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The Effect of Reciprocating and Rotary Systems on Postoperative Endodontic Pain: A Systematic Review and Meta-analysis

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ABSTRACT

Introduction: The objective of this study was to evaluate the influence of the instrumentation kinematics on endodontic postoperative pain. **Methods and Materials**: PubMed, Scopus, Web of Science, Lilacs, Cochrane Library and the System for Information on Gray Literature in Europe were searched electronically without time or language limitations up to June 2020. Subsequently, data extraction, quality assessment and meta-analysis were conducted. The meta-analysis was performed using random-effects inverse-variance methods, and heterogeneity was tested using the I^2 index (P<0.05). **Results**: A total of 318 articles were successfully identified in the search. Sixteen studies were used in qualitative synthesis and fourteen used for quantitative synthesis. Meta-analysis showed that patients treated with reciprocating system had lower risk of pain 48 h after endodontic treatment (Risk ratio [RR]=1.04, 95% Confidence interval [CI]=1.01-1.06, P=0.003) (I^2=0%), but the mean postoperative pain for the reciprocating system was greater 24 h post endodontic treatment (Standardized mean difference [SMD]=0.25, 95% CI=0.06 to 0.44, P=0.01) (I^2=43%). Other time points presented similar rates of postoperative pain (P>0.05). The certainty of evidence ranges from very low to high. **Conclusions**: The rate of postoperative endodontic pain was low, and reciprocating systems evoked more pain within the 24 h interval. Overall, the incidence and level of postoperative pain did not vary between reciprocating and rotary systems. There is no consensus if there is a relationship between the kinematics (rotary and reciprocating) and the incidence of postoperative pain.

Keywords: Endodontics; Postoperative Pain; Reciprocating Systems; Rotary Systems; Systematic Review

Introduction

Postoperative endodontic pain is an undesirable clinical condition of multifactorial aetiology, and has an incidence of 3%–58% [1-3]. The main causes are insufficient instrumentation, extrusion of irrigants and debris *via* the apical foramen, untreated canals, lack of apical patency, presence of preoperative pain and periapical lesions [4, 5]. To avoid this situation, the endodontist must determine the appropriate working length [6], irrigate frequently during the chemical-mechanical preparation [7] and select the correct instruments [8, 9].

Ni-Ti instruments, in addition to providing a more centralized preparation of the root canal [10], promote less extrusion of debris compared with manual instruments [11, 12]. Extrusion of infected debris may exacerbate an existing inflammatory process or initiate periapical inflammation [13], causing postoperative pain [14] .

New instruments are increasingly being launched in the market. These files can be used in rotary or reciprocating kinematics [15, 16]. The concept of reciprocating instruments involves a single file for the preparation of the root canal [17]. The reciprocating motion involves an initial rotation of the instrument in a counter clockwise

direction, during which the instrument penetrates and cuts the dentin, and then rotates in the opposite direction, during which the instrument is released [18]. Some studies have found that rotary instrumentation showed better results regarding extrusion of debris [19, 20]. In contrast, Silva *et al.* [21] observed that rotary instrumentation extruded more debris than the reciprocating instruments tested.

Clinically, there is no consensus on whether there is a relationship between the kinematics of the instrument and the incidence of postoperative pain. In their study Nekoofar *et al.* [5] concluded that postoperative pain was more frequent when using reciprocating instruments. However, Kherlakain *et al.* [18] and Molashashi *et al.* [22] verified that there was no relationship between the presence of pain and the kinematics used. To clarify this clinical issue, A systematic review was undertaken to compare postoperative pain after instrumentation with rotary and reciprocating systems and found less severe pain at 48 h with the reciprocation system [23] We conducted another meta-analysis on the same topic by including more trials and hence, providing evidence with more power.

The aim of this systematic review and meta-analysis is to evaluate the influence of rotary and reciprocating kinematics on the incidence of postoperative pain after endodontic treatment of permanent teeth. This study addresses the following PICO strategy [24] question: Do reciprocating systems (I) result in greater postoperative pain (O) than rotary systems (C) in patients undergoing endodontic treatment (P)?.

