restorative therapy. If most of the crown has been lost, it is not uncommon that the restoration needs support from a post, ie insertion of a post into one or more of the root canals. This is necessary to achieve adequate anchorage for build-up of a core that can sustain the restoration of the crown portion of the tooth.

In selecting the type of restoration, the clinician must consider a number of factors. Loss of the pulp means that the patient can no longer perceive loading forces on a tooth as readily as before, thus there is a risk that mechanical forces during function or clenching of the teeth can result in cracks and/or root fractures. However, little is known about factors, which contribute to the development of such complications. So-called full coverage crowns are considered to offer better protection than less complex intra-coronal restorations, which only replace lost tooth substance. Yet, in cases of only minor loss of tooth structure, full crown therapy can be an unnecessarily expensive form of treatment, which also requires removal of sound tooth substance. It is therefore important for the clinician to know whether crown therapy in general offers better preservation of root-filled teeth than less complicated restorations, not least from a health economics perspective. In cases where most or all of the coronal structure has been lost, an artificial replacement crown must be constructed. This may be fabricated in a laboratory by a dental technician, or at the chairside, ie directly in the mouth, by the dentist. Anchorage by a post in the root canal or by a post and core construction can improve retention of the crown, but can increase the risk of root fracture.

Another form of restoration used in endodontic treatment is the temporary restoration, ie a restoration used between treatment sessions to seal off the root canal system from bacterial penetration and to protect the remaining tooth structure from fracture. Temporary restorations are also used while monitoring the outcome of endodontic treatment, before proceeding with the permanent root filling and restoration. Many different temporary materials are used. However, little information is available as to which are most effective in preventing bacterial invasion and risk of tooth fracture during and after root canal treatment.

Evidence-graded results

- There is no scientific basis on which to assess whether in the long-term a crown preserves a root-filled tooth better than an intra-coronal restoration.

- There is limited scientific evidence to show that in a short-term perspective of, 2–3 years, premolars with little remaining crown substance, restored with post retained crowns, have a higher survival rate for both the restoration and the tooth than premolars crowned without post retention (⊕⊕○○).

Table 3.7.1 *Importance of post and crown construction in restoration of a root-filled tooth.*

Effect measure	Number of patients (number of studies)	Median risk in standard – group (min–max)	Relative risk (95% CI)	Absolute effect Per 1 000 Patients	Scien-tific support	Remarks
Lost filling or tooth	555 (2)	Standard = without core 0.14 (0.12–0.16)	0.4 (0.08; 0.71)	Around 200 fewer after 2–3 years	⊕⊕○○	Quality: –2

- There is no scientific basis on which to assess whether post retention, in itself, contributes to long-term survival of a root-filled tooth.

- There is limited scientific evidence to show that in the short term, root-filled crowned premolars with extensive loss of tooth substance and without post retention are at greater risk of loss of the crown restoration than teeth with more remaining tooth substance (⊕⊕○○).

***Table 3.7.2** Importance of amount of remaining tooth substance in restoration of a root-filled tooth.*

Effect measure	Number of patients (number of studies)	Median risk In standard – group (min-max)	Relative risk (95% CI)	Absolute effect per 1 000 patients	Scien-tific support	Remarks
Lost filling or tooth	555 (2)	Standard = no remaining walls 0.41 (0.38–0.43)	0.32 (0.00; 0.63)	Around 275 fewer after 2–3 years	⊕⊕○○	Quality: –2

- There is no scientific basis on which to assess which type of temporary restoration best protects the tooth during or after root canal treatment.

Questions addressed

- Are there methods of permanently restoring root-filled teeth, which provide long-term survival of the tooth, without the loss of the restoration?

- Are there methods of temporarily restoring the root-filled tooth, which prevent fracture or bacterial leakage?

Criteria for inclusion

Articles published between 1950 and 2010. Articles in any language with at least a summary in English or Swedish. Prospective study design.

Facts 3.7.1 Criteria for inclusion.

Population	Studies in vivo on humans. Root-filled teeth in the permanent dentition requiring restoration or build-up
Interven-tion	Restoration or reconstruction of lost tooth substance,with or without post retention. Methods available or expected to become available in Sweden
Control	Temporary or permanent restorations, with or without post retention. Control group and/or comparison for relevant factors within the cohort
Outcome	Long-term survival of restoration and tooth. At least one year's follow-up, with the exception of studies of temporary fillings The minimum allowable unit for evaluation of effect measure to be the individual tooth. Maximum attrition 30%

Result of literature search and selection of studies

The literature search yielded 1 607 abstracts, of which 1 505 were considered irrelevant. Subsequently, 102 articles were ordered and read in full-text version. Fifteen studies were included, none of which was assessed as being of high quality. Two studies were assessed as moderate quality and the remaining 13 as low quality. The results are presented in a flow diagram in Figure 3.7.1.

Description of studies and results

No studies meeting the inclusion criteria could be identified as addressing the following areas:

- The ability of temporary fillings to resist tooth fracture or prevent bacterial invasion of the root canal.

- Separate comparisons between crowns and fillings with reference to survival of the tooth.

The importance of various forms of post retention

In a study of 162 teeth, the two-year survival rate of prefabricated posts and cores was analysed in relation to tooth type, amount of tooth substance remaining and type of restoration (low quality) [1]. Full crowns were used to restore 121 of the teeth and the remaining 51 were restored with composite material. Four percent of the posts loosened and endodontic complications developed in 3% of the teeth. No significant differences in outcome were found with respect to the type of post and core or restoration.

In a study of moderate quality, a survival analysis was conducted of root-filled teeth restored using various types of prefabricated and custom-made post retention [2]. The control group comprised teeth without post and core constructions. Only premolars were included. The amount of tooth substance remaining was one of the parameters. All teeth were restored with metal- ceramic crowns. The three-year survival rate for the restorations was 76.7%. The prognosis was better for crowns with cores than those without. The best survival rate was noted for teeth restored with prefabricated cores. Statistically significant differences were found with respect to the amount of tooth substance remaining, ie the more remaining tooth substance, the better the prognosis.

A randomised controlled study of low quality, with a follow-up time of six to ten years, evaluated four different types of metal posts (prefabricated or cast posts and cores of noble metal) [3]. Technically inadequate root fillings were retreated before the prosthetic treatment. Few treatment failures were registered (3–6%). The failures were not related to any particular type of post-core construction.

A randomised controlled study of moderate quality investigated the importance of post retention and the amount of tooth substance remaining on survival of the tooth and the restoration; the follow-up time was two years [4]; only premolars were included. 240 teeth were allotted to six treatment groups, stratified according to the amount of tooth substance remaining. Half the teeth in each group were restored with posts and the other half without. All the teeth were restored with crowns. Treatment was successful in 81% of cases. Failure (defined as loss of the restoration and root fracture) occurred primarily in teeth with extensive loss of tooth substance. Two teeth developed apical periodontitis after the post retained crown had become loose. The outcome for teeth with post retained crowns was significantly better than for those without post retention.

In a controlled clinical multicentre study, three different post and core constructions in root filled teeth were investigated (low quality) [5]. Cast, prefabricated metal or composite post and core constructions were used and evaluated after 15–17 years. No difference was observed for the different post and core constructions as long as the remaining tooth substance was adequate.

In a randomised controlled study of low quality, two different core materials (prefabricated carbon fibre or metal) were compared in crown therapy on root-filled teeth; the follow-up time was 80 to 100 months [6]. No statistically significant difference in outcome was observed in relation to the two post-core constructions.

In premolars with class II cavities, a randomised study of low quality was undertaken in which teeth with moderate loss of tooth substance received carbon fibre cores and were restored with composite material, or metal-ceramic crowns [7]. Three years of observation disclosed no significant difference in longevity of the teeth or the restorations. A randomised clinical study of low quality from the same research group investigated different restorations in root-filled maxillary and mandibular premolars, respectively [8]. The root-filled teeth in one group were restored with amalgam and in another group with a carbon fibre core and composite filling. Treatments were evaluated after one, three and five years; carious lesions, filling- and core fractures were the outcome parameters. The results showed more root fractures and fewer carious lesions in the amalgam than in the composite group. There was no significant difference between the maxillary and mandibular premolars.

In a prospective, 2-year study of low quality, three types of translucent fibre-posts in root-filled premolars were evaluated [9]. In 4% of cases the core loosened and in 3% there were endodontic complications.

Treatment with parallel or conical glass fibre reinforced post retained cores was evaluated in a prospective but non-randomised study of low quality [10]. After varying observation times (from 5 to 56 months), 31 of the 149 treated teeth had failed, with an annual failure rate of 6.7%. Most of the failures comprised core fractures (n=14) and loosened cores (n=9). Anterior teeth were at significantly greater risk of failure than premolars and molars (hazard ratio = 3.1). The same applied to single crowns in comparison with bridge abutments (hazard ratio = 4.3). In another study of low quality, failures were recorded in 4 and 11% after one and two years respectively, with no statistically significant difference between the two types of post [11]. A five-year follow-up of the same group of patients as in earlier studies showed a total of 41 failures (33%) [10,12], comprising 41% post fractures, 34% loosened posts and 10% tooth fractures. Endodontic complications devel-oped in three teeth. A randomised study from the group compared two types of root canal posts (titanium and glass fibre) over a period of 36 months (low quality) [13]. The survival rate for both types of post was 100%.

Teeth restored with post retained and non-post retained crowns were compared in a controlled clinical study of low quality, comprising 183 patients in the test group and 60 in the control group [14]. Successful outcomes were recorded in 93.5% of the test group and 95% of the control group after a follow-up time of two years.

In a clinical controlled study of low quality, the survival of root-filled teeth restored with post retained cores and cast crowns was evaluated after 5, 10, 15 and 25 years respectively [15]. The teeth were either free-standing or bridge abutments. Crowned teeth with vital pulps served for comparison of outcome. No statistically significant differences were observed between the groups. Caries was the main reason for failure (loss of the tooth or the restoration). There was a low frequency of failure attributable to inadequate prosthetic reconstruction or endodontic treatment. After 15 and 25 years attrition was substantial in this study.

Discussion

The general dental practitioner makes decisions on an almost daily basis as to how a root-filled tooth should be optimally restored, to ensure long-term function. The decision-making process comprises not only the choice of restoration but also a risk assessment with respect to caries and marginal periodontitis.

The results of the systematic review indicate that the choice of restoration is important to long-term survival of the tooth. Most treatment failures are attributable to caries, fracture of the restoration or the tooth, or loosening of the crown or the post and core. Several studies indicate that the amount of coronal tooth substance remaining is critical. Other likely key factors are ensuring an adequate root filling in the apical part of the root when using a core or post, and that the crown maintains a good marginal seal.

Despite a large number of studies (n=1 628) in this field, only two of 15 of the included could be used for evidence-based conclusions. These showed that the more coronal tooth substance is remaining, the greater the longevity of both the tooth and the restoration. The studies also show an increased risk of failure of crown therapy in the absence of a post retained core in cases where there was little coronal tooth substance remaining. These studies emphasise the importance of a ferrule of at least 2 mm of sound tooth substance. The generalisability of the findings these studies provide is however limited, because the material comprised exclusively premolar teeth in the maxilla and the mandible.

Shortcomings in patient selection and study design were the usual reasons for exclusion of studies from the review. With respect to temporary fillings, there are considerable laboratory studies of permeability and sealing properties, but none of the studies on humans met our inclusion criteria.

During the period of time spanned by the literature search, there has been considerable development of restorative materials and techniques. New materials and methods have been introduced, while others have become obsolete. For example, the use of amalgam has been abandoned in Sweden. Instead, advances have been in the direction of so-called bonding techniques, whereby resin composites or ceramic material are adhered to the tooth substance. Tooth structure is then preserved and as a consequence, the indications for post retention have decreased in recent years. Development in this field is rapid. With the CE labeling within EU restorative materials are denoted as medical-technical products. This means that they are not subject to the same stringent clinical testing as for example pharmaceuticals, where the requirements are for relevant and adequate clinical evaluation. Such testing is often unavailable before restorative products become commercially available. Therefore, there is a need for well-conducted prospective studies, which evaluate how well newer methods for restoration preserve root-filled teeth long-term.

To determine whether crown therapy maintains root-filled teeth better than restoration with plastic materials such as resin composite is an issue of particular importance. In this context it needs be explored whether retention with a root canal post and which type of post or post and core offers the best long-term survival.

The studies we appraised have almost all been carried out on referred patients treated by specialists, working in teaching institutions or specialist clinics. The few cases of endodontic failure recorded in these studies can be due to the fact that the root canal treatments were of high quality throughout. Studies of the outcome of restoration of root-filled teeth carried out in the general practice of dentistry should therefore be given high priority.

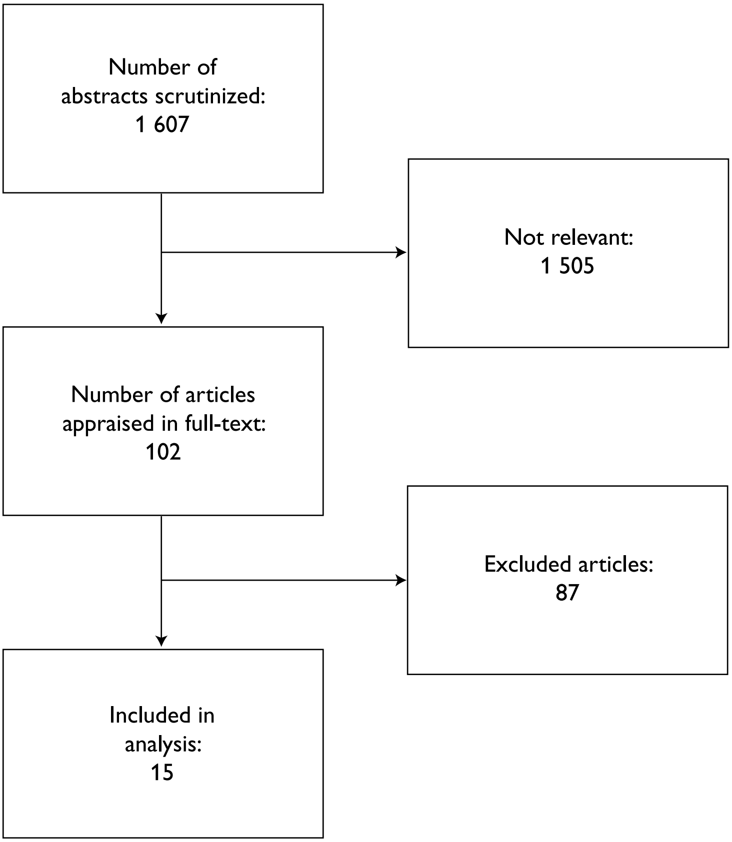

Figure 3.7.1 *Flow diagram of literature search.*

Table 3.7.3 *Permanent and temporary build-ups of endodontically treated teeth.*

Author Year Reference Country	Aim	Study design	Sample characteristics	Intervention Control	Main findings	Study quality Comments
Cagidiaco et al 2007 [1] Italy	2-year outcome of post and core restorations	CCT 50 consecutively selected patients (18–75 years mean 56 years) Study variables: Type of restoration, tooth type, remaining tooth tissue	162 teeth root canal treated or in need of root canal treatment. 2 operators Data collected: age, gender, tooth type (anterior or posterior), number	All teeth received fibre post. At least 4 mm root filling material left apically of post. 121 teeth restored with metal ceramic crown, 41 with a composite restoration. 23–25 month follow-up Evaluation parameters: Debonding, post fracture, root fracture, problems with core, apical pathology No drop-outs	Debonding: 7 cases (4.3%). Apical pathology: 5 cases (3%). All failures in crown-covered teeth. No factors possible to statistically identify as predictors of failure. No loss of teeth Remaining tooth structure and 2 mm ferrule effect important parameters	Low No randomisation on type of restoration (crown or composite) Dependent observers
Cagidiaco et al 2008 [2] Italy	Impact of residual coronal dentin, placement of a prefabricated post or customised post or no post on 3-year survival rate	RCT Consecutively chosen patients in need of endodontic treatment and restoration. Private clinic. One operator Teeth presenting with various amounts of remaining tooth substance	345 patients 18–76 years average age 58 Inclusion: Teeth with antagonist and neighbour teeth on both sides. No apical pathology Study material divided in 6 groups: 1) All coronal walls present 2) 3 coronal walls present 3) 2 coronal walls present 4) 1 coronal wall present 5) No coronal walls but possible to get a 2 mm ferrule around the tooth 6) No ferrule, no coronal walls Subgroups: A) No root canal retention B) Light post C) EverStick fibres in root canal A) B) and C) randomly selected	Recall radiographs after 1, 6, 12 and 24 months. Failures: post debonding, post fracture, vertical/horizontal tooth fracture, need for new coronal restoration, apical pathology No drop-outs	Overall survival rate over 36 months was 76.7%. Lowest survival rate 62.5% for teeth without canal retention. Light post 90.9% and customised EverStick 76.7% All failures consisted of debonding and occurred in teeth presenting with reduced tooth substance with one wall at the most. Group without canal retention: 13 root fractures, 32 crown displacements. Decrease of failure risk: Prefabricated post: hazard ratio = 0.1. Conclusion: "Endodontically treated teeth should have post and full crown coverage. The ferrule effect impacts clinical success rate"	Moderate Two independent observers Randomisation procedure not described

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Table 3.7.3 continued

Author Year Reference Country	Aim	Study design	Sample characteristics	Intervention Control	Main findings	Study quality Comments
Ellner et al 2003 [3] Sweden	Outcome of 4 different metallic post systems evaluated over a period of 10 years	RCT 5 operators	50 roots on 31 patients (14 women 17 men)/age 16–75 Inclusion: Need for single crown on single rooted tooth, no bruxism, at least 2 mm ferrule, root filled. Poor root fillings retreated. At least 4 mm of gutta-percha left in canal, post 8 mm or at least as long as artificial crown Randomisation by lot	Comparison between the post systems and contra lateral or adjacent tooth. 6–10 years of follow-up. Clinical and radiological evaluation Outcome measure: Survival of restoration and apical findings 30 patients completed the study. Mean observation time: 103 months	Overall failure: 3 cases (6%). 2 loss of retention, 1 root fracture. No statistically significant differences between the posts. 10 teeth showed apical pathology at start. 3 had still at end of study. 3 teeth with no apical radiolucens at start showed small, asymptomatic radiolucent lesion	Low Small sample No blinding Dependent observer
Ferrari et al 2007 [4] Italy	Impact of post vs no post retained crowns on clinical performance of premolars with various degrees of coronal tissue loss	RCT Consecutively chosen patients in a private office One operator	210 patients, 18–76 years 6 experimental groups, 40 teeth per group Inclusion criteria: Teeth with antagonist and neighbour teeth on both sides. No mean age 54 years Randomisation by toss of coin	Experimental groups based on amount of dentin left on coronal level after endodontic treatment. Randomisation on post/no post per each group Evaluation parameters: post debonding, post fracture, root fracture, endodontic failure, loss of crown Survival analysis over 24 months No loss to follow-up	Overall tooth/restoration survival = 81%. All teeth exhibiting 4 walls of crown dentin survived 2 years of clinical service regardless of restorative procedure. Increased failure risk for teeth with no post and reduced amount of residual dentin	Moderate Blinding procedure not stated 2 independent observers for outcome assessment No adjustment for number of teeth/patient

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Table 3.7.3 continued

Author Year Reference Country	Aim	Study design	Sample characteristics	Intervention Control	Main findings	Study quality Comments
Fokkinga et al 2007 [5] The Netherlands	Long-term survival of different types of root canal posts and crown restoration	RCT, multi-centre study 18 operators	257 patients, 307 posts. 17–71 years, mean 36 years Inclusion criteria: Teeth in need of single restoration Exclusion criteria: Abutment teeth for fixed or removable dentures	3 groups with cast posts, prefabricated metal post and composite core, composite core. All groups tested for minimal or substantial remaining dentin End points: Caries, recementation, tooth extraction Follow-up 15–17 years After 5 years 11% loss to follow-up. After 10 years 19%, 15 years 32%, 17 years 72%	Type of root canal post insignificant if substantial amount of coronal dentin remains	Low No blinding of operators or observers More than 1 tooth per patient
King et al 2003 [6] United Kingdom	Comparison of carbon-fibre post and prefabricated metal posts for root canal retained crowns	RCT 1 operator	18 patients, 27 teeth. Inclusion criteria: Single-rooted maxillary teeth, adequate root filling, no apical pathology, root fracture or root perforation Exclusion criteria: Abutment teeth, lack of adequate posterior support or occlusal interference	2 groups: Carbon-fibre post (n=16), prefabricated metal posts (n=11) Follow-up period: 80–100 months 4 patients lost to follow-up (2 patients per group)	More failures in carbon fibre group, no p-values shown. 71% survival for carbon-fibre posts, 89% for prefabricated metal posts	Low One examiner. No blinding Lack of sample characteristics Randomisation procedure questionable

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Table 3.7.3 continued

Author Year Reference Country	Aim	Study design	Sample characteristics	Intervention Control	Main findings	Study quality Comments
Mannocci et al 2002 [7] Italy United Kingdom	Comparison of full coverage metal ceramics with bonded composites on root filled premolars with fibre posts	RCT Subjects randomly selected to two treatment groups 1 operator	Population: 117 (54 men 63 women) 35–55 years mean 48 Inclusion criteria: 1 premolar, no previous endodontic treatment, class II caries, need for endodontic treatment, preserved cusps, occlusal function, and no bridge abutment. Periodontal bone loss less than 40% Exclusion criteria: Active periodontal disease Randomisation by toss of coin	Group I: Composite restoration without cusp coverage Group II: Full metal ceramic crown. Both with carbon-fibre post Outcome measures: Root fracture, post fracture, post decementation, marginal gap, secondary caries. Clinical and radiologic examination 3 year follow-up Drop-out rate: 9%	No loss of teeth. Decementation (3 cases), marginal gap (4 cases). No differences between restoration modes	Low Patient sample not described. Consecutive? Study performed on premolars with considerable amount of remaining tooth structure
Mannocci 2005 [8] Italy United Kingdom	Comparison of 2 modes of restorative treatment for root-filled teeth; carbon-fibre posts and composite filling vs amalgam filling	CT	32–63 years of age. Mean age 45 years. 219 referred patients 1996/1997 Inclusion criteria: 1 maxillary or mandibular premolar in need of endodontic treatment. Healthy patient willing to return for follow-ups. Orthodontic class I, teeth without previous endodontic treatment and caries lesion class II and intact cusp structure Exclusion criteria: Bridge abutment. Shortened dental arch. Need for removable denture. More than 40% periodontal bone loss. Gingival Index >1 according to Löe & Silness	Group I: Amalgam restoration, Group II: Carbon-fibre post and composite restoration Re-examination at 1, 3, 5 years Evaluation parameters: Post or root fracture, decementation, marginal gap secondary caries at tooth/restoration interface Drop-outs: 3 patients after 1 year, 9 patients, after 3 years, 21 patients after 5 years	More root fractures with amalgam-restored teeth. More caries with composites. Overall no significant difference between treatment modes	Low No blinding Calibrated examiners Lack of correct survival analysis

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Table 3.7.3 continued

Author Year Reference Country	Aim	Study design	Sample characteristics	Intervention Control	Main findings	Study quality Comments
Monticelli et al 2003 [9] Italy	Clinical performance of 3 types of translucent posts (Aesthetic + plus, DT, FRC Postec Post) for porcelain crown restoration of endodontically treated teeth	CCT 1 operator	225 patients treated during a 3-year period (18–78 years mean 51 years) Endodontically treated premolars presenting with two coronal walls only	3 groups with 75 patients in each receiving either. 1) Aesthetic plus or 2) DT post or 3) FRC Postec Posts Follow-up after 6, 12 and 24 months. Success defined as no defects on core or crown and no periapical pathology No drop-outs	14 (6.2%) failures; debonding 8 (3.5%), recurrence of periapical pathology 6 (2.7%). No difference between posts systems. Debonding occurred on teeth with less than 2 mm of remaining coronal dentin	Low Unclear description of sample Consecutive patients?
Naumann et al 2005 [10] Germany USA	Comparison between 2 tapered and 1 parallel-sided glass-fibre posts	Prospective cohort study Dental school clinic Operators: Dental students	157 posts in 128 patients, (53 men, 69 women) age 15–98 years Inclusion criteria: symptom-free root-filled teeth with a minimum of 4 mm of apical seal Exclusion criterion: untreated advanced periodontal disease	3 test groups based on type of post 5–56 months of follow-up (5 531 "tooth months") Clinical and radiographic evaluation parameters: root fracture, decementation, post fracture, endodontic failure, core failure 8 posts/6 patients lost to follow-up	31 failures (=6.7%/year) Post fracture (45%), loss of retention 9 (29%). 1 vertical and 2 horizontal fractures gave 3 fatal failures. 2 endodontic failures. Front teeth and canines higher failure rate. Abutment for removable prosthesis higher than abutment in fixed prosthesis. Teeth with no approximal contacts higher failure than those with contacts. Remaining tooth substance and load seemed more significant for tooth and restoration survival than type of post or endodontic cause	Low Unclear sample selection No criteria based on amount of remaining tooth substance Number of operators not stated One observer Post systems not randomly selected

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Table 3.7.3 continued

Author Year Reference Country	Aim	Study design	Sample characteristics	Intervention Control	Main findings	Study quality Comments
Naumann et al 2005 [11] Germany	Comparison of tapered or parallel-sided posts for restoration of endodontically treated teeth with regard to degree of tooth tissue loss	CCT Dental school clinic 1 operator performed posts and cores Dental students carried out final restoration	83 patients (15–98 years) received 105 glass-fibre reinforced posts. Patients screened by the principal investigator. Data collected: Age, gender, date of insertion of post, tooth type, post size, number of proximal contacts, antagonists, type of final restorations, amount of remaining tooth Inclusion criteria: Symptom-free teeth with a minimum of 4 mm of apical seal Exclusion criterion: Untreated advanced periodontal disease	2 types of posts placed consecutively Recall 6, 12 and minimum 24 months. Evaluation parameters: loss of post retention, root fracture or failure of core build up, secondary caries or endodontic problems 3 drop-outs	After one year 3.8% failures. After 2 years 11.4%. 1 root fracture (not a root with post), 3 posts lost retention, 9 posts fracture. 12 of 16 failures on teeth without vertical wall for retention of core. No significant differences between the 2 types of posts. No endodontic failure Results pointed to amount of remaining tooth substance being a more important outcome parameter than type of post	Low One examiner. Dependent? Blinding not stated No randomisation on post type
Naumann et al 2008 [12] Germany	5-year evaluation of glass-fibre posts survival and identification of risk factors	Prospective cohort 157 posts in 127 patients, inclusion criteria: symptom free root fillings, no untreated periodontitis No exclusion criteria. One operator, on post placement. Final restorations made by dental students	127 patients, 50 men 71 women, 15–98 years Variables: type of tooth, type of post, number of approximal contacts, antagonist presence, periodontal support, mobility, number of surfaces providing adhesion for core, type of final restoration	3 different types of posts, placed consecutively Clinical and radiographic follow-up: 5–79 months Failure criteria: Loss of retention, root or post fracture, apical pathology, and failures inducing new restoration Follow-up data missing for 6 patients leaving 149 posts in 121 patients for analysis	Overall failure rate 32.5%. Post fracture 41%. Loss of retention, 34%. 4 teeth extracted due to horizontal or vertical fractures. 3 endodontic failures Restored anterior teeth significantly higher failure rate than posterior, HR=2.9	Low One examiner Blinding? No randomisation on post type High proportion of front teeth and teeth with a small amount of remaining tooth substance

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Table 3.7.3 continued

Author Year Reference Country	Aim	Study design	Sample characteristics	Intervention Control	Main findings	Study quality Comments
Naumann et al 2007 [13] Germany USA	Survival of endodontically treated teeth restored with glassfibre or titanium root canal posts	RCT Dental school clinic. Inclusion criteria: 2 or fewer cavity walls, symptom-free teeth with at least 4 mm of apical seal, no periodontitis, some tooth mobility, willingness to return for follow-ups Exclusion criteria: Residual root canal thickness of 1 mm bruxism. Post placement under existing crown	98 patients, consecutively selected 1 operator performed posts and cores Endodontic treatment by students, during 15 months	2 treatment groups with different root canal posts, one titanium, one glass-fibre Follow-up for 3, 6, 12, 24, 36 months as far as loss of restoration, tooth loss, root fractures, post loss, post fracture, endodontic failure, secondary caries, failure of core build-up 7 patients dropped out before treatment. 4 patients at follow-up	100% survival regardless of post type	Low No information on sample characteristics One blinded examiner Interim analysis Number of operators unknown

The table continues on the next page

Table 3.7.3 continued

Author Year Reference Country	Aim	Study design	Sample characteristics	Intervention Control	Main findings	Study quality Comments
Salvi et al 2007 [14] Switzerland	Survival and rate of complications of root-filled teeth restored with different root canal posts	CCT	183 patients, 248 test teeth, 60 control teeth Inclusion and exclusion criteria not stated One operator	Intervention 1: Root canal treatment + cast post. Intervention 2: Root canal treatment + direct post. Different types of crown restoration Control: Root canal treatment and no post. Different types of crown restoration Follow-up: 2 years Failure of technical and biological complication Bivariate statistical analysis for success vs failure 5.2% or 17 teeth lost to follow-up	Success 93.5% for post-treated teeth vs 95% for control	Low No blinding. One operator No randomisation procedure or information on included patients Questionable survival analysis No withdrawal analysis

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Table 3.7.3 continued

Author Year Reference Country	Aim	Study design	Sample characteristics	Intervention Control	Main findings	Study quality Comments
Valderhaug et al 1997 [15] Norway	Changes in apical and clinical status of teeth with a vital pulp and root-filled teeth restored with crowns and bridge retainers over 25 years	Cohort study Duration: 25 years Recruitment year 1967/1968. Study group 114 patients/158 fixed prosthesis on 397 teeth (46 single crowns, and 112 in bridge work) Operators: Dental students. Cast dowels and full crowns in all root-filled teeth. Vital teeth restored with full/partial crowns	Patients of 25–69 years mean 48 years Exclusion criteria: Patients >70 years and not attending annual check-up during a 5 year period On average 9.5 teeth in maxilla and 10 in mandible restored. 106 root-filled and 291 vital teeth, all restored with crowns	Evaluation followed CDA/Ryge system and PAI. Criterion for failure: Fractured, lost or mobile crown or bridge retainer, tooth fracture, caries, loss of attachment or pathological findings. Drop-outs: After 5 years 16%. After 10 years 30%. After 20 years 60% and after 25 years 72%	After 5 years 4 vital teeth had apical pathology Survival rate not possible to relate to type or size of fix prosthesis or age or gender. Main reason; caries 12%, pulp deterioration 10%, and due to retreatment 30% of the construction Survival rate for restored teeth after 5 years was 98%, and after 10 years 92%	Low Patient selection not clearly defined No group characteristic Several operators (Senior dental students) 1 dependent observer No blinding

CCT = Controlled clinical trial; CDA = Californian Dental Association; CT = Computed tomography; HR = Hazard ratio; n = Number; p = Probability; PAI = Periapical index; RCT = Randomised controlled trial

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3.8 Risks for development or exacerbation of disease in other organs from infections of the pulp and periapical tissues

Background

During the last twenty years there have been reports of an association between periodontitis and cardiovascular disease. It is postulated that inflammation and infection induce arteriosclerotic changes in the peripheral and coronary circulation. The inflammatory response to infections of the dental pulp share many features with periodontitis both in terms of the microbiota involved and the clinical manifestations in both acute and chronic conditions. However, the potential for inflammation arising from infection in the dental pulp to have deleterious effects on the cardiovascular and other organ systems has to date not received the same attention. It is equally likely that spread of infectious elements from the root canal system can occur when associated with both acute and chronic lesions of apical periodontitis as well as in conjunction with endodontic treatment, whereby bacteria and bacterial metabolites may be disseminated to the tissues. Indeed infections originating in the pulp and periapical tissues are common conditions in the general population, and a possible relationship to conditions in the cardiovascular or other organ systems might therefore be a major factor relating to treatment and prevention of these systemic diseases.

