

Single versus multiple visits for endodontic treatment of permanent teeth (Review)

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This record should be cited as:

Figini L, Lodi G, Gorni F, Gagliani M. Single versus multiple visits for endodontic treatment of permanent teeth. *Cochrane Database of Systematic Reviews* 2007, Issue 4. Art. No.: CD005296. DOI: 10.1002/14651858.CD005296.pub2.

This version first published online: 17 October 2007 in Issue 4, 2007.

Date of most recent substantive amendment: 21 August 2007

ABSTRACT

Background

Root canal treatment (RoCT), or endodontic treatment, is a common procedure in dentistry. The main indications for RoCT are irreversible pulpitis and necrosis of the dental pulp caused by carious processes, tooth cracks or chips, or dental trauma. Successful RoCT is characterised by an absence of symptoms and clinical signs in teeth without radiographic evidence of periodontal involvement. The success of RoCT depends on a series of variables related to the preoperative condition of the tooth, as well as the endodontic procedures.

Objectives

To compare the effectiveness of single- and multiple-visit RoCT, measured as tooth extraction due to endodontic problems and radiological success.

To assess the difference in short- and long-term complications between single- and multiple-visit RoCT.

Search strategy

The following databases were searched for relevant trials: Cochrane Oral Health Group's Trials Register, CENTRAL, MEDLINE, and EMBASE. Handsearching was performed for the major oral medicine journals. References of included studies and reviews were checked. Endodontics experts were contacted through e-mail. No language limitations were imposed. Date of last search was 6th March 2007.

Selection criteria

Randomised and quasi-randomised controlled trials of patients needing RoCT were included. Surgical endodontic treatment was excluded. The outcomes considered were the number of teeth extracted for endodontic problems; radiological success after at least 1 year, that is, absence of any periapical radiolucency; postoperative pain; painkiller use; swelling; or sinus track formation.

Data collection and analysis

Data were collected using a specific extraction form. The validity of included studies was assessed on the basis of allocation concealment, blindness of the study, and loss of participants. Data were analysed by calculating risk ratios. When valid and relevant data were collected, a meta-analysis of the data was undertaken.

Main results

Twelve randomised controlled trials were included in the review. Four studies had a low risk of bias, four a moderate risk, and another four had a high risk of bias. The frequency of radiological success and immediate postoperative pain were not significantly different between single- and multiple-visit RoCT. Patients undergoing single-visit RoCT reported a higher frequency of painkiller use and swelling, but the results for swelling were not significantly different between the two groups. We found no study that included tooth loss and sinus track formation among its primary outcomes.

Authors' conclusions

No difference exists in the effectiveness of RoCT, in terms of radiological success, between single- and multiple-visit RoCT. Most short- and long-term complications are also similar in terms of frequency, although patients undergoing a single visit may experience a slightly higher frequency of swelling and are significantly more likely to take painkillers.

PLAIN LANGUAGE SUMMARY

Single versus multiple visits for endodontic treatment of permanent teeth

Root canal treatment or endodontic treatment, is a common procedure in dentistry. The main indications for root canal treatment are irreversible inflammation of the dental pulp (pulpitis) and death of the dental pulp caused by carious processes, tooth cracks or chips, or dental trauma. Successful root canal treatment is characterised by an absence of symptoms and clinical signs in teeth without radiographic evidence of periodontal involvement. The success of root canal treatment depends on a series of variables related to the preoperative condition of the tooth, as well as the endodontic procedures.

No difference exists in the effectiveness of root canal treatment, in terms of radiological success, between single- and multiple-visit root canal treatment. Most short- and long-term complications are also similar in terms of frequency, although patients undergoing a single visit may experience a slightly higher frequency of swelling and are significantly more likely to take painkillers.

BACKGROUND

Root canal treatment (RoCT), or endodontic treatment, is a common procedure in dentistry. The main indications for RoCT are irreversible pulpitis and necrosis of the dental pulp caused by carious processes, tooth cracks or chips, or dental trauma. Root canal treatment is a procedure performed to remove organic tissue, infected debris, and pathogenic bacteria from the root canal system by means of mechanical instrumentation associated with copious irrigation with disinfectant agents. After drying, the endodontic space is filled with an intracanal filling usually made from root canal cement and gutta-percha, a rubber-based material. The placement of a safe coronal seal completes the RoCT procedure. All these procedures have been summarised by Orstavik 1998; the basic biological rationale for achieving final success of RoCT consists primarily of eliminating microorganisms from the entire root canal system. Different therapeutic procedures can be employed, depending upon the biological condition of the tooth being treated, its pathological state, clinician expertise, instrument availability, and patient preference. Successful RoCT is characterised by the absence of symptoms and clinical signs of infection in a tooth without radiographic evidence of periodontal involvement (Friedman 2002). The success of RoCT depends on a series of variables related to the preoperative condition of the tooth, as well as the endodontic procedures.

Root canal treatment can be followed by numerous short- and long-term complications (Battrum 1996). The former include immediate postoperative inflammation of periradicular tissues associated with pain, either spontaneous or provoked. The correlation of postoperative pain with different variables, including the number of visits needed to complete RoCT, operative procedures,

pulp vitality, and dental anatomy, has been the objective of numerous studies (Albashaireh 1998; DiRenzo 2002; Eleazer PD 1998; Gambarini 1991; Pekruhn 1981; Roane 1983; Soltanoff 1978). The main long-term complications include the persistence of inflammation and/or fistula or sinus track, pain, and an absence of radiographic healing. Several studies have investigated the frequency of radiographic healing in teeth with preoperative periapical pathology and have compared single- and multiple-visit approaches, employing interappointment medication (Katebzadeh 2000; Peters 2002; Soltanoff 1978; Trope 1999; Weiger 2000). The results of such investigations have led to conflicting conclusions. Some studies (Fava 1995) have suggested that the use of different medications in between visits can contribute to the elimination of all bacteria. In contrast, others have emphasised the need to seal the endodontic space in a single visit, as temporary cements are unreliable in maintaining a good coronal seal during the time between visits. In addition, postoperative complications have been reported with both methods, varying from 5% (Abbott 2000) to > 20% (Friedman 1995).

The aim of this review was to clarify whether completion of root canal treatment in a single visit or over a few visits, employing bacteriostatic or bactericidal medications, makes any difference in term of efficacy or complications or both.

OBJECTIVES

To test the null hypothesis that no difference exists in effectiveness, measured as tooth loss and radiological failure, between single- and multiple-visit root canal treatment (RoCT).

To test the null hypothesis that no difference exists in short- and long-term complications between single- and multiple-visit RoCT. To investigate whether single- and multiple-visit RoCT offer similar prognosis for pulpitic teeth (vital), necrotic teeth, or previously treated teeth.

CRITERIA FOR CONSIDERING STUDIES FOR THIS REVIEW

Types of studies

Randomised and quasi-randomised (i.e. those using an alternative assignment based on, for example, birth date) controlled trials with a minimal follow up of 12 months for evaluation of the final outcome. The same study designs were considered without any limitations in the follow-up evaluation of long- and short-term complications. Split-mouth studies were also considered.

Types of participants

Patients aged > 10 years who underwent root canal treatment. All subjects had teeth with a completely formed apex and without internal reabsorption.

Types of intervention

Root canal treatment in single or multiple visits, i.e. two or more appointments.

No difference in systemic medical treatment (antibiotics, non-steroidal anti-inflammatories or analgesics) could be present in the two groups.

Types of outcome measures

The outcome measures for effectiveness were the following.

- Tooth extraction due to endodontic problems (binary, yes/no).
- Radiological failure after 1 year, i.e. the presence of any periapical radiolucency (binary, yes/no). 'Additional Table 01' summarises how we adapted the most common scales of radiological success to a binary outcome.

The outcome measures for complications were the following.

- Postoperative pain (binary, yes/no).
- Swelling (binary, yes/no).
- Painkiller use (binary, yes/no).
- Sinus track or fistula formation (binary, yes/no).

SEARCH METHODS FOR IDENTIFICATION OF STUDIES

See: Cochrane Oral Health Group methods used in reviews.

The following databases were searched for relevant trials:

Cochrane Oral Health Group's Trials Register (to March 2007)
Cochrane Central Register of Controlled Trials (CENTRAL) (*The Cochrane Library* 2007, Issue 1)
MEDLINE (1966 to March 2007)
EMBASE (1974 to March 2007).

Studies to include in the review were searched for in MEDLINE using the PubMed software and the following search strategy. The numbers in parentheses indicate the number of records retrieved in PubMed on 6th March 2007:

- #1Search endodontic* (11565)
- #2Search root canal therapy (13439)
- #3Search dental pulp capping OR pulpectomy OR pulpotomy (3025)
- #4Search endodontic* OR pulpectom OR pulpotom (11565)
- #5Search root canal (therapy OR treat) (11407)
- #6Search (pulp AND cap*) OR (pulp* AND devitali*) (1104)
- #7Search single AND (visit* OR appointment* OR session*) (10572)
- #8Search multi AND (visit* OR appointment* OR session*) (1302)
- #9Search (first OR second OR third) AND (visit* OR appointment* OR session*) (31650)
- #10Search (1st OR 2nd OR 3rd) AND (visit* OR appointment* OR session*) (1751)
- #11Search (one OR two OR three) AND (visit* OR appointment* OR session*) (66975)
- #12Search #7 OR #8 OR #9 OR #10 OR #11 (83203)
- #13Search #1 OR #2 OR #3 OR #4 OR #5 OR #6 (22020)
- #14Search #12 AND #13 (401)

This strategy was adapted for the other databases.

The following journals were identified as being important for conducting manual searches to include in this review, when these had not already been searched as a part of the Cochrane Journal Handsearching Programme (*check* at www.ohg.cochrane.org in the Journal Handsearching Programme section to know which journals are handsearched):

Giornale Italiano di Endodonzia, Revue Française de Endodontie, German Endodontie, Endodontic Practice.

Proceedings from major dental organisations International Federation on Endodontic Associations (IFEA), European Society of Endodontology (ESE), Italian Endodontic Society (SIE), International Association for Dental Research (IADR), British Endodontics Society, Brazilian Endodontics Society from 1980 to 2004.

Studies in all languages were considered for translation.

All references in the identified papers were checked and the authors contacted to identify any additional published or unpublished data.

METHODS OF THE REVIEW

The titles and abstracts (when available) of all reports identified through the electronic searches were scanned independently by two review authors (Massimo Gagliani (MG) and Lara Figini (LF)). For studies appearing to meet the inclusion criteria, or for which insufficient data were in the title and abstract to make a clear decision, the full report was obtained. The full reports obtained from all the electronic databases and other methods of searching were assessed independently by two review authors (MG and LF) to establish whether the studies met the inclusion criteria. Any disagreements were resolved by discussion. A third individual (Giovanni Lodi (GL)) was consulted if unresolved disagreements occurred.

All studies meeting the inclusion criteria underwent a validity assessment and data extraction. The validity of the studies was judged according to the criteria for randomised trial data suggested by the *Cochrane Handbook for Systematic Reviews of Interventions* 4.2.6 (updated September 2006) (Higgins 2006) and *Evidence-Based Medicine: How to practice and teach EBM* (Sackett 1997). In particular, study validity was judged on the basis of the following.

(1) Allocation concealment, recorded as (A) Adequate (criterion met), (B) Unclear, or (C) Inadequate (criterion unmet), as described in the *Cochrane Handbook for Systematic Reviews of Interventions* 4.2.6.

(2) Participant loss. At least 80% of the patients who entered the trial were included in the final analysis: (A) Yes (criterion met), (B) No (criterion unmet), or (C) Unclear.

The global validity of the studies was assessed using the following three categories.