Table 1. Search strategy used for each database

Database	Strategy
PubMed (Medline)	#1 ((((((((((((((((((((((((Permanent teeth[MeSH Terms]) OR Permanent teeth[Title/Abstract]) OR Permanent Dentition[Title/Abstract]) OR Dentition, Secondary[Title/Abstract]) OR Dentition, Adult[Title/Abstract]) OR Permanent teeth[Title/Abstract]) OR Molar[MeSH Terms]) OR Molar[Title/Abstract]) OR Molars[Title/Abstract]) OR Endodontics[MeSH Terms]) OR Endodontics[Title/Abstract]) OR Endodontic treatment[Title/Abstract]) OR Root Canal Preparation[MeSH Terms]) OR Canal Preparation, Root[Title/Abstract]) OR Canal Preparations, Root[Title/Abstract]) OR Preparation, Root Canal[Title/Abstract]) OR Preparations, Root Canal[Title/Abstract]) OR Root Canal Therapy[MeSH Terms]) OR Root Canal Therapy[Title/Abstract]) OR Canal Therapies, Root[Title/Abstract]) OR Canal Therapy, Root[Title/Abstract]) OR Therapies, Root Canal[Title/Abstract]) OR Therapy, Root Canal[Title/Abstract]) OR Root Canal Treatment[Title/Abstract]) OR Root Canal Treatments[Title/Abstract] **#2** ((((((((Reciprocating Systems[Title/Abstract]) OR Reciprocating System[Title/Abstract]) OR Reciprocating[Title/Abstract]) OR WaveOne[Title/Abstract]) OR Reciproc[Title/Abstract]) OR Unicone[Title/Abstract]) OR Endodontic Instrument[Title/Abstract]) OR Endodontic Instruments[Title/Abstract]) OR Nickel-titanium instruments[Title/Abstract] **#3** ((((((((((((((((((((((((((Canal Instrumentation Technique[Title/Abstract]) OR Instrumentation Techniques[Title/Abstract]) OR Instrumentation Technique[Title/Abstract]) OR Rotary System[Title/Abstract]) OR Rotary Systems[Title/Abstract]) OR Rotary Preparation[Title/Abstract]) OR Rotary[Title/Abstract]) OR Protaper[Title/Abstract]) OR Protaper Next[Title/Abstract]) OR Revo-s[Title/Abstract]) OR Hyflex[Title/Abstract]) OR K3[Title/Abstract]) OR K3XF[Title/Abstract]) OR Hero 642[Title/Abstract]) OR Easy ProDesign Logic[Title/Abstract]) OR Easy ProDesign S[Title/Abstract]) OR One Shape[Title/Abstract]) OR Mtwo[Title/Abstract]) OR TF System[Title/Abstract]) OR F6 Skytaper[Title/Abstract]) OR Race[Title/Abstract]) OR F360[Title/Abstract]) OR Twisted File[Title/Abstract]) OR Biorace[Title/Abstract]) OR Hero Shaper[Title/Abstract]) OR Profile[Title/Abstract]) OR Protaper Gold[Title/Abstract] #4 ((((((Postoperative Pain[MeSH Terms]) OR Postoperative Pain[Title/Abstract]) OR Postoperative Pains[Title/Abstract]) OR Post Endodontic Pain[Title/Abstract]) OR Post Obturation Pain[Title/Abstract]) OR Post preparation pain[Title/Abstract]) OR Post treatment pain[Title/Abstract] **#1 AND #2 AND #3 AND #4**
Scopus	**#1** TITLE-ABS-KEY("Permanent Teeth") OR TITLE-ABS-KEY("Permanent Dentition") OR TITLE-ABS-KEY("Secondary Dentition") OR TITLE-ABS-KEY("Adult Dentition") OR TITLE-ABS-KEY(Molar) OR TITLE-ABS-KEY(Molars) OR TITLE-ABS-KEY(Éndodontics) OR TITLE-ABS-KEY("Endodontic Treatment") OR TITLE-ABS-KEY("Root Canal Preparation") OR TITLE-ABS-KEY("Root Canal Preparations") OR TITLE-ABS-KEY("Root Canal Therapy") OR TITLE-ABS-KEY("Root Canal Therapies") OR TITLE-ABS-KEY("Root Canal Treatment") OR TITLE-ABS-KEY("Root Canal Treatments") **#2** TITLE-ABS-KEY("Reciprocating Systems") OR TITLE-ABS-KEY("Reciprocating System") OR TITLE-ABS-KEY(Reciprocating) OR TITLE-ABS-KEY(WaveOne) OR TITLE-ABS-KEY(Unicone) OR TITLE-ABS-KEY("Endodontic Instrument") OR TITLE-ABS-KEY("Endodontic Instruments") OR TITLE-ABS-KEY("Nickel-titanium instruments") **#3** TITLE-ABS-KEY("Canal Instrumentation Technique") OR TITLE-ABS-KEY("Canal Instrumentation Techniques") OR TITLE-ABS-KEY('Instrumentation Technique") OR TITLE-ABS-KEY ("Rotary System") OR TITLE-ABS-KEY("Rotary Systems') OR TITLE-ABS-KEY("Rotary Preparation") OR TITLE-ABS-KEY(Rotary) OR TITLE-ABS-KEY(Protaper) OR TITLE-ABS-KEY ("Protaper Next") OR TITLE-ABS-KEY (Revo-s) OR TITLE-ABS-KEY (Hyflex) OR TITLE-ABS-KEY(K3) OR TITLE-ABS-KEY(K3XF) OR TITLE-ABS-KEY("Hero 642") OR TITLE-ABS-KEY ("Easy ProDesign Logic") OR TITLE-ABS-KEY (Easy ProDesign S") OR TITLE-ABS-KEY("One Shape") OR TITLE-ABS-KEY (Mtwo) OR TITLE-ABS-KEY("TF System") OR TITLE-ABS-KEY("F6 Skytaper") OR TITLE-ABS-KEY(Race) OR TITLE-ABS-KEY(F360) OR TITLE-ABS-KEY("Twisted File") OR TITLE-ABS-KEY(Biorace) OR TITLE-ABS-KEY("Hero Shaper") OR TITLE-ABS-KEY(Profile) OR TITLE-ABS-KEY("Protaper Gold") **#4** TITLE-ABS-KEY("Postoperative Pain") OR TITLE-ABS-KEY("Postoperative Pains") OR TITLE-ABS-KEY("Post Endodontic Pain") OR TITLE-ABS-KEY("Post Obturation Pain") OR TITLE-ABS-KEY("Post preparation pain") OR TITLE-ABS-KEY("Post treatment pain") **#1 AND #2 AND #3 AND #4**