This review presents the scientific evidence underlying the influence of endodontic inflammatory conditions on diseases of the heart, brain, upper respiratory tract and cardiovascular system, with special reference to studies investigating whether there is an increased risk of disease following bacterial infection originating in the pulp and surrounding periapical tissues.

Evidence-graded results

- The scientific basis is insufficient to assess the association between infections of endodontic origin and disease conditions of other organs (⊕○○○).

Question addressed

- Is there a risk that acute and chronic disease processes originating in the pulp will lead to disease in other organs of the body?

The question is limited to the risk of spread of infection to the brain, heart and the upper respiratory tract from acute endodontic conditions and the risk of cardiovascular disease arising from chronic forms of apical periodontitis. Possible associations in medically compromised individuals, such as those taking immunosuppressant medication, have not been evaluated.

Criteria for inclusion and exclusion

Facts 3.8.1 Inclusion criteria.

Population	Individuals with permanent teeth
Interven-tion	Teeth with inflammation and/or infection of the pulp and periapical tissues
Control	Teeth which show no radiographic findings or clinical signs indicating inflammation and/or infection of the pulp or periapical tissues
Outcome	Endocarditis Heart infarct Coronary Heart Disease (CHD) according to the WHO definition Stroke Death

Facts 3.8.2 Exclusion criteria.

- Articles in languages other than Scandinavian, English or German, which do not have an English summary (abstract)
- Animal studies
- Retrospective studies
- Studies in which the outcome measure is not defined
- Undefined population
- Attrition not reported

Results of literature search and selection of studies

The literature search yielded 932 articles. Of these, 60 were ordered in the full-text version. A further ten studies were identified from a manual search of reference lists. Eight studies, all observational, were included. A case-control study evaluated a potential relationship between endocarditis and various dental treatment procedures [1], while four studies analysed the relationship between cardiovascular disease and apical periodontitis and/or root-filled teeth [2–5]. See flow diagram in Figure 3.8.1.

Description of the studies and results

Relationship between endodontic infections and other disease states (other than cardiovascular disease)

Endocarditis was the subject of an observational study of low quality [1], analysing the relative risk for endocarditis associated with various treatment procedures in the oral cavity and the rest of the body. A combined dental treatment index showed no association with the occurrence of endocarditis, but root canal treatment gave a weak statistical relationship p=0.065) with an odds ratio = 2.5 (95% CI 1.0–6.5). Multivariate analysis disclosed an even weaker association, odds ratio = 1.7 (95% CI, 0.5–5.2).

Several case reports address the relationship between acute and chronic endodontic infections and other disease states. There are descriptions of spread of infection to the floor of the mouth and the mediastinum, so-called Ludwig's Angina, cases of cerebral arterial thrombosis and cerebral ischaemia. All cases were caused by apical periodontitis of pulpal origin [6,7,8]. The literature search failed to identify any studies, which investigate the risk for and frequency of such conditions.

Association between endodontic infections and cardiovascular disease

All four included studies are observational in design: one is a cross-sectional study [3] and the other three are case-control studies [2,4,5]. One of the studies reported an association between apical periodontitis and cardiovascular disease in middle-aged and younger men (<40) over a 32-year period [2]. An analysis of female patients however, showed no increased risk of ischaemic heart disease among those with apical periodontitis, after adjustment for other variables in the analysis [3]. One study reported that dental diseases were risk indicators in relation to mortality from cardiovascular disease [5]. However, this study found no significantly increased risk associated with apical periodontitis. Yet another case-control study comprised analysis of a large number of individuals receiving medical care, with respect to the relationship between the number of root-filled teeth in the dentition and the development of cardiovascular disease [4]. Only a weak association was reported with respect to individuals with one or two root fillings (relative risk = 1.21, 95% CI 1.05–1.40). The study showed obvious weaknesses in the selection of variables.

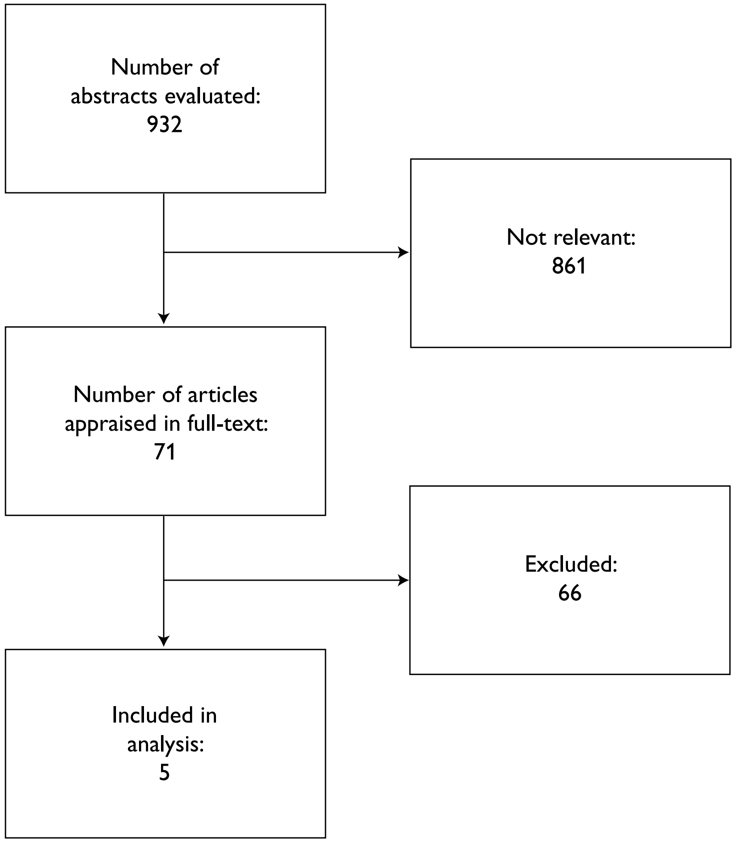

Figure 3.8.1 *Flow diagram of literature search.*

Table 3.8.1 Infections from the dental pulp or periapical tissue as a risk for diseases in other organs.

Author Year Reference Country	Study design	Population characteristics	Cases/Controls Number of individuals	Exposure	Results	Comparison Level of significance	Withdrawal Drop-outs	Study quality	Comments
Caplan et al 2006 [2] USA	Case-control	853. Mean age at baseline 47.4 years. Mean follow-up time 24 years	Cases: Coronary heart disease (CHD) 166 Controls: no CHD diagnosis 542	Lesions of endodontic origin (LEO) 250	Cases: 58 LEO, Control: 192 LEO	RR of CHD at LEO 0.97 95% CI (0.73–1.28)	145 (17%)	Moderate	After adjustment for demographic, medical and dental covariates there was an increased risk for persons under 40 years
Frisk et al 2003 [3] Sweden	Cross-sectional	1 056 women (population study of women in Gothenburg) data from examination 1992–1993. Mean age 64.7 years (SD 10.7)	Cases: Coronary heart disease CHD (angina pectoris and/or myocardial infarction) 106 patients. Controls: No CHD. 950 patients	Independent variables: Root-filled teeth, teeth with periapical bone lesion. Number of patients not given	Cases: Mean number of root-filled teeth 3.0 (SD 8.9), no teeth with periapical lesion 0.4 (SD 0.8) Controls: Mean number of root-filled teeth 3.4 (SD 3.2), no teeth with periapical lesion 0.4 (SD 0.8)	No significant association between root-filled teeth and CHD nor between teeth with periapical disease and CHD	No data	Moderate	Prospective design with randomly selected individuals. No adjustment for chronic marginal periodontitis
Jansson et al 2001 [5] Sweden	Case-control	1 393 patients stratified sample of normal population examined 1970–71. Age 18–66 years, 687 male/706 female	Cases: Dead by cardiovascular disease (CVD) 162 patients. Controls: Alive 1 062	Number of periapical lesions. Number of patients not given	Case: Mean for all cases 18–66 years: 1.11 periapical lesions Controls: Mean for all controls 18–66 years: 1.04 periapical lesions	Number of periapical lesions. Partial correlation 0.05, $p<0.05$	169 patients dead by other causes	Low	Results adjusted for age and gender. In survival analysis number of periapical lesions not a single variable but included in a summary index

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Table 3.8.1 continued

Author Year Reference Country	Study design	Population characteristics	Cases/Controls Number of individuals	Exposure	Results	Comparison Level of significance	Withdrawal Drop-outs	Study quality	Comments
Joshipura et al 2006 [4] USA	Case-control	35 764 male health professionals. Age 40–75 years. Data collection 1986–2000	Cases: Coronary heart disease (CHD) WHO criteria 1 275 patients. Controls: No CHD diagnosis	At least one root canal treatment (RCT) reported by the patient in all 12 494 patients	Cases: Data not given. Controls: Data not given	RR for 1 RCT (95% CI) adjusted for age, smoking, family history of MI was 1.25 (1.08–1.44). RR for 2 RCT (95% CI) in multivariate analysis was 1.21 (1.05–1.40)	Missing data 1 081 (3%)	Low	Recall bias MI? MI, myo cardial infarction
Lacassin et al 1995 [1] France	Case-control	171 cases matched to 171 controls as regards gender age and cardiac condition. Mean age 58 years (±15). Male 226/female 116. Native valve disease 38.5%. Prosthetic valve 24.0%. No known cardiac disease 37.5%	Cases: Definite, probable or possible infective endocarditis (Von Reyns' criteria). 171 patients Controls: Matched 171 persons as regards age, gender and cardiac disease without signs of endocarditis	Root canal treatment (RCT) within 3 months before endocarditis 21 patients	Cases: 15 patients had root canal treatment (9%). 8 patients had appropriate ab-prophylaxis. Control: 6 patients had root canal treatment (3.5%). 6 patients had appropriate ab-prophylaxis	Adjusted odds ratio (95% CI) 2.5 (1.0–6.5). Multivariate analysis: Odds ratio (95% CI) 1.7 (0.5–5.2)	244 (59%) See comments	Low	Prospective design and large sample size. Recordings of exposure may be biased Excluded from the original sample of 415 patients: Younger than 15 years (17), valve replacement previous year (33), premature death (82), hospitalized (87), intravenous drug users (20), coxiella brunetii infection (5)

CHD = Coronary heart disease; CI = Confidence interval; CVD = Cardiovascular disease; LEO = Lesions of endodontic origin; P = Probability; RCT = Randomised controlled trial; RR = Relative risk; SD = Standard deviation

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3.9 Risks of serious side-effects and complications associated with endodontic treatment procedures

Background

Although endodontic procedures, including root canal filling, should be confined to the root canal space, complications of various nature including damage to the neighbouring tissue structures may occur. While some have negligible consequences for the patient, others can result in extensive tissue damage and serious systemic effects. Such side-effects include allergic reactions, local and peripheral nerve damage, inflammatory conditions with tissue necrosis and respiratory obstruction.

Many adverse effects are directly attributable to the medicaments and materials, used for canal disinfection and root canal filling. Even mechanical debridement to remove soft and hard tissues from root canals can result in acute conditions, if infectious agents are extruded into the periapical tissues.

This section is limited to the occurrence of side-effects and treatment complications of a more serious nature giving rise to conditions, which may be long-lasting and difficult to treat. We have not addressed the risk and occurrence of complications associated with debridement and instrumentation of root canals, including root perforations and instrument fractures. Nor have we considered complications due to operator negligence, such as dropped instruments entering the gastrointestinal or the respiratory tract because of absent rubber dam application, or emphysema caused by applying compressed air to the root canal. However, the distinction between iatrogenic injury and side effect of endodontic treatment is not clear-cut. We have tried to make this distinction by excluding reports where the treatment complication is clearly due to a careless operating and by denoting side effect as "an unexpected treatment complication of a serious nature".

Evidence-graded results

- Side-effects and treatment complications are reported in the form of allergic reactions, nerve damage, inflammatory changes with tissue necrosis and life-threatening infections, as a direct sequelae to endodontic procedures, eg in conjunction with disinfection and root filling. There is no scientific basis on which to assess the risk and risk factors for the development of such conditions.

Questions addressed

- What types of serious side-effects can occur in association with endodontic treatment?

- What aspects of endodontic treatment are associated with the greatest risk and how common are various side-effects?

Facts 3.9.1 Inclusion criteria.

Articles (case reports, case series, cohort analyses) covering the following aspects were included:

- Side effect related to procedure involved in endodontic treatment (instrumentation, use of disinfectants, filling of the prepared canal)

- Allergic reaction associated with use of, eg disinfectant or material during endodontic treatment

- Acute condition arising from endodontic treatment, requiring hospital treatment

  We have considered relevant publications where there was a clear association in time between the side effect or complication and the provision of an endodontic treatment.

- In cases of allergic reaction, the association should have been investigated with respect to the medicament or material which is suspected of causing the reaction

- Case reports should in such cases also report the type of medicament or material (possibly specifying the brand) associated with the resultant side effect or damage

Facts 3.9.2 Exclusion criteria.

Articles covering the following aspects were excluded:

- Discoloration of teeth and damage to the periodontium associated with bleaching procedures
- The development of emphysema following application of compressed air to an open root canal
- Damage to the periodontium as a result of root perforation
- A flare-up (acute condition) with limited spread of inflammation following root canal treatment and/or root filling
- Osteonecrosis related to medication with bisphosphonate
- Instrument fracture
- Blocked or ledged root canal
- Injection of root canal medicament instead of local anaesthetic
- Treatment complications associated with apical surgery
- Poorly documented cases, in which the relationship between cause and effect is doubtful

Results of literature search and selection of studies

In all, the search yielded 575 abstracts. For search strategies see Appendix 1. The search failed to identify any systematic literature review or extensive cohort study analysing types and frequency of serious side-effects related to endodontic treatment, probably because they are relatively uncommon in clinical practice. The assessment was therefore based on case reports and case series. Full-text versions of 111 articles were ordered. Except for the search of the databases, a manual search of reference lists, relevant chapters in textbooks and review articles gave a further 29 articles. The final appraisal comprised a total of 185 articles read in full-text versions. See also flow diagram in Figure 3.9.1.

Description of studies and results

In all, 117 articles were included as a basis for analysis and compilation of various side-effects. The following categories were identified:

- Pain, peripheral soft tissue damage and osteonecrosis
- Damage to the inferior alveolar nerve or the maxillary sinus
- Allergic conditions
- Acute infections and inflammatory conditions.

Pain, peripheral soft tissue damage and osteonecrosis

Serious side-effects in the form of pain with subsequent soft tissue swelling and/or tissue necrosis are reported in association with the use of various intra-canal medicaments including calcium hydroxide paste as an interappointment dressing, root canal irrigation with unbuffered sodium hypochlorite and the use of material containing paraformaldehyde for pulp devitalisation.

Side-effects associated with calcium hydroxide as an intra-canal dressing

In Sweden, calcium hydroxide is commonly used in pulp and root canal treatment. Because of its high pH (pH >12) the agent has disinfectant properties, it inhibits bacterial growth and is therefore appropriate as a temporary root filling while the effect of endodontic intervention is monitored. It provides conditions conducive for hard tissue, repair both coronally, after pulp capping and apically, after pulpectomy. Two articles describe very serious tissue necrosis in the oral mucous membrane, the face and scalp after introduction of calcium hydroxide into the root canal by means of a syringe [1] (one case), [2] (two cases). It is obvious that in the reported cases the paste was extruded through the apical foramen into the adjacent blood vessels and spread to the capillary network. While this treatment complication can be attributed to incompetent management, these articles are included in order to illustrate the risk associated with the use of this material. Some overfilling of calcium hydroxide is otherwise generally well-tolerated [3,4], as long as larger amounts are not expressed into the surrounding tissues, for example, in cases of horizontal fracture or root perforation. Under such circumstances, local tissue necrosis can occur, causing a communication into the oral cavity [5,6].

Side-effects associated with root canal irrigation

A solution of sodium hypochlorite (NaOCl) is often used for root canal irrigation. This is a powerful oxidating agent, which in unbuffered form has a high pH (11–12). It has a nonselective effect on bacteria, through oxidation, hydrolysis and osmosis. A positive property of this agent is that it can break up necrotic tissue and thus contribute to effective cleaning of the root canal. However, even in relatively low concentrations (1%), the agent can cause haemolysis, skin ulceration and necrosis if the solution is injected directly, or if by some other means it comes into contact with the surrounding tissues. Typical of the symptoms, which can occur, are sudden pain or rapidly progressive soft tissue swelling in the mouth, the lips, the face and the orbital area. This may be followed by sloughing of the soft tissue, a "sensation of pins and needles" (paraesthesia) and locked temporomandibular joint (trismus). Some 20 case reports, which describe the development of such injury are presented in Table 3.9.1. The initial course of events can often be dramatic, but relatively short if adequate treatment is provided. A case of life-threatening respiratory obstruction developed after irrigation of the root canals of a mandibular second molar [7]. Hours after treatment, swelling developed in the submandibular and sublingual area, which subsequently spread bilaterally; there was pronounced elevation of the tongue. After two days in intensive care the patient recovered, but it took a further month before the patient became asymptomatic. In most cases the patients have become completely asymptomatic within two to eight weeks. In some cases there has been prolonged and sometimes perman-ent paraesthesia in the facial region [8–10].

Other complications associated with root canal irrigation

Temporary eye damage has been reported following accidental splashing of 5.25% NaOCl- solution [11]. Cases of severe pain and development of facial emphysema have been reported after root canal irrigation with a combination of sodium hypochlorite and hydrogen peroxide [12]. In one case, irrigation of a third molar with 3% hydrogen peroxide led to respiratory distress after the initial development of subcutaneous emphysema, which then spread and exerted pressure on the lungs [13].

Devitalisation of the pulp with paraformaldehyde

Paraformaldehyde is used as a disinfectant, as a component of root filling material and as an agent to devitalise vital pulps. In the latter application it is used to necrotise the pulp to allow painless removal; a paste of paraformaldehyde is then applied to the exposed, bleeding tissue for one week. If the temporary dressing provides a poor seal, the material can leak out during this period, and cause extensive damage to the supporting tissues of the teeth. Such complications are well-known and have been reported over many years. The literature review disclosed six reports [14–18,19]. The reports describe bone necrosis and formation of sequestra, which eventually resulted in the loss of teeth. Arsenic trioxide has the same field of application as paraformaldehyde and can result in similar injury [20–24]. Today, these materials are rarely used in Sweden. However, with respect to both agents, there are relatively recent reports from other countries [17,19,20,22–24].

Damage to the inferior alveolar nerve or the maxillary sinus

Inferior alveolar nerve

There is a risk of damage to the inferior alveolar nerve associated with endodontic treatment of mandibular molars and premolars, particularly if the apices of these teeth are located in close proximity to the nerve canal. Both instruments and solid or fluid root filling materials (sealers) can cause damage. Sealers in particular can be expressed along parts of the mandibular canals. Typical symptoms arise. The patients often describe the sudden onset of pain followed by a feeling of anaesthesia within the area supplied by the inferior alveolar nerve. If local anaesthesia has been used for treatment there is no sensation of pain, but the feeling of anaesthesia persists long after the time it usually takes for it to wear off. Neuralgia-like attacks of pain can occur and persist, as can local symptoms often associated with inflammation such as pain on percussion and palpation. Loss of sensation and “pins and needles” in the lower lip are more persistent symptoms and can continue for months and years. Overfilling seems to be the most common cause of persistent nerve damage. Injury due to penetration of a root canal instrument has been reported in only one case resulting in paraesthesia lasting for a little over a week [25].

Upon overfilled root canals, the extent and duration of the nerve damage is determined not only by the pressure the material exerts, but also by its chemical properties (for an overview see, eg Scolozzi [26]). In this context, formaldehyde-containing (Endomethasone, N2, SPAD) or formaldehyde-releasing root filling materials (AH26) have long been of concern. Among the reports we have identified, such root filling materials are involved in the vast majority of cases (Table 3.9.2). In many of these cases, injury to the nerve led to persistent symptoms. Treatment complications are also reported for other root filling materials such as thermoplastic application of gutta-percha or gutta-percha in combination with calcium hydroxide and zinc oxide-based sealers (Table 3.9.2).

Little is known of the effect of surgically removing root filling material from the mandibular canal. There are reported cases where the painful condition has been treated successfully and normal nerve function restored. In some cases this has happened after a relatively short period (weeks) and in other cases it has taken several months, up to a year. There are also reported cases of persistent paraesthesia, despite the evident elimination of all the material.

Maxillary sinus

Instruments, medicaments and root filling material can be forced into the maxillary sinus and cases are reported, where chronic sinusitis developed [27,28]. A few cases of aspergillosis have also been reported, where the presence of endodontic material in the maxillary sinus is considered to be the cause [29–35]. In other cases of sinus perforation, no pronounced negative effects were observed [36–40].

Allergic reactions

General urticaria, itching, facial swelling, swelling of the oral mucous membranes, cardiovascular problems and loss of consciousness through anaphylactic shock are described in relation to several materials and medicaments used in root canal treatment (Table 3.9.3). In recent years the risk of an immediate hypersensitivity reaction to contact with latex-containing products has received particular attention [41]. In endodontic treatment there is thus the risk of an allergic reaction in a sensitized patient, primarily to the use of rubber dam. Gutta-percha points for root filling are also based on natural rubber, but a cross-reaction with latex could not be confirmed in the two reported cases of suspected allergic reaction after the root canal was overfilled with gutta-percha [42,43]. Most reports of allergic reaction concern root filling materials containing formaldehyde.

Acute infections and inflammatory conditions

Several reports describe cases which can be directly associated with endodontic infections, with rapid onset of an acute condition, extensive swelling, high temperature and potential obstruction of the airways [44]. There are descriptions of organ abscesses, bacterial endocarditis and brain abscesses with possible links to endodontic infections. More or less prolonged loss of sensation and paraesthesia in relation to the inferior alveolar nerve are also reported [45–48]. Meanwhile we have found only a few case reports where acute conditions can be traced to a direct effect of endodontic treatment. In one case the patients developed an endocarditis five days after endodontic treatment of a maxillary premolar, despite antibiotic prophylaxis [49]. Septicaemia has also been reported after endodontic over-instrumentation [50]. Koch and coworkers report a case of orbital infection initiated or exacerbated by endodontic treatment of a maxillary molar [51]. The condition developed rapidly and penetrated not only the maxillary sinus and ethmoidal spaces but also the orbital walls within 48 hours, despite the absence of a history of prior infection in the region. The tooth had been root filled with considerable overfill of Endomethasone. Also described in the literature are cases of rapid onset of swelling of the floor of the mouth and the tongue and respiratory distress, after root filling of a molar with a necrotic pulp, which had not been adequately debrided previously [7,52].

Discussion

The review shows that endodontic treatment can be associated with risks for a variety of serious side-effects. However, there is a lack of scientific documentation to allow an assessment of the magnitude of the risk. Through meticulous history taking to identify patients at risk of allergy and by exercising due care in handling instruments, medicaments and root filling materials, it should be possible to reduce the number of cases to a very low level.

Based on the articles identified in this review, it seems that there is a risk for serious side-effects associated with irrigation of root canals with disinfectants such as sodium hypochlorite. The solution can be forced out into the adjacent tissues through perforations or open apical foramina. Another risk is overfilling. Root filling material can clearly both sensitize a patient and trigger an allergic reaction in an already sensitized patient. If the material is extruded into the mandibular canal it can cause nerve damage through mechanical pressure or chemical effects or both. Formaldehyde, which is an ingredient in several root filling materials (Endomethasone, N2, SPAD), or is released during the setting phase of certain sealer materials (AH26), is over-represented among cases describing allergic reactions and damage to the mandibular nerve. The agent is a well-known allergen. At high concentrations it also exerts pronounced tissue toxic effects.

It has not been possible to determine the prevalence and incidence of side-effects in clinical endodontic practice. It is probable that not all cases of side-effects are disclosed and serious treatment complications may not invariably be reported. We are also aware that the search has not identified all cases, which are published in various national journals. It should be possible to access the computerised system of patient records now used by the Swedish Dental Services, to acquire more knowledge about the risks and nature of serious side-effects, which can occur in association with endodontic treatment measures.

Table 3.9.1 *Reports of serious tissue damage associated with the use of sodium hypochlorite as an irrigant and disinfectant in root canal therapy. More than one case may be described in one and the same report.*

Persistence of symptoms	References
2–8 weeks	[7,53–65]
3–6 months	[64,66,67,68 (two cases)]
Permanent	[8–10,59,69]

Table 3.9.2 *Reports of damage to the inferior alveolar nerve associated with temporary or permanent root canal fillings. The compilation includes case reports, which disclose the type or brand of root filling material and to what extent the symptoms disappeared, with or without surgical intervention. More than one case may be described in the same report.*

Persistence of symptoms	Root filling material	References
Short-term (1–8 weeks)	AH26 with or without Gutta-percha Gutta-percha Iodoform paste	[25,70,71] [72] [73]
Long-term (>2 months)	AH26 with or without Gutta-percha Gutta-percha and zinc oxide eugenol sealer Calcium hydroxide Chloropercha Formaldehyde-containing (Endomethasone, N2, SPAD)	[25,26,74,75] [76] [77] [78] [77,79,80]
Persistent	Gutta-percha and zinc oxide eugenol sealer Hydron 1 Formaldehyde-containing (Endomethasone, N2, SPAD) Thermoplastic gutta-percha	[26] (>18 months) [82] (>3 months) [83–94] (>3 months upp till >5 years) [81,95,96] (>1 year)

Örstavik cites a further six references which are not presented in this compilation, comprising 15 cases, nine of which were related to formaldehyde-containing root filling material [92].

Table 3.9.3 *Reported allergic reactions to different materials used for endodontic treatment.*

Material/ medicament	**Number of reports**	**References**
Eugenol	2	[97,98]
Paraformaldehyde	9	[99–109]
Gutta-percha	2	[42] (latex sensitivity) [43] (latex sensitivity)
Epoxy	2	[110] (AH 26 sealer) [111] (AH + sealer)
Rubber dam	4	[112] (latex sensitivity) [113] (latex sensitivity) [114] (latex sensitivity) [115] (not latex)
Sodium hypochlorite	2	[116] [117]

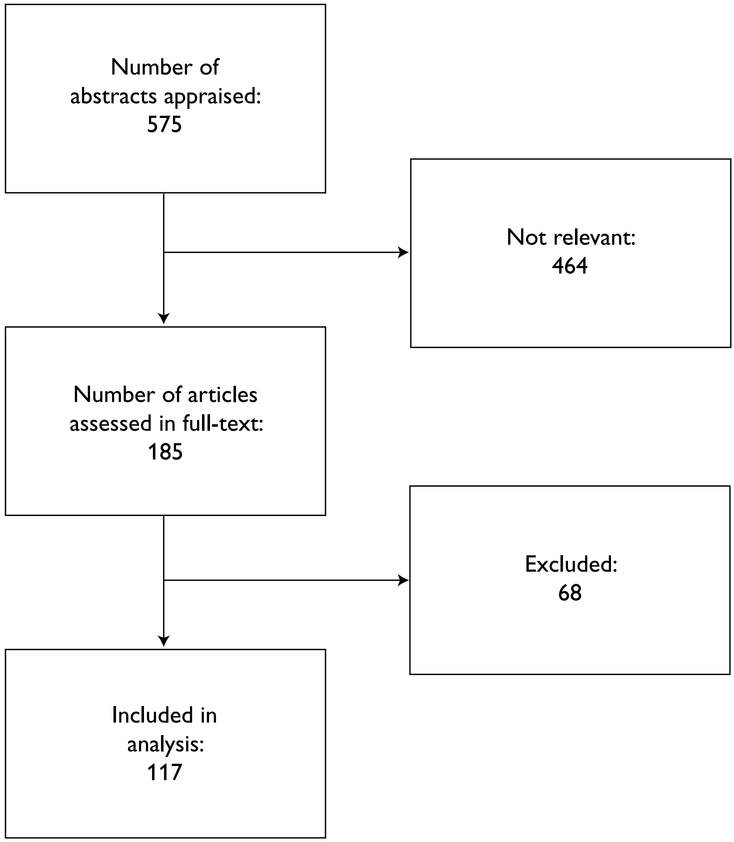

***Figure 3.9.1** Flow diagram of literature search.*

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4. Ethical and social aspects

Assessments by SBU are to include medical, economic, social and ethical aspects. The introduction to this chapter comprises a summary of what is meant by ethical and social aspects. This is followed by a discussion of ethical and social aspects of methods for diagnosis and treatment of diseases of the dental pulp.

What is meant by ethical aspects?

Ethics deals with that which is good/beneficial or evil/harmful, respectively: what should or should not be done and what characteristics make us respectively better or worse individuals. The central question in normative ethics concerns the correct procedure; its role is to clarify how ethical issues should be managed, ie what should be done in a certain situation and what should be avoided [1]. A course of action can be disqualified on ethical grounds in two different ways. Either there is something objectionable in the course of action itself that makes it unacceptable, regardless of the expected consequences of the action, eg because those concerned are not treated with respect and dignity, or because the exposure to risk is unacceptably high. Or the expected negative consequences exceed the expected benefit, and thus the action is contraindicated. If there is profound objection in principle against the course of action then there is no cause to reason further and weigh the positive and negative consequences. In other cases these consequences should be considered.

Ethics in health care is concerned primarily with how the individual patient should be treated, ie what is beneficial and what is harmful to the patient, respectively. Several patient-related interests become relevant, particularly health, well-being, autonomy and integrity. Ethics in dentistry, however, covers more than the individual patient. Effectiveness, priority and fairness are also relevant aspects of ethics, as are questions about how to weigh up the interests of the patient against research interests.