(1) Low risk of bias: all of the criteria met.

(2) Moderate risk of bias: not all cases included in categories (1) or (2).

(3) High risk of bias: one or more criteria unmet.

The critical appraisal of the studies was carried out by two review authors (MG and LF) without concealing the names of authors, institutions, and medical journals. Data about the study, its eligibility, validity, design, and outcome were recorded by each review author on a custom-designed form. In case of disagreement, consensus was sought out through discussion, and a new form was consequently filled out.

In cases when valid and relevant data were collected, a meta-analysis of the data was undertaken. For each intervention, statistical analyses evaluated differences among the outcomes considered. Dichotomous data were expected for the main outcome measurements. To compare dichotomous data risk ratio was employed. A meta-analysis could only be conducted if the studies were judged sufficiently similar in terms of design, types of patient, and interventions. In addition, heterogeneity between trial results was tested using a standard chi-squared test. A standard result model was used in the statistical analyses.

The patient was the statistical unit. Studies considering the tooth as the statistical unit were considered in cases where the number of teeth was not too much larger than the number of patients. During interpretation of results, it was noted that when data from teeth were included, the confidence interval is narrower than it should be.

When raw data were not available, they were obtained by consulting tables and graphs, or by contacting the authors.

Subgroup analysis was planned to investigate the relevance of pretreatment conditions (vital teeth versus necrotic pupal teeth), pretreatment symptoms (symptomatic versus asymptomatic teeth), pretreatment radiographic periapical appearance (apical radiolucency versus no apical radiolucency), endodontic technique, and antimicrobials employed (antimicrobial A versus antimicrobial B).

A sensitivity analysis was performed, excluding the studies of lower methodological quality (i.e. studies with an elevated risk of bias).

DESCRIPTION OF STUDIES

Fifty-four potentially eligible randomised controlled trials were identified; 41 were excluded (*see* 'Characteristics of excluded studies' table), and one is awaiting assessment (Papworth B 1998), leaving 12 studies to be included in this review. All studies compared root canal treatment (RoCT) performed in a single visit to root canal treatment performed in multiple visits. In the multiple-visit approach, the majority of authors completed the treatment in two visits (Al-Negrish 2006; Albashaireh 1998; DiRenzo 2002; Gesi 2006; Ghoddusi 2006; Peters 2002; Trope 1999; Weiger 2000; Yoldas 2004), while in one study RoCT lasted three visits (Mulhern 1982). In two studies the number of visits is not specified (Oginni 2004; Soltanoff 1978). All studies had a two-arm design, with the exception of two studies with three arms, in which the authors compared a single visit, multiple visits without intracanal medication, and multiple visits with intracanal medication (calcium hydroxide) (Ghoddusi 2006; Trope 1999). In order to include such data in the meta-analysis we decided to combine the two multivisit arms, we considered it acceptable as in the same meta-analysis we pooled data from studies that used or did not use a dressing.

All studies considered one tooth per patient, with the exception of Oginni 2004 and Trope 1999. Trope 1999 considered 102 teeth in 81 patients (61 patients had a single tooth, 18 had two and 2 patients had three teeth). In Oginni 2004 patients requiring root canal treatment on more than one tooth, underwent consecutive treatment of each tooth with an interval at least 4 weeks to allow proper evaluation. There were 283 teeth randomised in 255 patients. For each study (Oginni 2004; Trope 1999) the analysis was conducted at the level of the tooth (consideration was given to the width of the confidence interval).

Al-Negrish 2006; Ghoddusi 2006; Mulhern 1982; Peters 2002; Trope 1999; Weiger 2000 included patients with necrotic teeth only, Yoldas 2004 is the only one that included only retreatment, while Gesi 2006 included only patients with vital teeth. Three studies included both necrotic teeth and vital teeth (Albashaireh 1998; DiRenzo 2002; Oginni 2004), but two of them did not provide details on the numbers of the two categories (DiRenzo 2002; Oginni 2004). One study did not provide details on the pretreatment status (Soltanoff 1978).

In the multiple-visit approach, five studies (Albashaireh 1998; DiRenzo 2002; Ghoddusi 2006; Mulhern 1982; Trope 1999) did not use any intracanal medications in the interappointment period. In five studies (Al-Negrish 2006; Gesi 2006; Peters 2002; Weiger 2000; Yoldas 2004), the root canals were medicated with a calcium hydroxide paste, while two studies did not specify the type of interappointment medication (Oginni 2004; Soltanoff 1978). In nine studies, sodium hypochlorite was used as an irrigant (Al-Negrish 2006; Albashaireh 1998; DiRenzo 2002; Gesi 2006; Mulhern 1982; Peters 2002; Trope 1999; Weiger 2000; Yoldas 2004), and in two studies, saline solution was used as irrigant (Ghoddusi 2006; Soltanoff 1978). In the study of Oginni 2004, the type of irrigant used was not specified.

We found no study providing information on tooth extraction due to endodontic problems as outcome measure.

Radiological failure was investigated in five studies (Gesi 2006; Peters 2002; Soltanoff 1978; Trope 1999; Weiger 2000). Methods adopted to construct scales for radiological success or failure are shown in 'Additional Table 01.' Follow up varied from 1 (Trope 1999) to 5 (Weiger 2000) years.

Eight studies investigated postoperative pain (Al-Negrish 2006; Albashaireh 1998; Gesi 2006; Ghoddusi 2006; Mulhern 1982; Oginni 2004; Soltanoff 1978; Yoldas 2004). The methods for evaluating postoperative pain are summarised in the 'Characteristics of included studies' table. We dichotomised all data into 'pain' or 'no pain' values. We considered only pain after canal obturation, assessing pain incidence in the canal in the immediate postobturation period (until 72 hours), at 1 week, and at 1 month. We did not consider pain during the interappointment period in the multiple-visit approach, as we could not compare this with a similar situation in the single-visit approach.

Six studies investigated the incidence of swelling or flare-up or both (Al-Negrish 2006; DiRenzo 2002; Ghoddusi 2006; Mulhern 1982; Oginni 2004; Yoldas 2004). The definitions of flare-up can vary (see 'Additional Table 02'). Only DiRenzo 2002; Mulhern 1982 and Ghoddusi 2006 clearly defined flare-up as swelling. Therefore, we considered only studies clearly indicating swelling as an outcome. We considered swelling incidence in the operative and postoperative periods.

Three studies examined the need for patients to take analgesics to relieve pain (Mulhern 1982; Soltanoff 1978; Yoldas 2004).

We found no studies providing information on fistula or sinus track formation as outcome measure.

All the studies were performed in university clinics or hospitals, with the exception of Gesi 2006, which was undertaken in private practice. In all studies, the treatment was conducted by expert endodontists, except for DiRenzo 2002 and Mulhern 1982, in which the treatment was performed by postgraduate students, and for Ghoddusi 2006, in which the operators were general practitioners. Oginni 2004; Soltanoff 1978; Trope 1999 and Yoldas 2004 did not provide details about the operators.

METHODOLOGICAL QUALITY

On the basis of the criteria used in the critical appraisal, four studies were shown to have a low risk of bias (DiRenzo 2002; Gesi 2006; Trope 1999; Weiger 2000). Four studies were judged as having a moderate risk of bias (Ghoddusi 2006; Mulhern 1982; Oginni 2004; Soltanoff 1978), and in these studies, the allocation concealment was not described. The remaining studies (Al-Negrish 2006; Albashaireh 1998; Peters 2002; Yoldas 2004) were considered as posing a high risk of bias. In three of these (Al-Negrish 2006; Albashaireh 1998; Peters 2002), the randomisation was inadequate for alternative assignment (randomly and consecutively, quasi-random method), and in Yoldas 2004, the randomisation was not explained in a satisfactory way. In all the included studies, > 80% of the patients who enrolled were included in the final analysis.

RESULTS

No study reported tooth extraction due to endodontic problems or fistula or sinus track formation.

Pain (Comparison 01 Outcome 01)

Postoperative pain (up to 72 hours)

Results from six studies (Al-Negrish 2006; Albashaireh 1998; Ghoddusi 2006; Mulhern 1982; Oginni 2004; Soltanoff 1978) that included 1047 patients were available for the analysis of pain incidence 72 hours after canal obturation. Between-study heterogeneity was assessed using the standard chi-squared (χ^2) test and I-squared (I^2) test. The studies were homogeneous (χ^2 8.68; degrees of freedom (df) 5; $P = 0.12$; I^2 42.4%), and a meta-analysis was performed on the combined data. Incidence of postoperative pain at 72 hours was similar in the two groups (risk ratio (RR) 0.99 (95% confidence interval (CI) 0.83 to 1.18)). Sensitivity analyses performed on four studies (Ghoddusi 2006; Mulhern 1982; Oginni 2004; Soltanoff 1978) corroborated the previous result.

Pain at 1 week

Results from five studies (Al-Negrish 2006; Gesi 2006; Mulhern 1982; Oginni 2004; Soltanoff 1978) that included 936 patients were available for analysis of pain at 1 week. The studies were homogeneous (χ^2 3.73; df 4; $P = 0.44$; I^2 0%), allowing data

pooling. One-week postoperative pain was less common following multiple-visit root canal treatment (RoCT) compared to single-visit treatment, but the difference was not statistically significant (RR 1.07 (95% CI 0.72 to 1.57)). Sensitivity analyses performed on four studies (Gesi 2006; Mulhern 1982; Oginni 2004; Soltanoff 1978) corroborated this result (RR 1.17 (95% CI 0.78 to 1.76)).

Pain at 1 month

Only two studies reported pain 1 month after canal obturation (Albashaireh 1998; Oginni 2004). In both studies, no patient had persistent pain at 1 month. Thus, a meta-analysis of the studies was not possible.

Results from Yoldas 2004 were excluded from pain meta-analysis because the pain data were not divided according to time of onset. Single- and multiple-visit RoCT showed no significant difference in incidence of pain (RR 1.88 (95% CI 0.87 to 4.07)). The incidence of pain was greatest during the first 48 hours after obturation, and then decreased steadily in the subsequent 7 days. Of the 227 patients enrolled in the study, 68 had symptomatic and 159 had asymptomatic teeth. When data were analysed to consider the presence of symptoms before RoCT, postoperative pain was found significantly more often in patients with symptomatic teeth.

Painkiller use (Comparison 01 Outcome 02)

Results from three studies (Mulhern 1982; Soltanoff 1978; Yoldas 2004), including 559 patients, were available for the analyses. In all three studies use of painkillers after canal obturation was more common among patients undergoing the single-visit approach. Studies were homogeneous ($\chi^2 1.31$; $df 2$; $P = 0.52$; $I^2 0\%$). Meta-analysis showed that use of painkillers was significantly more common in patients undergoing single-visit RoCT (RR 2.42 (95% CI 1.62 to 3.62)). This was confirmed also by sensitivity analysis (RR 2.36 (95% CI 1.51 to 3.66)) including two studies (Mulhern 1982; Soltanoff 1978).

Gesi 2006; Ghoddsi 2006 and Mulhern 1982 reported pain incidence in the interappointment period of the multiple-visit procedure, such data are not included in the meta-analysis, as they cannot be compared with a similar outcome of the single-visit approach.

Radiological failure (Comparison 01 Outcome 03)

Results from five studies (Gesi 2006; Peters 2002; Soltanoff 1978; Trope 1999; Weiger 2000) that included 657 patients were available for the meta-analysis. The radiological failure rate was based on binary data, that is, radiological healing versus lack of such healing; scores including more than two values were dichotomised according to the methods indicated in 'Additional Table 01.' The studies included were homogeneous ($\chi^2 3.41$; $df 4$; $P = 0.49$; $I^2 0\%$), and following data pooling, single-visit RoCT appeared to be slightly more effective than multiple-visit RoCT, although the difference was not statistically significant (RR 0.85 (95% CI 0.59 to 1.23)). These results were corroborated by sensitivity analyses performed in the four studies (RR 0.88 (95% CI 0.60 to 1.30)).