Web of Science	**#1** TS=("Permanent Teeth" OR "Permanent Dentition" OR "Secondary Dentition" OR "Adult Dentition" OR Molar OR Molars OR Endodontics OR "Endodontic Treatment" OR "Root Canal Preparation" OR "Root Canal Preparations" OR "Root Canal Therapy" OR "Root Canal Therapies" OR "Root Canal Treatment" OR "Root Canal Treatments") #2 TS=("Reciprocating Systems" OR "Reciprocating System" OR Reciprocating OR WaveOne OR Unicone OR "Endodontic Instrument" OR "Endodontic Instruments" OR "Nickel-titanium instruments") #3 TS=("Postoperative Pain" OR "Postoperative Pains" OR "Post Endodontic Pain" OR "Post Obturation Pain" OR "Post preparation pain" OR "Post treatment pain") **#1 AND #2 AND #3**
Grey Literature	**#1** ("Permanent Teeth" OR "Permanent Dentition" OR "Secondary Dentition" OR "Adult Dentition" OR Molar OR Molars OR Endodontics OR "Endodontic Treatment" OR "Root Canal Preparation" OR "Root Canal Preparations" OR "Root Canal Therapy" OR "Root Canal Therapies" OR "Root Canal Treatment" OR "Root Canal Treatments") **#2** ("Reciprocating Systems" OR "Reciprocating System" OR Reciprocating OR WaveOne OR Unicone OR "Endodontic Instrument" OR "Endodontic Instruments" OR "Nickel-titanium instruments") **#3** ("Postoperative Pain" OR "Postoperative Pains" OR "Post Endodontic Pain" OR "Post Obturation Pain" OR "Post preparation pain" OR "Post treatment pain") **#1 AND #2 AND #3**
Cochrane Library	**#1** MeSH descriptor: [Dentition, Permanent] explode all trees>75 **#2** MeSH descriptor: [Molar] explode all trees>2407 **#3** MeSH descriptor: [Endodontics] explode all trees>1373 **#4** MeSH descriptor: [Root Canal Preparation] explode all trees>640 **#5** MeSH descriptor: [Root Canal Therapy] explode all trees>1071 **#6** Root Canal Treatment > 1345 **#7** #1 or #2 or #3 or #4 or #5 or #6>4292 **#8** Reciprocating System*>73 **#9** Reciproc>101 **#10** WaveOne>47 **#11** Endodontic Instrument*>579 **#12** Nickel-titanium instruments>81 **#13** #8 or #9 or #10 or #11 or #12>725 **#14** MeSH descriptor: [Pain, Postoperative] explode all trees> 14898 **#15** Post Endodontic Pain>227 **#16** Post Obturation Pain>58 **#17** Post preparation pain>1503 **#18** Post treatment pain>18178 **#19** #15 or #16 or #17 or #18>18435 **#20** #7 and #13 and #19
Lilacs	**#1** (mh:(Dentes Permanentes)) OR (mh:(Permanent Teeth)) OR (mh:(Dientes Permanentes)) OR (tw:(Dentes Permanentes)) OR (tw:(Permanent Teeth)) OR (tw:(Dientes Permanentes)) OR (mh:(Molar)) OR (tw:(Molar)) OR (mh:(Endodontia)) OR (tw:(Endodontia)) OR (mh:(Endodontics)) OR (tw:(Endodontics)) OR (mh:(Endodoncia)) OR (tw:(Endodoncia)) OR (mh:(Preparo de Canal Radicular)) OR (tw:(Preparo de Canal Radicular)) OR (mh:(Root Canal Preparation)) OR (tw:(Root Canal Preparation)) OR (mh:(Preparación del conducto radicular)) OR (tw:(Preparación del conducto radicular)) OR (mh:(Tratamento do Canal Radicular)) OR (tw:(Tratamento do Canal Radicular)) OR (mh:(Root Canal Therapy)) OR (tw:(Root Canal Therapy)) OR (mh:(El tratamiento de conducto)) OR (tw:(El tratamiento de conducto)) OR (tw:(Root Canal Treatment)) OR (tw:(Tratamiento de conducto)) #2 (tw:(Sistemas Reciprocantes)) OR (tw:(Sistema Reciprocante)) OR (tw:(Reciprocating Systems)) OR (tw:(Reciprocating System)) OR (tw:(Sistemas de movimiento alternativo)) OR (tw:(Sistema de movimiento alternativo)) OR (tw:(Reciprocante)) OR (tw:(Reciprocating)) OR (tw:(vaivén)) OR (tw:(WaveOne)) OR (tw:(Reciproc)) OR (tw:(Unicone)) OR (tw:(Endodontic Instrument)) OR (tw:(Endodontic Instruments)) OR (tw:(Instrumento endodôntico)) OR (tw:(Instrumentos endodônticos)) OR (tw:(instrumento endodóntico)) OR (tw:(instrumentos endodónticos)) OR (tw:(Nickel-titanium instruments)) OR (tw:(Instrumentos de níquel-titanio)) #3 (mh:(Postoperative Pain)) OR (tw:(Postoperative Pain)) OR (mh:(Dor Pós-Operatória)) OR (tw:(Dor Pós-Operatória)) OR (mh:(El dolor postoperatorio)) OR (tw:(El dolor postoperatorio)) OR (tw:(Postoperative Pains)) OR (tw:(Los dolores postoperatorios)) OR (tw:(Dores no pós-operatório)) OR (tw:(Post Endodontic Pain)) OR (tw:(Dor Pós Endodontia)) OR (tw:(Dolor poste radicular)) OR (tw:(Post Obturation Pain)) OR (tw:(Dolor poste obturación)) OR (tw:(Dor pós obturação)) OR (tw:(Post preparation pain)) OR (tw:(Dor pós preparação)) OR (tw:(Dolor después de la preparación)) OR (tw:(Post treatment pain)) OR (tw:(Dor pós-tratamento)) OR (tw:(Dolor post tratamiento)) **#1 AND #2 AND #3**