The following four principles, which are well-established in biomedical ethics, are often presented as a basis for ethics in health and medical care [2,3]. They are also reflected in the Swedish Laws on Health and medical care (HSL) and in the parliamentary resolution on priority in medical care:

1. The *do-good principle* means that one should try to help the patient by satisfying their (medical and basic human) needs;

2. The *do no harm principle* means that one should avoid harming the patient. One should for example avoid taking unjustifiable risks;

3. The *autonomy principle* means that one should respect the patient's right to self-determination, which implies that one must keep patients informed and guarantee them the right to decline the treatment being offered;

4. The *principle of fairness or justice* means that patients with similar needs should be treated similarly. That is, it is the patient's treatment need which should determine the course of action, not – for example – the patients cultural background, gender, financial or social standing.

These principles in themselves do not suggest an order of priority in cases of conflict. One can for example, imagine situations where the treatment which is most likely to improve the patient's dental health is at the same time associated with greater risk than other treatment options: which principle should be applied, the "do-good" or the "do no harm" principle? A similar conflict can arise between the "do-good" principle and the autonomy principle, in cases where the patient does not want to accept the treatment, which the dentist recommends. The four principles are not however, intended as a total ethics package for solving ethical problems. The purpose is more to remind us of core ethical principles, which should be taken into account in assessing which of the treatment options is the right one.

In addition to well-being, health, autonomy and justice, personal integrity is usually proposed as an important aspect of ethics [4,5]. Respect for a human being's personal integrity implies respect for their right to personal space. Anyone who enters this personal space without permission is infringing on personal integrity, such as when an unauthorised person looks at a patient's radiographs or accesses a patient's treatment records. Personal integrity involves a person's right to determination over their own space and is thus closely related to autonomy.

In evaluation of methods for treatment of various dental problems, the ethical and social perspectives of the following questions should be addressed:

- How do the various treatment options influence the patient's well-being and social situation?

- Does the question of fairness arise in choice of treatment?

What is meant by social aspects?

In this context, social aspects are those which touch on the individual's life in the community, for example, living conditions, family life, social interactions and lifestyle. Social aspects encompass both individual and structural factors, which influence a person's health and well-being. Examples of factors that can be important in relation to oral health are dietary habits, educational level, social network, socioeconomic aspects and age- and gender-related aspects of dental problems, and also recognised and potential social consequences of these problems or treatment methods. For example, what importance has such factors as lifestyle, dietary habits and educational standard on the development of dental problems? What are the consequences of the various treatment options for family life, social interaction and career potential? SBU reports address primarily the social consequences of the treatment methods under evaluation.

There is a clear relationship between social and ethical aspects of dental care: because many social aspects are of relevance to ethics, considerable overlap is to be expected. One example is the individual's ability to influence and accept responsibility for decisions, and to benefit from information, for example with respect to measures to prevent oral disease. Another example of an area where social and ethical aspects overlap is the allocation of resources for various courses of treatment. This example shows that in some cases social and ethical aspects are also closely linked to economic aspects.

Ethical and social aspects on methods of diagnosis and treatment of diseases of the dental pulp

We have identified the following themes as relevant:
1) positive and negative effects of various methods of diagnosis and treatment of diseases of the dental pulp, 2) autonomy and information and 3) fairness and priority aspects.

Positive and negative effects of diagnosis and treatment

Despite the improvement of dental health in Sweden over time, the need for root canal treatment and associated diagnostics remains high. A central factor in determining what should be done is the anticipated outcome, depending on the measure selected. It is therefore particularly important to have access to reliable empirical results of positive and negative effects of diagnosis and treatment.

The project group's extensive review of the current state of knowledge shows primarily that within all areas there is a lack of reliable or adequate scientific support on which to draw definite conclusions with respect to a number of questions. In general, there seems to be a lack of support for definite conclusions about the relative merits of various diagnostic and treatment methods. In a few cases it is impossible to determine whether accepted practice is better than no action at all.

The knowledge gaps are attributable primarily to the fact that the studies which have been conducted to date have been inadequate in some respect, for example too few patients, inadequate follow-up period or the methods used for analysis have not been sufficiently reliable. For some of the questions, no studies at all are available. In some cases, the absence of studies is due to the fact that it has not been ethically acceptable to conduct the studies necessary to answer important questions on treatment effects.

If there is a well-established consensus that treatment is better than no treatment, then further exploration of the question may seem less urgent. For example, there is consensus that it is better to treat teeth with necrotic and infected pulps than no treatment. In other questions the profession is not in agreement and there is a large variation in clinical practice. An example is the management of root-filled teeth with radiographic signs of persistent, asymptomatic apical periodontitis. In such cases the lack of data can be attributable to practical rather than ethical hindrances.

There is also a large knowledge gap with respect to the risks associated with different diagnostic and treatment methods. Although many side-effects and complications are reported in the literature, such as allergic reactions, nerve damage, tissue necrosis and serious infections, there is a lack of scientific evidence with respect to how frequently such events occur, or which stages of treatment represent a particularly high risk. This aspect of endodontic practice warrants more research.

The fact that there is in general no specific scientific basis for selection of methods for diagnosis and treatment, does not imply that there are no grounds at all for recommending a particular method in routine clinical practice. For example, methods, which may expose the patient to great risk should be avoided. Methods, which are particularly expensive should also be avoided until they have been tested in scientific studies. Moreover preference should be given to diagnostic and treatment procedures, which are supported by relevant established theoretical hypotheses, until such time as empirical support is available, rather than selecting methods which are not based on theory.

For several decades there have been reports of an association between certain oral diseases and cardiovascular disease. Whether there is a similar association between inflammation originating in the dental pulp and cardiovascular problems, and also whether there is a deleterious influence on other organs, has not been confirmed. Although there is insufficient scientific evidence to dismiss the possibility of such an association it is not possible to discern, from the available studies, any clear covariance between endodontic infection and cardiovascular disease.

It is of some general interest to note that there is good support for the claim that the risk that patients will develop cancer because of extensive radiographic examinations is negligible. It is therefore irrational for patients with dental problems to decline radiographic examination on these grounds.

Autonomy and information

Both the right to autonomy and the right to information are relevant to diagnosis and treatment of diseases of the dental pulp: What should patients decide with respect to their dental care? What information should the dentist provide and should any information be withheld from the patient?

The mouth is an intimate part of the body. It is therefore reasonable to assume that it is important for people to make their own decisions about their teeth, not least with respect to treatment. On the other hand, not everyone can afford the kind of dentistry they would like to have. When some or all dental treatment is publicly funded, then it is reasonable that the public has a decisive influence over what level of dentistry should be provided in this way. The way in which dental care is financed is usually considered to be the major determinant of how much freedom of decision is left to the individual patient, not least because the cost of financing treatment through public funding might otherwise become very high.

In order to make informed decisions about their own dental care, patients require relevant information. In circumstances where there is a lack of knowledge about the expected benefits of different treatment options, it is difficult to provide information, which offers the patient a basis for decision-making. It is also difficult to analyse the value the state receives for the subsidies it pays for more extensive treatment. It is therefore important from both an individual patient and a community perspective that research is conducted to improve our knowledge of the effects of various treatment methods. This will allow the clinician to offer better information to patients and thus for the patient to assess various treatment options.

As shown by the survey of routine endodontic practice that accompanied this systematic review of the literature, asymptomatic periapical bone lesion associated with root-filled teeth is often left without treatment. Similarly, it is quite common for the dentist to leave asymptomatic root-filled teeth with radiographically inadequate root fillings, without informing the patient. Moreover, it is not unusual for such teeth to be restored with crowns, or used as abutments in bridge constructions, despite the risk that problems may ensue. Is this still wrong? Is the dentist under an obligation to inform the patient of the situation?

With respect to diseases of the pulp and periodontal tissues, a not inconsiderable portion of treatment stems from previously less successful treatment. Should the dentist inform the patient about previously inadequate treatment if at the time the patient is not having any problems, but there is a risk of future complications? From the perspective of autonomy, the answer to these questions seems obvious. Anyone wanting such information about their dental status should have the right to this if the information is related to a dental appointment (however, a patient should not have the right to request a dental examination for the purpose of possibly disclosing unsatisfactory treatment, unless there are clear indications, such as a dental problem – unless the patient pays the fee for examination). A difficulty is that some patients do no wish to receive such information, ie they prefer not to know unless the information has a direct bearing on treatment [7–9]. The dentist needs to ascertain beforehand what attitude the patient has to such information, in order to show due consideration to both patients who want to be fully informed and those who do not. This is of course the case when the dentist has treated the patient for several years and knows the patient well. However, if the dentist is new or has a new patient, there is no background knowledge about the patient. To wait until an appointment for examination or treatment and then ask the patient whether he wishes to receive such information is unacceptable because the patient may draw the conclusion that the dentist now has some information, or would otherwise not have asked.

It may be challenging to have to inform a patient that previous treatment has not been successful, as there is a risk of singling out a colleague in a negative way. This is sometimes unavoidable if the patient is to receive relevant information, for example, if only one dentist has done root fillings for the patient. In such situations it is important to combine objectivity in presenting the information with a respectful attitude to the colleague.

Fairness and prioritising

In Sweden dental care is managed differently from other health care and the same applies to financing. For all citizens up to the age of 20 years, dental care is provided free of charge. The financial support from the state to those aged over 20 years is called a dental care subsidy and comprises a general dental care allowance and a safety net or high cost ceiling. The dental care allowance comprises an annual dental care cheque, which covers a small part of the cost of a visit to the dentist. The safety net means that the state pays a proportion of more extensive treatment such as prostheses, tooth supported bridges and implants. The Dental and Pharmaceutical Benefits Agency (TLV) determines what treatment is to be covered by the safety net and also determines benchmark fees for these items of treatment.

The fact that adult patients to a great extent pay for their own dentistry has consequences for distribution of care. People who are well off can have access to care, which takes a lot of resources, whereas those less well off can be forced to go without. Subsidies for more extensive treatment move the boundaries delineating who can receive the more expensive dental treatment. Primarily it can be expected that those who are worst off are least able to avail themselves of the benefits of subsidies.

According to the Public Health Report by The Swedish National Board of Health and Welfare in 2009, there has been a general improvement in dental health of the population. At the same time the dental health of socioeconomically weak groups has deteriorated [10]. According to the ULF-examination (survey of living conditions in Sweden) of 2004–2005 (which was conducted prior to the dental care reform of 2008) 14% of those aged 16 to 84, who were asked, stated that they had needed dental treatment in the past year but had not visited a dentist. In the age group 25–34 this applied to 20%. According to the investigation the main reason for not seeking treatment was that the person felt that they couldn't afford it. Over-represented among those who refrained from dental care, despite a perceived treatment need, were those with low disposable incomes, single parents and those born overseas [11]. A doctoral thesis from 2007 showed that many homeless people have poor dental status and seek treatment only for severely acute conditions [12].

Applying the concept of fairness, ie equal treatment according to need, which permeates Swedish health care in general, the situation with respect to dental care is problematic. Because some people have fewer resources than others, the ideal of offering similar treatment according to treatment need will not be achieved as long as patients themselves have to pay for some of their dental care. A policy of greater consideration of dental health for those who are financially weakest would require alternatives to the present subsidies for dental visits and expensive treatment. Such an alternative would be to determine a minimum dental status, for which society would undertake full financial responsibility. Because of the high cost of such a system, it would probably be necessary to remove the present government subsidies for some treatment.

A reasonable level of publicly financed dental care?

Under such a system it would also be necessary to determine what level of dental status it would be reasonable to try to achieve. There are aspects other than the purely medicinal to be considered. The following hierarchy of measures could be considered:

1. Measures to save life and preserve general health;
2. Measures to eliminate pain;
3. Measure to eliminate disease such as inflammation or infection;
4. Measures to maintain or restore function;
5. Measures to reduce the risk of, or prevent disease;
6. Measures to restore the aesthetics of the teeth or the dentition;
7. Measures to improve the aesthetics of the teeth or the dentition.

Points 1–4 are key interventions for publicly financed medical care. It can therefore be considered reasonable to include such measures in publicly financed dental care. Prevention of disease (5) is also in many cases seen as an important and justifiable aspect of health and medical care, but in practice is often overruled by the previous points. Aesthetic reconstruction (6) also occurs in other fields of health care. However, there are tight restrictions on aesthetic improvement (7). Exceptions can however be made if there is a high risk that otherwise the patient will suffer deep psychological distress. In certain cases it has been proposed that breast enhancement for women with small breasts or hardly any breasts at all could be justified on these grounds.

Historically, one approach has been to distinguish between biological and other grounds for care. If the treatment measures are to be meaningful for the patient then such a distinction is doubtful from a normative perspective [13,14]. Nor is the implication of the expression “biological basis” absolutely clear. For example, in endodontics much effort is devoted to save teeth, which could sometimes be replaced by implants when such treatment is simpler and has a more predictable outcome. The biological perspective can be interpreted as justifying measures for saving poor teeth. But if a core aspect of the biological perspective is function then it could instead be interpreted as justifying dental implants. If function is to be the primary goal then it is not always certain that any measures at all are required or it may be sufficient just to extract the troublesome tooth. It is doubtful that there is any intrinsic value in preserving such body parts as the dentition, but it can be important for function and from the patient's own life perspective.

It is very doubtful that it is possible to propose the extent of publicly financed dental care scheme on the basis of biology or concepts about normality. It is preferable to tackle directly the normative questions concerning publicly financed dental care, for example:

- Is there a minimum level of dental status, which all citizens should have the right to achieve or preserve? If so, what is this level and on what basis is it proposed?

- To what extent should individual preferences be allowed to influence care?

- To what extent should patient satisfaction (rather than medical or technical outcome) influence the choice of diagnostic and treatment methods?

The way in which these questions are answered has consequences both for economic policy and distribution policy.

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5. Health economic aspects

Evidence-graded results

- There is a lack of scientific evidence of the cost effectiveness of different methods of treating diseases of the dental pulp.

Questions addressed

- What is the cost-effectiveness of various methods of treating revers-ible and irreversible disease of the dental pulp?

- What is the cost-effectiveness of various treatments for long-term survival of endodontic treatment?

Results of literature search and selection of studies

The search was conducted by the addition of "costs and cost-analysis" to the odontological search strategies used for the project (Appendix 1). Of a total of 89 abstracts, five articles were ordered in the full-text versions. Three studies were included; two articles were excluded because of short-comings in quality. See flow diagram in Figure 5.1.

Assessment of the quality of the economic studies

Two economists applied independently the SBU appraisal sheet for assess-ment of the quality of economic studies (Appendix 2). The relevance of the studies and their quality from an odontological perspective was appraised by the project's odontological experts.

Description of studies and results

The included articles comprise a questionnaire to university lecturers [1] and two modelling studies [2,3].

The systematic review of the literature covered economic aspects with respect to the following questions [4]:

- Is the treatment effect or economic outcome, respectively, better or worse for initial non-surgical root canal treatment than for tooth extraction without replacement of the extracted tooth?

- Is the treatment effect or economic outcome, respectively, better or worse for root canal treatment than for tooth extraction and replacement with a fixed partial denture?

- Is the treatment effect or economic outcome, respectively, better or worse for root treatment than for tooth extraction and replacement of the extracted tooth with an implant?

Two empirical studies were included in the review; one a prospective study of patient satisfaction and willingness to pay for an implant-supported crown [5] and one a retrospective study which compared an implant-supported crown with a fixed partial denture [6]. In the systematic literature review, it was concluded that at present, because there are so few published empirical economics studies it was not possible to answer the questions about economics listed in the project.

In a Canadian modelling study, 40 teachers were instructed to rank their preferences for three other strategies instead of traditional root filling with a crown restoration, namely a dental implant, a bridge, or a removable partial denture [1]. The basis for ranking the treatment preferences was information about treatment prognoses and with respect to fees, information about the patient's willingness to pay for various treatment outcomes. Income from fees was calculated as a net amount after deduction of state dental care subsidies. The cost benefit showed that a removable partial denture gave the best expected outcome of treatment costs in relation to treatment benefit (derived from willingness to pay). The factors of greatest importance for the predicted benefit of a treatment were partly the position of the tooth in the mouth and partly community subsidies for the different treatment options.

In a decision model applied to Swedish cost data, alternative strategies for follow-up of a completed endodontic treatment were analysed [3]. One strategy involved follow-up of all patients after four years, if no symptoms had developed in the meantime. Another strategy involved follow-up after one year and further follow-up after three years, but then only for those patients who had had symptoms during the first year. The two strategies were tested according to six alternatives. Data on sensitivity and specificity were retrieved from published studies. The outcome was strongly influenced (as expected) by the assumed level of prevalence. The cost effective strategy, defined as the cost per percentage improvement in the number of true positive cases, was follow-up after one year with further follow-up after three years of cases with clinical symptoms.

An American decision analysis explored two questions [2]:

- What are the costs and benefits respectively of pulp capping compared with endodontic treatment?

- At what per cent level of satisfactory treatment does pulp capping become a cost-effective treatment strategy compared with endodontic treatment?

The anticipated final treatment was given maximum uncertainty, ie 50% for the alternatives being compared, but in the sensitivity analysis varied from 1 to 99%. At the highest level of uncertainty, ie likelihood 50%, pulp capping gave the lowest anticipated cost (USD 780 vs 856). At a likelihood of final treatment outcome of pulp capping corresponding to only 16% or less, endodontic treatment was cost-effective. According to the authors the modelling calculations showed that endodontic treatment should not be routinely undertaken in teeth, which do not show symptoms of pulpal inflammation.

Discussion

In Chapter 3, on the effects of various methods of endodontic treatment, the review disclosed only limited scientific support. Consequently, there is also a lack of supporting evidence for the cost-effectiveness of various treatment methods. With respect to empirical health economics studies, the only paper, which could be included, is a systematic review of two empirical studies. The review concluded that because there are so few empirical studies published to date, there is a lack of evidence to support the cost-effectiveness of various endodontic treatment methods. This is not to say that various methods are not both clinically effective and cost-effective; however, this has yet to be confirmed in empirical health economics studies.

Individual patients generally pay a large proportion of fees for dental services from their own pockets, despite the newly modified dental insurance system in Sweden. Compared with medical care in Sweden, the proportion of dental care financed through taxes varies markedly. The willingness of patients to pay for various potential dental treatment options can therefore be assumed to govern the choice of treatment. The change in subsidy system in the form of the dental care reform of 2008 can be assumed to influence patients' choices. It is therefore important to study questions about willingness to pay for dental care, but this was outside the scope of the present project.

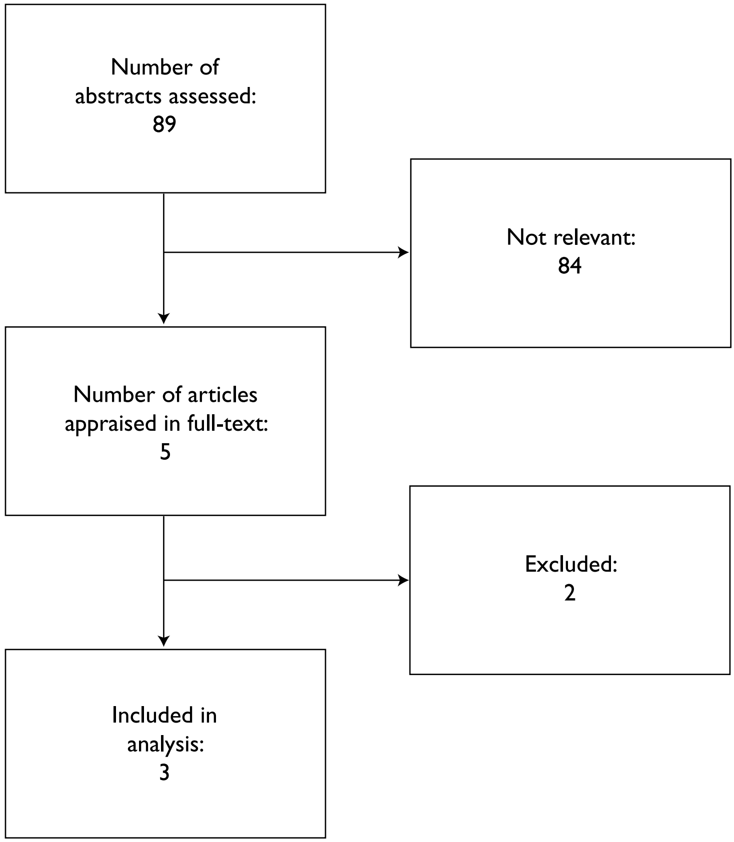

Figure 5.1 *Flow diagram of literature search.*

Table 5.1 *Health economy.*

Author Year Reference Country	**Study design Reliability test**	**Intervention Patient characteristics**	**Control Patient characteristics**	**Drop-outs**	**Results**	**Study quality Comments**
Balevi et al 2007 [1] Canada	Model Decision-tree Enquiry to 40 teachers NA	Preferences to different strategies. Utility measurements. Standard gamble technique. Responders 75% were male	NA	Intervention: NA Control: NA	I: Highest utility molars: Single tooth implant. Willingness to pay Can$1.871 Control: NA	Moderate
Maryniuk et al 1990 [2] USA	Model Decision analysis Outcome: Costs NA	Pulp capping vs endodontic therapy for a tooth to receive cast restoration	NA	Intervention: NA Control: NA	I: Pulp capping strategy has lowest expected cost for all "p" of successful intervention p>0.16 (one-way) or p>0.56 (two-way). At p>0.50 pulp capping was preferred option at US$780 Control: NA	Low Patient's loss of time or discomfort was not included in the model
Reit 1987 [3] Sweden	Model Decision tree including recall strategies NA	Screening after 1 year of endodontic treatment + follow-up at year 4 of lesions found at year 1	Screening of all patients having had endodontic treatment at year 4	Intervention: NA Control: NA	I: Screening after 1 year the most cost-effective strategy SEK2 709 per % increase of true positive cases Control: NA	Moderate Prevalence of disease of high importance for economic outcome

I = Intervention; NA = Not applicable; P = Probability

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6. **Survey of established endodontic practice in Sweden: a questionnaire study**

Background

Endodontic treatment may be successfully carried out using a variety of techniques and materials. In the absence of unambiguous, evidence-based studies, many different treatment philosophies and attitudes flourish. During the past 15 years, there have been important technological advances. This means that endodontic treatment is now more predictable and probably has better outcomes than previously. Using modern treatment techniques, root canal treatment can also be completed more quickly, which means that it is now much more common for root fillings to be completed in one appointment. This procedure is however, controversial and there is a lack of consensus as to what should be regarded as a treatment carried out in accordance with scientific evidence and well-established practice. There are also disagreements as to how a pulp exposed by caries or other causes should be treated: whether to dress the exposure like a wound, or radically remove the entire pulp by pulpectomy. There are also diverse opinions as to whether new treatment should be instigated in cases where endodontic treatment has not resulted in complete periapical bone healing, but the tooth is asymptomatic. In order to document established practice with respect to endodontic treatment methods and treatment decisions, the Project Group undertook a questionnaire study in 2009 among a representative selection of Swedish dentists.

Questionnaire study

The questionnaire comprised three separate inquiry forms: A, B and C (Appendix 3). The introductory questions about the dental practitioner's background were common to all three inquiry forms and covered gender, type of practice (public or private practice) county, age, number of years of clinical experience, use of mechanical root canal instrumentation and current practice (children's dentistry, general adult dentistry, specialist dentistry, not involved in endodontics, or not practising clinical dentistry). Thereafter, the three inquiry forms comprised questions with both multiple choice and written responses: we elected to include relatively few variables and to separate these into three different inquiry forms, to be sent to three different samples of dentists, in order to improve the chances of a high response rate. In the analysis of the results, all background factors were included in a multivariate logistical regression model.

The questionnaire addressed dentists practicing in Sweden. A random sample, comprising 2 012 of 8 705 dentists, was taken from PAR (the Swedish register of postal addresses). The regions were weighted so that 22% of addresses were in the Stockholm region, 13% in the Malmö region, 15% in the Gothenburg region and the remaining 50% in the rest of the country. The three questionnaires were evenly distributed to addresses throughout these four regions.

In April 2009, 2 012 inquiry forms were distributed: 671 type A, 671 type B and 670 type C. After one month, 1 243 responses had been received: 422 type A, 421 type B and 400 type C. After an initial reminder, 769 inquiry forms were distributed and one month later 314 responses were received. After a second reminder, 455 forms were sent out, resulting in 45 responses. After collection was terminated, a 18 further forms were received and 382 remained unaccounted for. In all, 1 612 responses were received, corresponding to a response rate of 80%, with the following distribution: Type A n = 546; Type B n = 542 and Type C n = 524.

In analysing the results, specialists were excluded, as were those who were not involved in clinical endodontics or not in clinical practice, and also those aged 70 to 79 and 80 to 89 years. This resulted in a sample comprising 418 respondents in group A, 412 in group B and 388 in group C. Moreover the variables county, age, number of years of clinical experience and use of mechanical instrumentation were dichotomised as follows:

County:	Sparsely populated county (<22.5 persons/km^2) Not sparsely populated county (>22.5 persons/ km^2)
Age:	20–49 years; 50–69 years
Number of years a dentist:	1–25 years; >25 years
Use of mechanical instrumentation:	Uses; does not use

All three inquiry forms included the question about the use of mechanical root canal instrumentation. After exclusion of responses from specialists, from those not practising clinical endodontics, not in clinical practice or aged 70 or older, the remaining 1 210 responses were included in the analysis.

The statistical analyses were undertaken using the Chi^2 test and multiple logistical regression analysis. In all analyses, 95% confidence limits were applied. The results were presented with the aid of Chi^2 and odds ratio (OR).

Results inquiry form A

Background information.

Mark the appropriate box with a cross!

1. Gender?

	(%)
❑ Female	**36.4**
❑ Male	**63.6**

2. Practice?

	(%)
❑ Public	**41.8**
❑ Private	**58.2**

3. County?
Responses distributed according to county

	(%)
❑ Blekinge	**3.0**
❑ Dalarna	**2.8**
❑ Gotland	**0.4**
❑ Gävleborg	**2.2**
❑ Halland	**3.1**
❑ Jämtland	**0.8**
❑ Jönköping	**3.0**
❑ Kalmar	**2.8**
❑ Kronoberg	**2.0**
❑ Norrbotten	**2.6**
❑ Skåne	**12.4**
❑ Stockholm	**26.0**
❑ Södermanland	**1.4**
❑ Uppsala	**0.8**
❑ Värmland	**3.7**
❑ Västerbotten	**2.8**
❑ Västernorrland	**2.8**
❑ Västmanland	**2.8**
❑ Västra Götaland	**17.9**
❑ Örebro	**2.4**
❑ Östergötland	**4.7**
Sparsely populated county	**21.1**
Not sparsely populated	**78.9**

4. Age?

	(%)
❑ 20–29	**0.6**
❑ 30–39	**1.2**
❑ 40–49	**7.2**
❑ 50–59	**47.0**
❑ 60–69	**43.3**
❑ 70–79	**0.6**
❑ 80–89	**0**

5. Number of years as a dentist?

	(%)
❑ <1 yr	**0.2**
❑ 1–5 yr	**0.8**
❑ 6–10 yr	**0.2**
❑ 11–25 yr	**14.1**
❑ >25 yr	**84.7**

6. Do you use mechanical instrumentation?

	(%)
❑ Always (exclusively)	**5.9**
❑ Always (but combined hand instrumentation)	**27.8**
❑ Mostly	**15.0**
❑ Sometimes	**18.1**
❑ No, never	**33.1**

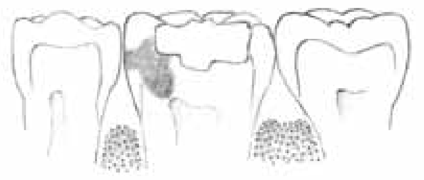
7. Present type of dentistry?

	(%)
❑ Children exclusively	**1.2**
❑ Children and adults	**61.1**
❑ Adults only	**21.8**
❑ Specialist, namely	**8.3**
❑ No endodontics	**2.9**
❑ Non-practising	**4.7**

Inquiry form A

1. Treatment of carious exposures of vital pulps

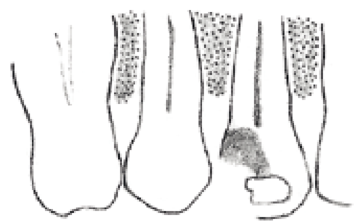
a) During routine examination of a 22-year old patient you find that 36 has a deep carious lesion (see illustration). The patient has no symptoms and a periapical radiograph shows no pathological changes.



While excavating caries from 36 you expose the pulp. The pulp is vital and you consider it to be bleeding normally.

How would you treat this tooth?	**Results (%)**
❑ Partial pulpotomy (according to Cvek)	13.5
❑ Pulp capping	65.8
❑ Pulpectomy (extirpation)	17.8
❑ Other option	2.9

b) During routine examination of a 50-year old patient you find that 14 has a deep carious lesion (see illustration). The patient has no symptoms and a periapical radiograph shows no pathological changes.



While excavating caries from 14 you expose the pulp. The pulp is vital and you consider it to be bleeding normally.

How would you treat this tooth?	**Results (%)**
❑ Partial pulpotomy (according to Cvek)	6.8
❑ Pulp capping	41.0
❑ Pulpectomy (extirpation)	47.1
❑ Other option	5.1

On analysis the variables were dichotomised so that pulpectomy was compared with pulpotomy or pulp capping. Those who responded with "other option" were excluded. The analysis shows that in Case b, pulpectomy was a significantly more frequent choice than in Case a (Chi^2 = 86.70; $p < 0.05$). Logistical regression analysis showed that in Case b, more men than women tended to choose pulpectomy (OR = 1.57; 1.01–2.45).

2. What strategy do you usually use when you root-fill a tooth?

One-step ie instrumentation and root filling in one appointment or two-step ie instrumentation at one appointment and root filling at a later appointment?

Diagnosis	One-step (%)	Two-step (%)	More than two appointments (%)
Pulpitis	30.1	66.0	3.9
Necrotic pulp with no periapical changes	15.5	76.1	8.4
Necrotic pulp with periapical osteitis/ apical periodontitis	3.4	58.8	37.8

Each diagnosis was analysed separately and the number of treatment sessions was dichotomised in two ways: one-step as opposed to two or more treatment sessions and one or two steps as opposed to more than two treatment sessions. The analysis showed that for endodontic treatment of teeth with periapical pathology, use of mechanical instrumentation compared with non-use (OR = 1.97; 1.27–3.05), age 20–49 years compared with 50–69 years (OR = 3.52; 1.28–9.74) and >25 years experience compared with <25 years experience (OR = 2.38; 1.07–5.26) were predictive of a preference for 1–2 treatment sessions rather than more sessions. In cases of treatment of teeth with necrotic pulps but no discernible periapical pathology, use of mechanical instrumentation compared with non-use was also predictive of a preference for one-step treatment (OR = 2.0; 1.02–3.92). No other differences were detected.

3. Restoration of a root-filled tooth

You have a patient aged 55 years who is healthy and has a normal dentition. There are 29 teeth, of which 13 are sound and unrestored. Caries risk is considered low and periodontal status is good. The patient has an amalgam crown on 17, and Class I and class II fillings otherwise.