Swelling (Comparison 01 Outcome 04)

We could not compare all the studies reporting flare-up (*see* 'Additional Table 02') because they did not provide a comparable definition of flare-up. Many studies included both swelling and severe pain in the definition of flare-up, so it was not possible to discriminate these data. Only three studies considered flare-up as swelling (DiRenzo 2002; Ghoddsi 2006; Mulhern 1982); these included 192 patients, and data were available for analysis. The studies were homogeneous ($\chi^2 1.67$; $df 2$; $P = 0.43$; $I^2 0\%$), and swelling appeared to be less common with multiple-visit RoCT than with single-visit RoCT, but the difference was not statistically significant (RR 1.40 (95% CI 0.67 to 2.93)).

Subgroup analysis in necrotic teeth

We repeated the analysis, dividing the studies according to pre-treatment status. We found seven studies (Al-Negrish 2006; Ghoddsi 2006; Mulhern 1982; Peters 2002; Trope 1999; Weiger 2000; Yoldas 2004) that included only necrotic teeth and one study that included only vital teeth (Gesi 2006). In addition, it was possible to extract data regarding vital teeth from another study (Albashaireh 1998). Data pooling was possible only for studies including necrotic teeth, as those with vital teeth had non-comparable outcomes. Incidence of pain remained non-significantly different when necrotic teeth were considered, although it was less common with the single-visit approach. Radiological failure was less common after a single visit and the result was close to statistical significance (RR 0.62 (95% CI 0.37 to 1.02)). The results for swelling and any complications were not affected by this subgroup analysis.

There were insufficient data to undertake subgroup analyses on other predefined criteria.

DISCUSSION

The main objective for an endodontist undertaking root canal treatment (RoCT) is to be successful in terms of preventing, and when necessary, healing endodontic diseases, such as apical periodontitis, and avoiding patient discomfort in the process if possible. The basic biological rationale for achieving ultimate success with RoCT consists primarily of eliminating microorganisms from the entire root canal system and creating an environment that is most favorable for healing. Several studies have shown that it is very difficult to achieve a bacteria-free root canal system, even after adequate cleaning, shaping, and irrigation (Bystrom 1981; Orstavik 1991; Sjogren 1997). Two approaches have been proposed to solve this problem. In one case, residual bacteria are eliminated or prevented from repopulating the root canal system by introducing an interappointment dressing into the root canal, generally falling into the following categories: phenolic derivatives (eugenol, camphorated para-monochlorophenol, camphorated phenol, metacresyl acetate, beechwood creosote), aldehydes (formocresol), halides (iodine-potassium iodide), calcium hydrox-

ide, antibiotics, and various other combinations. The most popular intracanal medication currently in use is calcium hydroxide. Some studies (Kvist 2004; Orstavik 1991; Reit 1988) have shown that calcium hydroxide fails to produce sterile root canals and even allows regrowth in some cases. However, even a negative culture before obturation gives no guarantee of healing in all cases (Sjogren 1997; Trope 1999; Weiger 2000). The second approach is aimed at eliminating the remaining bacteria or rendering them harmless by entombing them by complete and three-dimensional obturation, finishing the treatment in one visit, to deprive the microorganisms of nutrition and the space required to survive and multiply (Oliet 1983; Soltanoff 1978; Weiger 2000). The antimicrobial activity of the sealer or the zinc (Zn) ions of gutta-percha can kill the residual bacteria (Moorer 1982; Siqueira 2000).

Endodontic success indicators can be short or long term. The short-term indicators concern the absence of any postoperative discomfort, the most important short-term outcome of RoCT. Pain perception is highly subjective and modulated by multiple physical and psychological factors, and the measurement of pain is fraught with hazards and opportunities for errors. The level of discomfort must be rated in categories arranged in advance and exactly described (slight pain: the tooth involved was slightly painful for a time, regardless of duration, but no need existed to take analgesics). This is stated in Al-Negrish 2006; Albashairah 1998; Oginni 2004 and Yoldas 2004, who gave accurate criteria for the categories of patient pain; however, it was not given by Mulhern 1982 and Soltanoff 1978, who were more imprecise in their definition of different pain categories. For this reason, we considered only two categories (pain and no pain), and we did not consider pain intensity because it is too subjective. According to our review, the incidence of postobturation pain is similar with single- and multiple-visit RoCT, although painkiller use is significantly less in patients undergoing multiple-visit RoCT. It is possible that in the single-visit approach the working time is longer, causing a more severe acute inflammatory response in the interappointment period. Another factor could be the beneficial effect of the intracanal medication in the between-visit interval.

Incidence of short-term swelling (another sign of infectious complication) was lower with the multiple-visit approach. Note that in the three studies considering this outcome (DiRenzo 2002; Ghoddsi 2006; Mulhern 1982), all teeth undergoing RoCT had necrotic pulp. DiRenzo 2002 and Mulhern 1982 gave conflicting results for the incidence of swelling; both used 2.5% sodium hypochlorite as an irrigant, and no intracanal interappointment medication with the multiple-visit approach, closing the empty canals only with a sterile dry cotton pellet and a temporary restoration for 1 week. In any case, the incidence of swelling in these two studies was very small (two episodes in Mulhern 1982 and only one in DiRenzo 2002). The Ghoddsi 2006 study is of particular interest. In fact, when no interappointment canal medication was employed, the incidence of swelling was very similar in the two groups, while when calcium hydroxide was left in the canals

between visits, the multiple-visit treatment performed much better. Such a difference may have occurred because normal saline solution was used as the sole irrigant during RoCT. Thus, with the single-visit approach, nothing with any antibacterial activity was included in the RoCT. While with the multiple-visit treatment employing interappointment medication, antibacterial activity was provided by calcium hydroxide.

Long-term success is based mainly on the healing of periapical lesions whenever present, and the prevention of new lesions. The healing rate can be established by radiographic interpretation, a method very dependent on human visual perception. Trope 1999 was the only study that performed an extensive calibration of the evaluators (nine observers: four graduate oral and maxillofacial radiology residents, two graduate endodontic residents, one oral epidemiologist, one general dentist, and one experienced endodontist, all blinded to the treatment groups and aims of the study). In Weiger 2000 the radiographs were judged by both dentists involved in the study in a blinded manner. Peters 2002 reported that three experienced endodontists who had not been involved in the treatment or follow up were asked to analyse the radiographs. Radiological success was more common in the single-visit group, although the result did not reach statistical significance. It became significant, however, when only necrotic teeth were considered; therefore, intracanal interappointment medication may be unnecessary when the operator, during a single visit, carefully cleans the canals with an adequate irrigant. It is accepted that multiple visits are appropriate for symptomatic teeth with long-standing chronic periapical lesions, and for those undergoing retreatment, based on the rationale that placing an interim dressing of an iodine-calcium hydroxide combination is known to be effective against *Streptococcus faecalis*, an organism commonly found in failed cases. Unfortunately, we could not investigate this question in this review because only one study (Yoldas 2004) considered retreatment, and it had a high risk of bias.

Thus, the effectiveness of single- and multiple-visit root canal treatment is not substantially different. Most short- and long-term complications are similar in terms of frequency, although patients undergoing single-visit RoCT may experience a higher frequency of swelling and are more likely to take analgesics. Our results with healing reveal that single-visit RoCT appears to be slightly more effective than multiple-visit RoCT, without the difference reaching statistical significance, and very similar results were obtained by another systematic review (Sathorn 2005).

AUTHORS' CONCLUSIONS

Implications for practice

There is no evidence to suggest that one treatment regimen (single-visit or multiple-visit root canal treatment) is better than the other. Neither can prevent 100% of short- and long-term complications.

It is likely that the benefit of a single-visit treatment, in terms of time and convenience, for both patient and dentist, has the cost of a higher frequency of late postoperative pain (and as a consequence, painkiller use) and swelling.

Implications for research

Because of the increasing use of rotary nickel-titanium (NiTi) instruments, a well designed randomised controlled trial comparing single-visit and multiple-visit root canal treatment, both performed with such instruments, would be an important contribution.

It would be very helpful for clinicians that researchers include in their studies tooth loss as primary outcome, even reporting if none occur.

POTENTIAL CONFLICT OF INTEREST

None know.

ACKNOWLEDGEMENTS

The review authors wish to thank Emma Tavender, Luisa Fernandez, Sylvia Bickley and Marco Esposito for their support. Dr Cristina Frezzini for her help in retrieving papers. All the researchers of the cited studies who have provided some of the data useful in the review and the referees for their precious suggestions. A special thanks to Silvia Motta for translation from Russian language and to Hu Luca for translation from Chinese.

SOURCES OF SUPPORT

External sources of support

- No sources of support supplied

Internal sources of support

- No sources of support supplied

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TABLES

Characteristics of included studies

Study	Al-Negrish 2006
Methods	Quasi-randomised parallel-group, clinical trial; high risk of bias. 93.3% of patients who entered the study were included in the final analysis.
Participants	120 participants (66 female and 54 males) aged 15–45 years. 8 patients (6 females and 2 males, 6 from Group 1 and 2 from Group 2) were excluded from the analysis of the results as they failed to attend postoperative visits. Inclusion criteria: patients with asymptomatic necrotic central incisor teeth. Exclusion criteria: any evidence of periapical radiolucent lesion, teeth tender to touch, with intracanal calcification or incompletely formed apices, retreatments, teeth with pulpal sensitivity and vitality. Diagnostic criteria for pulpally or periapical disease: Rx signs, pulp testing, presence or absence of haemorrhage upon access opening.

Characteristics of included studies (Continued)

Interventions	Single visit (Group 1) or multiple visits (Group 2). Rubber dam isolation. Use of magnification loupes not specified. Canal shaping: step-back technique with conventional K files and gates. Irrigation: 2.5% sodium hypochlorite. Working length determined by Rx, obturation with gutta-percha and a zinc oxide eugenol sealer (Tubliseal, Kerr) in lateral condensation. In the Group 2 the number of visits were 2 (the second appointment 7 days later), the canals were medicated for 7 days with a calcium hydroxide paste with a dry sterile cotton pledget and a temporary filling restoration.
Outcomes	Pain (after 2-day postobturation period, and after 7-day postobturation period) was reported as: 1 no pain, 2 slight pain, 3 moderate pain, 4 severe pain. We considered only 2 categories: No pain and pain (slight, moderate and severe pain). Flare-up: percentage of patients experiencing moderate to severe pain evaluated after 2 and 7 days (see 'Additional Table 02').
Notes	
Allocation concealment	C – Inadequate

Study **Albashaireh 1998**

Methods	Quasi-randomised parallel-group, clinical trial; high risk of bias. 97% of patients who entered the study were included in the final analysis.
Participants	300 participants, 291 were included in the final analysis. Sex not reported, age range from 15 to 65. All patients referred to the Conservation Unit (Jordan University of Science and Technology) for conventional endodontic treatment during the period of the investigation (30 days), were included in the study. Exclusion criteria: teeth tender to touch, with extensive intracanal calcification and incompletely formed apices. Diagnostic criteria for pulpal or periapical disease: pulpal vitality and sensitivity (pulp-testing and direct presence or absence of haemorrhage), presence of periapical radiolucency in periapical radiographs.
Interventions	Single visit (Group 1) or multiple visits (Group 2). 1 operator. Rubber dam isolation, use of magnification loupes and working length not reported. Canal shaping with step-back technique, obturation with gutta-percha and a calcium hydroxide-based root canal sealer (Sealapex) with lateral condensation technique. Irrigation with 2.6% sodium hypochlorite solution. In Group 2 no medicament was placed, but a dry sterile cotton pledget sealed in pulp chamber with a temporary filling restoration.
Outcomes	Pain (incidence and degree of pain at the 1st, and 30th postobturation day) was reported as: 1 no pain, 2 slight pain, 3 moderate pain, 4 severe pain. We considered only 2 categories: no pain and pain (slight, moderate and severe pain).
Notes	
Allocation concealment	C – Inadequate

Study **DiRenzo 2002**

Methods	Randomised, parallel-group, clinical trial. Low risk of bias. 90% of patients who entered the study were included in the final analysis.
Participants	80 participants, 72 were included in the final analysis. Sex and ethnic group not reported. Age of patients: over 18 years old. Inclusion criteria: mature vital and non-vital permanent maxillary and mandibular molars. Exclusion criteria: pregnancy, use of antibiotics or corticosteroids at the time of treatment, immunocompromised states, subjects under 18 years old. Diagnostic criteria for pulpal or periapical disease not specified.
Interventions	Single visit (Group 1) or multiple visits (Group 2). 2 operators (postgraduate students). Rubber dam isolation. Use of magnification loupes not specified. Canal shaping with hand files and NiTi rotary files. Irrigation with 2.5% NaOCl. Working length determined by an electronic apex locator and 2 or more angled radiographs. Obturation with gutta-percha and Roth 811 sealer in lateral condensation. In the Group 2 the treatment were done in 2 visits, and the teeth in the interappointment period were closed with a sterile dry cotton pellet and Cavit temporary restorative cement.