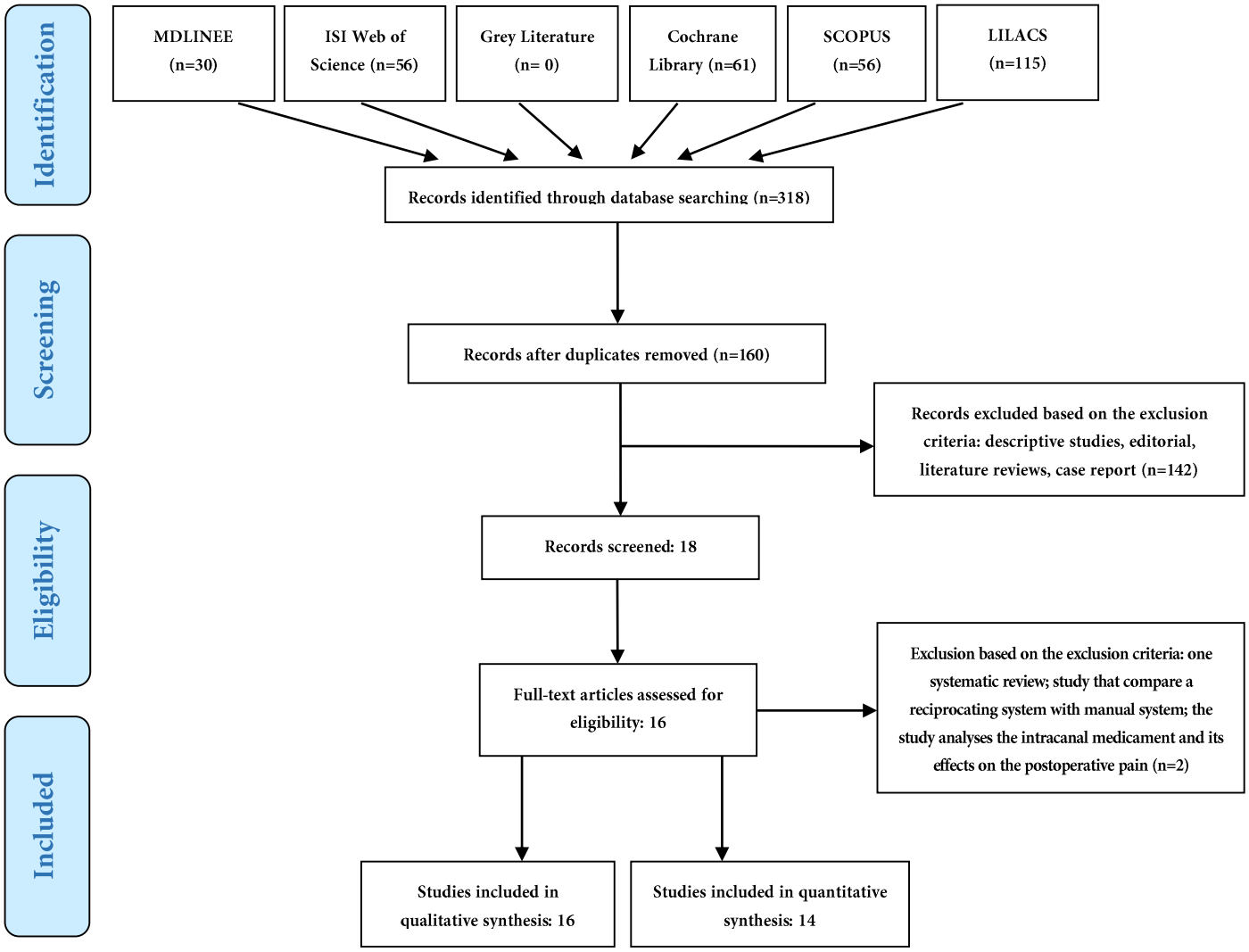

Figure 1. Search strategy flowchart

Methods and Materials

This systematic review and meta-analysis followed the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (http://www.prisma-statement.org) [25]. It was also registered in the PROSPERO database under protocol CRD42016048379.

Literature search strategy

The search covered electronic databases and the reference lists of relevant articles published up to June 2020. The following electronic databases were searched: PubMed (Medline), Scopus, Web of Science, Lilacs, Cochrane Library and System for Information on Gray Literature in Europe (SiGLE), in a comprehensive and unrestricted manner with regard to the year or language of publication. The MeSH terms used were "permanent teeth", "endodontics", "root canal preparation", "root canal therapy" and "postoperative pain", adapted for each database. In addition, free terms related to each topic were included using the Boolean operators "AND" and "OR" to match the search terms (Table 1).

Eligibility criteria

The eligibility criteria for the terms used for the research were based on the population (patients undergoing endodontic treatment in permanent teeth), intervention (patients treated with reciprocating systems), control (patients treated with rotary systems) and outcomes (postoperative pain). Only randomized clinical trials (RCT) and controlled clinical trials were selected in this systematic review. Observational studies, case reports, case series, in vitro studies, literature reviews, editorials and letters to editor were excluded.

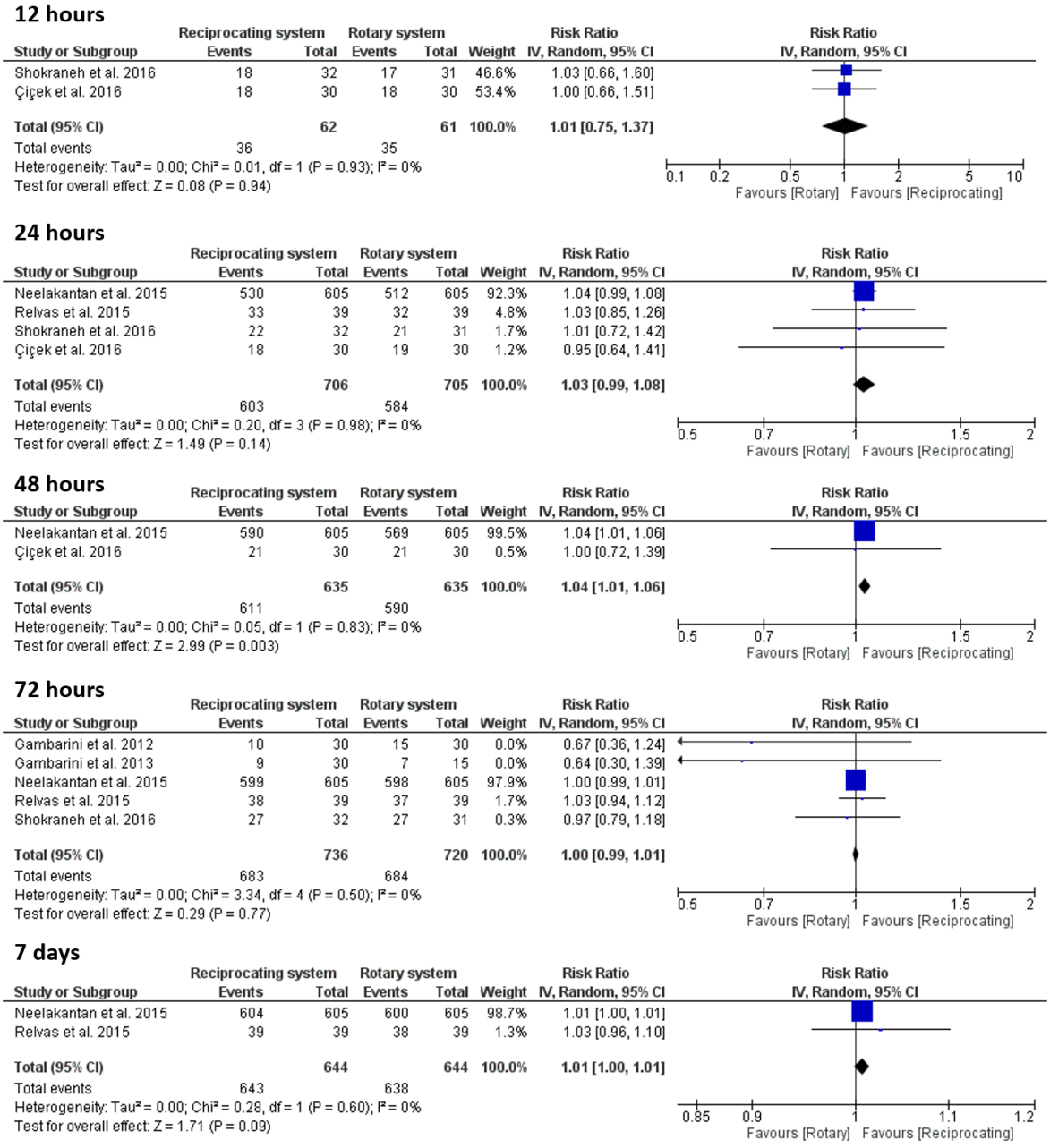

Figure 2. Forest plot of prevalence of "no pain" (events) after endodontic treatment with reciprocating and rotary systems at different time intervals

Screening and data extraction

Two independent reviewers (JCLN and LMF) retrieved relevant publications involving postoperative pain after endodontic treatment of permanent teeth. Titles and abstracts were analysed during the initial screening. Subsequently, full-texts articles that appeared to meet the inclusion criteria were retrieved to confirm eligibility. Disagreements were resolved by consensus after discussion with a third reviewer (TFRL). Both reviewers also performed data extraction by adding information to an electronic spreadsheet. The following information was retrieved: authors, country, study design, number of patients, age, type of teeth evaluated, pulp diagnosis, exclusion criteria, systems evaluated, working length, irrigant solution, postoperative pain evaluation method, time intervals, statistical analysis, results and conclusion. In the event that details were not clear to the reviewers, the authors were contacted by e-mail for clarification.