You have just completed a root filling on tooth 46, of which more than 4 of the 5 surfaces are missing. The reason for root filling was pulpitis following a cusp fracture. You are pleased with the result of your root filling.

a) What do you recommend to the patient as a permanent restoration?

	Results (%)
❑ Composite crown?	17.1
❑ Laboratory fabricated crown?	77.5
❑ Other option	5.4

b) How long do you wait before permanent restoration of the tooth?

	Results (%)
❑ No waiting time at all	17.4
❑ Wait one week	9.7
❑ Wait 2–4 weeks	51.6
❑ Longer	21.3

The response “Other option” in Question 3a was not included in the analysis. Moreover the information about the expectancy intervals was dichotomised to “do not wait at all” as opposed to “wait”, and “wait 0–4 weeks” as opposed to “wait more than 4 weeks”. The regression analysis disclosed no differences with respect to the background factors that could be related to treatment preference. Dentists in private practice showed a greater tendency to delay permanent restoration than those in the public dental service (OR = 2.10; 1.20–3.66).

Results inquiry form B

Background information

Mark the appropriate box with a cross!

1. Gender? (%)

❑ Female	**38.3**
❑ Male	**61.7**

2. Practice? (%)

❑ Public	**42.1**
❑ Private	**57.9**

3. County?

Responses distributed according to county

	(%)
❑ Blekinge	**2.0**
❑ Dalarna	**3.0**
❑ Gotland	**0.2**
❑ Gävleborg	**2.2**
❑ Halland	**3.4**
❑ Jämtland	**0.8**
❑ Jönköping	**3.2**
❑ Kalmar	**2.4**
❑ Kronoberg	**2.6**
❑ Norrbotten	**2.6**
❑ Skåne	**13.8**
❑ Stockholm	**23.1**
❑ Södermanland	**2.6**
❑ Uppsala	**2.2**
❑ Värmland	**3.8**
❑ Västerbotten	**4.0**
❑ Västernorrland	**2.4**
❑ Västmanland	**2.2**
❑ Västra Götaland	**15.4**
❑ Örebro	**2.6**
❑ Östergötland	**5.1**
Sparsely populated county	**22.1**
Not sparsely populated	**77.9**

4. Age? (%)

❑ 20–29	**0.2**
❑ 30–39	**0.6**
❑ 40–49	**5.4**
❑ 50–59	**53.6**
❑ 60–69	**39.4**
❑ 70–79	**0.8**
❑ 80–89	**0**

5. Number of years as a dentist?

	(%)
❑ <1 yr	**0**
❑ 1–5 yr	**0.3**
❑ 6–10 yr	**0.7**
❑ 11–25 yr	**14.2**
❑ >25 yr	**84.8**

6. Do you use mechanical instrumentation?

	(%)
❑ Always (exclusively)	**6.0**
❑ Always (but combined hand instrumentation)	**26.3**
❑ Mostly	**13.4**
❑ Sometimes	**22.2**
❑ No, never	**32.0**

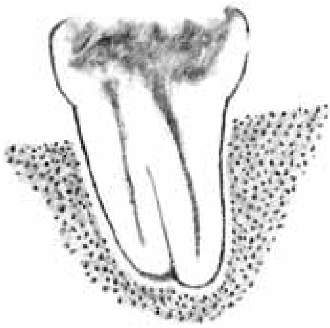
7. Present type of dentistry?

	(%)
❑ Children exclusively	**1.6**
❑ Children and adults	**61.6**
❑ Adults only	**20.8**
❑ Specialist, namely	**6.9**
❑ No endodontics	**4.2**
❑ Non-practising	**4.8**

Inquiry form B

1. Acute pulpitis

A 45 year-old man seeks emergency treatment for severe toothache from the left side of his lower jaw, onset a week ago, increasing intensity over the past few days and disturbing his sleep at night. The attacks of pain are at times spontaneous but occur more frequently at mealtimes.



You find that 36 has a missing filling and is carious. The tooth gives a marked positive response to testing for sensitivity to cold, which also triggers an attack of acute pain. A radiograph shows marked loss of substance with suspected pulpal exposure.

The patient would like to retain the tooth and you consider that restoration of the tooth is quite feasible.

How do you handle the acute condition? Because you have seen the patient for emergency treatment despite a full appointment list, you have clearly very little time available, 15 minutes' treatment time at the most. The patient is in good health, the diagnosis is very obvious, and in the event of using local anaesthesia it works quickly and allows you to work on the tooth. Mark with one or more crosses below the measure or measures ,which best correspond with what you would normally do in such a case.

	Results (%)
❑ Prescribe a prescription-only analgesic	13.6
❑ Prescribe antibiotics	3.4
❑ Excavate caries to the point of a bleeding pulp	27.7
❑ Prepare the pulp chamber and remove any bleeding pulp tissue	77.1
from the chamber	23.8
❑ Begin debriding the root canals	
❑ Apply a medicament to the pulp chamber/root canal	63.7
❑ Apply a temporary dressing	76.4

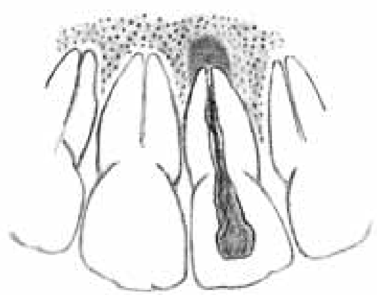
❑ If you prescribe an analgesic: which one?
❑ If you prescribe an antibiotic: which one?
❑ If you place a medicament in the tooth: which one?

There are no differences in prescribing of analgesics or antibiotics respectively in relation to background factors. Women are more inclined than men to excavate caries to the point of pulpal bleeding (OR = 1.65; 1.03–2.64), as are non-users of mechanical instrumentation (OR = 1.80; 1.12–2.87). More of the public service dentists than those in private practice carries out pulpotomy (OR = 3.02; 1.67–5.44), as do users of mechanical instrumentation compared with non-users (OR = 2.12; 1.28–3.51). More men than women begin debridement of the root canals (OR = 1.84; 1.04–3.26). More private than public service dentists begin debridement of the root canals (OR = 4.21; 2.23–7.95) and use an intracanal medicament between appointments (OR = 1.86; 1.20–2.90) more frequently than public service dentists.

The results must be interpreted with caution because it appears that some parts of the question may have been misunderstood. It does not seem reasonable that 86.4% would not prescribe an analgesic under the given conditions. Moreover it is difficult to accept that 23.6% of the respondents would leave the root canal open after emergency treatment. It is possible that a majority of the respondents elected to mark only one response, without this representing the course of action they would in fact have chosen.

2. Apical radiolucency on a root-filled tooth

During routine examination of a healthy 45-year old man who is one of your patients, you detect apical bone destruction on a radiograph of 21. The patient informs you that the tooth was root-filled five years ago.



The root filling is somewhat short, with an apical lumen and does not look well-sealed. The tooth shows no other pathology, is asymptomatic and aesthetically acceptable. You do not have access to previous radiographs.

The patient has a full dentition and your examination discloses no need for treatment other than that which might arise as a result of the findings about 21.

On the evidence of the radiograph of 21, what information and proposal for treatment would you give your patient? Indicate the option, which is in closest agreement with what you would normally do in cases such as this.

		Results (%)
1.	Ignore the finding and do not inform the patient	**0**
2.	Inform the patient of your finding but tell him that no intervention is required	**1.7**
3.	Inform the patient of your findings, recommend re-examination and a control radiograph in one year's time	**37.2**
4.	Inform the patient of your finding and recommend that you redo the root filling	**59.4**
5.	Inform the patient of your finding and recommend that you do an apicoectomy (apical surgery)	**0.7**
6.	Inform the patient of your finding and suggest treatment with antibiotics	**0**
7.	Suggest referral to a specialist for assessment and possible treatment	**1.0**
8.	Inform the patient of your finding, recommend extraction and replacement with an implant	**0**
9.	Inform the patient of your finding, recommend extraction and replacement with a bridge	**0**

The results were analysed by dichotomising the data to "active intervention" (responses 4–9; 61.1%) as opposed to non-active (responses 1–3; 38.9%). Regression analysis revealed that none of the background factors was predictive for active or inactive measures respectively.

3. Choice of root filling material

Teeth can be root-filled in various ways. Indicate the method and material, which you use most often by marking the appropriate box/es with a cross.

a) Method	**Results (%)**
❑ Gutta-percha with solid core material in combination with cement/sealer (combine with appropriate sealer material under b)	**77.4**
❑ Rosinchloroform – gutta-percha	**23.1**
❑ Resin-based material EndoRez/Resilon-Epiphany	**4.6**
❑ Resorcinal – formaldehyde	**0**
❑ Thermafil/Softcore (combine with appropriate sealer under b)	**1.5**
❑ Warm gutta-percha System B, Obtura or similar (combine with appropriate sealer under b)	**1.5**
❑ Other method, specify:	
b) Sealer material (if applicable)	**Results (%)**
❑ AH Plus/AH PlusJet	**31.6**
❑ Apexit, ApexitPlus	**5.8**
❑ Endomethasone	**0.5**
❑ Gutta Flow	**2.2**
❑ Chloropercha	**0.7**
❑ N2	**1.2**
❑ RoekoSeal	**3.2**
❑ Sealapex	**11.2**
❑ Tubli-Seal	**23.6**
❑ TopSeal	**1.0**
❑ Other sealer material, specify:	

The results show that nearly every fourth respondent uses rosin chloroform and gutta-percha as the root filling method. The method is becoming obsolete because rosin chloroform is no longer commercially available. The validity of the results is therefore questionable, both in the short and long-term.

Results inquiry form C

Background information.

Place a cross in the appropriate box.

1. Gender? (%)

❑ Female	**38.5**
❑ Male	**61.5**

2. Practice? (%)

❑ Public	**40.2**
❑ Private	**59.8**

3. County?
Responses distributed according to county

	(%)
❑ Blekinge	**2.0**
❑ Dalarna	**3.1**
❑ Gotland	**0.4**
❑ Gävleborg	**2.4**
❑ Halland	**3.5**
❑ Jämtland	**0.7**
❑ Jönköping	**3.1**
❑ Kalmar	**3.1**
❑ Kronoberg	**2.2**
❑ Norrbotten	**3.3**
❑ Skåne	**13.7**
❑ Stockholm	**24.4**
❑ Södermanland	**2.8**
❑ Uppsala	**2.6**
❑ Värmland	**2.6**
❑ Västerbotten	**2.6**
❑ Västernorrland	**1.7**
❑ Västmanland	**3.5**
❑ Västra Götaland	**16.3**
❑ Örebro	**1.7**
❑ Östergötland	**4.4**
Sparsely populated county	**19.3**
Not sparsely populated	**80.7**

4. Age? (%)

❑ 20–29	**0.2**
❑ 30–39	**0.7**
❑ 40–49	**5.0**
❑ 50–59	**50.7**
❑ 60–69	**43.0**
❑ 70–79	**0.4**
❑ 80–89	**0**

5. Number of years as a dentist?

	(%)
❑ <1 yr	**0**
❑ 1–5 yr	**0.7**
❑ 6–10 yr	**0.4**
❑ 11–25 yr	**14.2**
❑ >25 yr	**84.7**

6. Do you use mechanical instrumentation?

	(%)
❑ Always (exclusively)	**5.0**
❑ Always (but combined hand instrumentation)	**27.5**
❑ Mostly	**13.8**
❑ Sometimes	**20.2**
❑ No, never	**33.5**

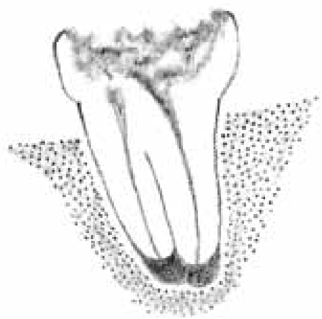
7. Present type of dentistry?

	(%)
❑ Children exclusively	**1.3**
❑ Children and adults	**62.1**
❑ Adults only	**22.3**
❑ Specialist, namely	**6.7**
❑ No endodontics	**3.5**
❑ Non-practising	**4.1**

Inquiry form C

1. Acute periapical osteitis/apical periodontitis

A 45-year old man seeks emergency treatment for severe toothache on the left side of his lower jaw, starting a week ago and increasing in intensity over the past few days with disturbed sleep. 36 is very tender to palpation and chewing. The pain is constant and not affected by food or drink.



You find that 36 has a missing filling and is carious. The tooth is not sensitive to a cold test. The tooth is tender to percussion and apically. No deep periodontal pockets. On the alveolar bone buccal to 36 is a local well-defined hard lump. The radiograph shows caries close to the pulp and marked destruction of periapical bone. Tender, palpable regional lymph nodes.

The patient would like to retain the tooth and you consider it quite feasible to restore it.

How do you manage the acute condition?
Because you had to find time to see the patient urgently despite a full appointment list you have clearly very little time available, 15 minutes' treatment time at the most. The patient is in good health, the diagnosis is very obvious, and in the event of using local anaesthesia it works quickly and allows you to work on the tooth. Mark with one or more crosses below the measure or measures, which best correspond with what you would normally do in such a case.

		Results (%)
1.	Prescribe a prescription – only analgesic	**27.1**
2.	Prescribe antibiotics	**50.3**
3.	Excavate caries crudely	**31.3**
4.	Access the pulp chamber and remove necrotic tissue in the crown portion	**72.2**
5.	Begin debridement of the root canals	**39.4**
6.	Apply a medicament to the pulp chamber/root canals	**63.4**
7.	Apply a temporary dressing	**76.0**

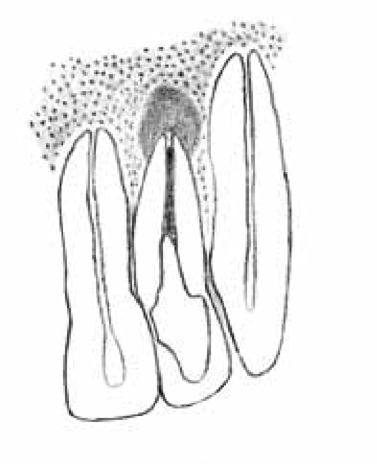
If you prescribe an analgesic: which one?
If you prescribe an antibiotic: which one?
If you place a medicament in the tooth: which one?

Dentists with more than 25 years' experience were more inclined to prescribe antibiotics (OR = 2.31; 1.12–4.77) debride the pulp chamber (OR = 2.54; 1.25–5.18), apply a temporary dressing (OR = 2.73; 1.33–5.58) and begin debridement of the root canals (OR = 2.24; 1.02–4.92) than dentists with less than 25 years' experience. Starting to debride the root canals was more common among private dentists than those in the public dental service (OR = 2.64; 1.55–4.51), those in the age group 20–49 years compared with those aged 50–69 years (OR = 3.05; 1.05–8.91) and those who do not use mechanical instrumentation compared with those who do (OR = 2.19; 1.38–3.48). Those from counties with <22.5 residents/km^2 were more inclined to use an intracanal medicament between appointments than those living in counties with >22.5 residents/km^2.

Once again the results must be interpreted with caution because there is a suspicion that a few points may have been misunderstood. In this question, as before, it was possible to respond by indicating more than one answer. There is a risk that several of the respondents indicated only one response without it representing the course of action they would normally take under the conditions described.

2. Periapical osteitis/apical periodontitis associated with a root-filled tooth

A 45-year old fully healthy man who has long been a patient of yours presents for his annual check-up. Five years ago you did a root filling and a post retained crown on 22 which had pulpal necrosis and apical periodontitis.



The tooth has been rather tender for some time and you take an x-ray, which shows marked persistent periapical bone destruction, of the same magnitude as when the root filling was done. Palpation on the buccal aspect reveals apical tenderness. There are no deep periodontal pocket probing depths around the tooth or other signs of a root fracture. The crown is clinically acceptable and the root filling looks good on the radiograph.

The patient has otherwise a full dentition and you find no need for other treatment than that which might be necessary following the findings with respect to 22.

With respect to the findings for 22, what proposals for treatment would you present to your patient?

		Results (%)
1.	Inform the patient of the radiographic findings; reassure him that no action is necessary and that the discomfort will soon disappear	**0.5**
2.	Prescribe antibiotics and follow-up with a new control in 3–6 months	**7.5**
3.	Suggest that you should remove the crown and the post, redo the root filling and then a new post and crown	**4.4**
4.	Suggest apical surgery	**51.8**
5.	Suggest referral to a specialist for assessment and possible treatment	**34.7**
6.	Suggest extraction and replacement with an implant	**0.8**
7.	Suggest extraction and replacement with a bridge	**0.3**

The responses to the questions were dichotomised by combining responses 1–2 (no active treatment) as opposed to active treatment responses 3–7. Most of the respondents recommended active treatment, Analysis with respect to background factors showed no significant differences.

3. Temporary protection of the root-filled tooth

a) In cases where you monitor the outcome of a root filling over a longer period of time, what do you use as a long-term temporary dressing/replacement before you proceed with permanent restoration of the tooth?

b) When you are restoring a root-filled tooth with a laboratory-fabricated crown, what do you use as a temporary replacement between appointments?

Indicate with a cross the alternatives you would choose.

	a) for long-term temporary restoration (%)	**b) as a dressing between impression taking and cementation of permanent crown**
Coltosol	19.1	9.3
Zinc oxide eugenol	21.9	5.9
IRM	51.3	13.7
Cavit	3.9	2.1
Prader's cement	5.2	1.8
Glass ionomer cement	52.3	5.2
Composite	18.3	2.6
Fermit	0	4.4
Methyl methacrylate	1.0	1.8
Temporary cement	3.1	27.3
Phosphate cement	9.8	11.1
Nobetec	2.6	19.6
Temporary crown	25.3	83.5

It can be seen that IRM and glass ionomer cement are popular choices of material for temporary, interappointment protection during root canal treatment. During prosthetic restoration of the root-filled tooth, a temporary crown is the most common form of coverage for the period between impression taking and cementation of the permanent crown.

Results: mechanical debridement (inquiry forms A, B, C)

Background information.

Place a cross in the appropriate box.

1. Gender?

	(%)
❑ Female	**37.7**
❑ Male	**62.3**

2. Practice?

	(%)
❑ Public	**41.4**
❑ Private	**58.6**

3. County?
Responses distributed according to county

	(%)
❑ Blekinge	**2.3**
❑ Dalarna	**2.9**
❑ Gotland	**0.3**
❑ Gävleborg	**2.4**
❑ Halland	**3.5**
❑ Jämtland	**0.8**
❑ Jönköping	**3.1**
❑ Kalmar	**2.7**
❑ Kronoberg	**2.3**
❑ Norrbotten	**2.8**
❑ Skåne	**13.3**
❑ Stockholm	**24.5**
❑ Södermanland	**2.3**
❑ Uppsala	**1.8**
❑ Värmland	**3.4**
❑ Västerbotten	**3.1**
❑ Västernorrland	**2.3**
❑ Västmanland	**2.8**
❑ Västra Götaland	**16.6**
❑ Örebro	**2.3**
❑ Östergötland	**4.7**
Sparsely populated county	**20.8**
Not sparsely populated	**79.2**

4. Age?

	(%)
❑ 20–29	**0.3**
❑ 30–39	**0.8**
❑ 40–49	**5.9**
❑ 50–59	**50.4**
❑ 60–69	**41.9**
❑ 70–79	**0.7**
❑ 80–89	**0**

5. Number of years as a dentist?

	(%)
❑ <1 yr	**0.1**
❑ 1–5 yr	**0.6**
❑ 6–10 yr	**0.4**
❑ 11–25 yr	**14.2**
❑ >25 yr	**84.7**

6. Do you use mechanical instrumentation?

	(%)
❑ Always (exclusively)	**5.7**
❑ Always (but combined hand instrumentation)	**27.2**
❑ Mostly	**14.1**
❑ Sometimes	**20.2**
❑ No, never	**38.8**

7. Present type of dentistry?

	(%)
❑ Children exclusively	**1.4**
❑ Children and adults	**61.6**
❑ Adults only	**21.6**
❑ Specialist, namely	**7.3**
❑ No endodontics	**3.5**
❑ Non-practising	**4.6**

The question "do you use mechanical instrumentation?" was put to all respondents. As with the other questions we excluded respondents over the age of 69 and those dentists who do not undertake endodontic treatment or are not in clinical practice. This left a selection of 1 210 dentists who responded to the question.

In dichotomising responses into those who use mechanical instrumentation (n=854) and those who were never user (n=356), no differences were found in relation to background factors. When the responses were analysed according to those who always use mechanical instrumentation (n=422) as opposed to those who never use it (n=356), there was a non-significant difference with respect to age: dentists aged 20–49 reported higher use than dentists aged 60–69 years (OR = 2.04; 0.97–4.28; p=0.59).

Discussion

Selection

Despite random selection of a large number of dentists, the distribution was skewed with respect to age and gender (compare [1]). The high proportion of older dentists can be attributable to the high intake of dental undergraduates during the early 1980's. Thereafter the number of undergraduate places at Swedish dental schools was successively reduced. Moreover, many young graduates from Swedish dental schools work abroad and the survey covered only dentists practising in Sweden. Attrition may also have been unevenly distributed with respect to age and gender, the response rate may have been lower among women dentists than men, and among younger dentists than among older dentists. Weighting of the selection may also have contributed, on the assumption that dentists practising in urban regions are on average older than in the rest of the country and predominantly male. Nor can the possibility of a random effect be discounted, despite the large cross-section.

Background factors

The factors chosen as independent variables in the regression analyses were expected to be significant in explaining the variations in the dependent variable (for example, treatment choice of pulp capping or pulpectomy). However, analysis disclosed that they were less important than we had anticipated. The variables population density, age and clinical experience are skewed in distribution and show indistinct differences with respect to the variables; one interpretation of this is that the selection may not reflect the whole population. Other variables however can be regarded as robust. Despite this, they do not explain the variation in the responses.

Treatment of an exposed vital pulp (inquiry form A, question 1a–b)

Dentists were more inclined to recommend pulpectomy in Case B than in Case A. It would seem that the age of the patient influenced choice of treatment. The type of tooth may also have had an influence. Tooth 14 in Case B can reasonably be expected to be easier to root-treat than tooth 36 in Case A.

That male dentists were more inclined than female dentists to recommend pulpectomy in Case B is difficult to explain, because the regression analysis took into account other background factors such as age and type of practice.

Strategy for root canal treatment (inquiry form A, question 2)

The question of the influence of the number of treatment sessions on treatment outcome has been the subject of debate in recent years. It is claimed that equally good outcomes can be attained for treatment of teeth with apical periodontitis in a single session as in two or more sessions. It is obvious that this discussion has not influenced clinical practice. Moreover, most respondents prefer two or more treatment sessions, even in cases where no root canal infection is suspected. The reason may be that many dentists consider endodontic treatment complicated and therefore prefer more than one treatment session in order to achieve a good treatment outcome.

The respondents who use mechanical instrumentation were more inclined to choose single session treatment in cases of pulpal necrosis and one to two sessions in cases of apical periodontitis. A contributory factor may be that these respondents are more interested in and more competent in endodontic treatment and that manual instrumentation reduces treatment time.

Dentists in the age group 20–49 years and those with more than 25 years' experience were more inclined to choose one to two sessions for treatment of teeth with apical periodontitis. The result seems contradictory, and may be attributable to the small size of the groups: relatively minor shifts in the number of individuals in these groups can be expected to cause significant changes to the results.

Restoration of a root-filled tooth (inquiry form A, question 3a–b)

Almost four out of five dentists chose to restore the endodontically treated tooth 46 with a crown. This can be regarded as an appropriate choice, as the results of several studies indicate that crown restoration of endodontically treated teeth is predictive of greater longevity than restoration with plastic filling material [2].

It is difficult to explain why dentists in private practice were more likely to delay restorative treatment than those in the public dental service, because the regression analysis took other background factors into account.

Radiolucency at the apex of a root-filled tooth (inquiry form B, question 2)

A little over 60% of the respondents recommended active intervention and almost all suggested revision of the root filling. That almost 40% did not choose treatment confirms the impression that clinical practice routines differ from the recommendations in the literature [3]. Studies show however, that in practice the choice of treatment is governed by the symptoms and the size of the lesion [4].

Preferred root filling material (inquiry form B, question 3a–b)

Traditional methods such as gutta-percha in combination with a sealer or gutta-percha with rosin chloroform are the most common materials for filling the root canals. More modern methods with resin-based materials or warm gutta-percha are used by only a few dentists.

A root-filled tooth with apical periodontitis (inquiry form C, question 2)

In this case, as in the case in question 2, inquiry form B, a previously root-filled 22 has developed apical periodontitis. In this case however, the tooth is symptomatic and moreover is restored with a post and core. Consequently a greater proportion of the respondents were inclined to recommend active treatment and the choice of treatment is also different. The most frequently recommended treatment was apical surgery.

Engine-driven instrumentation (inquiry forms A, B and C)

Around every third dentist responded that they never use engine-driven instrumentation. No clear differences could be discerned with respect to background factors. Engine-driven instrumentation was applied as an independent variable in all the analyses and was considered to represent an interest in endodontics. In those dentists who do not use engine-driven instrumentation, this could be an expression of less interest in endodontics than those dentists who have undergone training in the technique or use it occasionally. Differences could be discerned between users and non-users of engine-driven instrumentation with respect to the preferred number of treatment sessions.

Summary

This survey of endodontic practice amongst general practitioners discloses substantial differences among Swedish dentists with respect to endodontic treatment strategies and choice of materials. Only a small proportion of practitioners have adopted alternative methods, for example one-step treatment instead of several steps for treatment of teeth with infected root canals and new root filling materials. An exception is the use of engine-driven instrumentation, which to a varying extent is used by almost two-thirds of dentists.

Lack of evidence-based treatment principles and clinical evidence to support the effectiveness of various methods and materials are probably the most important factors underlying the great variation in practice routines and the limited adoption of new materials and methods. Dentists are largely dependent on knowledge acquired during undergraduate training and continuing education courses as well as clinical experience of their own and that of others.

The survey does not disclose the implications of these findings for the outcome of endodontic treatment in general dental practice. However, epidemiological data suggest that there is potential for improved outcomes in terms of periapical bone lesions associated with root-filled teeth.

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7. Summary: discussion and conclusions

This systematic review discloses extensive shortcomings in the scientific basis underlying methods applied for diagnosis and treatment in endodontics. It should nevertheless be acknowledged that substantial clinical experience of the methods has accumulated over the years. Furthermore studies in-vitro have contributed substantially to our knowledge base as to the function of materials and techniques for preparation and filling of root canals. Moreover animal studies have provided a valuable basis for understanding how the pulp and the periapical tissues respond to therapeutic interventions. Yet, clinical studies of high scientific quality are rare. Thus, there is only weak scientific support for clinical measures intended to restore healthy conditions in and around teeth with infected pulps. The obvious conclusion is that much evidence-based research is required to provide support for the principles underlying diagnosis and treatment of the disease conditions of the pulp.

Even with improved knowledge of the effectiveness of various methods, there are important practical parameters, which are not easily controlled for in clinical treatment studies, such as the operator's (dentist's) experience, ability, attention to detail and skill. It is seldom possible to determine how such factors influence the results of treatment studies or clinical evaluations. It is however, reasonable to assume that in a clinical discipline such as endodontics, these factors are of great importance, because treatment is often technically complicated. These factors probably also contribute to the great variation in endodontic treatment outcomes in cross-sectional studies. Future research should therefore be based on treatment protocols, which can be standardised as far as possible. Given that today devices are available, which can substantially facilitate the technical procedures, priority should be given to investigate how the application of such equipment influences treatment outcome.

Because there are no evidence-based conclusions for many of the questions addressed by this systematic review, it is not meaningful to propose recommendations for change of current clinical practice. Until studies of high quality become available, efforts should be directed towards achieving consensus on guidelines for endodontic diagnosis and treatment.

8. Knowledge gaps: research priorities

Despite over 100 years of development and application of methods for diagnosis and treatment of the diseases of the pulp, there is a lack of basic knowledge about their effectiveness. Certainly, many clinical investigations have confirmed that an inflamed pulp can be successfully treated without a root filling. However, to date there is no clear analysis of the presenting clinical conditions as to which cases are likely to respond well, or which treatment measures will render teeth functional and asymptomatic. Many follow-up studies have also demonstrated that teeth with necrotic and infected pulps can be treated endodontically to achieve a healthy outcome. However, there is a lack of scientific evidence to show which treatment protocols are the most effective and result in root-filled teeth with minimal risk of recurrent symptoms, periapical inflammation or fracture. Hence, there are significant knowledge gaps in this field of dentistry. This section of the report highlights areas in which there is a particularly urgent need for further knowledge development.

Diagnosis of pathological conditions in the pulp and periapical tissues

There is a great need for clinically applicable methods, which can determine accurately the status of the pulp in teeth affected by deep caries, trauma or other injuries. This information is important for assessing the prognosis of a treatment intended to preserve some or all of the pulp through pulp capping or pulpotomy. It would be most desirable to have specific markers, which can determine the severity of a pulpal condition. Yet it seems unlikely that such methodology will become available in the near future. However, the interpretation of prevalent clinical signs and symptoms warrant further investigation. These include symptoms of pain of varying intensity and duration and the character of the bleeding of an exposed pulp. Randomised clinical studies, in which the treatment of the pulpal exposure is standardised, should improve our knowledge of the prognostic value of such observations.

Digital volume tomography (CBCT) can be expected to assume increasing importance in diagnosis of periapical bone changes and in monitoring the status of root canal treated teeth. To date, the diagnostic accuracy of this methodology has not been adequately investigated and there is a need for studies comparing CBCT with conventional intra-oral radiography. Indeed such studies are limited by the difficulty of obtaining adequate reference tests. One possible solution to this problem might be the analysis of biopsies, taken in conjunction with apical surgery, where cases with negative and positive indications of apical periodontitis are compared.

Treatment of the pulp in teeth severely damaged by caries

A critical question in endodontics is how to best treat the pulp of teeth with deep caries. A primary question is whether a treatment intended to preserve the pulp, or a treatment aimed to remove it and replace it with a root filling is optimal. The question is highly relevant from a health economic aspect, because root filling and subsequent restoration of the tooth is expensive, both for the individual patient and for the society. A disadvantage of conservative treatment such as direct or indirect pulp capping is that failure may result in severe pain and suffering. In many cases, identifying the tooth in question can also be difficult. Randomised clinical studies employing well-defined samples of patients are urgently needed. Valid results, however, require extensive follow-up periods, five years or more, so that the frequency of late failures are recognised. Well-controlled prospective cohort studies are an alternative approach. The Public Dental Service in Sweden has a unique network of dental clinics, which could be used for prospective cohort studies to provide data on both treatment outcome and cost effectiveness of various treatment options.