Characteristics of included studies (Continued)

Outcomes	Pain: a modified VAS was used to measure pain at 6, 12, 24, 48 hours after the first appointment. Flare-up (as swelling that needs antibiotics and narcotic analgesics) (see 'Additional Table 02').
Notes	We were not able to extract the dichotomous data from the tables that reported VAS pain measurements. We sent an e-mail to authors to ask for these data. No answer obtained so we considered only result in flare-up.
Allocation concealment	A – Adequate

Study **Gesi 2006**

Methods	Randomised, clinical trial, low risk of bias. 100% of patients who entered the study were included in the final analysis of the outcome 'pain.' 71.8% of patients who entered the study were included in the final analysis of the outcome 'healing at 3 years follow up.'
Participants	256 participants, 244 were included in the final analysis. 141 females, 115 males. Range age and ethnic group not reported. Inclusion criteria: patients with teeth with painful and non-painful vital pulp, with bleeding upon access of the pulpal chamber. Exclusion criteria: patients with physical or mental disability, patients that took pain medications or in treatment with antibiotics for systemic or local infection. Diagnostic criteria for pulpal or periapical disease: vitality testing and thermal and mechanical stimulation.
Interventions	Single visit (Group 1) or multiple visits (Group 2). Single operator. Rubber dam. Use of magnification loupes not specified. Canal shaping: hand instrumentation with flexo-files using balanced force technique and crown-down technique. Irrigation: 3% sodium hypochlorite. Working length established by Rx. Obturation with gutta-percha and pulp canal sealer (Kerr) with lateral condensation. In the multiple approach the patients underwent 2 visits. In the interappointment period calcium hydroxide was employed as intracanal medication and Coltosol as temporary cement.
Outcomes	Pain: valuated at 1 week after canal obturation by clinical examination and by a verbal rating scale to assess pain experience. Patients with multivisit treatments were asked to evaluate their pain after 1 week for each visit. We considered pain-related data only after canal obturation. A verbal rating scale (VRS) graded 0-3 was used. Patients were asked to indicate 0 for no, 1 for mild, 2 for moderate and 3 for severe pain. Teeth were also tapped for percussion sensitivity. We considered only 2 categories: pain (mild, moderate, severe) and no pain. Healing: (follow up until 3 years): 2 endodontists, well experienced in radiographic assessment of endodontic treatments, neither of whom was the operator and both masked to the assigned treatment group, carried out the analysis of the radiographs. Parameters were presence or absence of periapical radiolucency (radiographic lesion) (see 'Additional Table 01'). In 2-or multirrooted teeth, the tooth was classified according to the diagnosis of the worst root.
Notes	
Allocation concealment	A – Adequate

Study **Ghoddusi 2006**

Methods	Randomised, parallel-group, clinical trial; moderate risk of bias. 85% of patients who entered the study were included in the final analysis.
Participants	69 patients enrolled, 60 were included in the final analysis. Of these subjects 2 were excluded because they did not pursue the treatment, 3 because of overfilling and 4 because of positive cavity test. 39 females and 30 males. Not specified age range and ethnic group. Inclusion criteria: patients with pulpally necrotised teeth referred to the Endodontics Department of Mashad Dental School. Exclusion criteria: patients taking some medication for systemic conditions. Diagnostic criteria for pulpal or periapical disease: thermal and electrical pulp test, pulp cavity test (direct presence or absence of haemorrhage), presence of periapical radiolucency in periapical radiographs.
Interventions	Single visit (Group 1) or multiple visits without any dressing (Group 2). Rubber dam isolation used. Use of magnification loupes and canal shaping not specified in a satisfactory way. Irrigation with saline solution. Working length evaluated by Rx, obturation with gutta-percha in lateral condensation. In the Group 2 after

Characteristics of included studies (Continued)

	the first appointment, the canal was left empty and the access cavities were sealed with sterilised cotton pellets and at least 3 mm of temporary filling material (Coltosol), the treatment was completed after 1 week.
Outcomes	Pain (incidence and degree of pain in the immediate canal postobturation until 72 hours) was reported as: 1 no pain, 2 mild pain, 3 moderate pain, 4 severe pain. We considered only 2 categories: no pain, and pain (mild, moderate and severe pain). Flare-up (swelling).
Notes	
Allocation concealment	B – Unclear

Study	Mulhern 1982
Methods	Randomised, clinical trial, moderate risk of bias. 100% of patients who entered the study were included in the final analysis.
Participants	60 participants, all of them were included in the final analysis: 31 females, 29 males. Range age from 13 to 75 years. Ethnic group reported: 1 Asian, 42 Whites and 17 Blacks. Inclusion criteria: non-surgical endodontic treatment of asymptomatic mature single-rooted teeth with necrotic pulps. Exclusion criteria: patients with severe medical conditions, using corticosteroids or anti-inflammatory drugs and/or recent or active antibiotics therapy. Diagnostic criteria for pulpal or periapical disease: Rx and vitality test.
Interventions	Single visit (Group 1) or multiple visits (Group 2). 2 operators (graduate endodontic students). Rubber dam. Use of magnification loupes and canal shaping not detailed. Irrigation: 2.5% sodium hypochlorite. Working length not reported. Obturation with lateral condensation was performed using gutta-percha and Kerr tubliseal. In the multiple approach the patients underwent 3 visits. In the interappointment period no medication was used, only a dry pledget of cotton with a double cement system of Cavit G and zinc oxyphosphate cement in the coronal access cavity was employed.
Outcomes	Pain: valuated at 48 hours after treatment (by a questionnaire) and at 1 week (clinical examination). Patients with multivisit treatment were asked to complete a questionnaire for each visit. Painkiller use. Flare-up (swelling) (see 'Additional Table 02').
Notes	
Allocation concealment	B – Unclear

Study	Oginni 2004
Methods	Randomised, clinical trial, moderate risk of bias. 85.86% of patients who entered the study were included in the final analysis about pain and flare-up in the 1st day; 80.21% of patients who entered the study were included in the final analysis about pain and flare-up in the 7th day; 78.4% of patients who entered the study were included in the final analysis at 30th day.
Participants	255 patients and 283 teeth were enrolled, 222 teeth were included in the final analysis about pain and flare-up. For patients with more than 1 tooth requiring treatment, the treatment of each tooth was separated by a period of at least 4 weeks. Sex, range or mean age, not reported. Inclusion criteria: all patients referred to the department of Restorative Dentistry for root canal therapy. Patients that did not turn up after the first appointment (incomplete treatment) were excluded from the study. Diagnostic criteria for pulpal or periapical disease: the pulp vitality was determined by an electric pulp tester in combination with the presence of pulpal haemorrhage.
Interventions	Single visit (Group 1) or multiple visits (Group 2). Rubber dam isolation, use of magnification loupes, canal shaping, irrigation, working length not reported. The root canals were obturated with multiple gutta-percha cones and a zinc oxide-eugenol based sealer, using the lateral condensation technique. Medication and number of visits in the multiple-visit treatment not reported.
Outcomes	Pain (incidence and degree of pain) at the 1st, 7th and 30th days postobturation. Pain was recorded as none, slight, or moderate/severe. We considered only 2 categories: pain (slight and moderate/severe), and no pain.

Characteristics of included studies (Continued)

Flare-up was defined as either patient's reporting pain not controlled with over-the-counter medication or increasing swelling or both (see 'Additional Table 02').

Notes

Allocation concealment B – Unclear

Study Peters 2002

Methods Quasi-randomised, clinical trial; high risk of bias. 97.44% of patients who entered the study were included in the final analysis.

Participants 39 participants, 38 were included in the final analysis. 19 females and 20 males, the mean age was 40 years and the range was from 19 to 86 years. Ethnic groups not specified. 1 patient lost (in the Group 2) because his series of radiographs for imperfections of radiographic technique was excluded. Inclusion criteria: root with 1 canal, teeth asymptomatic that did not respond to sensitivity testing and never had endodontic treatment, root that showed radiographic evidence of periapical bone loss. Exclusion criteria: maxillary molars, patients < 19 and > 86 years old. Diagnostic criteria for pulpal or periapical disease: Rx evaluated with PAI score, sensitivity testing.

Interventions Single visit (Group 1) or multiple visits (Group 2). 1 operator (endodontist). Use of rubber dam isolation and magnification loupes. Canal shaping: hand instrumentation by double flare technique. Irrigation: 2% sodium hypochlorite. Working length evaluated by Rx and electronic apex locator. Obturation: gutta-percha and AH 26 sealer in lateral condensation. In the Group 2 the number of visits were 2 (the second appointment 4 weeks later). In this group in the interappointment period the canals were dressed with a thick mix of calcium hydroxide in sterile saline and the cavity access filled with 2 layers of Cavit and a glass ionomer restoration.

Outcomes Healing (follow up 4.5 years). Routine evaluation during follow up: 3, 12, 24 months to 4.5 years. The authors evaluated the treatment outcome as: score A (success: the width and contour of the periodontal ligament is normal, or there is a slight radiolucent zone around excess filling material); score B (uncertain: the radiolucency is clearly decreased but additional follow up is not available); score C (failure: there is an unchanged, increased or new periradicular radiolucency). We considered only 2 categories: success (score A) and failure (score B and C) (see 'Additional Table 01).

Notes

Allocation concealment C – Inadequate

Study Soltanoff 1978

Methods Randomised, parallel-group, clinical trial; moderate risk of bias. 85.1% of patients who entered the study were included in the final analysis about pain and use of painkillers, 80.6% of patients who entered the study were included in the final analysis about healing. Study duration: 20 years.

Participants 330 participants, 281 were included in the final analysis about pain. Sex, range or mean age, ethnic group not reported. Inclusion and exclusion criteria not reported. Diagnostic criteria for pulpally or periapical disease not specified.

Interventions Single visit (Group 1) or multiple visits (Group 2). Rubber dam, use of magnification loupes, working length not reported. In multiple visits the medication and the total number of visits were not specified. In both groups sterile saline solution was used as irrigation, the canals were filled with gutta-percha cones and Ostby's Kloroperka as the cementing medium for lateral condensation.