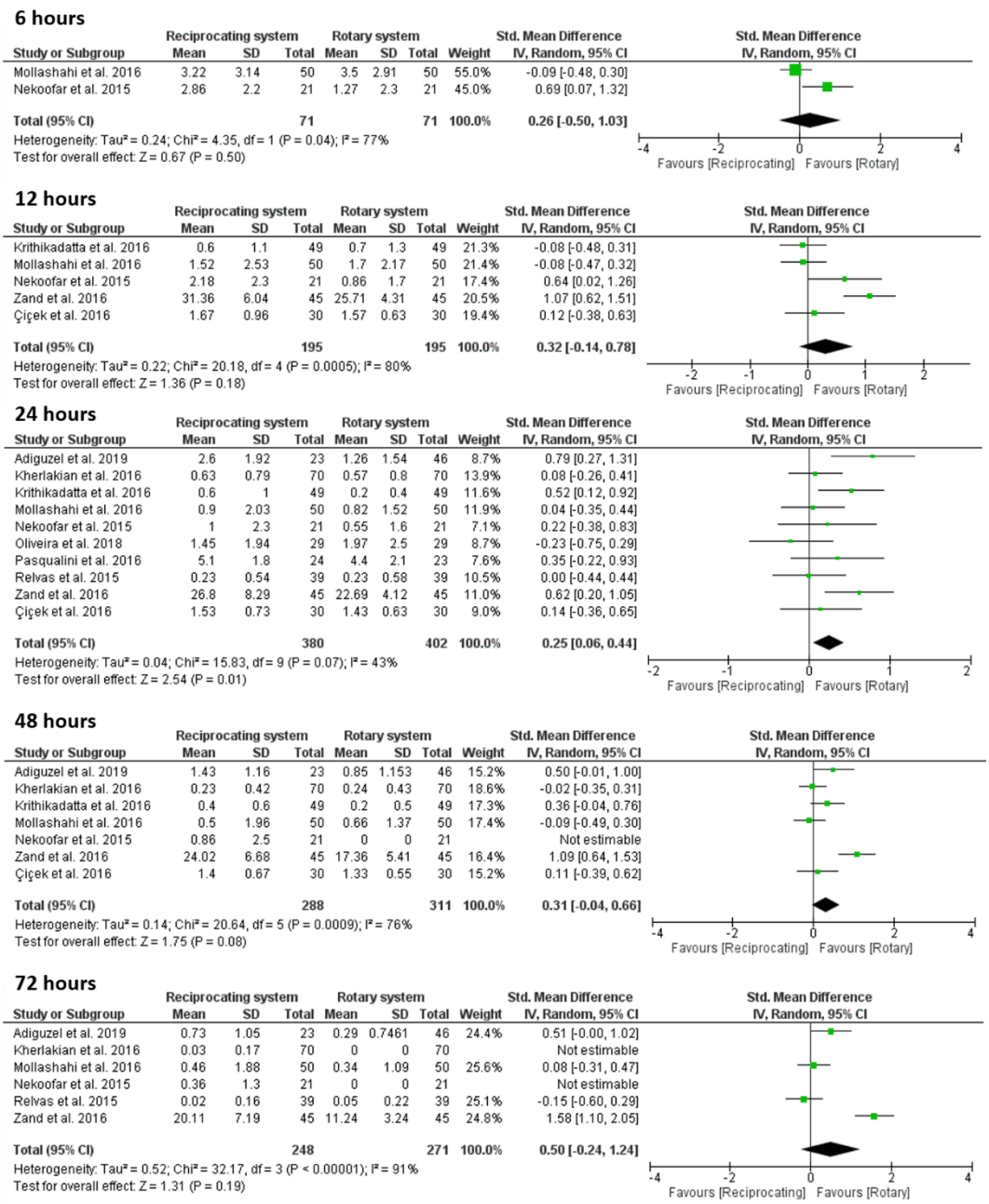

Figure 3. Forest plot of postoperative pain after endodontic treatment with reciprocating and rotary systems at different time intervals

Quality assessment

"The Cochrane Collaboration Risk of Bias tool" [26] was used to assess the methodological quality of the studies. Risk of bias judgment was indicated as low risk, high risk or unclear risk. Two reviewers (JCLN and LMF) made assessments independently and any disagreements were resolved by consensus.

Certainty of evidence

The certainty of the evidence (CE) for each meta-analysis were determined for the outcome using the Grading of Recommendations Assessment, Development and Evaluation (GRADE). Randimized clinical trials receive an initial "high" certainty (26). Each body of evidence is given an initial confidence rating, which is subsequently downgraded if serious or very serious problems, related to risk of bias, inconsistency, indirectness, imprecision and publication bias, are present; or upgraded if the magnitude of effect is large or very large, or if the effect of all plausible confounding factors would be to reduce the effect, or suggest a spurious effect. Publication bias was detected