Treatment of teeth with clinical and radiographic signs of apical periodontitis

The report shows that there is a lack of randomised well-controlled studies evaluating the importance of separate interventions and treatment steps for disinfection and root-filling of teeth with pulpal necrosis. This means that there is still uncertainty over which treatment methods are most effective for relief of symptoms and prevention of recurrent infection. Although in many cases teeth with root fillings have functioned well, the methods in use today rely on inadequate scientific data. There is an obvious need for observational studies analysing the impact of specific treatment parameters that can explain why root canal treated teeth fail, ie persistence of a pre-existing periapical inflammatory lesion, or development of a lesion, when there was none at the outset.

Accepted practice

Over the past 15 years improved equipment and methods for root canal treatment and root filling have been introduced: today, root canal treatment can probably be carried out with less time and with better outcome than previously. According to our survey of general practice routines, adoption of the new materials and techniques by Swedish dentists has been limited. There is a need to investigate to what extent application of the new techniques improves the outcome of root canal treatments.

In epidemiological cross-sectional studies, the frequency of periapical bone destruction, as an indication of apical periodontitis associated with root-filled teeth, varies between 25 and 40%. If such bone destruction is regarded as an indication for further endodontic treatment, there will be a substantial number of teeth potentially requiring retreatment. It has been calculated that in Sweden this might be as many as 2 million teeth. The investigation into practice routines implies that teeth with asymptomatic inflammatory processes are often left without intervention. However, whether this can be done without the risk of acute flare-up or adverse systemic effects has yet to be confirmed. The scientific evidence describing the natural course of events and prognosis for root-filled teeth is inadequate and needs further documentation. Important areas warranting investigation are:

- Long-term survival of root-filled teeth
- Factors which influence the loss of root-filled teeth
- To what extent root canal treatments fail to achieve healthy outcomes and require further treatment
- The risk that teeth with persistent but asymptomatic periapical lesions will lead to pain and swelling and/or increase in magnitude of bone destruction
- The risk to general health of not intervening in cases of teeth with apical periodontitis.

These questions are probably best addressed by large prospective cohort studies. The results of such investigations should provide valuable data for a critical review of the indications for endodontic retreatment.

There is also a need for more knowledge on endodontic retreatment methods (orthograde or retrograde or both), as to whether they are effective and result in long-term tooth survival. In this context it is also important to evaluate the alternative to retreatment, extraction of the tooth and replacement by a tooth-supported bridge or an implant from the perspective of patient satisfaction and cost effectiveness.

9. Glossary

Anaphylactic shock	Acute allergic reaction with fall in blood pressure, difficulty of breathing, development of a rash and oedema
Arteriosclerotic	Loss of elasticity of blood vessel walls (narrowing of blood vessels)
Aseptic	Method of treating wounds whereby the operator ensures that everything that comes into contact with the wound is free of bacteria
Aspergillosis	A group of diseases caused by infection with the fungus Aspergillus
Bilateral	Double-sided
Biofilm	Bacterial layer on eg a tooth surfaces (plaque)
Bisphosphonate	Pharmaceutical used to prevent breakdown of bone/osteoporosis
Bonding	Cementing, joining
Bone lesion	Damage/inflammatory process of the bone caused by eg infection
Canine	Cuspid or eye tooth
Cavity	Hole

Cohort study	A study about a group of people who form a cohort, ie they share certain specified characteristics, for example all people who have been treated for a certain disease during a specified time. Usually the study comprises two or more subgroups in the cohort, and these are examined long-term, for example in studies of survival or development of obesity. The study design has disadvantages in that the groups are not randomly allotted, which can mean that they are not fully comparable
Consecutive	Following after one another
Contraindication	Reasons for not choosing a treatment which would otherwise be appropriate
Control group	The participant group in a clinical trial which receives inactive treatment eg placebo, or the currently accepted treatment. The results for this group are compared with those of the group which receives the new treatment, eg a new medication. The term also applies to the control group in a case-control study
Controlled study	A comparative study, ie the participants are allotted to two or more groups. The most common example is the controlled clinical trial, other examples are case-control studies and cohort studies
Cortical	Bark, bark-like, the outer layer
Cortical bone	Compact bone
Devitalise	Kill
Dichotomise	Divide into two groups
Drainage	A means of removing fluid or secretions from wounds

Emphysema	Pathological collection of air in the tissues
Empirical	Knowledge gained by experience
Ethmoidal	Bone forming part of the eye socket
Exacerbation	Deterioration in the disease process
Extirpation	Total removal of an organ or part of an organ
Extraction	Removal of a tooth
Foramina	Small holes
Gingiva	Gums
Hydrolysis	Breakdown of a chemical agent by uptake of water
Iatrogenic	Caused by a dentist or doctor
Incisor	Front tooth
Intervention	A measure tested within the frame of a scientific study
Irreversible	Cannot be undone
Lamina dura	The compact outer layer of bone
Lateral condensation technique	Pressing the primary gutta-percha cone against the root canal wall, in order to make room for more gutta-percha points and thus reduce the amount of sealer required for root filling
Marginal periodontitis	Gum disease

Mediator substance	An agent which passes on signals
Molar	Posterior tooth, back tooth
Neuralgia	Intense stabbing pain in the form of short attacks, can occur daily for months or even longer. The trigeminal nerve is most frequently affected
Obstruction	Hindrance, something blocking the canal, making access more difficult
Orbit	Eye socket
Organ abscess	An accumulation of pus in an organ
Osmosis	Diffusion between two fluids through a semipermeable membrane
Osteonecrosis	Death of bone
Oxidation	Uptake of oxygen. Release of electrons (corrosion of metals in the presence of moisture)
Palpation	Use of light finger pressure against the surface of the body to examine the underlying tissue or organ
Percussion	Examination by tapping against a part of the body or a tooth
Periapical osteitis	Inflammation of the jaw bone around the apex of the tooth
Periodontal space	The space between the tooth and the bone
Periradicular	Around the root apex
Premolar	Side tooth, cheek tooth

Probing	Examination using a sharp pointed instrument
Pulp chamber	The part of the pulp cavity which is located in the crown of the tooth
Pulp capping	Treatment of a pulpal wound (exposure)
Pulse oximetry	Measurement of the oxygen content of the blood
Randomizing	Random allotment of participants to treatment or control groups in a study. This reduces the risk of systematic differences between the groups. Randomisation also makes it possible to determine the probability that the results of the investigation are due to chance
RCT	Randomised controlled trial
Relative risk (RR)	Results for the treatment group in relation to results for the control group
Reversible	Can be changed back
ROC	Receiver operating characteristic. A measure of comparison which gives a graphic illustration of the potential of a diagnostic method
Rubber dam	A thin sheet of rubber used to isolate teeth from the mouth
Sensory nerve	A nerve providing feeling (sensation) or senses
Septicaemia	Blood poisoning
Sequestrum	Dead bone tissue which has become detached from the surrounding bone

Spongy	Like a sponge
Subcutaneous	Under the skin
Sublingual	Situated under the tongue
Submandibular	Situated on or below the underside of the lower jaw
Subtraction radiography	Two radiographs of the same area, taken at intervals, are compared digitally. The difference between the two radiographs shows change occurring over time
Tenderness to percussion	Tenderness or pain when a body part or tooth is tapped
Test cavity	Careful drilling of a cavity
Tetrafluoroethane	Active constituent of a coolant spray
Thermal test	Application of heat or cold
Thermoplastic	Property of a material: can be softened by warming up and hardened by cooling down
Tooth extraction	Removal of a tooth
Translucent	Allowing the passage of light
Trepanation	Making an opening through the bone, for example with a drill
Urticaria	“Stinging nettle rash”: weals on the skin, usually in large numbers or covering a wide area, often an allergic reaction

10. **Project group, scientific reviewers, translaters and conflict of interest**

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Conflict of interest

SBU requires all participants in a project group to submit written declarations regarding potential linkages, or conflict of interest. Such conflicts of interest may exist if a member of the group receives financial compensation from parties with an interest in the group's findings. The chairman of the group and SBU then take a position on whether there are any circumstances that could be seen as potentially influencing an objective evaluation of the knowledge base or proposals for action based this evaluation.

In light of the fact that among the available experts in Sweden all declared some form of involvement in industry, such as being a member of an advisory board or receiving research support from pharmaceutical companies, SBU has extended the expert group with additional members that are not primarily involved in health care for hemophilic patients, nor have or have any commitments related to drug development or research in the area.

In accordance with SBU's requirements, the expert advisers as well as the external referees have submitted declarations of financial disclosures and potential conflict of interests. These documents are available at SBU.

Appendix 1. Search strategies

Abbreviations

*	Wildcard indicating a variable number of characters (including none)
/AE	Adverse effects (MeSH Subheading)
/CL	Classification (MeSH Subheading)
/CO	Complications (MeSH Subheading or EMTREE disease subheading)
/DI	Diagnosis (MeSH Subheading or EMTREE disease subheading)
/DU	Diagnostic use (MeSH Subheading)
/EP	Epidemiology (MeSH Subheading or EMTREE disease subheading)
/IP	Isolation and purification (MeSH Subheading)
/IS	Instrumentation (MeSH Subheading)
/MI	Microbiology (MeSH Subheading)
/MO	Mortality (MeSH Subheading)
/MT	Methods (MeSH Subheading)
/PD	Pharmacology (MeSH Subheading)
/RA	Radiography (MeSH Subheading)
/ST	Standards (MeSH Subheading)
/SU	Surgery (MeSH Subheading or EMTREE disease subheading)
/TH	Therapy (MeSH Subheading or EMTREE disease subheading)
/TO	Toxicity (MeSH Subheading)
/TU	Therapeutic use (MeSH Subheading)
De	Descriptor (EMBASE), Subject (PsycInfo)
Exp	Explode (EMBASE)
Me	Medical Subject Headings (MeSH, PubMed)
MJR	MeSH Major Topic (PubMed) OR EMTREE Major Focus (EMBASE)
PR	Record property
PT	Publication type
SB	Subset
Ti	Title
TiAb	Title/Abstract

3.1 *Diagnosis of the condition of the pulp.*

PUBMED (NLM)

Dental pulp diseases/CL (MJR)		Dental pulp diseases/CL (Me)
Dental pulp diseases/DI (MJR)		Dental pulp diseases/DI (Me)
Dental pulp test (MJR)		Dental pulp test (Me)
Diagnos* (Ti)		Diagnos* (Ti)
OR Test* (Ti)		OR Test* (Ti)
OR Indication* (Ti)		OR Indication* (Ti)
OR Clinical symptom* (Ti)		OR Clinical symptom* (Ti)
AND Pulp* (Ti)		AND Pulp* (Ti)
Dental pulp diseases (Me)	OR	Dental pulp diseases (Me)
AND Tooth discolouration (Me)		AND Tooth discolouration (Me)
NOT Case reports (PT)		NOT Case reports (PT)
OR Clinical conference (PT)		OR Clinical conference (PT)
OR Comment (PT)		OR Comment (PT)
OR Congresses (PT)		OR Congresses (PT)
OR Editorial (PT)		OR Editorial (PT)
OR Letter (PT)		OR Letter (PT)
OR News (PT)		OR News (PT)
OR Records with abstract (PR)		

Limit: Records with abstract (PR)

(((”dental pulp diseases/classification”[MeSH Major Topic] OR ”dental pulp diseases/diagnosis”[MeSH Major Topic] OR ”dental pulp test”[MeSH Major Topic] OR ((diagnos*[Title] OR test*[Title] OR indication*[Title] OR clinical symptom*[Title]) AND pulp*[Title]) OR (”dental pulp diseases”[MeSH Terms] AND ”tooth discoloration”[MeSH Terms])) NOT (”case reports”[Publication Type] OR ”clinical conference”[Publication Type] OR ”comment”[Publication Type] OR ”congresses”[Publication Type] OR ”editorial”[Publication Type] OR ”letter”[Publication Type] OR ”news”[Publication Type] OR hasabstract[text])) OR ((”dental pulp diseases/classification”[MeSH Terms] OR ”dental pulp diseases/diagnosis”[MeSH Terms] OR ”dental pulp test”[MeSH Terms] OR ((diagnos*[Title] OR test*[Title] OR indication*[Title] OR clinical symptom*[Title]) AND pulp*[Title]) OR (”dental pulp diseases”[MeSH Terms] AND ”tooth discoloration”[MeSH Terms])) NOT (”case reports”[Publication Type] OR ”clinical conference”[Publication Type] OR ”comment”[Publication Type] OR ”congresses”[Publication Type] OR ”editorial”[Publication Type] OR ”letter”[Publication Type] OR ”news”[Publication Type]) AND hasabstract[text]))

3.1 *continued*

EMBASE.COM (ELSEVIER)		
Tooth pulp disease (De)		
AND Diagnosis (Exp)		
Dental pulp test (TiAb)		
Diagnos* (Ti)		Case report (De)
OR Test* (Ti)	NOT	Editorial (De)
OR Indication* (Ti)		Letter (De)
OR Symptom* (Ti)		
AND Pulp* (Ti)		
Tooth pulp disease (De)		
AND Tooth discoloration (De)		

(('tooth pulp disease':de AND 'diagnosis'/exp) OR 'dental pulp test':ti,ab OR ((diagnos*:ti OR test*:ti OR indication*:ti OR symptom*:ti) AND pulp*:ti) OR ('tooth pulp disease':de AND 'tooth discoloration':de)) NOT ('case report':de OR 'editorial':de OR 'letter':de) AND [embase]/lim

3.1 *continued*

COCHRANE CENTRAL REGISTRY OF CONTROLLED TRIALS (WILEY)
Dental pulp diseases/CL (Me)
Dental pulp diseases/DI (Me)
Dental pulp test (Me)
Dental pulp diseases (Me)
AND Tooth discolouration (Me)
Diagnosis* (Ti)
OR Test* (Ti)
OR Indication* (Ti)
OR Clinical symptom* (Ti)
AND Pulp* (Ti)

#1 MeSH descriptor Dental Pulp Diseases explode all trees with qualifier: CL
#2 MeSH descriptor Dental Pulp Diseases explode all trees with qualifier: DI
#3 MeSH descriptor Dental Pulp Test explode all trees
#4 MeSH descriptor Tooth Discolouration explode all trees
#5 MeSH descriptor Dental Pulp Diseases explode all trees
#6 ((diagnos*):ti OR (test*):ti OR (indication*):ti OR (clinical symptom*):ti) AND (pulp*):ti
#7 (#1 OR #2 OR #3 OR #6 OR (#4 AND #5))

***3.2** Radiologic diagnosis of the periapical tissues.*

PUBMED (NLM)		
	Cone-beam computed tomography (Me, Ti)	
	Radiography, panoramic (Me)	
	Periapical radiography (TiAb)	
	CBCT (TiAb)	
Periapical diseases (Me)		
Dental pulp diseases (Me)	Radiologic (TiAb)	Sensitivity and specificity (Me)
Periapical bone defects (TiAb)	OR Radiology (TiAb)	ROC curve (Me)
Periapical bone destruction (TiAb)	OR Radiological (TiAb)	Diagnostic accuracy (TiAb)
Dental pulp disease (TiAb)	OR Radiography (TiAb)	Periapical diseases/DI (Me)
Pulpitis (TiAb)	OR Radiographic (TiAb)	Periapical diseases/RA (Me)
Pulp necrosis (TiAb)	OR Radiographical (TiAb)	Dental pulp diseases/DI (Me)
Bone lesions (TiAb)	AND Histologic (TiAb)	Dental pulp diseases/RA (Me)
	OR Histology (TiAb)	Cadaver (Me)
	OR Microscopy (TiAb)	
	OR Microscopic (TiAb)	
	OR Lesions (TiAb)	
	OR	
Endodontics (MJR)	Radiography, dental (MJR)	Records with abstract (PR)

(”sensitivity and specificity”[MeSH Terms] OR ”ROC curve”[MeSH Terms] OR ”diagnostic accuracy”[title/abstract] OR ”Periapical diseases/diagnosis”[MeSH Terms] OR ”Periapical diseases/radiography”[MeSH Terms] OR ”Dental pulp diseases/diagnosis”[MeSH Terms] OR ”Dental pulp diseases/radiography”[MeSH Terms] OR ”Cadaver”[MeSH Terms]) AND (”Cone-beam computed tomography”[MeSH Terms] OR ”Radiography, panoramic”[MeSH Terms] OR ”periapical radiography”[title/abstract] OR ”cone beam computed tomography”[title/abstract] OR ”CBCT”[title/abstract] OR ((”radiologic”[title/abstract] OR ”radiology”[title/abstract] OR ”radiological”[Title/abstract] OR ”radiography”[title/abstract] OR ”radiographic”[title/abstract] OR ”radiographical”[title/abstract]) AND (”histologic”[title/abstract] OR ”histology”[title/abstract] OR ”microscopy”[title/abstract] OR ”microscopic”[title/abstract] OR ”lesions”[title/abstract]))) AND (”Periapical Diseases”[MeSH Terms] OR ”Dental Pulp Diseases”[MeSH Terms] OR ”Periapical bone defects”[Title/abstract] OR ”Periapical bone destruction”[Title/Abstract] OR ”Dental pulp disease”[Title/abstract] OR ”pulpitis”[title/abstract] OR ”pulp necrosis”[title/abstract] OR ”bone lesions”[title/abstract])

(”Endodontics”[MeSH Major Topic] AND ”radiography, dental”[MeSH Major Topic] NOT hasabstract[text])

3.3 Treatment of teeth with inflamed pulps.

PUBMED (NLM)

Dental caries (Me)				Observational (Ti)		
Dental pulp exposure (Me)		Ultraconservative (Ti)		Clinical report (Ti)		
Dental pulp diseases (Me)		Pulpotomy (Me)		Follow-up studies (Me)		Case reports (PT)
Tooth fractures (Me)		Pulpotom* (Ti)		Comparative study (PT)		Clinical conference (PT)
		Dental pulp capping (Me)		Randomised controlled trial (PT)		Comment (PT)
Caries (Ti)	AND	Calcium hydroxide (Me)	AND	Review (PT)	NOT	Congresses (PT)
OR Carious (Ti)		Pulp capping (Ti)		Retrospective (Ti)		Editorial (PT)
OR Pulp* (Ti)				Retrospective studies (Me)		Letter (PT)
AND Vital (Ti)		Stepwise (TiAb)		Random* (TiAb)		News (PT)
OR Expos* (Ti)		AND Excavation (TiAb)		Allocat* (TiAb)		
OR Lesion* (Ti)				Systematic (SB)		
				Time factors (Me)		

Limits: Humans (Me)

((”dental caries”[MeSH Terms] OR ”dental pulp exposure”[MeSH Terms] OR ”dental pulp diseases”[MeSH Terms] OR ”Tooth fractures”[MeSH Terms] OR ((”caries”[Title] OR ”carious”[Title] OR pulp*[Title]) AND (vital[title] OR expos*[Title] OR lesion*[Title]))) AND (”ultraconservative”[Title] OR ”pulpotomy”[MeSH Terms] OR pulpotom*[Title/Abstract] OR ”dental pulp capping”[MeSH Terms] OR ”calcium hydroxide”[MeSH Terms] OR ”pulp capping”[Title] OR (”stepwise”[Title/Abstract] AND ”excavation”[Title/Abstract])) AND (”observational”[Title] OR ”Clinical report”[Title] OR ”Follow-Up Studies”[Mesh Terms] OR ”comparative study”[Publication Type] OR ”randomised controlled trial”[Publication Type] OR ”review”[Publication Type] OR ”retrospective”[Title] OR ”retrospective studies”[MeSH Terms] OR random*[Title/Abstract] OR allocat*[Title/Abstract] OR systematic[sb] OR ”time factors”[MeSH Terms])) AND (Humans[MeSH Terms]) NOT (”case reports”[Publication Type] OR ”clinical conference”[Publication Type] OR ”comment”[Publication Type] OR ”congresses”[Publication Type] OR ”editorial”[Publication Type] OR ”letter”[Publication Type] OR ”news”[Publication Type])

***3.3** continued*

EMBASE.COM (ELSEVIER)				
Dental caries (Exp)				Observational study (De)
Tooth pulp disease (Exp)		Endodontics (De)		Follow up (De)
Tooth fracture (Exp)		Calcium hydroxide (De)		Comparative study (Exp)
		Ultraconservative (Ti)		Randomised controlled trial (De)
Caries (Ti)		Pulpotom* (TiAb)		Review (De)
OR Carious (Ti)	AND	Pulp capping (Ti)	AND	Retrospective study (De)
OR Pulp* (Ti)				Systematic review (De)
AND Vital (Ti)		Stepwise (TiAb)		Time (Exp)
OR Expos* (Ti)		AND Excavation (TiAb)		Observational (Ti)
OR Lesion* (Ti)				Clinical report (Ti)
				Random* (TiAb)
				Allocat* (TiAb)

('dental caries'/exp OR 'tooth pulp disease'/exp OR 'tooth fracture'/exp OR ((caries:ti OR carious:ti OR pulp*:ti) AND (vital:ti OR expos*:ti OR lesion*:ti))) AND ('endodontics':de OR 'calcium hydroxide':de OR 'ultraconservative':ti OR pulpotom*:ti,ab OR 'pulp capping':ti OR (stepwise:ti,ab AND excavation:ti,ab)) AND ('observational study':de OR 'follow up':de OR 'comparative study'/exp OR 'randomised controlled trial':de OR 'review':de OR 'retrospective study':de OR 'systematic review':de OR time/exp OR 'observational':ti OR 'clinical report':ti OR random*:ti,ab OR allocat*:ti,ab) AND [embase]/lim

3.3 continued

COCHRANE CENTRAL REGISTRY OF CONTROLLED TRIALS (WILEY)		
Dental caries (Me)		
Dental pulp diseases (Me)		Pulpotomy (Me)
Tooth fractures (Me)		Dental pulp capping (Me)
Dental pulp exposure (Me)		Calcium hydroxide (Me)
		Ultraconservative (Ti)
Caries (Ti)	AND	Pulpotom* (TiAb)
OR Carious (Ti)		Pulp capping (Ti)
OR Pulp* (Ti)		
AND Vital (Ti)		Stepwise (TiAb)
OR Expos* (Ti)		AND Excavation (TiAb)
OR Lesion* (Ti)		

#1 MeSH descriptor Dental Caries explode all trees
#2 MeSH descriptor Dental Pulp Diseases explode all trees
#3 MeSH descriptor Tooth Fractures explode all trees
#4 MeSH descriptor Dental Pulp Exposure explode all trees
#5 ((caries):ti OR (carious):ti OR (pulp*):ti) AND ((vital):ti OR (expos*):ti OR (lesion*):ti)
#6 (ultraconservative):ti OR (pulpotom*):ti,ab OR (pulp capping):ti OR ((stepwise):ti,ab AND (excavation):ti,ab)
#7 MeSH descriptor Pulpotomy explode all trees
#8 MeSH descriptor Dental Pulp Capping explode all trees
#9 MeSH descriptor Calcium Hydroxide explode all trees
#10 (#1 OR #2 OR #3 OR #4 OR #5)
#11 (#6 OR #7 OR #8 OR #9)
#12 (#10 AND #11)

3.4 Treatment of teeth with necrotic pulps.

PUBMED (NLM)

Dental pulp cavity/PA (Me) Dental pulp diseases (Me) Periapical diseases (Me) Non-vital (TiAb) AND Pulp (TiAb)	AND	Root canal therapy (Me, TiAb) Root canal treatment (TiAb) Pulpectomy (Me, TiAb) Root canal obturation (Me, TiAb)	AND	Episode of care (Me) Calcium hydroxide/TU (Me) Root canal irrigants/TU (Me) Sodium hypochlorite/TU (Me) Chlorhexidine/TU (Me) Lasers, semiconductor/TU (Me) Photochemotherapy/TU (Me) Photosensitizing agents/TU (Me) Sterilization (Me) *session/s (TiAb) *visit/s (TiAb) *appointment/s (TiAb) Calcium hydroxide (TiAb) Sodium hypochlorite (TiAb) Chlorhexidine (TiAb) Laser (TiAb) Iodine potassium iodide (TiAb) Tincture iodine (TiAb) Ethyl alcohol (TiAb) Ethanol (TiAb) EDTA (TiAb)	AND	Controlled clinical trial (PT) Meta analysis (PT) Multicenter study (PT) Randomised controlled trial (PT) Allocat* (TiAb) Random* (TiAb) Systematic (SB)

((”dental pulp cavity/pathology”[MeSH Terms] OR ”dental pulp diseases”[MeSH Terms] OR ”Periapical Diseases”[Mesh] OR (”non-vital”[Title/Abstract] AND ”pulp”[Title/Abstract])) AND (”root canal therapy”[MeSH Terms] OR ”root canal therapy”[Title/Abstract] OR ”root canal treatment”[Title/Abstract] OR ”pulpectomy”[MeSH Terms] OR ”pulpectomy”[Title/Abstract] OR ”root canal obturation”[MeSH] OR ”root canal obturation”[TItle/Abstract]) AND (”episode of care”[MeSH Terms] OR ”calcium hydroxide/therapeutic use”[MeSH Terms] OR ”root canal irrigants/therapeutic use”[MeSH Terms] OR ”sodium hypochlorite/therapeutic use”[MeSH Terms] OR ”chlorhexidine/therapeutic use”[MeSH Terms] OR ”lasers, semiconductor/therapeutic use”[MeSH Terms] OR ”photochemotherapy/therapeutic use”[MeSH Terms] OR ”photosensitizing agents/therapeutic use”[MeSH Terms] OR ”sterilization”[MeSH Terms] OR *session[Title/Abstract] OR *sessions[Title/Abstract] OR *visit[Title/Abstract] OR *visits[Title/Abstract] OR *appointment[Title/Abstract] OR *appointments[Title/Abstract] OR ”calcium hydroxide” [Title/Abstract] OR ”sodium hypochlorite”[Title/Abstract] OR ”chlorhexidine”[Title/Abstract] OR ”laser”[Title/Abstract] OR ”iodine potassium iodide”[Title/Abstract] OR ”tincture iodine”[Title/Abstract] OR ”ethyl alcohol”[Title/Abstract] OR ”ethanol”[Title/Abstract] OR ”edta”[Title/Abstract])) AND (”controlled clinical trial”[Publication Type] OR ”meta analysis”[Publication Type] OR ”multicenter study”[Publication Type] OR ”randomized controlled trial”[Publication Type] OR allocat*[Title/Abstract] OR random *[Title/Abstract] OR systematic[sb])

3.4 *continued*

EMBASE.COM (ELSEVIER)						
				Patient scheduling (De)		
				*session/s (TiAb)		
				*visit/s (TiAb)		
				*appointment/s (TiAb)		
				Calcium hydroxide (TiAb, De)		Controlled clinical trial (De)
Tooth pulp disease (De)		Endodontics (De)		Hypochlorite sodium (De)		Randomised controlled trial (De)
Tooth periapical disease (De)		Root canal therapy (TiAb)		Sodium hypochlorite (TiAb)		Meta analysis (De)
	AND	Root canal treatment (TiAb)	AND	Chlorhexidine (TiAb, De)	AND	Multicenter study (De)
Non-vital (TiAb)		Pulpectomy (TiAb)		Lasers (TiAb, De)		Systematic review (De)
AND Pulp (TiAb)		Root canal obturation (TiAb)		Photochemotherapy (TiAb, De)		Random* (TiAb)
				Sterilization (TiAb)		Allocat* (TiAb)
				Iodine (TiAb)		
				Alcohol (TiAb, De)		
				Edetic acid (TiAb, De)		
				EDTA (TiAb)		

('tooth pulp disease':de OR 'tooth periapical disease':de OR ('non-vital':ti,ab AND 'pulp':ti,ab)) AND ('endodontics':de OR 'root canal therapy':ti,ab OR 'root canal treatment':ti,ab OR 'pulpectomy':ti,ab OR 'root canal obturation':ti,ab) AND ('patient scheduling':de OR *session:ti,ab OR *sessions:ti,ab OR *visit:ti,ab OR *visits:ti,ab OR *appointment:ti,ab OR *appointments:ti,ab OR 'calcium hydroxide':ti,ab,de OR 'hypochlorite sodium':de OR 'sodium hypochlorite':ti,ab OR 'chlorhexidine':ti,ab,de OR 'lasers':ti,ab,de OR 'photochemotherapy':ti,ab,de OR 'sterilization':ti,ab OR 'iodine':ti,ab OR 'alcohol':ti,ab,de OR 'edetic acid':ti,ab,de OR 'edta':ti,ab) AND ('controlled clinical trial':de OR 'randomised controlled trial':de OR 'meta analysis':de OR 'multicenter study':de OR 'systematic review':de OR random*:ti,ab OR allocat*:ti,ab) AND [embase]/lim

***3.4** continued*

COCHRANE CENTRAL REGISTRY OF CONTROLLED TRIALS (WILEY)

				Episode of care (Me)
				Calcium hydroxide/TU (Me)
				Root canal irrigants/TU (Me)
				Sodium hypochlorite/TU (Me)
				Chlorhexidine/TU (Me)
				Lasers, semiconductor/TU (Me)
				Photochemotherapy/TU (Me)
Dental pulp cavity/PA (Me)				Photosensitizing agents/TU (Me)
Dental pulp diseases (Me)		Root canal therapy (Me, TiAb)		Sterilization (Me)
Periapical diseases (Me)		Pulpectomy (Me, TiAb)		*session/s (TiAb)
	AND	Root canal obturation (Me, TiAb)	AND	*visit/s (TiAb)
Non-vital (TiAb)		Root canal treatment (TiAb)		*appointment/s (TiAb)
AND Pulp (TiAb)				Calcium hydroxide (TiAb)
				Sodium hypochlorite (TiAb)
				Chlorhexidine (TiAb)
				Laser (TiAb)
				Iodine potassium iodide (TiAb)
				Tincture iodine (TiAb)
				Ethyl alcohol (TiAb)
				Ethanol (TiAb)
				EDTA (TiAb)

#1 MeSH descriptor Dental Pulp Cavity explode all trees with qualifier: PA
#2 MeSH descriptor Dental Pulp Diseases explode all trees
#3 MeSH descriptor Periapical Diseases explode all trees
#4 (non-vital):ti,ab AND (pulp):ti,ab
#5 MeSH descriptor Root Canal Therapy explode all trees
#6 MeSH descriptor Pulpectomy explode all trees
#7 MeSH descriptor Root Canal Obturation explode all trees
#8 (root canal therapy):ti,ab OR (root canal treatment):ti,ab OR (pulpectomy):ti,ab OR (root canal obturation):ti,ab
#9 MeSH descriptor Episode of Care explode all trees
#10 MeSH descriptor Calcium Hydroxide explode all trees with qualifier: TU
#11 MeSH descriptor Root Canal Irrigants explode all trees with qualifier: TU
#12 MeSH descriptor Sodium Hypochlorite explode all trees with qualifier: TU
#13 MeSH descriptor Chlorhexidine explode all trees with qualifier: TU
#14 MeSH descriptor Lasers, Semiconductor explode all trees with qualifier: TU
#15 MeSH descriptor Photochemotherapy explode all trees with qualifier: TU
#16 MeSH descriptor Photosensitizing Agents explode all trees with qualifier: TU
#17 MeSH descriptor Sterilization explode all trees
#18 (*session):ti,ab OR (*sessions):ti,ab OR (*visit):ti,ab OR (*visits):ti,ab OR (*appointment):ti,ab OR (*appointments):ti,ab OR (calcium hydroxide):ti,ab OR (sodium hypochlorite):ti,ab OR (chlorhexidine):ti,ab OR (laser):ti,ab OR (iodine potassium iodide):ti,ab OR (tincture iodine):ti,ab OR (ethyl alcohol):ti,ab OR (ethanol):ti,ab OR (edta):ti,ab
#19 (#1 OR #2 OR #3 OR #4)
#20 (#5 OR #6 OR #7 OR #8)
#21 (#9 OR #10 OR #11 OR #12 OR #13 OR #14 OR #15 OR #16 OR #17 OR #18)
#22 (#19 AND #20 AND #21)