Outcomes Pain (incidence, severity and duration: less than 1 day, 1 to 3 days, 4 to 7 days, more than 1 week). Pain was categorised as: no pain, mild pain, moderate pain, severe pain. We considered only 2 categories: no pain and pain (mild, moderate, severe pain). Healing (observed radiographically in periods ranging from 6 months to 2 years postoperatively). The criteria for success or failure were: healed (success) and non-healed (failure).

Notes

Allocation concealment B – Unclear

Characteristics of included studies (Continued)

Study	Trope 1999
Methods	Randomised, parallel-group, clinical trial; low risk of bias. 100% of patients who entered the study were included in the final analysis. Study duration: 1 year.
Participants	81 participants with 102 teeth (61 patients had a single teeth to treat, 18 had 2, 2 had 3). 54 females and 27 males had a mean age of 44.6 years, with a range of 19 to 79. Inclusion criteria: presence of radiographically demonstrable apical periodontitis on a single-rooted tooth or on 1 root with a single canal in a multirouted tooth. Exclusion criteria: patients with diagnosis of diabetes, HIV infection or other immunocompromising disease, patients < 16 or > 80 years old and teeth with 2/3 of the root canal treated before enrolment.
Interventions	Single visit (Group 1) or multiple visits without any dressing (Group 2). 1 operator, 9 observers (4 graduate oral and maxillofacial radiology residents, 2 graduate endodontic residents, 1 oral epidemiologist, 1 general dentist, 1 experienced endodontist) to evaluated radiographs using the PAI scoring system. Rubber dam isolation used. Use of magnification loupes and canal shaping not specified in a satisfactory way. Irrigation with 2.5% NaOCl. Working length evaluated by Rx, obturation with gutta-pecha and Roth 801 sealer in lateral condensation. In the Group 2 the instrumentation was completed at the first appointment, the canal was left empty, the treatment was completed after 1 week.
Outcomes	Healing (follow up 52 weeks). The criteria for success or failure were the following: success (PAI 1 or 2), failure (PAI 3, 4, 5) (see 'Additional Table 01').
Notes	
Allocation concealment	A – Adequate

Study	Weiger 2000
Methods	Randomised, parallel-group, clinical trial; low risk of bias. 91.7% of patients who entered the study were included in the final analysis. Study duration: 5 years.
Participants	73 recruited participants: 6 lost (5 did not return at recall appointments, 1 deceased). 67 entered in the final analysis (37 females and 30 males). Mean age 38 years (range: 11-84). Inclusion criteria: teeth with periapical lesion radiographically demonstrated and where the vitality test was negative; in each patients only 1 tooth was selected. Exclusion criteria: teeth having pockets communicated with the lesion, teeth treated previously, patients that had taken antibiotics 4 weeks prior to the treatment. Diagnostic criteria for pulpally or periapical disease: Rx and vitality test.
Interventions	Single visit (Group 1) or multiple visits (Group 2). 2 operators (experienced endodontists). Use of rubber dam isolation. Use of magnification loupes not reported. Canal shaping: K- files and Gates Glidden used in step-back technique. Irrigation: 1% sodium hypochlorite. Working length determined by Rx. Obturation: gutta-percha with sealapex in lateral condensation. In the Group 2 the number of visits was 2 and the medication used was calcium hydroxide mixed with sterile physiological saline, that was left in the canals for 7-47 days. The cavity access was filled by a temporary cement.
Outcomes	Healing: (follow up 5 years). The criteria for success or failure were the following in the paper: complete healing, incomplete healing, no healing. The radiographs were judged by both dentists involved in the study by using a magnifying glass and a light box. The operators did not know whether the tooth belonged to the 1-visit or the 2-visit group. In case of disagreement a joint decision was made. We considered only 2 categories: success (complete healing) and failure (incomplete healing and no healing) (see 'Additional Table 01').
Notes	
Allocation concealment	A – Adequate

Study	Yoldas 2004
Methods	Randomised, parallel group, clinical trial; high risk of bias. 96% of patients who entered the study were included in the final analysis.

Participants	227 participants, 218 were included in the final analysis. Sex and ethnic group not reported. Age over 18 years old. Inclusion criteria: teeth with inadequate root canal filling. Exclusion criteria: patients with complicating systemic disease, severe pain or acute apical abscess or both, under 18 years of age, use of antibiotics or corticosteroids, multiple teeth requiring retreatment, root canals that could not be treated well with initial root canal treatment. Diagnostic criteria for pulpal or periapical disease: valuation of periapical status with Rx evaluated by 1 author according to PAI.
Interventions	Single visit (Group 1) or multiple visits (Group 2). 3 operators. Use of rubber dam and magnification loupes not specified. Canal shaping with Gates Glidden, hand files NiTi rotary instruments with step-back technique. Irrigation: 2.5% NaOCl. Working length: determined by apex locator and periapical radiograph. Obturation: gutta-percha and AH 26 sealer with lateral condensation. In the Group 2 the patients underwent 2 visits and the canals in the interappointment period were medicated with calcium hydroxide chlorhexidine paste and closed with a sterile dry cotton pellet and a temporary restorative material (Cavit) for 7 days.
Outcomes	Pain (1 week after initial appointment the patients were recalled and asked about the occurrence of postoperative pain): the level of discomfort was rated as follows: no pain, mild pain, moderate pain, severe pain. We considered only 2 categories: no pain, pain (mild, moderate, severe). Flare-up: patients with severe postoperative pain or occurrence of swelling or both (see 'Additional Table 02'). Painkiller use.
Notes	
Allocation concealment	C – Inadequate
NaOCl = sodium hypochlorite	
NiTi = nickel titanium	
PAI = periapical index	
VAS - visual analogue scale	

Characteristics of excluded studies

Study	Reason for exclusion
De Rossi A 2005	Animal study.
Eleazer PD 1998	This is a retrospective study.
Farzaneh 2004	The study was not randomised or quasi-randomised.
Fava 1989	This study was not randomised or quasi-randomised.
Fava 1994	This study design was unclear. We sent an e-mail to authors asking for more details about their randomisation method but we did not consider the answer satisfactory to consider the paper randomised or quasi-randomised.
Ferranti 1959	This study is not randomised or quasi-randomised.
Fox 1970	This is a retrospective study.
Friedman 1995	This study is not randomised or quasi-randomised.
Goreva 2004	This study is not randomised or quasi-randomised.
Hargreaves 2006	This is a review.
He 2004	This study is not randomised or quasi-randomised.
Holland 2003	Animal study.
Imura 1995	This study is not randomised or quasi-randomised.
Inamoto 2002	This study considers only single visit.
Kane 1999	This study considers only single visit.
Kane 2000	This study considers only single visit.
Kenrick 2000	It is a comment.
Kvist 2004	This study considers only single visit.

Characteristics of excluded studies (Continued)

Lagarde 1975	This is a retrospective study.
Landers 1980	This study considers only single visit.
Lipton 1982	It is a review.
Morse 1987	This study considers only single visit.
Ng 2004	The study was not randomised or quasi-randomised.
O'Keefe 1976	This study is not randomised or quasi-randomised.
Oliet 1983	This study is not randomised or quasi-randomised.
Pekruhn 1981	This study is not randomised or quasi-randomised.
Pekruhn 1986	This study is not randomised or quasi-randomised.
Peters 2002bis	This study considers only the microbiological aspects.
Roane 1983	This study is not randomised or quasi-randomised.
Rudner 1981	This study is not randomised or quasi-randomised.
Siqueira 2003	It is a review.
Sjogren 1997	This study considers only single visit and it is not randomised or quasi-randomised.
Soares 2001	This study considers only single visit.
Southard 1984	This study considers only single visit.
Spangberg 2001	This study is a letter.
Trusewicz 2005	This study considers only the microbiological aspects.
Waltimo 2005	The study does not include any of the outcomes considered in the review.
Walton 1992	This study is not randomised or quasi-randomised.
Weine 1997	This study is a comment.
Whitaker 2002	This study is a comment.
Yamada 1992	This study considers only single visit.

ADDITIONAL TABLES

Table 01. Endodontic radiological success: from scales to binary outcome

Classification	Success (binary)	Failure (binary)
Trope 1999; Orstavick; Kirkevang (PAI)	PAI score 1 (normal periapical), PAI score 2 (bone structural changes)	PAI score 3 (structural changes with mineral loss), PAI score 4 (radiolucency), PAI score 5 (radiolucency with features of exacerbation)
Strindberg; Gutmann	Success (normal to slightly thickened periodontal ligament space < 1 mm, elimination of previous rarefaction, normal lamina dura in relation to adjacent teeth, no evidence of resorption)	Questionable (increased periodontal ligament space > 1 mm and < 2 mm, stationary rarefaction or slight repair evident, increased lamina dura in relation to adjacent teeth, evidence of resorption); Failure (increased width of periodontal ligament space > 2 mm, lack of osseous repair within rarefaction or increased

Table 01. Endodontic radiological success: from scales to binary outcome (Continued)

Classification	Success (binary)	Failure (binary)
		rarefaction, lack of new lamina dura, presence of osseous rarefactions in periradicular areas where previously none existed)
Katebzadeh	Healed (normal pattern of trabecular bone and normal width of periodontal ligament space)	Improved (reduction in lesion size); Failed (increased or no change in the lesion size)
Halse & Molven	Healed (normal pattern of trabecular bone and normal width of periodontal ligament space)	Increased width of the periodontal space, pathological findings
Peters 2002; Reit & Grandhal; Kvist	Success (A) the width and contour of the periodontal ligament is normal, or there is a slight radiolucent zone around apical	Uncertain (B) the radiolucency is clearly decreased but additional follow up is not available; Failure (C) there is an unchanged, increased or new periradicular radiolucency
Weiger 2000	Complete healing: no clinical signs and symptoms, radiographically a periodontal ligament space of normal width	Incomplete healing: no clinical signs and symptoms, radiographically a reduction of the lesion in size or an unchanged lesion within an observation time of 4 years. No healing: clinical signs and symptoms indicating an acute phase of apical periotontitis and/or radiographically a persisting lesion after a follow-up time of 4-5 years and/or a new lesion formed at an initially uninvolved root of a multirouted tooth.
Soltanoff 1978	Healed (by Rx but the criteria not specified in a satisfactory way)	Not healed (by Rx but the criteria not specified in a satisfactory way)
Gesi 2006	Normal periapical condition or unclear apical condition (widened apical periodontal space or diffused lamina dura)	Presence of periapical radiolucency when there was a distinct radiolucent area associated with the apical portion of the root

Table 02. Definition of flare-up in the included studies

Authors	Definition
Al-Negrish 2006	Percentage of patients experiencing moderate to severe pain. Moderate pain: the tooth involved caused discomfort and/or pain which was either tolerable or was rendered tolerable by analgesics. Severe pain: the pain caused by the treated tooth disturbed normal activity or sleep and analgesics had little or no effect
DiRenzo 2002	Swelling that needs antibiotics and narcotic analgesics
Mulhern 1982	Swelling
Oginni 2004	Either patient's report of pain not controlled with over-the-counter medication and or increasing swelling
Yoldas 2004	Patients with severe postoperative pain and/or occurrence of swelling

Table 02. Definition of flare-up in the included studies (Continued)