Table 2. Evidence table summarizing the characteristics of included studies

Author	N	Age	Type of teeth	Pulp-diagnosis	Systems evaluated (n)	Working length (mm)	Main endodontic Irrigants	Follow-ups
Gambarini *et al.* [28]	60	21-72	Premolars Molars	Pulp necrosis	Twisted File (30) Reciproc (30)	0.0 [a*]	5% NaOCl	72 h
Gambarini *et al.* [29]	90	19-73	Premolars Molars	Pulp necrosis	Twisted File (30) WaveOne (30) TF Adaptive (30)	0.0 [a*]	5% NaOCl	72 h
Neelakantan *et al.* [30]	605	25-40	Mandibular Molars	Symptomatic vital pulp	One Shape (605) Reciproc (605)	0.5 [b*]	3% NaOCl	1, 2, 3, 4, 5, 6 and 7 days
Nekoofar *et al.* [5]	42	11-55	Premolars Molars	vital pulp	WaveOne (21) Protaper Universal (21)	0.5 [b]	2% Chlorhexidine	6, 12, 18, 24, 48 and 72 h
Kherlakian *et al.* [18]	210	19-73	Premolars Molarss	Vital pulp	Protaper Next (70) WaveOne (70) Reciproc (70)	0.5 [b]	2.5% NaOCl	24, 28, 72 h and 7 days.
Krithikhadatta *et al.* [31]	148	18-55	Premolars Molars	Vital/ necrotic pulp	WaveOne (49) Protaper Universal (49) MTwo (50)	1 mm short	5% NaOCl	Preop, 2, 4, 6, 12, 24, 36 and 48 h
Pasqualini *et al.* [32]	47	16-60	All type of teeth	Vital/ Necrotic Pulp	Protaper Universal (23) WaveOne (24)	0.0 [a]	5% NaOCl	1,2 ,3, 4, 5, 6 and 7 days
Relvas *et al.* [33]	78	18-64	Mandibular teeth	Pulp necrosis	ProTaper Universal (39) Reciproc (39)	0.0 [a *]	2.5% NaOCl	24, 72 h and 7 days
Shokraneh *et al.* [34]	93	20-45	Mandibular molars	Pulp necrosis	ProTaper Universal (31) WaveOne (32) Hand File (30)	1 [b]	5.25% NaOCl	6, 12 18, 24, 36 and 72 h
Zand *et al.* [35]	90	19-59	Mandibular molars	Pulp necrosis	Race (45) Reciproc (45)	0.5 [b*]	2.5% NaOCl	4, 12, 24, 48, 72 h and 7 days
Arslan *et al.* [36]	56	19-48	Molars	Vital pulp	Reciprocating SystemsG1-360° x 30°(14) G2.-270° x 30°(14) G3-150° x 30°(14) G4-Anti-spinning rotating system (14)	0.5 [b*]	1.25% NaOCl	24, 72, 120 h and 7 days
Mollashahi *et al.* [37]	150	20-50	Molars	Symptomatic vital pulp	One Shape (50) Reciproc (50) Hand File (50)	0.5 [b*]	2.5% NaOCl	Preop, 6, 12, 24, 48 and 72 h
ÇIÇEK *et al.* [38]	90	21-65	Uni-radicular teeth	Pulp necrosis	Hand File (30) WaveOne (30) ProTaper Next (30)	0.5 [b]	5.25% NaOCl 2% Chlorhexidine	12, 24 and 48 h
Saha *et al.* [39]	210	18-55	Premolars and Molars	Vital pulp	Self-Adjusting File (70) WaveOne Gold (70) ProTaper Next (70)	-	5.25% NaOCl	24, 48 and 72 h
Oliveira *et al.* [40]	58	18-66	Molar	Asymptomatic vital pulp	Reciproc (29) ProTaper Next (29)	1 [b]	2.5% NaOCl	24 h
Adiguzel *et al.* [41]	69	21-65	Mandibular molar	Pulp necrosis	Xp Endo Shaper (23) iRace (23) Reciproc Blue 23)	1 [b]	2.5% NaOCl	24, 48, 72 h and 1 week

RCT, randomized controlled trials; VAS, visual analogue scale; NRS, numerical rating scale; Preop: Preoperative; Sodium hypochlorite: NaOCl; a: point of apical locator; b: short

through visual analysis of funnel plot, independet of the number of studies included in meta-analysis. According to factors that decrease or increase confidence in the results the quality of the evidence can vary from very low to high.

Meta-analysis

The extracted data were analysed using RevMan software (Review Manager v. 5.3, Nordic Cochrane Centre, Copenhagen, Denmark) to investigate the influence of reciprocating *vs.* rotary techniques on postoperative pain after endodontic treatment. Two types of meta-analyses were performed: (meta-analysis 1) dichotomous data (the prevalence of "no pain" (events) and the total number of teeth treated) were used to calculate the risk ration (RR) with 95% confidence interval (CI); (meta-analysis 2) continuous data (mean and standard deviation for pain, and sample number) were used to calculate the standard mean difference (SMD) with 95% CI. Random effects models were used and heterogeneity was tested using the I^2 index. If some study present the individual/patient score, the mean and standard deviation, as well as the number of events, were calculated. So, the maximum number of trials were included in each analysis ($P<0.05$).

Results

The search strategy is summarized in Figure 1. The initial search identified 318 potential articles. Mendeley software 2017 for OSX was used at this stage. After removal of duplicates, 130 articles remained. After reading the titles and abstracts, 18 articles were selected for full-text reading. Sixteen articles were selected for quantitative synthesis and data extraction. Fourteen articles were selected for the meta-analysis.

The studies were published between 2012 and 2019 and involved a total of 2096 adult patients diagnosed with vital pulp or pulp necrosis. Endodontic treatment was performed on 2701 teeth. Neelakantan and Sharma [30] was the only study that included more than one tooth per patient. Reciprocating systems were used in 1259 teeth and rotary systems were used in 1302 teeth. Hand files were used for endodontic treatment of 110 teeth [22, 34, 38] and 30 were treated with TF Adaptive [29], which allows rotary and reciprocating motion. The Clinical trials were conducted in Italy [28, 29, 32], Brazil [18, 33, 40], India [30, 31, 39], Iran [5, 34, 37, 42] and Turkey [36, 38, 41]. The main differences between the studies were the type of teeth treated, pulp diagnosis, systems evaluated, working length, and time to evaluate postoperative pain (Table 2). In most articles, the endodontic treatment was performed at one visit, except for Nekoofar *et al.* [5].

The quality of the articles was evaluated following the recommendations described by the Cochrane Collaboration [26] and its results are presented in Table 3. When was evaluated blindness of studies of participants and professionals, all articles showed a low risk of bias [5, 18, 22, 28-34, 36, 38-42]. Regarding the randomization and allocation of participants, almost all studies presented a low risk of bias [5, 18, 22, 28-34, 36, 38-41]. On the other hand, blinding of outcome assessors was an unclear risk for six studies [5, 18, 28-30, 36] and a low risk for ten articles [22, 31-34, 38-42]. The incomplete outcomes was a low risk of bias for most studies, except for Gambarini *et al.* [28] and Kherlakian *et al.* [18], which was an unclear risk. Concerning the outcomes, all articles have a low risk of bias [5, 18, 22, 28-34, 36, 38-42]. Nine studies presented a high risk of bias due to other sources of bias [5, 18, 22, 28, 29, 31, 32, 36, 42].