***3.4** continued*

PUBMED (NLM)				
Dental pulp cavity/PA (Me) Dental pulp diseases (Me) Periapical diseases (Me) Non-vital (TiAb) AND Pulp (TiAb)	AND	Treatment outcome (Me, Ti) Prognosis (Me, Ti)	AND	Sensitivity and specificity (Me) Dental pulp cavity/MI (Me) Bacteria/IP (Me) Culturing (Ti) Polymerase chain reaction (Me) Real-time PCR (TiAb)

(”dental pulp cavity/pathology”[MeSH Terms] OR ”dental pulp diseases”[MeSH Terms] OR ”Periapical Diseases”[Mesh] OR (”non-vital”[Title/Abstract] AND ”pulp”[Title/Abstract])) AND ((”treatment outcome”[MeSH Terms] OR ”prognosis”[MeSH Terms] OR ”treatment outcome”[Title]) AND (”sensitivity and specificity”[MeSH Terms] OR ”dental pulp cavity/microbiology”[MeSH Terms] OR ”bacteria/isolation and purification”[MeSH Terms] OR ”culturing”[Title] OR ”Polymerase Chain Reaction”[Mesh] OR ”real-time PCR”[Title/Abstract]))

***3.4** continued*

EMBASE.COM (ELSEVIER)				
Tooth pulp disease (De) Tooth periapical disease (De) Non-vital (TiAb) AND Pulp (TiAb)	AND	Treatment outcome (Exp) Prognosis (TiAb, De) Outcome (TiAb) Course (TiAb)	AND	Sensitivity and specificity (De) Microbiol* (TiAb) Bacteria (TiAb) Bacterial (TiAb) Culturing (Ti) Reverse transcription polymerase chain reaction (De) Real-time PCR (TiAb)

(’tooth pulp disease’:de OR ’tooth periapical disease’:de OR (’non-vital’:ti,ab AND ’pulp’:ti,ab)) AND (’treatment outcome’/exp OR ’prognosis’:ti,ab,de OR ’outcome’:ti,ab OR ’course’:ti,ab) AND (’sensitivity and specificity’:de OR microbiol*:ti,ab OR bacteria:ti,ab OR bacterial:ti,ab OR culturing:ti OR ’reverse transcription polymerase chain reaction’:de OR ’real-time PCR’:ti,ab) AND [embase]/lim

3.4 continued

COCHRANE CENTRAL REGISTRY OF CONTROLLED TRIALS (WILEY)				
Dental pulp cavity/PA (Me) Dental pulp diseases (Me) Periapical diseases (Me) Non-vital (TiAb) AND Pulp (TiAb)	AND	Treatment outcome (Me, Ti) Prognosis (Me)	AND	Sensitivity and specificity (Me) Dental pulp cavity/MI (Me) Bacteria/IP (Me) Culturing (Ti) Real-time PCR (TiAb) Polymerase chain reaction (Me)

#1 MeSH descriptor Dental Pulp Cavity explode all trees with qualifier: PA
#2 MeSH descriptor Dental Pulp Diseases explode all trees
#3 MeSH descriptor Periapical Diseases explode all trees
#4 (non-vital):ti,ab AND (pulp):ti,ab
#5 (#1 OR #2 OR #3 OR #4)
#6 MeSH descriptor Treatment Outcome explode all trees
#7 MeSH descriptor Prognosis explode all trees
#8 (treatment outcome):ti
#9 (#6 OR #7 OR #8)
#10 MeSH descriptor Sensitivity and Specificity explode all trees
#11 MeSH descriptor Dental Pulp Cavity explode all trees with qualifier: MI
#12 MeSH descriptor Bacteria explode all trees with qualifier: IP
#13 (culturing):ti OR (real time PCR):ti,ab
#14 MeSH descriptor Polymerase Chain Reaction explode all trees
#15 (#10 OR #11 OR #12 OR #13 OR #14)
#16 (#5 AND #9 AND #15)

***3.4** continued*

PUBMED (NLM)						
Root canal therapy (Me, TiAb) Root canal treatment (TiAb) Pulpectomy (Me, TiAb) Root canal obturation (Me, TiAb) Dental pulp diseases/TH (Me) Periapical diseases/TH (Me) Pulpitis/TH (Me) Endodontic treatment (TiAb) Endodontic therapy (TiAb) Endodontic (Ti) Root canal (Ti) Pulpless (Ti)	AND	Episode of care (Me) *session/s (TiAb) *visit/s (TiAb) *appointment/s (TiAb)	AND	Controlled clinical trial (PT) Meta analysis (PT) Multicenter study (PT) Randomised controlled trial (PT) Multicenter study (PT) Randomised controlled trial (PT) Allocat* (TiAb) Random* (TiAb) Systematic (SB) Control* (Ti)	AND	Records with abstract (PR)

((”root canal therapy”[MeSH Terms] OR ”root canal therapy”[Title/Abstract] OR ”root canal treatment”[Title/Abstract] OR ”pulpectomy”[MeSH Terms] OR ”pulpectomy”[Title/Abstract] OR ”root canal obturation”[MeSH Terms] OR ”root canal obturation”[TItle/Abstract] OR ”dental pulp diseases/therapy”[MeSH Terms] OR ”Periapical Diseases/therapy”[MeSH Terms] OR ”pulpitis/therapy”[MeSH Terms] OR ”endodontic treatment”[Title/Abstract] OR ”endodontic therapy”[Title/Abstract] OR ”endodontic”[Title] OR ”root canal”[Title] OR ”pulpless”[Title]) AND (”episode of care”[MeSH Terms] OR *session[Title/Abstract] OR *sessions[Title/Abstract] OR *visit[Title/Abstract] OR *visits[Title/Abstract] OR *appointment[Title/Abstract] OR *appointments[Title/Abstract]) AND (”controlled clinical trial”[Publication Type] OR ”meta analysis”[Publication Type] OR ”multicenter study”[Publication Type] OR ”randomised controlled trial”[Publication Type] OR allocat*[Title/Abstract] OR random*[Title/Abstract] OR systematic[sb] OR control*[Title])) AND (hasabstract[text])

3.4 continued

EMBASE.COM (ELSEVIER)				
Endodontics (De)				
Endodont* (Ti)				
Root canal (Ti)				
Pulpless (Ti)				
Root canal therapy (TiAb)				Controlled clinical trial (De)
Root canal treatment (TiAb)		Patient scheduling (De)		Randomised controlled trial (De)
Pulpectomy (TiAb)		*session/s (TiAb)		Meta analysis (De)
Root canal obturation (TiAb)	AND	*visit/s (TiAb)	AND	Multicenter study (De)
		*appointment/s (TiAb)		Systematic review (De)
Tooth pulp disease (TiAb, De)				Random* (TiAb)
OR Tooth periapical disease (TiAb, De)				Allocat* (TiAb)
OR Pulpitis (TiAb, De)				
AND Therapy (TiAb)				
OR Treatment (TiAb)				

('endodontics':de OR endodont*:ti OR 'root canal':ti OR 'pulpless':ti OR 'root canal therapy':ti,ab OR 'root canal treatment':ti,ab OR 'pulpectomy':ti,ab OR 'root canal obturation':ti,ab OR (('tooth pulp disease':ti,ab,de OR 'tooth periapical disease':ti,ab,de OR 'pulpitis':ti,ab,de) AND ('therapy':ti,ab OR 'treatment':ti,ab))) AND ('patient scheduling':de OR *session:ti,ab OR *sessions:ti,ab OR *visit:ti,ab OR *visits:ti,ab OR *appointment:ti,ab OR *appointments:ti,ab) AND ('controlled clinical trial':de OR 'randomised controlled trial':de OR 'meta analysis':de OR 'multicenter study':de OR 'systematic review':de OR random*:ti,ab OR allocat*:ti,ab) AND [embase]/lim

***3.4** continued*

COCHRANE CENTRAL REGISTRY OF CONTROLLED TRIALS (WILEY)

Root canal therapy (Me, TiAb)		
Pulpectomy (Me, TiAb)		
Root canal obturation (Me, TiAb)		
Dental pulp disease/TH (Me)		
Periapical disease/TH (Me)		Episode of care (Me)
Pulpitis/TH (Me)		*session/s (TiAb)
Root canal treatment (TiAb)	AND	*visit/s (TiAb)
Endodontic treatment (TiAb)		*appointment/s (TiAb)
Endodontic therapy (TiAb)		
Endodontic (Ti)		
Root canal (Ti)		
Pulpless (Ti)		

#1 MeSH descriptor Root Canal Therapy explode all trees
#2 MeSH descriptor Pulpectomy explode all trees
#3 MeSH descriptor Root Canal Obturation explode all trees
#4 MeSH descriptor Dental Pulp Diseases explode all trees with qualifier: th
#5 MeSH descriptor Periapical Diseases explode all trees with qualifier: th
#6 MeSH descriptor Pulpitis explode all trees with qualifier: th
#7 MeSH descriptor Episode of Care explode all trees
#8 (root canal therapy):ti,ab OR (root canal treatment):ti,ab OR (pulpectomy):ti,ab OR (root canal obturation):ti,ab OR (endodontic treatment):ti,ab OR (endodontic therapy):ti,ab OR (endodontic):ti OR (root canal):ti OR (pulpless):ti
#9 (*session):ti,ab OR (*sessions):ti,ab OR (*visit):ti,ab OR (*visits):ti,ab OR (*appointment):ti,ab OR (*appointments):ti,ab
#10 (#1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #8)
#11 (#7 OR #9)
#12 (#10 AND #11)

3.4 *continued*

PUBMED (NLM)						
		Calcium hydroxide/TU (Me)				
		Root canal irrigants/TU (Me)				
Root canal therapy (Me, TiAb)		Sodium hypochlorite/TU (Me)				
Root canal treatment (TiAb)		Chlorhexidine/TU (Me)				
Pulpectomy (Me, TiAb)		Lasers, semiconductor/TU (Me)		Controlled clinical trial (PT)		
Root canal obturation (Me, TiAb)		Photochemotherapy/TU (Me)		Meta analysis (PT)		
Dental pulp diseases/TH (Me)		Photosensitizing agents/TU (Me)		Multicenter study (PT)		
Periapical diseases/TH (Me)		Sterilization (Me)		Randomised controlled trial (PT)		
Pulpitis/TH (Me)	AND	Calcium hydroxide (TiAb)	AND	Allocat* (TiAb)	AND	Records with abstracts (PR)
Endodontic treatment (TiAb)		Sodium hypochlorite (TiAb)		Random* (TiAb)		
Endodontic therapy (TiAb)		Chlorhexidine (TiAb)		Systematic (SB)		
Endodontic (Ti)		Laser (TiAb)		Control* (Ti)		
Root canal (Ti)		Iodine potassium iodide (TiAb)				
Pulpless (Ti)		Tincture iodine (TiAb)				
		Ethyl alcohol (TiAb)				
		Ethanol (TiAb)				
		EDTA (TiAb)				
OR						
		Root canal irrigants/PD (MJR)				
		Root canal therapy (MJR)				
		AND Dental pulp cavity/MI (MJR)	NOT	Records with abstracts (PR)		
		Disinfectants/PD (MJR)				
		AND Root canals (Ti)				

((”root canal therapy”[MeSH Terms] OR ”root canal therapy”[Title/Abstract] OR ”root canal treatment”[Title/Abstract] OR ”pulpectomy”[MeSH Terms] OR ”pulpectomy” [Title/Abstract] OR ”root canal obturation”[MeSH Terms] OR ”root canal obturation” [TIltle/Abstract] OR ”dental pulp diseases/therapy”[MeSH Terms] OR ”Periapical Diseases/therapy”[MeSH Terms] OR ”pulpitis/therapy”[MeSH Terms] OR ”endodontic treatment”[Title/Abstract] OR ”endodontic therapy”[Title/Abstract] OR ”endodontic” [Title] OR ”root canal”[Title] OR ”pulpless”[Title]) AND (”calcium hydroxide/therapeutic use”[MeSH Terms] OR ”root canal irrigants/therapeutic use”[MeSH Terms] OR ”sodium hypochlorite/therapeutic use”[MeSH Terms] OR ”chlorhexidine/therapeutic use” [MeSH Terms] OR ”lasers, semiconductor/therapeutic use”[MeSH Terms] OR ”photochemotherapy/therapeutic use”[MeSH Terms] OR ”photosensitizing agents/therapeutic use”[MeSH Terms] OR ”sterilization”[MeSH Terms] OR ”calcium hydroxide”[Title/Abstract] OR ”sodium hypochlorite”[Title/Abstract] OR ”chlorhexidine”[Title/Abstract] OR ”laser”[Title/Abstract] OR ”iodine potassium iodide”[Title/Abstract] OR ”tincture iodine”[Title/Abstract] OR ”ethyl alcohol”[Title/Abstract] OR ”ethanol”[Title/Abstract] OR ”edta”[Title/Abstract]) AND (”controlled clinical trial”[Publication Type] OR ”meta analysis”[Publication Type] OR ”multicenter study”[Publication Type] OR ”randomised controlled trial”[Publication Type] OR allocat*[Title/Abstract] OR random*[Title/Abstract] OR systematic[sb] OR control*[Title])) AND (hasabstract[text]) (”root canal irrigants/pharmacology”[MeSH Major Topic] OR (”root canal therapy”[MeSH Major Topic] AND ”Dental pulp cavity/microbiology”[MeSH Major Topic]) OR (”Disinfectants/pharmacology”[MeSH Major Topic] AND ”root canals”[Title])) NOT (hasabstract[text])

***3.4** continued*

EMBASE.COM (ELSEVIER)				
Endodontics (De)				
Endodont* (Ti)		Calcium hydroxide (TiAb, De)		
Root canal (Ti)		Hypochlorite sodium (De)		
Pulpless (Ti)		Sodium hypochlorite (TiAb)		Controlled clinical trial (De)
Root canal therapy (TiAb)		Chlorhexidine (Tiab, De)		Randomised controlled trial (De)
Root canal treatment (TiAb)		Lasers (TiAb, De)		Meta analysis (De)
Pulpectomy (TiAb)	AND	Photochemotherapy (TiAb, De)	AND	Multicenter study (De)
Root canal obturation (TiAb)		Sterilization (TiAb)		Systematic review (De)
		Iodine (TiAb)		Random* (TiAb)
Tooth pulp disease (TiAb, De)		Alcohol (TiAb, De)		Allocat* (TiAb)
OR Tooth periapical disease (TiAb, De)		Edetic acid (TiAb, De)		
OR Pulpitis (TiAb, De)		EDTA (TiAb)		
AND Therapy (TiAb)				
OR Treatment (TiAb)				

('endodontics':de OR endodont*:ti OR 'root canal':ti OR 'pulpless':ti OR 'root canal therapy':ti,ab OR 'root canal treatment':ti,ab OR 'pulpectomy':ti,ab OR 'root canal obturation':ti,ab OR (('tooth pulp disease':ti,ab,de OR 'tooth periapical disease':ti,ab,de OR 'pulpitis':ti,ab,de) AND ('therapy':ti,ab OR 'treatment':ti,ab))) AND ('calcium hydroxide':ti,ab,de OR 'hypochlorite sodium':de OR 'sodium hypochlorite':ti,ab OR 'chlorhexidine':ti,ab,de OR 'lasers':ti,ab,de OR 'photochemotherapy':ti,ab,de OR 'sterilization':ti,ab OR 'iodine':ti,ab OR 'alcohol':ti,ab,de OR 'edetic acid':ti,ab,de OR 'edta':ti,ab) AND ('controlled clinical trial':de OR 'randomised controlled trial':de OR 'meta analysis':de OR 'multicenter study':de OR 'systematic review':de OR random*:ti,ab OR allocat*:ti,ab) AND [embase]/lim

3.4 continued

COCHRANE CENTRAL REGISTRY OF CONTROLLED TRIALS (WILEY)

		Calcium hydroxide/TU (Me)
		Root canal irrigants/TU (Me)
		Sodium hypochlorite/TU (Me)
Root canal therapy (Me, TiAb)		Chlorhexidine/TU (Me)
Pulpectomy (Me, TiAb)		Lasers, semiconductor/TU (Me)
Root canal obturation (Me, TiAb)		Photosensitizing agents/TU (Me)
Periapical diseases/TH (Me)		Sterilization (Me)
Pulpitis/TH (Me)		Calcium hydroxide (TiAb)
Root canal treatment (TiAb)	AND	Sodium hypochlorite (TiAb)
Endodontic treatment (TiAb)		Chlorhexidine (TiAb)
Endodontic therapy (TiAb)		Laser (TiAb)
Endodontic (Ti)		Iodine potassium iodide (TiAb)
Root canal (Ti)		Tincture iodine (TiAb)
Pulpless (Ti)		Ethyl alcohol (TiAb)
		Ethanol (TiAb)
		EDTA (TiAb)
		Photochemotherapy (Me)

#1 MeSH descriptor Root Canal Therapy explode all trees
#2 MeSH descriptor Pulpectomy explode all trees
#3 MeSH descriptor Root Canal Obturation explode all trees
#4 MeSH descriptor Periapical Diseases explode all trees with qualifier: th
#5 MeSH descriptor Pulpitis explode all trees with qualifier: th
#6 (root canal therapy):ti,ab OR (root canal treatment):ti,ab OR (pulpectomy):ti,ab OR (root canal obturation):ti,ab OR (endodontic treatment):ti,ab OR (endodon tic therapy):ti,ab OR (endodontic):ti OR (root canal):ti OR (pulpless):ti
#7 MeSH descriptor Calcium Hydroxide explode all trees with qualifier: tu
#8 MeSH descriptor Root Canal Irrigants explode all trees with qualifier: tu
#9 MeSH descriptor Sodium Hypochlorite explode all trees with qualifier: tu
#10 MeSH descriptor Chlorhexidine explode all trees with qualifier: tu
#11 MeSH descriptor Lasers, Semiconductor explode all trees with qualifier: tu
#12 MeSH descriptor Photosensitizing Agents explode all trees with qualifier: tu
#13 MeSH descriptor Sterilization explode all trees
#14 (calcium hydroxide):ti,ab OR (sodium hypochlorite):ti,ab OR (chlorhexidine):ti,ab OR (laser):ti,ab OR (iodine potassium iodide):ti,ab OR (tincture iodine):ti,ab OR (ethyl alcohol):ti,ab OR (ethanol):ti,ab OR (edta):ti,ab
#15 MeSH descriptor Photochemotherapy explode all trees
#16 (#1 OR #2 OR #3 OR #4 OR #5 OR #6)
#17 (#7 OR #8 OR #9 OR #10 OR #11 OR #12 OR #13 OR #14 OR #15)
#18 (#16 AND #17)

3.4 continued

PUBMED (NLM)						
Root canal therapy (Me, TiAb)						
Root canal treatment (TiAb)				Controlled clinical trial (PT)		
Pulpectomy (Me, TiAb)				Meta analysis (PT)		
Root canal obturation (Me, TiAb)		Root canal obturation/IS (MJR)		Multicenter study (PT)		
Dental pulp diseases/TH (Me)		Root canal obturation/MT (MJR)		Randomised controlled trial (PT)		
Periapical diseases/TH (Me)	AND	Root canal obturation/ST (MJR)	AND	Allocat* (TiAb)	AND	Records with abstracts (PR)
Pulpitis/TH (Me)		Root canal therapy/MT (MJR)		Random* (TiAb)		
Endodontic treatment (TiAb)		Root canal therapy/ST (MJR)		Systematic (SB)		
Endodontic therapy (TiAb)				Control* (Ti)		
Endodontic (Ti)						
Root canal (Ti)						
Pulpless (Ti)						
OR						
		Root canal obturation/IS (MJR)				
		Root canal obturation/ST (MJR)				
		Root canal preparation/IS (MJR)				
		Root canal preparation/ST (MJR)	NOT	Records with abstracts (PR)		
		Root canal therapy/IS (MJR)				
		Root canal therapy/ST (MJR)				

((”root canal therapy”[MeSH Terms] OR ”root canal therapy”[Title/Abstract] OR ”root canal treatment”[Title/Abstract] OR ”pulpectomy”[MeSH Terms] OR ”pulpectomy” [Title/Abstract] OR ”root canal obturation”[MeSH Terms] OR ”root canal obturation” [TItle/Abstract] OR ”dental pulp diseases/therapy”[MeSH Terms] OR ”Periapical Diseases/therapy”[MeSH Terms] OR ”pulpitis/therapy”[MeSH Terms] OR ”endodontic treatment”[Title/Abstract] OR ”endodontic therapy”[Title/Abstract] OR ”endodontic” [Title] OR ”root canal”[Title] OR ”pulpless”[Title]) AND (”root canal obturation/instrumentation”[MeSH Major Topic] OR ”root canal obturation/methods”[MeSH Major Topic] OR ”root canal obturation/standards”[MeSH Major Topic] OR ”root canal therapy/methods”[MeSH Major Topic] OR ”root canal therapy/standards”[MeSH Major Topic]) AND (”controlled clinical trial”[Publication Type] OR ”meta analysis”[Publication Type] OR ”multicenter study”[Publication Type] OR ”randomised controlled trial”[Publication Type] OR allocat*[Title/Abstract] OR random*[Title/Abstract] OR systematic[sb] OR control*[Title])) AND (hasabstract[text]) (”root canal obturation/instrumentation” [MeSH Major Topic] OR ”root canal obturation/standards”[MeSH Major Topic] OR ”root canal preparation/instrumentation”[MeSH Major Topic] OR ”root canal preparation/standards”[MeSH Major Topic] OR ”root canal therapy/instrumentation”[MeSH Major Topic] OR ”root canal therapy/standards”[MeSH Major Topic]) NOT (hasabstract[text])

3.4 continued

EMBASE.COM (ELSEVIER)				
Endodontics (De) Endodont* (Ti) Root canal (Ti) Pulpless (Ti) Root canal therapy (TiAb) Root canal treatment (TiAb) Pulpectomy (TiAb) Root canal obturation (TiAb) Tooth pulp disease (TiAb, De) OR Tooth periapical disease (TiAb, De) OR Pulpitis (TiAb, De) AND Therapy (TiAb) OR Treatment (TiAb)	AND	Dental equipment (TiAb, De) Instrumentation (De)	AND	Controlled clinical trial (De) Randomised controlled trial (De) Meta analysis (De) Multicenter study (De) Systematic review (De) Random* (TiAb) Allocat* (TiAb)

('endodontics':de OR endodont*:ti OR 'root canal':ti OR 'pulpless':ti OR 'root canal therapy':ti,ab OR 'root canal treatment':ti,ab OR 'pulpectomy':ti,ab OR 'root canal obturation':ti,ab OR (('tooth pulp disease':ti,ab,de OR 'tooth periapical disease':ti,ab,de OR 'pulpitis':ti,ab,de) AND ('therapy':ti,ab OR 'treatment':ti,ab))) AND ('dental equipment':ti,ab, de OR instrumentation:de) AND ('controlled clinical trial':de OR 'randomised controlled trial':de OR 'meta analysis':de OR 'multicenter study':de OR 'systematic review':de OR random*:ti,ab OR allocat*:ti,ab) AND [embase]/lim

***3.4** continued*

COCHRANE CENTRAL REGISTRY OF CONTROLLED TRIALS (WILEY)		
Root canal therapy (Me, TiAb)		
Root canal treatment (TiAb)		
Pulpectomy (Me, TiAb)		Root canal obturation/IS (Me)
Root canal obturation (Me, TiAb)		Root canal obturation/MT (Me)
Periapical diseases/TH (Me)		Root canal obturation/ST (Me)
Pulpitis/TH (Me)	AND	Root canal therapy/IS (Me)
Endodontic treatment (TiAb)		Root canal therapy/MT (Me)
Endodontic therapy (TiAb)		Root canal therapy/ST (Me)
Endodontic (Ti)		
Root canal (Ti)		
Pulpless (Ti)		

#1 MeSH descriptor Root Canal Therapy explode all trees
#2 MeSH descriptor Pulpectomy explode all trees
#3 MeSH descriptor Root Canal Obturation explode all trees
#4 MeSH descriptor Periapical Diseases explode all trees with qualifier: th
#5 MeSH descriptor Pulpitis explode all trees with qualifier: th
#6 (root canal therapy):ti,ab OR (root canal treatment):ti,ab OR (pulpectomy):ti,ab OR (root canal obturation):ti,ab OR (endodontic treatment):ti,ab OR (endodon tic therapy):ti,ab OR (endodontic):ti OR (root canal):ti OR (pulpless):ti
#7 MeSH descriptor Root Canal Obturation explode all trees with qualifier: IS
#8 MeSH descriptor Root Canal Obturation explode all trees with qualifier: MT
#9 MeSH descriptor Root Canal Obturation explode all trees with qualifier: ST
#10 MeSH descriptor Root Canal Therapy explode all trees with qualifier: IS
#11 MeSH descriptor Root Canal Therapy explode all trees with qualifier: ME
#12 MeSH descriptor Root Canal Therapy explode all trees with qualifier: ST
#13 (#7 OR #8 OR #9 OR #10 OR #11 OR #12)
#14 (#1 OR #2 OR #3 OR #4 OR #5 OR #6)
#15 (#13 AND #14)

***3.4** continued*

PUBMED (NLM)						
Root canal therapy (Me, TiAb)		N2 dental cement (SN)		Controlled clinical trial (PT)		
Root canal treatment (TiAb)		N2 (Ti)		Meta analysis (PT)		
Pulpectomy (Me, TiAb)		FR dental filling (SN)		Multicenter study (PT)		
Root canal obturation (Me, TiAb)		Root filling (TiAb)		Randomised controlled trial (PT)		
Dental pulp diseases/TH (Me)		Root canal sealer (TiAb)		Allocat* (TiAb)		
Periapical diseases/TH (Me)	AND	Root canal filling materials (Me)	AND	Random* (TiAb)	AND	Records with abstracts (PR)
Pulpitis/TH (Me)		Gutta-percha (TiAb)		Systematic (SB)		
Endodontic treatment (TiAb)		Chloroform (SN, TiAb)		Control* (Ti)		
Endodontic therapy (TiAb)		Chloropercha (TiAb)		Follow-up studies (Me)		
Endodontic (Ti)		Endomethasone (TiAb)		Prospective studies (Me)		
Root canal (Ti)						
Pulpless (Ti)						

((”root c<anal therapy”[MeSH Terms] OR ”root canal therapy”[Title/Abstract] OR ”root canal treatment”[Title/Abstract] OR ”pulpectomy”[MeSH Terms] OR ”pulpectomy”[Title/Abstract] OR ”root canal obturation”[MeSH Terms] OR ”root canal obturation”[TItle/Abstract] OR ”dental pulp diseases/therapy”[MeSH Terms] OR ”Periapical Diseases/therapy”[MeSH Terms] OR ”pulpitis/therapy”[MeSH Terms] OR ”endodontic treatment”[Title/Abstract] OR ”endodontic therapy”[Title/Abstract] OR ”endodontic”[Title] OR ”root canal”[Title] OR ”pulpless”[Title]) AND (”n2 dental cement”[Substance Name] OR ”n2”[Title] OR ”fr dental filling”[Substance Name] OR ”root filling”[Title/Abstract] OR ”root canal sealer”[Title/Abstract] OR ”root canal filling materials”[MeSH Terms] OR ”gutta percha”[Title/Abstract] OR ”chloroform”[Title/Abstract] OR ”chloroform”[Substance Name] OR ”chloropercha”[Title/Abstract] OR ”endomethasone”[Title/Abstract]) AND (”controlled clinical trial”[Publication Type] OR ”meta analysis”[Publication Type] OR ”multicenter study”[Publication Type] OR ”randomised controlled trial”[Publication Type] OR allocat*[Title/Abstract] OR random*[Title/Abstract] OR systematic[sb] OR control*[Title] OR ”follow up studies”[MeSH Terms] OR ”prospective studies”[MeSH Terms])) AND (hasabstract[text])

***3.4** continued*

EMBASE.COM (ELSEVIER)				
Endodontics (De)				
Endodont* (Ti)				
Root canal (Ti)				
Pulpless (Ti)		Root canal filling material (De)		Controlled clinical trial (De)
Root canal therapy (TiAb)		Gutta-percha (TiAb, De)		Randomised controlled trial (De)
Root canal treatment (TiAb)		Endomethasone (TiAb)		Meta analysis (De)
Pulpectomy (TiAb)		Chloropercha (TiAb)		Multicenter study (De)
Root canal obturation (TiAb)	AND	Chloroform (TiAb, De)	AND	Systematic review (De)
		Root canal sealer (TiAb)		Random* (TiAb)
Tooth pulp disease (TiAb, De)		Root filling (TiAb)		Allocat* (TiAb)
OR Tooth periapical disease (TiAb, De)		N2 dental cement (TiAb)		Follow up (De)
OR Pulpitis (TiAb, De)		N2 (Ti)		Prospective study (De)
AND Therapy (TiAb)		FR dental filling (TiAb)		
OR Treatment (TiAb)				

('endodontics':de OR endodont*:ti OR 'root canal':ti OR 'pulpless':ti OR 'root canal therapy':ti,ab OR 'root canal treatment':ti,ab OR 'pulpectomy':ti,ab OR 'root canal obturation':ti,ab OR (('tooth pulp disease':ti,ab,de OR 'tooth periapical disease':ti,ab,de OR 'pulpitis':ti,ab,de) AND ('therapy':ti,ab OR 'treatment':ti,ab))) AND ('root canal filling material':de OR 'gutta percha':ti,ab,de OR 'endomethasone':ti,ab OR 'chloropercha':ti,ab OR 'chloroform':ti,ab,de OR 'root canal sealer':ti,ab OR 'root filling':ti,ab OR 'n2 dental cement':ti,ab OR 'n2':ti OR 'fr dental filling':ti,ab) AND ('controlled clinical trial':de OR 'randomised controlled trial':de OR 'meta analysis':de OR 'multicenter study':de OR 'systematic review':de OR random*:ti,ab OR allocat*:ti,ab OR 'follow up':de OR 'prospective study':de) AND [embase]/lim