Authors	Definition
Ghoddusi 2006	Swelling

ANALYSES

Comparison 01. Single visit versus multiple visits

Outcome title	No. of studies	No. of participants	Statistical method	Effect size
01 Pain			Relative Risk (Fixed) 95% CI	Subtotals only
02 Painkiller use			Relative Risk (Fixed) 95% CI	Subtotals only
03 Radiological failure			Relative Risk (Fixed) 95% CI	Subtotals only
04 Swelling			Relative Risk (Fixed) 95% CI	Subtotals only
05 Subgroup analysis in necrotic teeth			Relative Risk (Fixed) 95% CI	Subtotals only

Comparison 02. Sensitivity analysis

Outcome title	No. of studies	No. of participants	Statistical method	Effect size
01 Pain			Relative Risk (Fixed) 95% CI	Subtotals only
02 Painkiller use			Relative Risk (Fixed) 95% CI	Subtotals only
03 Radiological failure			Relative Risk (Fixed) 95% CI	Subtotals only
04 Swelling			Relative Risk (Fixed) 95% CI	Subtotals only
05 Subgroup analysis in necrotic teeth			Relative Risk (Fixed) 95% CI	Subtotals only

COVER SHEET

Title	Single versus multiple visits for endodontic treatment of permanent teeth
Authors	Figini L, Lodi G, Gorni F, Gagliani M
Contribution of author(s)	Lara Figini: main review author, participation in all phases of the review's preparation. Giovanni Lodi: contributor in all phases of the review's preparation, articles retrieval, data collection, interpretation of results. Massimo Gagliani: group co-ordinator, articles retrieval, data collection, interpretation of results. Fabio Gorni: prospective handsearching, interpretation of results.
Issue protocol first published	2005/2
Review first published	2007/4
Date of most recent amendment	22 August 2007
Date of most recent SUBSTANTIVE amendment	21 August 2007
What's New	Information not supplied by author
Date new studies sought but none found	Information not supplied by author

Date new studies found but not yet included/excluded Information not supplied by author

Date new studies found and included/excluded Information not supplied by author

Date authors' conclusions section amended Information not supplied by author

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DOI 10.1002/14651858.CD005296.pub2

Cochrane Library number CD005296

Editorial group Cochrane Oral Health Group

Editorial group code HM-ORAL

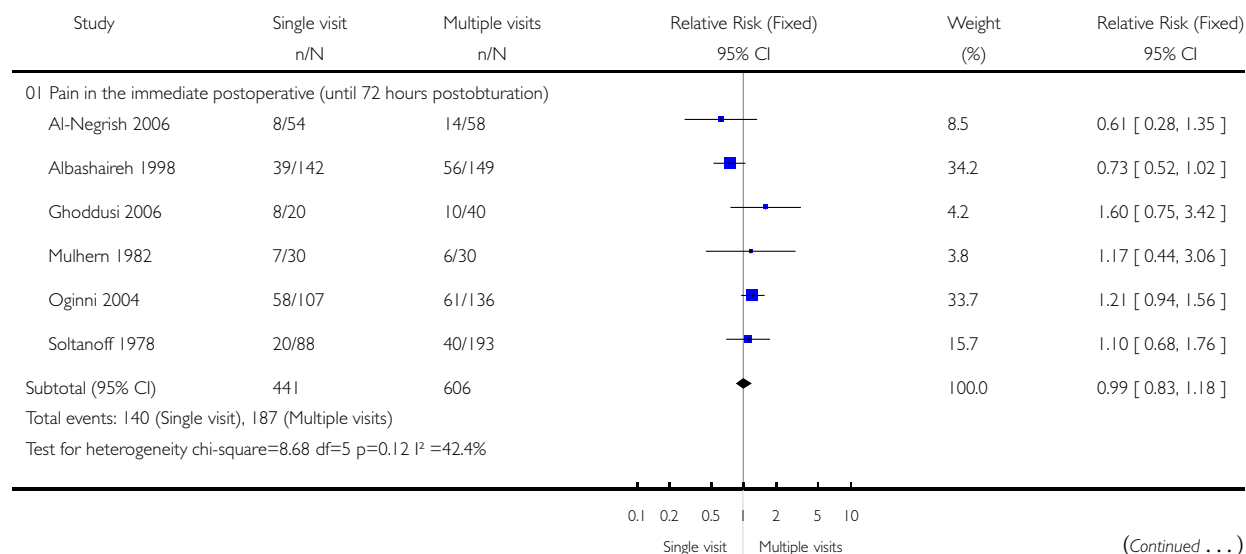
GRAPHS AND OTHER TABLES

Analysis 01.01. Comparison 01 Single visit versus multiple visits, Outcome 01 Pain

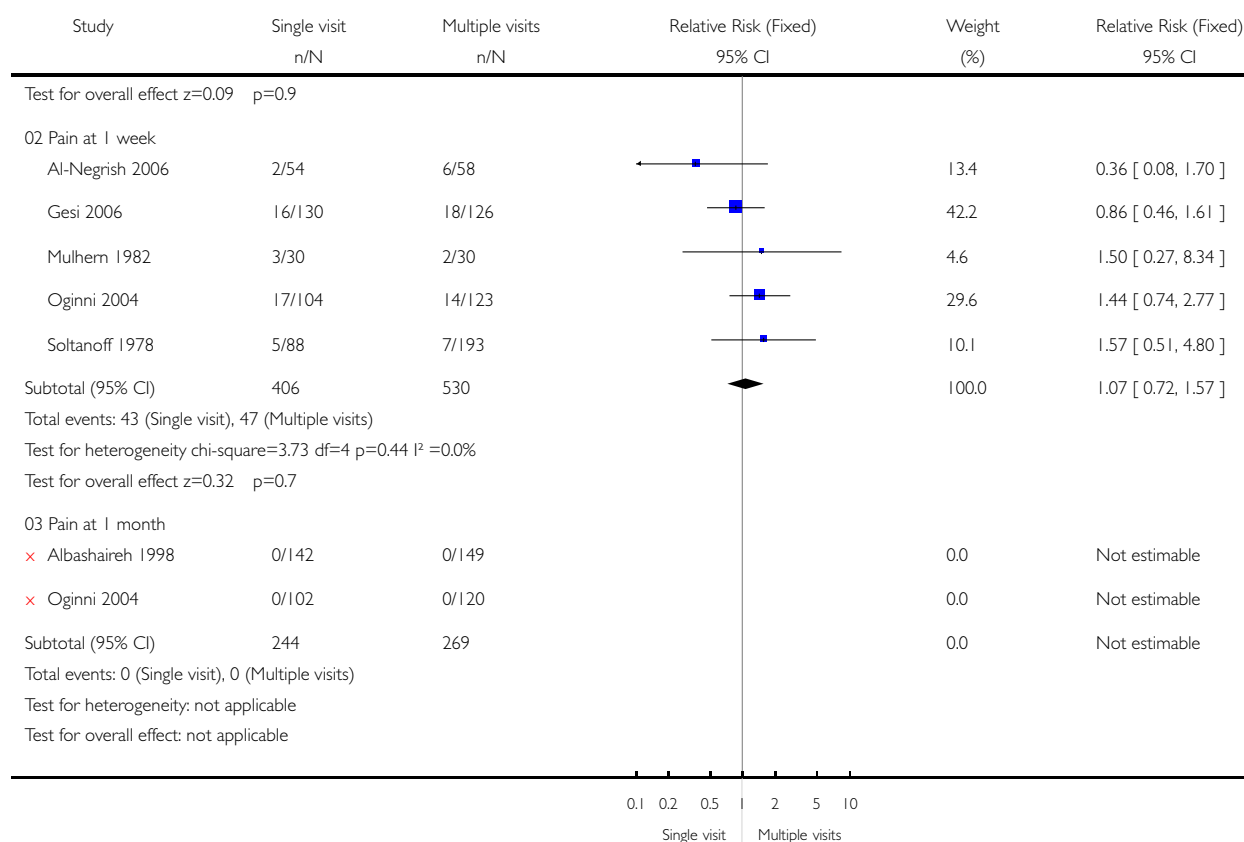
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Comparison: 01 Single visit versus multiple visits

Outcome: 01 Pain



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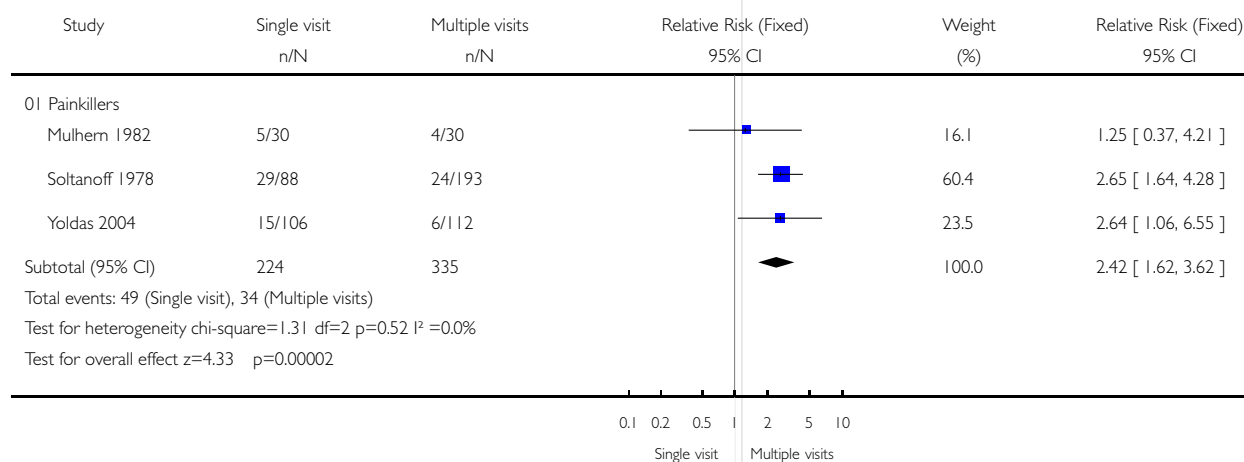


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Review: Single versus multiple visits for endodontic treatment of permanent teeth

Comparison: 01 Single visit versus multiple visits

Outcome: 02 Painkiller use

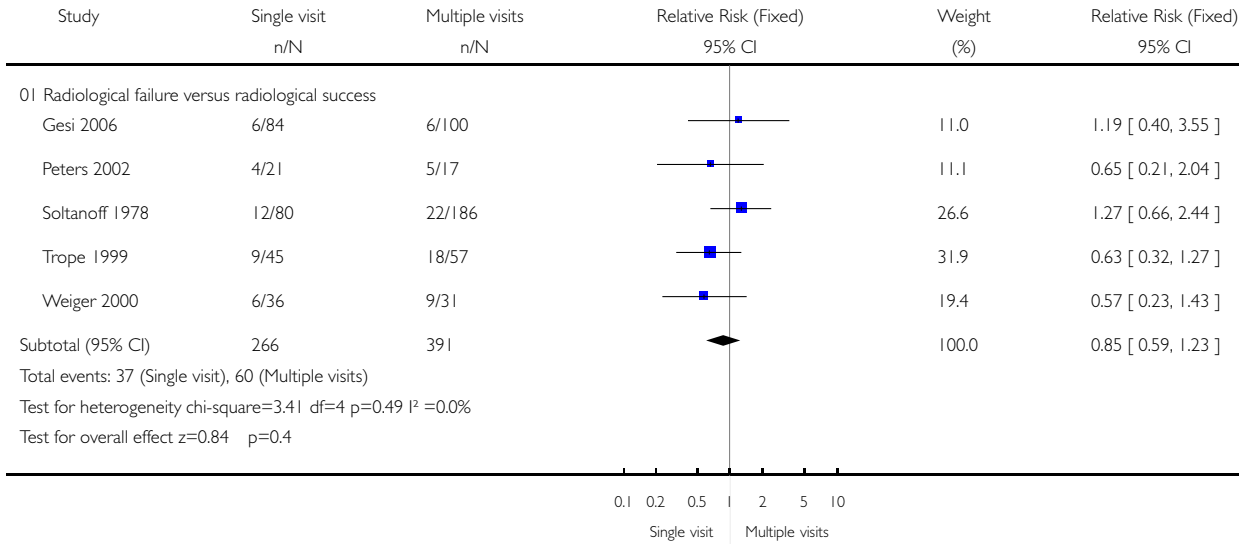


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Review: Single versus multiple visits for endodontic treatment of permanent teeth