Table 3. Risk of bias of selected studies

Author	Random Sequence Generation	Allocation concealment	Binding of participants/ professionals	Blinding of outcome assessors	Incomplete outcomes	Relative outcome report	Other sources of bias
Gambarini *et al.* [28]	Low	Low	Low	Unclear	Low	Low	High
Gambarini *et al.* [29]	Low	Low	Low	Unclear	Unclear	Low	High
Neelakantan *et al.* [30]	Low	Low	Low	Unclear	Low	Low	Low
Nekoofar *et al.* [5]	Low	Low	Low	Unclear	Low	Low	High
Kherlakian *et al.* [18]	Low	Low	Low	Unclear	Unclear	Low	High
Krithikadatta *et al.* [31]	Low	Low	Low	Low	Low	Low	High
Pasqualini *et al.* [32]	Low	Low	Low	Low	Low	Low	High
Relvas *et al.* [33]	Low	Low	Low	Low	Low	Low	Low
Shokraneh *et al.* [34]	Low	Low	Low	Low	Low	Low	Low
Arslan *et al.* [36]	Low	Low	Low	High	Low	Low	High
Zand *et al.* [35]	Low	Unclear	Low	Low	Low	Low	High
Mollashahi *et al.* [37]	Low	Low	Low	Low	Low	Low	High
Çiçek *et al.* [38]	Low	Low	Low	Low	Low	Low	Low
Saha *et al.* [39]	Low	Low	Low	Low	Low	Low	Low
Oliveira *et al.* [40]	Low	Low	Low	Low	Low	Low	Low
Adiguzel *et al.* [41]	Low	Low	Low	Low	Low	Low	Low

The results were presented separately in two meta-analysis with the data available in the studies included in this systematic review. One of the studies [36] presented its quantitative results only as graphics, which did not allow quantitative evaluation. These authors did not provide data for "no pain" separately from "mild pain", hindering the analysis of cases without pain. Therefore, 14 studies were included in the meta-analysis.

Meta-analysis 1, Dichotomous data: Figure 2 shows a forest plot for the prevalence of individuals with "no pain". The results of the meta-analysis showed that the rotary system and the reciprocating system were similar at 12 h (RR=1.01, 95% CI=0.75 to 1.37, *P*=0.94) (I^2=0%); 24 h (RR=1.03, 95% CI=0.99 to 1.08, *P*=0.14) (I^2=0%); 72 h (RR=1.00, 95% CI=0.99 to 1.01, *P*=0.77) (I^2=0%) and 7 days (RR=1.01, 95% CI=1.00 to 1.01, *P*=0.09) (I^2=0%). However at 48 h, patients treated with reciprocating system showed lower risk of pain than patients treated with rotary system (RR=1.04, 95% CI=1.01-1.06, *P*=0.003) (I^2=0%). The certainty of evidence ranges from very low to moderate (Table 4).

Meta-analysis 2, Continuous data. Figure 3 shows a forest plot for the postoperative pain intensity using the mean pain scores.

Meta-analysis of the quantitative evaluation of postoperative pain showed a greater pain level for the reciprocating system (*n*=380) than for the rotary system (*n*=402) within 24 h after endodontic treatment (SMD=0.25, 95% CI=0.06 to 0.44, *P*=0.01) (I^2=43%). Considering the other time intervals, the reciprocating and rotary systems had similar rates of postoperative pain at 6 h (SMD=0.26, 95% CI=-0.50 to 1.03, *P*=0.50) (I^2=77%); 12 h (SMD=0.32, 95% CI=-0.14 to 0.78, *P*=0.18) (I^2=80%); 48 h (SMD=0.31, 95% CI=-0.04 to 0.66, *P*=0.08) (I^2=76%); 72 h (SMD=0.50, 95% CI=-0.24 to 1.24, *P*=0.19) (I^2=91%). The certainty of evidence ranges from very low to high (Table 5).

Discussion

This systematic review and meta-analysis compared the rate of postoperative pain between reciprocating and rotary systems, for which two analyses were performed. Initially, the absence of pain after endodontic treatment intervals was analysed within the time intervals of 12, 24, 48, 72 h and 7 days. Subsequently, the level of postoperative endodontic pain was analysed at the time intervals of 6, 12, 24, 48 and 72 h.

Six articles were included in the first analysis [28-30, 33, 34, 38]. The absence of pain after endodontic treatment was more frequent than the presence of pain, and there was no statistical difference between rotary and reciprocating systems, except for 48 h; patients treated with reciprocating system showed lower risk of pain. At 12 h, 24 h, 72 h and 7 days, the magnitude of the heterogeneity (I2) was 0%, which confirms the similarity of the surveys analysed at each time interval. Within 48 h, the I^2 value

Table 4. Certainty of evidence of dichotomous data

Participants (RCTs)	Indirectness	Imprecision	Overall certainty	Study event rates (%)		Relative effect (95% CI)	Anticipated absolute effects	
				Rotary	Reciprocanting		Risk with Rotary	Risk difference (Reciprocanting)
123 (2)	**12 h**							
	very serious [a,b]	very serious [c,d]	Very low	35/61 (57.4%)	36/62 (58.1%)	1.01 (0.75 to 1.37)	574 per 1.000	6 more per 1.000 (from 143 fewer to 212 more)
1411 (4)	**24 h**							
	serious [b]	not serious	Moderate	584/705 (82.8%)	603/706 (85.4%)	1.03 (0.99 to 1.08)	828 per 1.000	25 more per 1.000 (from 8 fewer to 66 more)
1270 (2)	**48 h**							
	serious [b]	not serious	Moderate	590/635 (92.9%)	611/635 (96.2%)	1.04 (1.01 to 1.06)	929 per 1.000	37 more per 1.000 (from 9 more to 56 more)
1456 (5)	**72 h**							
	serious [b]	not serious	Moderate	684/720 (95.0%)	683/736 (92.8%)	1.00 (0.99 to 1.01)	950 per 1.000	10 fewer per 1.000 (from 76 fewer to 76 more)
1288 (2)	**7 days**							
	serious [b]	not serious	Moderate	638/644 (99.1%)	643/644 (99.8%)	1.01 (1.00 to 1.01)	991 per 1.000	**10 more per 1.000 (from 0 fewer to 10 more)**

CI: Confidence interval; RR: Risk ratio; a: Meta-analysis included only one pulp condition; b: Meta-analysis included studies that performed only one visit; c: Total number of events is less than 300; d: Upper or lower confidence limit crosses the effect size is greater than 25% of estimated effect in either direction

was 50%, which confirms moderate heterogeneity of the studies analysed. Other researchers have also noted that the absence of pain is more common than its presence after endodontic treatment [43-45]. In a recent systematic review [46], no postoperative pain was reported in 60% of cases within the first 24 h, increasing to 89% after 7 days.

Ten articles were included in the second analysis [5, 18, 22, 31-33, 38, 40-42]. Statistically significant differences were detected only for the 24 h interval indicating that reciprocating systems caused more pain. Although a significant difference was observed, the level of postoperative pain detected at 24 h was low in most of the studies, expect for Pasqualini *et al.* [32], who reported a pain level of 5.1 on a 10-point scale, and Zand *et al.* [42], who reported a moderate pain. No statistical differences were found at intervals <24 h.