3.4 continued

COCHRANE CENTRAL REGISTRY OF CONTROLLED TRIALS (WILEY)		
Root canal therapy (Me, TiAb)		
Root canal treatment (TiAb)		
Pulpectomy (Me, TiAb)		Root canal filling materials (Me)
Root canal obturation (Me, TiAb)		Chloroform (NoExp, TiAb)
Dental pulp diseases/TH (Me)		N2 (Ti)
Periapical diseases/TH (Me)		Root filling (TiAb)
Pulpitis/TH (Me)	AND	Root canal sealer (TiAb)
Endodontic treatment (TiAb)		Gutta-percha (TiAb)
Endodontic therapy (TiAb)		Chloropercha (TiAb)
Endodontic (Ti)		Endomethasone (TiAb)
Root canal (Ti)		
Pulpless (Ti)		

#1 MeSH descriptor Root Canal Therapy explode all trees
#2 MeSH descriptor Pulpectomy explode all trees
#3 MeSH descriptor Root Canal Obturation explode all trees
#4 MeSH descriptor Dental Pulp Diseases explode all trees with qualifier: Th
#5 MeSH descriptor Periapical Diseases explode all trees with qualifier: th
#6 MeSH descriptor Pulpitis explode all trees with qualifier: th
#7 (root canal therapy):ti,ab OR (root canal treatment):ti,ab OR (pulpectomy):ti,ab OR (root canal obturation):ti,ab OR (endodontic treatment):ti,ab OR (endodon tic therapy):ti,ab OR (endodontic):ti OR (root canal):ti OR (pulpless):ti
#8 MeSH descriptor Root Canal Filling Materials explode all trees
#9 MeSH descriptor Chloroform, this term only
#10 (n2):ti OR (root filling):ti,ab OR (root canal sealer):ti,ab OR (gutta percha):ti,ab OR (chloroform):ti,ab OR (chloropercha):ti,ab OR (endomethasone):ti,ab
#11 (#1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7)
#12 (#8 OR #9 OR #10)
#13 (#11 AND #12)

3.4 continued

PUBMED (NLM)				
Root canal therapy (MJR)	AND	Prognosis (Me)	AND	Dental pulp diseases (Me)

”root canal therapy”[MeSH Major Topic] AND ”prognosis”[MeSH Terms] AND ”dental pulp diseases”[MeSH Terms]

3.4 continued

EMBASE.COM (ELSEVIER)				
Endodontics (De)	AND	Tooth pulp disease (De)	AND	Prognosis (De)

’endodontics’:de AND ’tooth pulp disease’:de AND ’prognosis’:de AND [embase]/lim

3.4 continued

COCHRANE CENTRAL REGISTRY OF CONTROLLED TRIALS (WILEY)				
Root canal therapy (Me)	AND	Prognosis (Me)	AND	Dental pulp diseases (Me)

#1 MeSH descriptor Root Canal Therapy explode all trees
#2 MeSH descriptor Prognosis explode all trees
#3 MeSH descriptor Dental Pulp Diseases explode all trees
#4 (#1 AND #2 AND #3)

***3.4** continued*

PUBMED (NLM)

				Sensitiv* (TiAb)
Dental pulp cavity/MI (Me)				Sensitivity and specificity (Me)
Endodontic infections (TiAb)		Bacteriological techniques (Me)		Diagnos* (TiAb)
		Colony count, microbial (Me)		Diagnosis (NoExp)
Dental pulp (TiAb)		Culture media/DU (Me)		Diagnosis, differential (NoExp)
OR Root canal/s (TiAb)		Polymerase chain reaction (Me)		/DI (NoExp)
AND Microbiology (TiAb)	AND	Infection/RA (Me)	AND	False positive (TiAb)
OR Microbiological (TiAb)		Bacteria/IP (Me)		False negative (TiAb)
OR Bacteria (TiAb)		Culturing (TiAb)		Reliability (TiAb)
OR Bacterial (TiAb)		Real time PCR (TiAb)		Validity (TiAb)
OR Infection (TiAb)		Polymerase chain reaction (TiAb)		Accuracy (TiAb)
				Precision (TiAb)
				Comparative study (PT)

((”dental pulp cavity/microbiology”[MeSH Terms] OR ”endodontic infections”[Title/Abstract] OR ((”dental pulp”[Title/Abstract] OR ”root canal”[Title/Abstract] OR ”root canals”[Title/Abstract]) AND (”microbiology”[Title/Abstract] OR ”microbiological”[Title/Abstract] OR ”bacteria”[Title/Abstract] OR ”bacterial”[Title/Abstract] OR ”infection”[Title/Abstract]))) AND (”bacteriological techniques”[MeSH Terms] OR ”colony count, microbial”[MeSH Terms] OR ”culture media/diagnostic use”[MeSH Terms] OR ”polymerase chain reaction”[MeSH Terms] OR ”infection/radiography”[MeSH Terms] OR ”bacteria/isolation and purification”[MeSH Terms] OR ”culturing”[Title/Abstract] OR ”real time pcr”[Title/Abstract] OR ”polymerase chain reaction”[Title/Abstract])) AND (sensitiv*[Title/Abstract] OR ”sensitivity and specificity”[MeSH Terms] OR diagnos*[Title/Abstract] OR diagnosis[MeSH:noexp] OR ”diagnosis, differential”[MeSH:noexp] OR diagnosis[Subheading:noexp] OR ”false positive”[Title/Abstract] OR ”false negative”[Title/Abstract] OR ”reliability”[Title/Abstract] OR ”validity”[Title/Abstract] OR ”accuracy”[Title/Abstract] OR ”precision”[Title/Abstract] OR ”Comparative study”[Publication Type])

***3.4** continued*

EMBASE.COM (ELSEVIER)

				Microbiological examination (TiAb, De)		Sensitiv* (TiAb)
				Bacteriological techniques (TiAb)		Sensitivity and specificity (De)
				Bacterial count (TiAb, De)		Diagnos* (TiAb)
				Colony count (TiAb)		Diagnosis (De)
				Culturing (TiAb)		Differential diagnosis (De)
		Microbiology (TiAb, De)		Real time PCR (TiAb)		Diagnostic accuracy (De)
Tooth pulp (TiAb, De)		Infection (TiAb, De)		Polymerase chain reaction (TiAb)		Diagnostic error (Exp)
Dental pulp (TiAb)		Bacteria (TiAb, De)				Diagnostic test (Exp)
Pulp (Ti)	AND	Microbiological (TiAb)	AND	Culture medium (De)	AND	False positive (TiAb)
Root canal/s (TiAb)		Bacterial (TiAb)		AND Diagnosis (De)		False negative (TiAb)
Endodontics (De)		Infectious (TiAb)				Reliability (TiAb)
				Infection (De)		Validity (TiAb)
				AND Tooth radiography (De)		Accuracy (TiAb)
						Precision (TiAb)
				Bacteria (De)		Comparative study (De)
				AND Isolation and purification (De)		Intermethod comparison (De)

((('tooth pulp':ti,ab,de OR 'dental pulp':ti,ab OR 'pulp':ti OR 'root canal':ti,ab OR 'root canals':ti,ab OR 'endodontics':de) AND ('microbiology':ti,ab,de OR 'infection':ti,ab,de OR 'bacteria':ti,ab,de OR 'microbiological':ti,ab OR 'bacterial':ti,ab OR 'infectious':ti,ab)) AND ('microbiological examination':ti,ab,de OR 'bacteriological techniques':ti,ab OR 'bacterial count':ti,ab,de OR 'colony count':ti,ab OR ('culture medium':de AND 'diagnosis':de) OR (infection:de AND 'tooth radiography':de) OR culturing:ti,ab OR (bacteria:de AND 'isolation and purification':de) OR 'culturing':ti,ab OR 'real time pcr':ti,ab OR 'polymerase chain reaction':ti,ab)) AND (sensitiv*:ti,ab OR 'sensitivity and specificity':de OR diagnos*:ti,ab OR 'diagnosis':de OR 'differential diagnosis':de OR 'diagnostic accuracy':de OR 'diagnostic error'/exp OR 'diagnostic test'/exp OR 'false positive':ti,ab OR 'false negative':ti,ab OR 'reliability':ti,ab OR 'validity':ti,ab OR 'accuracy':ti,ab OR 'precision':ti,ab OR 'comparative study':de OR 'intermethod comparison':de) AND [embase]/lim

***3.4** continued*

COCHRANE CENTRAL REGISTRY OF CONTROLLED TRIALS (WILEY)

				Sensitivity and specificity (Me)
Dental pulp cavity/MI (Me)				Diagnosis (NoExp)
Endodontic infections (TiAb)		Bacteriological techniques (Me)		Diagnosis, differential (Me)
		Colony count, microbial (Me)		/DI
Dental pulp (TiAb)		Culture media/DU (Me)		Sensitiv* (TiAb)
OR Root canal/s (TiAb)		Polymerase chain reaction (Me, TiAb)		Diagnos* (TiAb)
AND Microbiology (TiAb)	AND	Infection/RA (Me)	AND	False positive (TiAb)
OR Microbiological (TiAb)		Bacteria/IP (Me)		False negative (TiAb)
OR Bacteria (TiAb)		Culturing (TiAb)		Reliability (TiAb)
OR Bacterial (TiAb)		Real time PCR (Tiab)		Validity (TiAb)
OR Infection (TiAb)				Accuracy (TiAb)
				Precision (TiAb)

#1 MeSH descriptor Dental Pulp Cavity explode all trees with qualifier: MI
#2 (endodontic infections):ti,ab
#3 (dental pulp):ti,ab OR (root canal):ti,ab OR (root canals):ti,ab
#4 (microbiology):ti,ab OR (microbiological):ti,ab OR (bacteria):ti,ab OR (bacterial):-ti,ab OR (infection):ti,ab
#5 MeSH descriptor Bacteriological Techniques explode all trees
#6 MeSH descriptor Colony Count, Microbial explode all trees
#7 MeSH descriptor Culture Media explode all trees with qualifier: DU
#8 MeSH descriptor Polymerase Chain Reaction explode all trees
#9 MeSH descriptor Infection explode all trees with qualifier: RA
#10 MeSH descriptor Bacteria explode all trees with qualifier: IP
#11 (culturing):ti,ab OR (real time pcr):ti,ab OR (polymerase chain reaction):ti,ab
#12 MeSH descriptor Sensitivity and Specificity explode all trees
#13 MeSH descriptor Diagnosis, this term only
#14 MeSH descriptor Diagnosis, Differential explode all trees
#15 Any MeSH descriptor with qualifier: DI
#16 (sensitiv*):ti,ab OR (diagnos*):ti,ab OR (false positive):ti,ab OR (false negative):ti,ab OR (reliability):ti,ab OR (validity):ti,ab OR (accuracy):ti,ab OR (precision):ti,ab
#17 (#1 OR #2 OR (#3 AND #4))
#18 (#5 OR #6 OR #7 OR #8 OR #9 OR #10 OR #11)
#19 (#12 OR #13 OR #14 OR #15 OR #16)
#20 (#17 AND #18 AND #19)

__3.5__ Revision of endodontic treatment.

PUBMED (NLM)				
		Surgical retreatment (TiAb)		
		Follow-up studies (Me)		
		Recurrence (Me)		Follow-up (Ti)
		Treatment outcome (Me)		Controlled clinical trial (PT)
		Disease progression (Me)		Meta analysis (PT)
Root canal therapy (Me, TiAb)		Time factors (Me)		Multicenter study (PT)
Root canal treatment (TiAb)		Time course (TiAb)		Randomised controlled trial (PT)
Pulpectomy (Me, TiAb)		Success rate (TiAb)		Allocat* (TiAb)
Root canal obturation (Me, TiAb)	AND	Failure (TiAb)	AND	Random* (TiAb)
Dental pulp diseases/SU (Me)		Outcome (Ti)		Systematic (SB)
Apical surgery (TiAb)		/AE		Cohort studies (NoExp)
Apical microsurgery (TiAb)		Discomfort (Ti)		Follow-up studies (Me)
		Adverse effect* (Ti)		Prospective studies (Me)
		Adverse event* (Ti)		Comparative study (PT)
		Adverse outcome* (Ti)		
		Retreatment (Me)		
		Reoperation (Me)		
OR				
Root canal therapy (MJR)	AND	Retreatment (Me)	AND	Treatment outcome (Me)

(”root canal therapy”[MeSH Terms] OR ”root canal therapy”[Title/Abstract] OR ”root canal treatment”[Title/Abstract] OR ”pulpectomy”[MeSH Terms] OR ”pulpectomy”[Title/Abstract] OR ”root canal obturation”[MeSH Terms] OR ”root canal obturation”[TItle/Abstract] OR ”Dental pulp diseases/surgery”[MeSH] OR ”apical surgery” [Title/Abstract] OR ”apical microsurgery”[Title/Abstract]) AND (”surgical retreatment”[Title/Abstract] OR ”follow up studies”[MeSH Terms] OR ”recurrence”[MeSH Terms] OR ”treatment outcome”[MeSH Terms] OR ”disease progression”[MeSH Terms] OR ”time factors”[MeSH Terms] OR ”time course”[Title/Abstract] OR ”success rate” [Title/Abstract] OR ”failure”[Title/Abstract] OR ”outcome”[Title] OR ”adverse effects” [MeSH Subheading] OR ”discomfort”[Title] OR adverse effect*[Title] OR adverse event* [Title] OR adverse outcome*[Title] OR ”retreatment”[MeSH Terms] OR ”reoperation” [MeSH Terms]) AND (”follow-up”[Title] OR ”controlled clinical trial”[Publication Type] OR ”meta analysis”[Publication Type] OR ”multicenter study”[Publication Type] OR ”randomised controlled trial”[Publication Type] OR allocat*[Title/Abstract] OR random* [Title/Abstract] OR systematic[sb] OR ”Cohort Studies”[Mesh:noexp] OR ”Follow-up studies”[MeSH Terms] OR ”prospective studies”[MeSH Terms] OR ”comparative study”[Publication Type])

”root canal therapy”[MeSH Major Topic] AND ”retreatment”[MeSH Terms] AND ”treatment outcome”[MeSH Terms]

__3.5__ continued

EMBASE.COM (ELSEVIER)

				Cohort analysis (De)
		Retreatment (TiAb, De)		Randomised controlled trial (De)
		Recurrent disease (De)		Meta analysis (De)
		Treatment outcome (Exp)		Systematic review (De)
Endodontics (De)		Disease course (Exp)		Risk (Exp)
Root canal therapy (TiAb)		Time course (TiAb)		Case control study (De)
Root canal treatment (TiAb)		Success rate (TiAb)		Evaluation and follow up (Exp)
Pulpectomy (TiAb)	AND	Failure (TiAb)	AND	Failure (Ti)
Root canal obturation (TiAb)		Outcome (Ti)		Survival (Ti)
Apical surgery (TiAb)		Adverse outcome (De)		Loss (Ti)
Apical microsurgery (TiAb)		Adverse (Ti)		Risk (Ti)
		Discomfort (Ti)		Symptom* (Ti)
		Reoperation (De)		Random* (TiAb)
				Cohort (Ti)
				Observational (Ti)

('endodontics':de OR 'root canal therapy':ti,ab OR 'root canal treatment':ti,ab OR 'pulpectomy':ti,ab OR 'root canal obturation':ti,ab OR 'apical surgery':ti,ab OR 'apical microsurgery':ti,ab) AND ('retreatment':ti,ab,de OR 'recurrent disease':de OR 'treat-ment outcome'/exp OR 'disease course'/exp OR 'time course':ti,ab OR 'success rate':ti,ab OR 'failure':ti,ab OR 'outcome':ti OR 'adverse outcome':de OR 'adverse':ti OR 'discom-fort':ti OR 'reoperation':de) AND ('cohort analysis':de OR 'randomised controlled trial':de OR 'meta analysis':de OR 'systematic review':de OR 'risk'/exp OR 'case control study':de OR 'evaluation and follow up'/exp OR 'failure':ti OR 'survival':ti OR 'loss':ti OR 'risk':ti OR symptom*:ti OR random*:ti,ab OR 'cohort':ti OR 'observational':ti) AND [embase]/lim

***3.5** continued*

COCHRANE CENTRAL REGISTRY OF CONTROLLED TRIALS (WILEY)		
		Recurrence (Me)
		Treatment outcome (Me)
		Disease progression (Me)
		Time factors (Me)
		Retreatment (Me)
Root canal therapy (Me, TiAb)		Reoperation (Me)
Pulpectomy (Me, TiAb)		/AE
Root canal obturation (Me, TiAb)		Surgical retreatment (TiAb)
Dental pulp diseases/SU (Me)	AND	Time course (TiAb)
Root canal treatment (TiAb)		Success rate (TiAb)
Apical surgery (TiAb)		Failure (TiAb)
Apical microsurgery (TiAb)		Outcome (TiAb)
		Discomfort (Ti)
		Adverse effect* (Ti)
		Adverse event* (Ti)
		Adverse outcome* (Ti)

#1 MeSH descriptor Root Canal Therapy explode all trees
#2 MeSH descriptor Pulpectomy explode all trees
#3 MeSH descriptor Root Canal Obturation explode all trees
#4 MeSH descriptor Dental Pulp Diseases explode all trees with qualifier: su
#5 (root canal therapy):ti,ab OR (root canal treatment):ti,ab OR (pulpectomy):ti,ab OR (root canal obturation):ti,ab OR (apical surgery):ti,ab OR (apical microsurgery):ti,ab
#6 MeSH descriptor Recurrence explode all trees
#7 MeSH descriptor Treatment Outcome explode all trees
#8 MeSH descriptor Disease Progression explode all trees
#9 MeSH descriptor Time Factors explode all trees
#10 MeSH descriptor Retreatment explode all trees
#11 MeSH descriptor Reoperation explode all trees
#12 Any MeSH descriptor with qualifier: AE
#13 (surgical retreatment):ti,ab OR (time course):ti,ab OR (success rate):ti,ab OR (failure):ti,ab OR (outcome):ti OR (discomfort):ti OR (adverse effect*):ti OR (adverse event*):ti OR (adverse outcome*):ti
#14 (#1 OR #2 OR #3 OR #4 OR #5)
#15 (#6 OR #7 OR #8 OR #9 OR #10 OR #11 OR #12 OR #13)
#16 (#14 AND #15)

***3.6** Treatment of acute conditions.*

PUBMED (NLM)		
Pulpitis (Me, Ti)		
Pulpectomy (Me, Ti)		
Pulpotomy (Me, Ti)		Emergency (Ti)
Periapical periodontitis (Me, Ti)		Emergencies (Me, Ti)
Endodontic (Ti)		Acute (Ti)
	AND	Exacerbation (Ti)
Dental (Ti)		Symptomatic (Ti)
OR Pulpal (Ti)		Acute disease (Me)
OR Tooth (Ti)		
AND Pain (Ti)		
OR Painful (Ti)		

(”emergency”[title] OR ”emergencies”[title] OR ”acute”[title] OR ”exacerbation”[title] OR ”symptomatic”[title] OR ”acute disease”[MeSH Terms] OR ”emergencies”[MeSH Terms]) AND (”Pulpitis”[MeSH Terms] OR ”Pulpectomy”[MeSH Terms] OR ”Pulpotomy”[MeSH Terms] OR ”Periapical Periodontitis”[MeSH Terms] OR ”pulpitis”[title] OR ”pulpotomy”[title] OR ”pulpectomy”[title] OR ”apical periodontitis”[title] OR ”endodontic”[title] OR ((”dental”[title] OR ”pulpal”[title] OR ”tooth”[title]) AND (”pain”[title] OR ”painful”[title])))

3.6 continued

PUBMED (NLM)		
		Evaluation (Ti)
		Observational (Ti)
		Clinical report (Ti)
		Follow-up studies (Me)
		Comparative study (PT)
Cracked tooth syndrome/TH (Me)	AND	Randomised controlled trial (PT)
		Review (PT)
		Retrospective (Ti)
		Retrospective studies (Me)
		Random* (TiAb)
		Allocat* (TiAb)
		Systematic (SB)
		Time factors (Me)

”Cracked Tooth Syndrome/therapy”[Mesh] AND (”evaluation”[title] OR ”observational”[Title] OR ”Clinical report”[Title] OR ”Follow-Up Studies”[Mesh Terms] OR ”comparative study”[Publication Type] OR ”randomised controlled trial”[Publication Type] OR ”review”[Publication Type] OR ”retrospective”[Title] OR ”retrospective studies”[MeSH Terms] OR random*[Title/Abstract] OR allocat*[Title/Abstract] OR systematic[sb] OR ”time factors”[MeSH Terms])

3.6 continued

EMBASE.COM (ELSEVIER)		
		Observational study (De)
		Follow up (De)
		Comparative study (Exp)
		Randomised controlled trial (De)
		Review (De)
		Retrospective study (De)
Tooth fracture (De)	AND	Systematic review (De)
		Time (Exp)
		Observational (Ti)
		Clinical report (Ti)
		Random* (TiAb)
		Allocat* (TiAb)
Limits: Humans		

’tooth fracture’:de AND [humans]/lim AND [embase]/lim AND (’observational study’:de OR ’follow up’:de OR ’comparative study’/exp OR ’randomised controlled trial’:de OR ’review’:de OR ’retrospective study’:de OR ’systematic review’:de OR time/exp OR ’observational’:ti OR ’clinical report’:ti OR random*:ti,ab OR allocat*:ti,ab)

3.6 continued

COCHRANE CENTRAL REGISTRY OF CONTROLLED TRIALS (WILEY)
Cracked tooth syndrome/TH (Me)

#1 MeSH descriptor Cracked Tooth Syndrome explode all trees with qualifier: TH

***3.7** Permanent and temporary restoration of root-filled teeth.*

PUBMED (NLM)				
				Cohort studies (Me)
				Randomised controlled trial (PT)
				Meta analysis (PT)
		Dental restoration, permanent (Me)		Review (PT)
Endodontics (Me)		Dental restoration (TiAb)		
Endodont* (TiAb)		Coronal restoration (TiAb)		Odds ratio (Me)
Root canal therapy (TiAb)		Apical retrofilling (TiAb)		OR Risk factors (Me)
Root canal treatment (TiAb)	AND	Apical retrograde root fillings (TiAb)		OR Time factors (Me)
Root canal obturation (TiAb)		Crown (TiAb)		OR Case control studies (Me)
Root filling* (TiAb)		Dental post/s (TiAb)		OR Evaluation studies (PT)
		Root canal posts (TiAb)	AND	OR Comparative study (PT)
		Conventional treatment (TiAb)		OR Failure (Ti)
		Conventional therapy (TiAb)		OR Survival (Ti)
				OR Loss (Ti)
	OR			OR Risk (Ti)
				OR Symptom* (Ti)
Root canal therapy (Me)				NOT Case reports (PT)
Dental pulp diseases/TH /Me)	AND	Dental restoration failure (MJR)		OR Comment (PT)
				OR Editorial (PT)
				OR Letter (PT)
				OR News (PT)

((("endodontics"[MeSH Terms] OR endodont*[Title/Abstract] OR "root canal therapy"[Title/Abstract] OR "root canal treatment"[Title/Abstract] OR root canal obturation[Title/Abstract] OR root filling*[Title/Abstract]) AND ("dental restoration, permanent"[MeSH Terms] OR "dental restoration"[Title/Abstract] OR coronal restoration[Title/Abstract] OR "apical retrofilling"[Title/Abstract] OR "apical retrograde root fillings"[Title/Abstract] OR "crown"[Title/Abstract] OR "dental post"[Title/Abstract] OR "dental posts"[Title/Abstract] OR "root canal posts"[Title/Abstract] OR "conventional treatment"[Title/Abstract] OR "conventional therapy"[Title/Abstract])) OR (("Dental Restoration Failure"[Majr]) AND ("Root Canal Therapy"[Mesh] OR "Dental Pulp Diseases/therapy"[Mesh]))) AND (("cohort studies"[MeSH Terms] OR "randomised controlled trial"[Publication Type] OR "meta analysis"[Publication Type] OR "review"[Publication Type]) OR (("odds ratio"[MeSH Terms] OR "risk factors"[MeSH Terms] OR "time factors"[MeSH Terms] OR "case control studies"[MeSH Terms] OR "evaluation studies"[Publication Type] OR "comparative study"[Publication Type] OR "failure"[Title] OR "survival"[Title] OR "loss"[Title] OR "risk"[Title] OR symptom* [Title]) NOT ("case reports"[Publication Type] OR "comment"[Publication Type] OR "editorial"[Publication Type] OR "letter"[Publication Type] OR "news"[Publication Type])))

***3.7** continued*

EMBASE.COM (ELSEVIER)

				Cohort analysis (De)
				Randomised controlled trial (De)
		Tooth crown (De)		Meta analysis (De)
		Dental restoration (TiAb)		Systematic review (De)
Endodontics (De)		Coronal restoration (TiAb)		Risk (Exp)
Endodont* (TiAb)		Apical retrofilling (TiAb)		Case control study (De)
Root canal therapy (TiAb)		Apical retrograde root filling/s (TiAb)		Evaluation and follow up (Exp)
Root canal treatment (TiAb)	AND	Crown (TiAb)	AND	Failure (Ti)
Root canal obturation (TiAb)		Dental post/s (TiAb)		Survival (Ti)
Root filling/s (TiAb)		Root canal posts (TiAb)		Loss (Ti)
		Conventional therapy (TiAb)		Risk (Ti)
		Conventional treatment (TiAb)		Symptom* (Ti)
				Random* (Ti)
				Cohort (Ti)
				Observational (Ti)

('endodontics':de OR endodont*:ti,ab OR 'root canal therapy':ti,ab OR 'root canal treatment':ti,ab OR 'root canal obturation':ti,ab OR 'root filling':ti,ab OR 'root fillings':ti,ab) AND ('tooth crown':de OR 'dental restoration':ti,ab OR 'coronal restoration':ti,ab OR 'apical retrofilling':ti,ab OR 'apical retrograde root filling':ti,ab OR 'apical retrograde root fillings':ti,ab OR 'crown':ti,ab OR 'dental post':ti,ab OR 'dental posts':ti,ab OR 'root canal posts':ti,ab OR 'conventional treatment':ti,ab OR 'conventional therapy':ti,ab) AND ('cohort analysis':de OR 'randomised controlled trial':de OR 'meta analysis':de OR 'systematic review':de OR 'risk'/exp OR 'case control study':de OR 'evaluation and follow up'/exp OR 'failure':ti OR 'survival':ti OR 'loss':ti OR 'risk':ti OR symptom*:ti OR random*:ti,ab OR 'cohort':ti OR 'observational':ti) AND [embase]/lim

3.7 continued

COCHRANE CENTRAL REGISTRY OF CONTROLLED TRIALS (WILEY)

		Dental restoration, permanent (Me)
Endodontics (Me)		Dental restoration (TiAb)
Endodont* (TiAb)		Coronal restoration (TiAb)
Root canal therapy (TiAb)		Apical retrofilling (TiAb)
Root canal treatment (TiAb)	AND	Apical retrograde root fillings (TiAb)
Root canal obturation (TiAb)		Crown (TiAb)
Root filling* (TiAb)		Dental post/s (TiAb)
		Root canal posts (TiAb)
		Conventional treatment (TiAb)
		Conventional therapy (TiAb)
	OR	
Root canal therapy (Me)		
Dental pulp diseases (Me)	AND	Dental restoration failure (Me)

#1 MeSH descriptor Endodontics explode all trees
#2 (endodont*):ti,ab OR (root canal therapy):ti,ab OR (root canal treatment):ti,ab OR (root canal obturation):ti,ab OR (root filling*):ti,ab
#3 MeSH descriptor Dental Restoration, Permanent explode all trees
#4 (dental restoration):ti,ab OR (coronal restoration):ti,ab OR (apical retro-filling):ti,ab OR (apical retrograde root fillings):ti,ab OR (crown):ti,ab OR (dental post):ti,ab OR (dental posts):ti,ab OR (root canal posts):ti,ab OR (conventional treatment):ti,ab OR (conventional therapy):ti,ab
#5 MeSH descriptor Dental Restoration Failure explode all trees
#6 MeSH descriptor Root Canal Therapy explode all trees
#7 MeSH descriptor Dental Pulp Diseases explode all trees with qualifier: th
#8 ((#1 OR #2) AND (#3 OR #4))
#9 (#5 AND (#6 OR #7))
#10 (#8 OR #9)

***3.7** continued*

PUBMED (NLM)				
Endodontics (Me)		Dental restoration, temporary (Me)		
Endodont* (TiAb)				Cohort studies (Me)
Root canal therapy (TiAb)		Temporary (TiAb)		Randomised controlled trial (PT)
Root canal treatment (TiAb)	AND	OR Interim (TiAb)	AND	Meta analysis (PT)
Root canal obturation (TiAb)		OR Provisional (TiAb)		Review (PT)
Root filling* (TiAb)		AND Endodontic restoration (TiAb)		Systematic (SB)
		OR Coronal (TiAb)		
		OR Dental cements (Me)		

(”endodontics”[MeSH Terms] OR endodont*[Title/Abstract] OR ”root canal therapy” [Title/Abstract] OR ”root canal treatment”[Title/Abstract] OR root canal obturation [Title/Abstract] OR root filling*[Title/Abstract]) AND (”dental restoration, temporary” [MeSH Terms] OR ((temporary[Title/Abstract] OR interim[Title/Abstract] OR provisional[Title/Abstract]) AND (”endodontic restoration”[Title/Abstract] OR coronal [Title/Abstract] OR ”dental cements”[MeSH Terms]))) AND (”cohort studies”[MeSH Terms] OR ”randomised controlled trial”[Publication Type] OR ”meta analysis”[Publication Type] OR ”review”[Publication Type] OR systematic[sb])

***3.7** continued*

EMBASE.COM (ELSEVIER)				
				Cohort analysis (De)
				Randomised controlled trial (De)
				Meta analysis (De)
				Systematic review (De)
Endodontics (De)		Temporary (TiAb)		Risk (Exp)
Endodont* (TiAb)		OR Interim (TiAb)		Case control study (De)
Root canal therapy (TiAb)		OR Provisional (TiAb)		Evaluation and follow up (Exp)
Root canal treatment (TiAb)	AND	AND Endodontic restoration (TiAb)	AND	Failure (Ti)
Root canal obturation (TiAb)		OR Coronal (TiAb)		Survival (Ti)
Root filling/s (TiAb)		OR Tooth cement (De)		Loss (Ti)
				Risk (Ti)
				Symptom* (Ti)
				Random* (Ti)
				Cohort (Ti)
				Observational (Ti)