Comparison: 01 Single visit versus multiple visits

Outcome: 03 Radiological failure

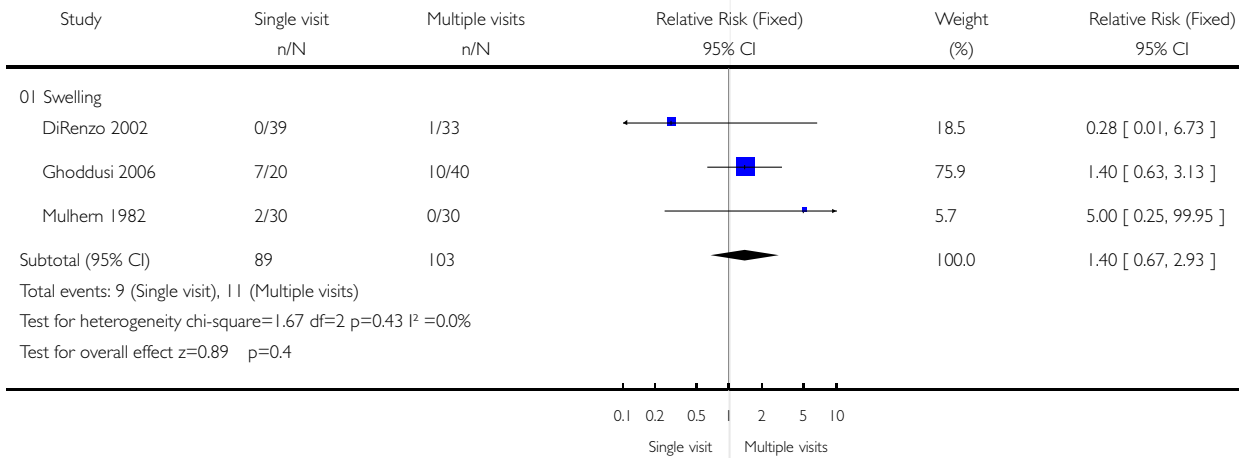


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Review: Single versus multiple visits for endodontic treatment of permanent teeth

Comparison: 01 Single visit versus multiple visits

Outcome: 04 Swelling

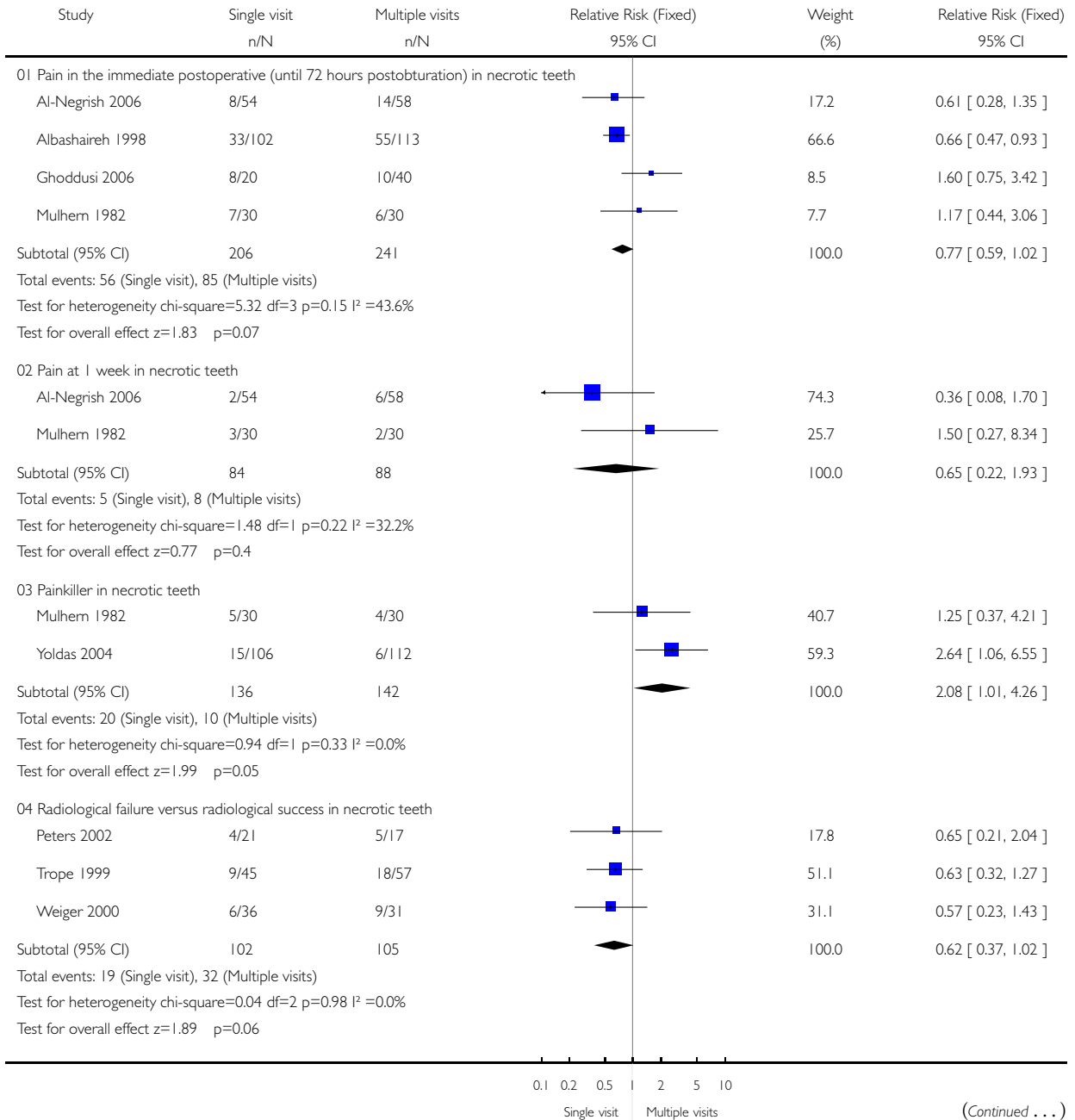


Analysis 01.05. Comparison 01 Single visit versus multiple visits, Outcome 05 Subgroup analysis in necrotic teeth

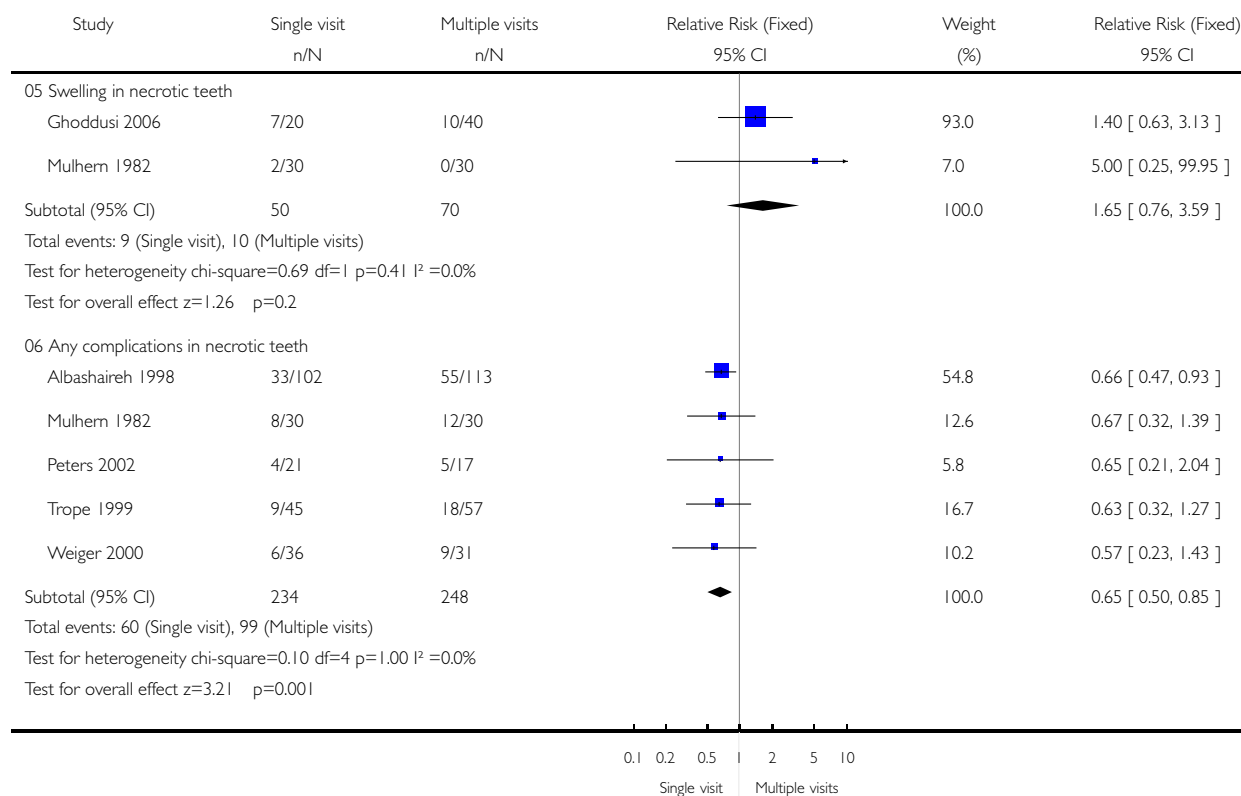
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Comparison: 01 Single visit versus multiple visits