A recent review and meta-analysis [46] also studied the effects of different kinematics in the presence of postoperative pain. However, the authors searched only two databases, the search period was shorter than ours and there was a restriction on the language in the selection of articles. In addition, temporal analysis of pain was not performed as in the present review. The authors concluded that rotary systems were associated with fewer episodes of pain, whereas in this review such relationship was found only within 24 h.

Some clinical factors may also affect postoperative pain. Ng *et al.* [2] observed that sex, type of tooth and periapical lesion size may be relevant factors. Gotler *et al.* [3] found that the incidence of postoperative pain was higher in vital teeth than in necrotic teeth and in retreatment cases. On the other hand, Ince *et al.* [47] concluded that the postoperative pain did not differ between vital and necrotic teeth.

With regard to pulp and periradicular status, seven of the articles in this review included only teeth with necrotic pulp [28, 29, 33, 34, 38, 41, 42] and seven articles only teeth with vital pulp [5, 18, 22, 30, 36, 39, 40]. The other articles included teeth with vital and necrotic pulp [31, 32], making comparisons between studies difficult. Another factor that affects pain after endodontic treatment is preoperative pain [47, 48] and in this review, just one study measured pain before endodontic treatment [30].

Table 5. Certainty of evidence for continuous data

Participants (RCTs)	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Overall certainty	Study event rates (%)		Anticipated absolute effects[a]
							Rotary	Reciprocating	
	6 h								
142 (2)	serious [a]	serious [b]	serious [c]	very serious [d,e]	strong association	Very low	71	71	SMD 0.26 SD higher (0.5 lower to 1.03 higher)
	12 h								
390 (3)	not serious	serious [b]	not serious	serious [d]	strong association	Moderate	195	195	SMD 0.32 SD higher (0.14 lower to 0.78 higher)
	24 h								
782 (10)	serious [f]	not serious	not serious	not serious	strong association	High	402	380	SMD 0.25 higher (0.06 higher to 0.44 higher)
	48 h								
599 (4)	not serious	serious [b]	not serious	not serious	strong association	High	311	288	SMD 0.31 SD higher (0.04 lower to 0.66 higher)
	72 h								
519 (6)	not serious	very serious [b,g]	very serious [h,i]	serious [e]	none	Very low	271	248	SMD 0.5 higher (0.24 lower to 1.24 higher)

SMD: Standardized mean difference; a: All included studies presented high risk of bias; b: Substantial or considerable heterogeneity; c: Meta-analysis included only one pulp condition; d: Total number of participants is less than 400; e: Upper or lower confidence limit crosses the effect size is greater than 0.5 in either direction

Extrusion of debris during the chemical-mechanical preparation may also be related to a higher incidence of postoperative pain [46, 49]. There is a balance between microorganisms and host defence in chronic apical periodontitis [50]. However, when microorganisms are extruded apically during instrumentation, an imbalance occurs which may trigger an acute inflammatory reaction. It is also accepted that uncontaminated dentin and extruded pulp tissue may initiate an inflammatory process in the apical region [51, 52]. It is argued that hand instruments generally extrude more debris than Ni-Ti instruments [53-55], but there is no consensus on the extrusion of debris between rotary and reciprocating systems [16, 54]. Some authors agree that rotary instruments extrude less debris [19, 55, 56]. This could explain the lower presence of pain after 24 h when these systems are used. Robinson *et al.* [57] verified that reciprocating systems caused a greater accumulation of debris in isthmus areas than rotary systems, suggesting that this could lead to an unsuccessful treatment. In a systematic review, Caviedes-Bucheli *et al.* [58] verified that all instruments caused apical extrusion of debris; however, rotary instruments had less debris extrusion. By relating this finding to inflammation in the periapical region, the authors agreed that the design of the instrument is the most influential factor for neuropeptide expression after root canal preparation, regardless of the number of files or the type of movement [58].

Another factor that interferes with the extrusion of debris and incidence of postoperative pain is the working length [58]. In this review, some articles did not include this information [22, 29, 30, 33, 36, 39, 40, 42], which led us to contact the authors for clarification. It was concluded that in seven articles, the working length was established as 0.5 mm short of the apical foramen [5, 18, 22, 30, 36, 38, 42]; in four articles, the working length was at 0 mm from the apical locator [28, 29, 32, 33], and in four articles the teeth were instrumented 1 mm short [31, 34, 40, 41]. Some authors have verified that when the working length is 1 mm short, the extrusion of debris is reduced [59-61]. However, two randomized clinical studies verifying the effect of foraminal enlargement on postoperative pain found a low pain frequency, comparable with instrumentation 1 mm below the foramen [62, 63]. For this reason, the working length was not an exclusion criterion in this review.

Most of the articles included in the present systematic review performed endodontic treatment in one visit, with the exception of Nekoofar *et al.* [5]. These authors performed the treatment in two visits, however without using intracanal medication. For this meta-analysis, only the results of the first session were considered, because instrumentation with the rotary and reciprocating systems was performed at this visit. Su *et al.* [49] performed a systematic review and meta-analysis to understand the healing process and evaluate postoperative pain after treatment for infected obturator canals after a single visit versus multiple visits. They found that the pain experience within the first 72 h in patients undergoing a single visit (26%) was statistically lower than with multiple visits (37%). Possibly the better results for the single session may be related to immediate obturation [49]. In endodontically treated vital teeth, the frequency of postoperative pain did not differ between single and multiple sessions [45, 64].

The limitations of this systematic review are related to the inherent characteristics of any meta-analyses, associated with methodological differences among the studies, such as sample variation (in relation to sex, age, tooth type and endodontic diagnosis), different instrumentation protocols (in relation to working length, irrigating solutions and apical enlargement), different number of operators and number of sessions. In addition, pain is subjective and varies according to the personal experiences of each patient; it often cannot be measured accurately with the scales proposed in these studies. Endodontic post-treatment pain is related to multiple factors; the instrument used is only one factor. Therefore, the results of this meta-analysis should be interpreted with caution, and new studies with well-designed methodologies should be undertaken in the search for new scientific evidence on this important topic.

Conclusion

Based on the results of this meta-analysis, it can be concluded that the incidence of postoperative pain after the use of Ni-Ti instruments is low and that reciprocating systems evoked more pain within the first 24 h after treatment. Overall, the incidence and level of postoperative pain did not vary between reciprocating and rotary systems.

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