(’endodontics’:de OR endodont*:ti,ab OR ’root canal therapy’:ti,ab OR ’root canal treatment’:ti,ab OR ’root canal obturation’:ti,ab OR ’root filling’:ti,ab OR ’root fillings’: ti,ab) AND ((’temporary’:ti,ab OR ’interim’:ti,ab OR ’provisional’:ti,ab) AND (’endocontic restoration’:ti,ab OR ’coronal’:ti,ab OR ’tooth cement’:de)) AND (’cohort analysis’:de OR ’randomised controlled trial’:de OR ’meta analysis’:de OR ’systematic review’:de OR ’risk’/exp OR ’case control study’:de OR ’evaluation and follow up’/exp OR ’failure’:ti OR ’survival’:ti OR ’loss’:ti OR ’risk’:ti OR symptom*:ti OR random*: ti,ab OR ’cohort’:ti OR ’observational’:ti) AND [embase]/lim

***3.7** continued*

COCHRANE CENTRAL REGISTRY OF CONTROLLED TRIALS (WILEY)		
		Dental restoration, temporary (Me)
Endodontics (Me)		
Endodont* (TiAb)		Temporary (TiAb)
Root canal therapy (TiAb)		OR Interim (TiAb)
Root canal treatment (TiAb)	AND	OR Provisional (TiAb)
Root canal obturation (TiAb)		AND Endodontic restoration (TiAb)
Root filling* (TiAb)		OR Coronal (TiAb)
		OR Dental cements (Me)

#1 MeSH descriptor Endodontics explode all trees
#2 (endodont*):ti,ab OR (root canal therapy):ti,ab OR (root canal treatment):ti,ab OR (root canal obturation):ti,ab OR (root filling*):ti,ab
#3 MeSH descriptor Dental Restoration, Temporary explode all trees
#4 MeSH descriptor Dental Cements explode all trees
#5 (temporary):ti,ab OR (interim):ti,ab OR (provisional):ti,ab
#6 (endodontic restoration):ti,ab OR (coronal):ti,ab
#7 (#1 OR #2)
#8 (#3 OR (#5 AND (#4 OR #6)))
#9 (#7 AND #8)

***3.8** Risks for development or exacerbation of disease in other organs from infections of the pulp and periapical tissues.*

PUBMED (NLM)				
		Cerebrovascular disorders (Me)		
Oral health (MJR)		Heart diseases (Me)		Cross sectional studies (Me)
Dental pulp diseases (Me)		Arthritis, rheumatoid (Me)		Case control studies (Me)
Periapical diseases (Me)		Diabetes mellitus (Me)		Cohort studies (Me)
Focal infection, dental (Me)		Lung diseases, obstructive (Me)		Risk factors (Me)
Dental caries/CO (Me)	AND	Infant, premature (Me)	AND	Odds ratio (Me)
Tooth diseases/CO (MJR)		Obstetric labour, premature (Me)		Meta analysis (PT)
Dental caries/EP (MJR)		Infant, low birth weight (Me)		Randomised controlled trial (PT)
Dental care/AE (MJR)		Sepsis (Me)		Review (PT)
		Bacteremia (Me)		
OR				
		Coronary (Ti)		
		Vascular (Ti)		
		Bacteremia (Ti)		
		Cerebro* (Ti)		
		Ischemia (Ti)		
		Myocardial (Ti)		
		Cardial (Ti)		
Root canal* (Ti)		Diabet* (Ti)		
Rootcanal* (Ti)		Arthrit* (Ti)		Relat* (Ti)
Endodont* (Ti)		Obstructive (Ti)		Conjunction (Ti)
Dental (Ti)	AND	Heart valve (Ti)	AND	Risk (Ti)
		Morbidity (Ti)		Associat* (Ti)
Apical (Ti)		Mortality (Ti)		Correlat* (Ti)
AND Periodont* (Ti)		Inflam* (Ti)		
		Pathol* (Ti)		
		Diseas* (Ti)		
		Systemic (Ti)		
		Athero* (Ti)		
		Sepsis (Ti)		
		Hematogen (Ti)		
OR				
		Tooth diseases/MO (Me)		
		Endodontics (MJR)		
		AND Oldmedline (SB)		

((”oral health”[MeSH Major Topic] OR ”dental pulp diseases”[MeSH Terms] OR ”periapical diseases”[MeSH Terms] OR ”focal infection, dental”[MeSH Terms] OR ”dental caries/complications”[MeSH Terms] OR ”tooth diseases/complications”[MeSH Major Topic] OR ”dental caries/epidemiology”[MeSH Major Topic] OR ”dental care/adverse effects”[MeSH Major Topic]) AND (”cerebrovascular disorders”[MeSH Terms] OR ”heart diseases”[MeSH Terms] OR ”arthritis, rheumatoid”[MeSH Terms] OR ”diabetes mellitus”[MeSH Terms] OR ”lung diseases, obstructive”[MeSH Terms] OR ”infant, premature”[MeSH Terms] OR ”obstetric labor, premature”[MeSH Terms] OR ”infant, low birth weight”[MeSH Terms] OR ”sepsis”[MeSH Terms] OR ”bacteremia”[MeSH Terms]) AND (”cross sectional studies”[MeSH Terms] OR ”case control studies”[MeSH Terms] OR ”cohort studies”[MeSH Terms] OR ”risk factors”[MeSH Terms] OR ”odds ratio” [MeSH Terms] OR (”meta analysis”[Publication Type] OR ”randomised controlled trial” [Publi-cation Type] OR ”review”[Publication Type]))) OR ((root canal*[Title] OR root-canal*[Title] OR endodont*[Title] OR dental[Title] OR (apical[Title] AND periodont* [Title])) AND (relat*[Title] OR conjunction[Title] OR risk[Title] OR associat*[Title] OR correlat*[Title]) AND (coronary[Title] OR vascular[Title] OR bacteremia[Title] OR cerebro*[Title] OR ischemia[Title] OR myocardial[Title] OR cardial[Title] OR diabet*[Title] OR arthrit*[Title] OR obstructive[Title] OR heart valve[Title] OR morbidity[Title] OR mortality[Title] OR inflam*[Title] OR pathol*[Title] OR diseas*[Title] OR systemic[Title] OR athero*[Title] OR sepsis[Title] OR hematogen[Title])) OR (”tooth diseases/mortality”[MeSH Terms] OR (oldmedline[sb] AND ”endodontics” [MeSH Major Topic]))

3.8 *continued*

EMBASE.COM (ELSEVIER)				
		Cerebrovascular disease (Exp)		
		Heart disease (Exp)		Cross sectional study (De)
Dental health (MJR)		Rheumatoid arthritis (Exp)		Cohort analysis (De)
Tooth pulp disease (De)		Diabetes mellitus (Exp)		Risk (Exp)
Tooth periapical disease (De)	AND	Obstructive airway disease (Exp)	AND	Case control study (Exp)
Tooth infection (Exp)		Immature and premature labour (Exp)		Randomised controlled study (De)
Dental caries (De)		Low birth weight (Exp)		Meta analysis (De)
		Sepsis (De)		Systematic review (De)
		Bacteremia (De)		

(’dental health’/mj OR ’tooth pulp disease’:de OR ’tooth periapical disease’:de OR ’tooth infection’/exp OR ’dental caries’:de) AND (’cerebrovascular disease’/exp OR ’heart disease’/exp OR ’rheumatoid arthritis’/exp OR ’diabetes mellitus’/exp OR ’obstructive airway disease’/exp OR ’immature and premature labor’/exp OR ’low birth weight’/exp OR ’sepsis’:de OR ’bacteremia’:de) AND (’cross-sectional study’:de OR ’cohort analysis’:de OR ’risk’/exp OR ’case control study’/exp OR ’randomised controlled study’:de OR ’meta analysis’:de OR ’systematic review’:de) AND [embase]/lim

3.8 continued

COCHRANE CENTRAL REGISTRY OF CONTROLLED TRIALS (WILEY)		
Oral health (Me)		Cerebrovascular disorders (Me)
Dental pulp diseases (Me)		Heart diseases (Me)
Periapical diseases (Me)		Arthritis, rheumatoid (Me)
Focal infection, dental (De)		Diabetes mellitus (Me)
Dental caries/CO (Me)	AND	Lung diseases, obstructive (Me)
Tooth diseases/CO (Me)		Infant, premature (Me)
Dental caries/EP(Me)		Obstetric labor, premature (Me)
Dental care/AE (Me)		Infant, low birth weight (Me)
		Sepsis (Me)

#1 MeSH descriptor Oral Health explode all trees
#2 MeSH descriptor Dental Pulp Diseases explode all trees
#3 MeSH descriptor Periapical Diseases explode all trees
#4 MeSH descriptor Focal Infection, Dental explode all trees
#5 MeSH descriptor Dental Caries explode all trees with qualifier: CO
#6 MeSH descriptor Tooth Diseases explode all trees with qualifier: CO
#7 MeSH descriptor Dental Caries explode all trees with qualifier: EP
#8 MeSH descriptor Dental Care explode all trees with qualifier: AE
#9 (#1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8)
#10 MeSH descriptor Cerebrovascular Disorders explode all trees
#11 MeSH descriptor Heart Diseases explode all trees
#12 MeSH descriptor Arthritis, Rheumatoid explode all trees
#13 MeSH descriptor Diabetes Mellitus explode all trees
#14 MeSH descriptor Lung Diseases, Obstructive explode all trees
#15 MeSH descriptor Infant, Premature explode all trees
#16 MeSH descriptor Obstetric Labour, Premature explode all trees
#17 MeSH descriptor Infant, Low Birth Weight explode all trees
#18 MeSH descriptor Sepsis explode all trees
#19 (#10 OR #11 OR #12 OR #13 OR #14 OR #15 OR #16 OR #17 OR #18)
#20 (#9 AND #19)

***3.9** Risks of serious side-effects or complications associated with endodontic treatment.*

PUBMED (NLM)				
Endodontics (NoExp, Ti)				
Endodontic (Ti)				
Rubber dams (MJR, Ti)				
Root canal treatment (Ti)		/AE		
Root canal therapy (Ti)		/CO		
Dental pulp capping (MJR)		Hypersensitivity (MJR)		
Pulp capping (Ti)		Allergy (Ti)		
Pulpotomy (Ti)		Allergic (Ti)	AND	Dentistry (Me)
Pulpectomy (Ti)		Hypersensitivity (Ti)		
Root canal filling materials/AE (MJR)	AND	Hypersensitive (Ti)	OR	
Root canal filling materials/TO (MJR)		Paresthesia (MJR, Ti)		
Formaldehyde/AE (MJR)		Chronic pain (Ti)	NOT	Medline (SB)
Calcium hydroxide/TO (MJR)		Endocarditis, bacterial (NoExp)		
Eugenol/AE (MJR)		Endocarditis (Ti)		
Camphorated phenol (SN)		Dermatitis, contact (MJR)		
Root canal irrigants/AE (MJR)				
Hydrogen peroxide/AE (MJR)				
Sodium hypochlorite/AE (MJR)				

((”Endodontics”[MeSH:NoExp] OR ”endodontic”[title] OR ”endodontics”[title] OR ”Rubber dams”[MeSH Major Topic] OR ”rubber dams”[title] OR ”root canal treatment”[title] OR ”root canal therapy”[title] OR “dental pulp capping”[MeSH Major Topic] OR “pulp capping”[Title] OR “pulp capping”[title] OR “pulpotomy”[title] OR “pulpectomy”[title] OR “Root canal filling materials/adverse effects”[MeSH Major Topic] OR “Root canal filling materials/toxicity”[MeSH Major Topic] OR “formaldehyde/adverse effects”[MeSH Major Topic] OR “calcium hydroxide/toxicity”[MeSH Major Topic] OR “Eugenol/adverse effects”[MeSH Major Topic] OR “camphorated phenol”[Substance Name] OR “root canal irrigants/adverse effects”[MeSH Major Topic] OR “hydrogen peroxide/adverse effects”[MeSH Major Topic] OR “Sodium hypochlorite/adverse effects”[MeSH Major Topic]) AND (“adverse effects”[Subheading] OR “complications”[Subheading] OR “Hypersensitivity”[MeSH Major Topic] OR “allergy”[title] OR “allergic”[title] OR “hypersensitivity”[title] OR “hypersensitive”[title] OR “paresthesia”[MeSH Major Topic] OR “paresthesia”[title] OR “chronic pain”[title] OR “Endocarditis, Bacterial”[MeSH:NoExp] OR “endocarditis”[title] OR “Dermatitis, Contact”[MeSH Major Topic]) AND (“Dentistry”[MeSH Terms])) OR ((“Endodontics”[MeSH:NoExp] OR “endodontic”[title] OR “endodontics”[title] OR “Rubber dams”[MeSH Major Topic] OR “rubber dams”[title] OR “root canal treatment”[title] OR “root canal therapy”[title] OR “dental pulp capping”[MeSH Major Topic] OR “pulp capping”[Title] OR “pulp capping”[title] OR “pulpotomy”[title] OR “pulpectomy”[title] OR “Root canal filling materials/adverse effects”[MeSH Major Topic] OR “Root canal filling materials/toxicity”[MeSH Major Topic] OR “formaldehyde/adverse effects”[MeSH Major Topic] OR “calcium hydroxide/toxicity”[MeSH Major Topic] OR “Eugenol/adverse effects”[MeSH Major Topic] OR “camphorated phenol”[Substance Name] OR “root canal irrigants/adverse effects”[MeSH Major Topic] OR “hydrogen peroxide/adverse effects”[MeSH Major Topic] OR “Sodium hypochlorite/adverse effects”[MeSH Major Topic]) AND (“adverse effects”[Subheading] OR “complications”[Subheading] OR “Hypersensitivity”[MeSH Major Topic] OR “allergy”[title] OR “allergic”[title] OR “hypersensitivity”[title] OR “hypersensitive”[title] OR “parest-hesia”[MeSH Major Topic] OR “paresthesia”[title] OR “chronic pain”[title] OR “Endocarditis, Bacterial”[MeSH:NoExp] OR “endocarditis”[title] OR “Dermatitis, Contact”[MeSH Major Topic]) NOT Medline[sb])

***5** Health economic aspects.*

PUBMED (NLM)*		
Economics (Me)		
Costs and cost-analysis (Me)		
Cost allocation (Me)		
Cost benefit analysis (Me)		
Cost control (Me)		Low (Ti)
Cost savings (Me)		OR High (Ti)
Cost of illness (Me)		OR Health care (Ti)
Cost sharing (Me)		OR Estimate* (Ti)
Deductibles and coinsurance (Me)		OR Variable (Ti)
Medical savings accounts (Me)		OR Unit (Ti)
Health care costs (Me)		AND Cost* (Ti)
Direct service costs (Me)		
Drug costs (Me)	OR	Fiscal (Ti)
Employer health costs (Me)		Funding (Ti)
Hospital costs (Me)		Financial (Ti)
Health expenditures (Me)		Finance (Ti)
Capital expenditures (Me)		Economic* (Ti)
Value of life (Me)		Pharmacoeconomic* (Ti)
Economics, hospital (Me)		Price (Ti)
Economics, medical (Me)		Prices (Ti)
Economics, nursing (Me)		Pricing (Ti)
Economics, pharmaceutical (Me)		
Fees and charges (Me)		
Budgets (Me)		
Willingness to pay (TiAb)		

(”economics”[MeSH Terms] OR ”costs and cost analysis”[MeSH Terms] OR ”cost allocation”[MeSH Terms] OR ”cost benefit analysis”[MeSH Terms] OR ”cost control”[MeSH Terms] OR ”cost savings”[MeSH Terms] OR ”cost of illness”[MeSH Terms] OR ”cost sharing”[MeSH Terms] OR ”deductibles and coinsurance”[MeSH Terms] OR ”medical savings accounts”[MeSH Terms] OR ”health care costs”[MeSH Terms] OR ”direct service costs”[MeSH Terms] OR ”drug costs”[MeSH Terms] OR ”employer health costs”[MeSH Terms] OR ”hospital costs”[MeSH Terms] OR ”health expenditures”[MeSH Terms] OR ”capital expenditures”[MeSH Terms] OR ”value of life”[MeSH Terms] OR ”economics, hospital”[MeSH Terms] OR ”economics, medical”[MeSH Terms] OR ”economics, nursing”[MeSH Terms] OR ”economics, pharmaceutical”[MeSH Terms] OR ”fees and charges”[MeSH Terms] OR ”budgets”[MeSH Terms]) OR (((low[Title] OR high[Title] OR ”health care”[Title] OR estimate*[Title] OR variable[Title] OR unit[Title]) AND cost*[Title]) OR fiscal[Title] OR funding[Title] OR financial[Title] OR finance[Title] OR economic*[Title] OR pharmacoeconomic*[Title] OR price[Title] OR prices[Title] OR pricing[Title])

* For health economy searches, this filter replaced the ‘study design’-filter for each of the following search strategies: PULP CAPPING, CRACKED TOOTH SYNDROME, DIAGNOSIS, CULTURING, NUMBER OF VISITS, STERILIZATION, INSTRUMENTIZATION, FILLING MATERIALS, INFECTION DIAGNOSTICS, ENDODONTIC RESTORATION, RETREATMENT.

***5** continued*

NHS ECONOMIC EVALUATION DATABASE (WILEY)
The NHSEED searches are identical with the previously reported search strategies for the Cochrane Central Register of Controlled Trials

***5** continued*

HEALTH ECONOMIC EVALUATIONS DATABASE (WILEY)
Endodontics (AD)
Root canal therapy (AD)
Root canal treatment (AD)
Endodontic (AD)
Dental pulp (AD)

(endodontics OR root canal therapy OR root canal treatment
OR endodontic OR dental pulp)

Appendix 3. **Questionnaire**

Survey of accepted practice for a planned SBU report on endodontics

Questionnaire to dentists

Dear Colleague,
The Swedish Council on Health Technology Assessment (SBU), in collaboration with the Swedish National Board of Health and Welfare (Socialstyrelsen), is undertaking a project to evaluate the scientific support for different measures for endodontic diagnosis and treatment. The report is intended to form the basis of national guidelines for dentists. As part of the evaluation the project group has decided to seek answers to a number of questions about accepted endodontic practice. You have been selected in a randomized process to answer the enclosed questions. Your co-operation would be greatly appreciated. We would like to receive your response in the enclosed envelope by May 1st 2009 at the latest. If you are not in practice and/or do not include endodontics in your practice, we request that you still return the questionnaire to us, with a note to this effect.

If you have any queries or would like further information,
please contact the project leader Sofia Tranæus (08 412 32 14)
or by email tranaeus@sbu.se

With thanks for your participation
Kind regards

Gunnar Bergenholtz
Chairman of SBU's project group for endodontics

Background information

Place a cross in the appropriate box.

1. Gender?
❑ Female
❑ Male

2. Practice?
❑ Public
❑ Private

3. County?
Responses distributed according to county
❑ Blekinge
❑ Dalarna
❑ Gotland
❑ Gävleborg
❑ Halland
❑ Jämtland
❑ Jönköping
❑ Kalmar
❑ Kronoberg
❑ Norrbotten
❑ Skåne
❑ Stockholm
❑ Södermanland
❑ Uppsala
❑ Värmland
❑ Västerbotten
❑ Västernorrland
❑ Västmanland
❑ Västra Götaland
❑ Örebro
❑ Östergötland
Sparsely populated county
Not sparsely populated

4. Age?
❑ 20–29
❑ 30–39
❑ 40–49
❑ 50–59
❑ 60–69
❑ 70–79
❑ 80–89

5. Number of years as a dentist?
❑ <1 yr
❑ 1–5 yr
❑ 6–10 yr
❑ 11–25 yr
❑ >25 yr

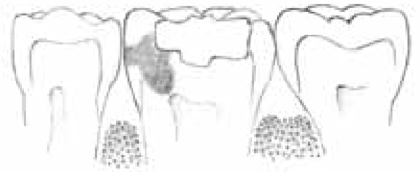
6. Do you use mechanical instrumentation?
❑ Always (exclusively)
❑ Always (but combined hand instrumentation)
❑ Mostly
❑ Sometimes
❑ No, never

7. Present type of dentistry?
❑ Children exclusively
❑ Children and adults
❑ Adults only
❑ Specialist, namely
❑ No endodontics
❑ Non-practising

Inquiry form A

1. Treatment of carious exposure of vital pulp

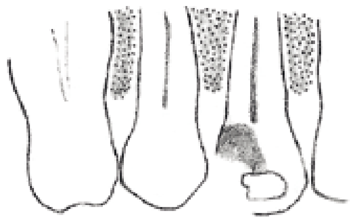
a) During routine examination of a 22-year old patient you find that 36 has a deep carious lesion (see illustration). The patient has no symptoms and a periapical radiograph shows no pathological changes.



While excavating caries from 36 you expose the pulp. The pulp is vital and you consider it to be bleeding normally.

How would you treat this tooth?
❑ Partial pulpotomy (according to Cvek)
❑ Pulp capping
❑ Pulpectomy (extirpation)
❑ Other option

b) During routine examination of a 50-year old patient you find that 14 has a deep carious lesion (see illustration). The patient has no symptoms and a periapical radiograph shows no pathological changes.



While excavating caries from 14 you expose the pulp. The pulp is vital and you consider it to be bleeding normally.

How would you treat this tooth?
❑ Partial pulpotomy (according to Cvek)
❑ Pulp capping
❑ Pulpectomy (extirpation)
❑ Other option

2. What strategy do you usually use when you root-fill a tooth?

One-step ie instrumentation and root filling in one appointment or two-step ie instrumentation at one appointment and root filling at a later appointment?

Mark the appropriate box with a cross.

Diagnosis	One-step	Two-step	More than two appointments
Pulpitis	❑	❑	❑
Necrotic pulp with no perapical changes	❑	❑	❑
Necrotic pulp with periapical osteitis/ apical periodontitis	❑	❑	❑

3. Restoration of a root-filled tooth

You have a patient aged 55 years who is in good health and has a normal dentition. There are 29 teeth, of which 13 are sound and unrestored. Caries risk is considered low and periodontal status is good. The patient has an amalgam crown on 17, and Class I and class II fillings otherwise.

You have just completed a root filling on tooth 46, of which more than 4 of the 5 surfaces are missing. The reason for root filling was pulpitis following a cusp fracture. You are pleased with the result of your root treatment.

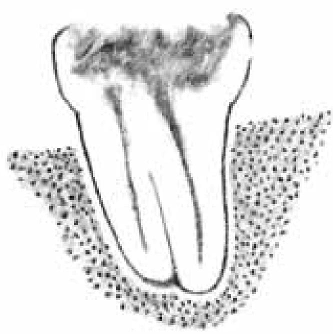
a) What do you recommend to the patient as a permanent restoration?
❑ Composite crown?
❑ Laboratory fabricated crown?
❑ Other option

b) How long do you wait before permanent restoration of the tooth?
❑ No waiting time at all ❑ Wait 2–4 weeks
❑ Wait one week ❑ Longer

Inquiry form B

1. Acute pulpitis

A 45-year old man seeks emergency treatment for severe toothache from the left side of his lower jaw, onset a week ago, increasing intensity over the past few days and disturbing his sleep at night. The attacks of pain are at times spontaneous but occur more frequently at mealtimes.



You find that 36 has a missing filling and is carious. The tooth gives a marked positive response to testing for sensitivity to cold, which also triggers an attack of acute pain. A radiograph shows marked loss of substance with suspected pulpal exposure.

The patient would like to retain the tooth and you consider that restoration of the tooth is quite feasible.

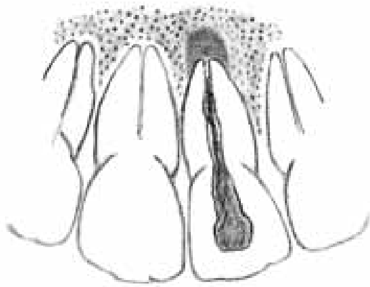
How do you handle the acute condition? Because you have seen the patient for emergency treatment despite a full appointment list, you have clearly very little time available, 15 minutes' treatment time at the most. The patient is in good health, the diagnosis is very obvious, and in the event of using local anaesthesia it works quickly and allows you to work on the tooth. Mark with one or more crosses below the measure or measures ,which best correspond with what you would normally do in such a case.

❑ Prescribe a prescription only analgesic
❑ Prescribe antibiotics
❑ Excavate caries to the point of a bleeding pulp
❑ Prepare the pulp chamber and remove any bleeding pulp tissue from the chamber
❑ Begin debriding the root canals
❑ Apply a medicament to the pulp chamber/root canal
❑ Apply a temporary dressing

❑ If you prescribe an analgesic: which one?
❑ If you prescribe an antibiotic: which one?
❑ If you place a medicament in the tooth: which one?

2. Apical radiolucency on a root-filled tooth

During routine examination of a healthy 45-year old man who is one of your patients, you detect apical bone destruction on a radiograph of 21. The patient informs you that the tooth was root-filled five years ago.



The root filling is somewhat short, with an apical lumen and does not look well-sealed. The tooth shows no other pathology, is asymptomatic and aesthetically acceptable. You do not have access to previous radiographs.

The patient has a full dentition and your examination discloses no need for treatment other than that which might arise as a result of the findings about 21.

On the evidence of the radiograph of 21, what information and proposal for treatment would you give your patient? Indicate the option, which is in closest agreement with what you would normally do in cases such as this.

1. Ignore the finding and do not inform the patient
2. Inform the patient of your finding but tell him that no intervention is required
3. Inform the patient of your findings, recommend re-examination and a control radiograph in one year's time
4. Inform the patient of your finding and recommend that you redo the root filling
5. Inform the patient of your finding and recommend that you do an apicoectomy (apical surgery)
6. Inform the patient of your finding and suggest treatment with antibiotics
7. Suggest referral to a specialist for assessment and possible treatment
8. Inform the patient of your finding, recommend extraction and replacement with an implant
9. Inform the patient of your finding, recommend extraction and replacement with a bridge

3. Choice of root filling material

Teeth can be root-filled in various ways. Indicate the method and material, which you use most often by marking the appropriate box/es with a cross.

a) Method

- ❑ Gutta-percha with solid core material in combination with cement/sealer (combine with appropriate sealer material under b)
- ❑ Rosinchloroform – gutta-percha
- ❑ Resin-based material EndoRez/Resilon-Epiphany
- ❑ Resorcinal – formaldehyde
- ❑ Thermafil/Softcore (combine with appropriate sealer under b)
- ❑ Warm gutta-percha System B, Obtura or similar (combine with appropriate sealer under b)
- ❑ Other method, specify:

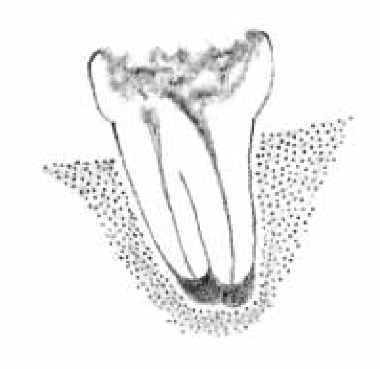
b) Sealer material (if applicable)

- ❑ AH Plus/AH PlusJet
- ❑ Apexit, ApexitPlus
- ❑ Endomethasone
- ❑ Gutta Flow
- ❑ Chloropercha
- ❑ N2
- ❑ RoekoSeal
- ❑ Sealapex
- ❑ Tubli-Seal
- ❑ TopSeal
- ❑ Other sealer material, specify:

Inquiry form C

1. Acute periapical osteitis/apical periodontitis

A 45-year old man seeks emergency treatment for severe toothache on the left side of his lower jaw, starting a week ago and increasing in intensity over the past few days with disturbed sleep. 36 is very tender to palpation and chewing. The pain is constant and not affected by food or drink.



You find that 36 has a missing filling and is carious. The tooth is not sensitive to a cold test. The tooth is tender to percussion and apically. No deep periodontal pockets. On the alveolar bone buccal to 36 is a local well-defined hard lump. The radiograph shows caries close to the pulp and marked destruction of periapical bone. Tender, palpable regional lymph nodes.

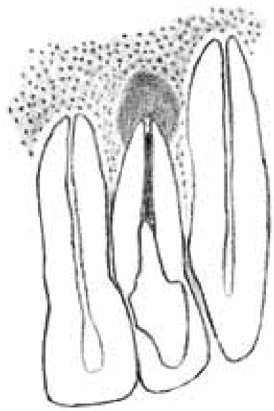
The patient would like to retain the tooth and you consider it quite feasible to restore it.

How do you manage the acute condition?
Because you had to find time to see the patient urgently despite a full appointment list you have clearly very little time available, 15 minutes' treatment time at the most. The patient is in good health, the diagnosis is very obvious, and in the event of using local anaesthesia it works quickly and allows you to work on the tooth. Mark with one or more crosses below the measure or measures, which best correspond with what you would normally do in such a case.

1. Prescribe a prescription – only analgesic
2. Prescribe antibiotics
3. Excavate caries crudely
4. Access the pulp chamber and remove necrotic tissue in the crown portion
5. Begin debridement of the root canals
6. Apply a medicament to the pulp chamber/root canals
7. Apply a temporary dressing

If you prescribe an analgesic: which one?
If you prescribe an antibiotic: which one?
If you place a medicament in the tooth: which one?

2. Periapical osteitis/ apical periodontitis associated with a root-filled tooth



A 45-year old fully healthy man who has long been a patient of yours presents for his annual check-up. Five years ago you did a root filling and a post retained crown on 22 which had pulpal necrosis and apical periodontitis.

The tooth has been rather tender for some time and you take an x-ray, which shows marked persistent periapical bone destruction, of the same magnitude as when the root filling was done. Palpation on the buccal aspect reveals apical tenderness. There are no deep periodontal pocket probing depths around the tooth or other signs of a root fracture. The crown is clinically acceptable and the root filling looks good on the radiograph.

The patient has otherwise a full dentition and you find no need for other treatment than that which might be necessary following the findings with respect to 22.

With respect to the findings for 22, what proposals for treatment would you present to your patient?

1. Inform the patient of the radiographic findings; reassure him that no action is necessary and that the discomfort will soon disappear
2. Prescribe antibiotics and follow-up with a new control in 3-6 months
3. Suggest that you should remove the crown and the post, redo the root filling and then a new post and crown
4. Suggest apical surgery
5. Suggest referral to a specialist for assessment and possible treatment
6. Suggest extraction and replacement with an implant
7. Suggest extraction and replacement with a bridge

3. Temporary protection of the root-filled tooth

a) In cases where you monitor the outcome of a root filling over a longer period of time, what do you use as a long-term temporary dressing/replacement before you proceed with permanent restoration of the tooth?

b) When you are restoring a root-filled tooth with a laboratory-fabricated crown, what do you use as a temporary replacement between appointments?

Indicate with a cross the alternatives you would choose.

	a) for long-term temporary restoration	b) as a dressing between impression taking and cementation of permanent crown
Coltosol	❏	❏
Zinc oxide-eugenol	❏	❏
IRM	❏	❏
Cavit	❏	❏
Praders cement	❏	❏
Glass ionomer cement	❏	❏
Composite	❏	❏
Fermit	❏	❏
Methyl methacrylate	❏	❏
Temporary cement	❏	❏
Phosphate cement	❏	❏
Nobetec	❏	❏
Temporary crown	❏	❏

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