Outcome: 05 Subgroup analysis in necrotic teeth



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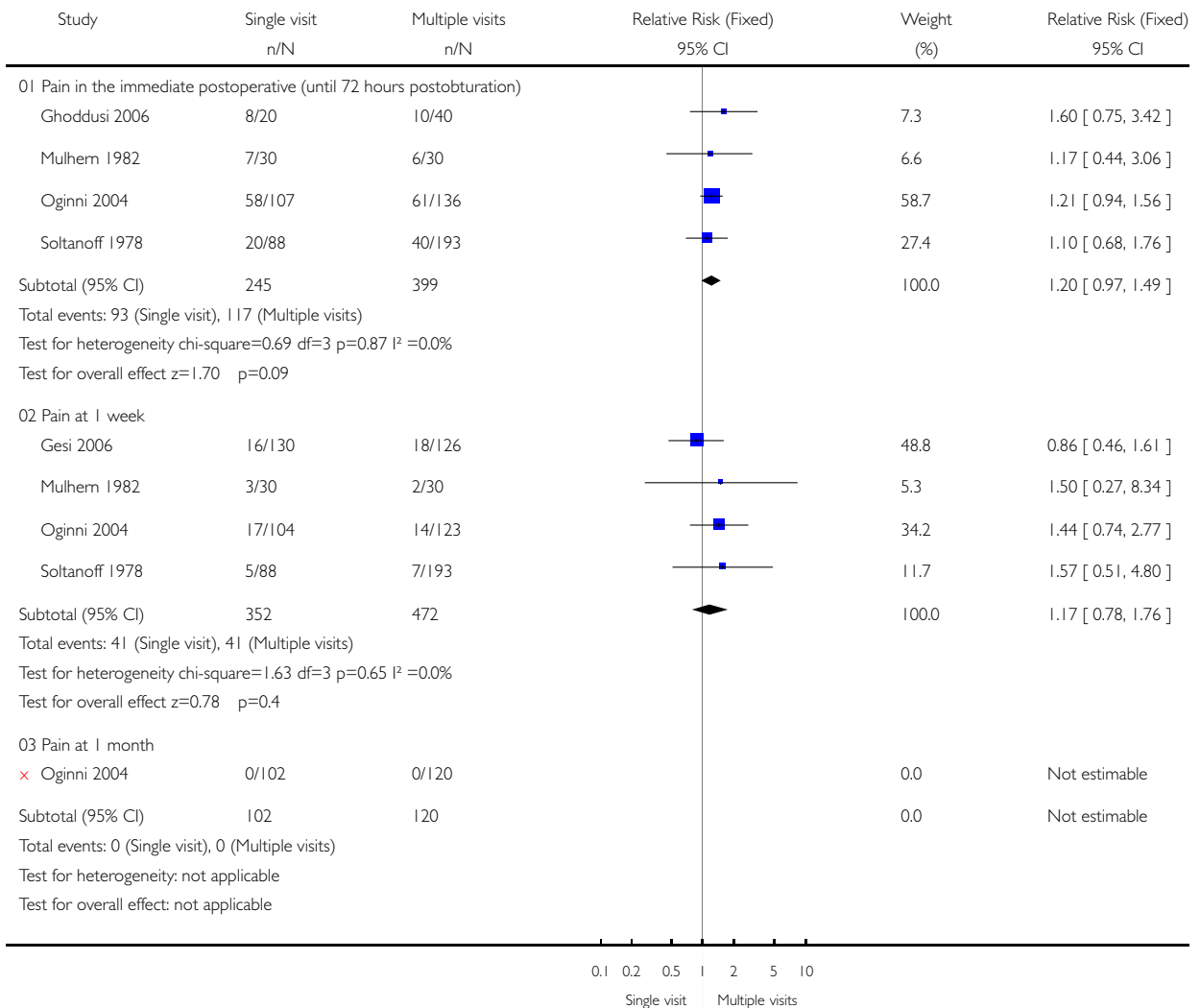


Analysis 02.01. Comparison 02 Sensitivity analysis, Outcome 01 Pain

Review: Single versus multiple visits for endodontic treatment of permanent teeth

Comparison: 02 Sensitivity analysis

Outcome: 01 Pain

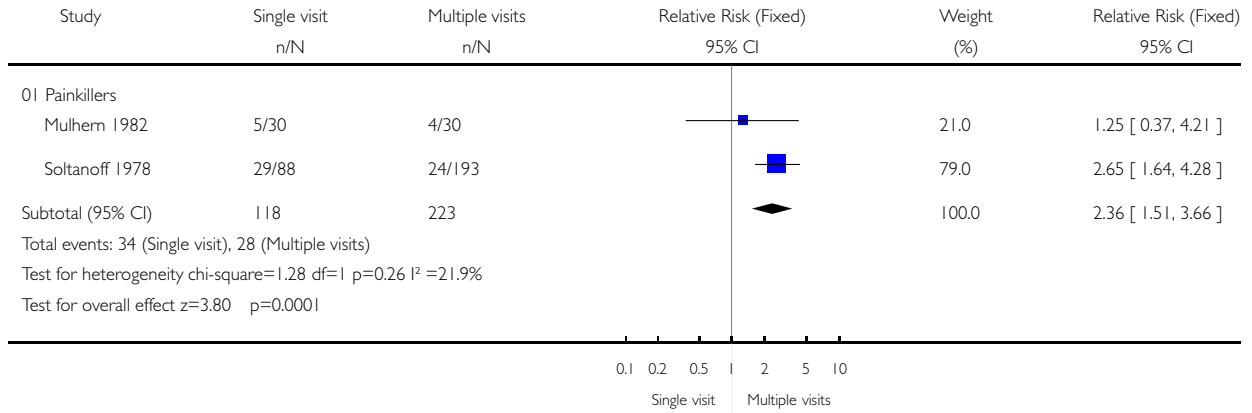


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Review: Single versus multiple visits for endodontic treatment of permanent teeth

Comparison: 02 Sensitivity analysis

Outcome: 02 Painkiller use

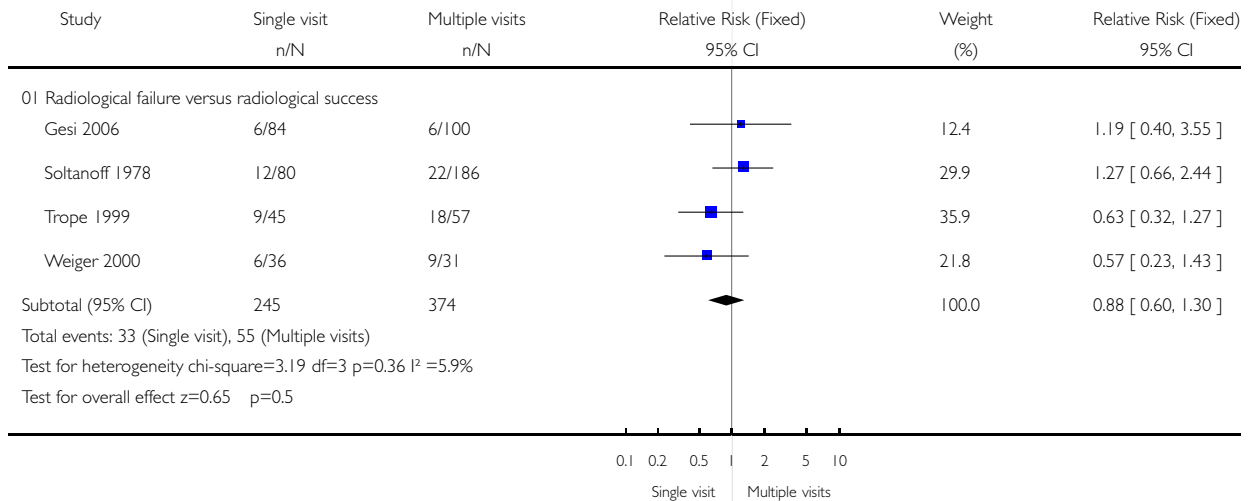


Analysis 02.03. Comparison 02 Sensitivity analysis, Outcome 03 Radiological failure

Review: Single versus multiple visits for endodontic treatment of permanent teeth

Comparison: 02 Sensitivity analysis

Outcome: 03 Radiological failure

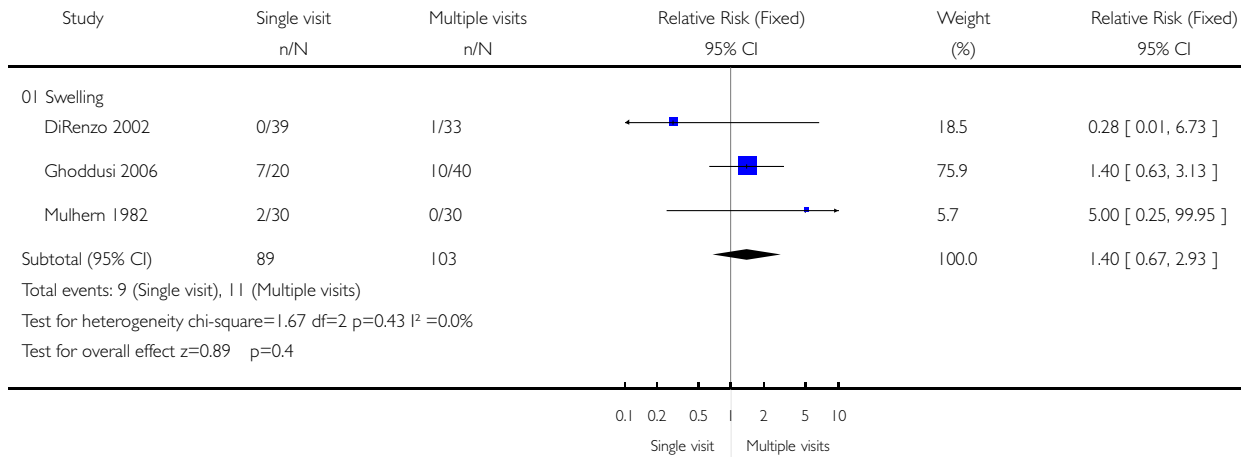


Analysis 02.04. Comparison 02 Sensitivity analysis, Outcome 04 Swelling

Review: Single versus multiple visits for endodontic treatment of permanent teeth

Comparison: 02 Sensitivity analysis

Outcome: 04 Swelling

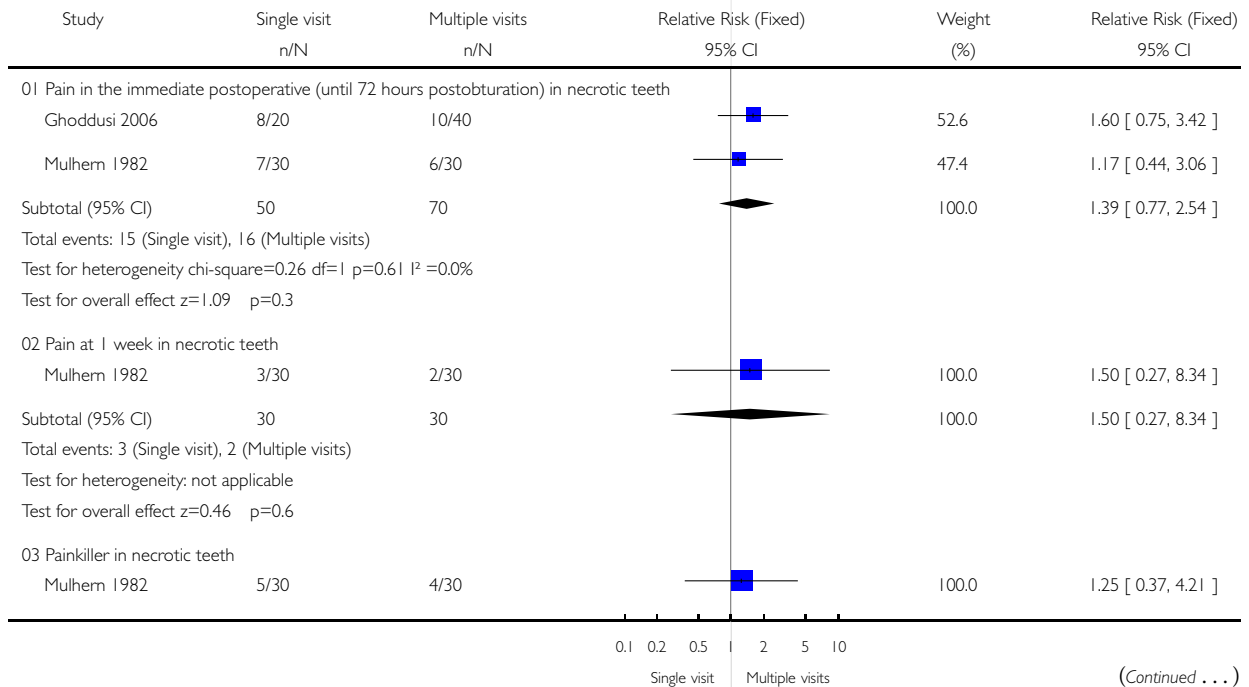


Analysis 02.05. Comparison 02 Sensitivity analysis, Outcome 05 Subgroup analysis in necrotic teeth

Review: Single versus multiple visits for endodontic treatment of permanent teeth

Comparison: 02 Sensitivity analysis

Outcome: 05 Subgroup analysis in necrotic teeth



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