IEJ Iranian Endodontic Journal

Effect of Reciprocating and Rotary Systems on Postoperative Pain: A Systematic Review and Meta-Analysis

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ARTICLE INFO

Article Type: **Meta-analysis**

Received: 04 Jul 2020
Revised: 05 Nov 2020
Accepted: 22 Nov 2020
Doi: *10.22037/iej.v16i1.27944*

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ABSTRACT

Introduction: Our study aimed to compare the incidence and intensity of postoperative pain after endodontic instrumentation with reciprocating and rotary systems. **Methods and Materials:** An electronic literature search was performed with MEDLINE *via* PubMed, Scopus, and Web of Science databases from January 2008 to June 2020. Two high-impact endodontic journals were also hand searched. The selection criteria were: 1) *Population*; patients requiring endodontic treatment (primary or secondary), 2) *Intervention and Comparison*; endodontic instrumentation with reciprocating versus rotary systems, and 3) *Outcome*; postoperative pain. We extrapolated all included research data and reported them as dichotomized ordinal variables to evaluate the incidence of pain and continuous variables to assess pain intensity. Standardized mean difference (SMD) was calculated with Inverse Variance method for pain intensity; the incidence of postoperative pain was calculated using relative risk (RR) with the Mantel-Haenszel method. Random-effects model and 95% confidence interval (CI) were used for all meta-analyses. The I^2 statistic was used to evaluate the statistical heterogeneity among studies ($P<0.05$). **Results:** Twenty-one articles were selected and 17 of them were included in the meta-analysis for the evaluation of postoperative pain in the first 24 h. The meta-analysis was performed in two steps: a) all studies were included; b) subsequently studies with preoperative pain were excluded. A significant difference was observed in the intensity of postoperative pain; with rotary system having more favorable in both steps [a) SMD: 0.27; 95% CI: 0.13 to 0.41; P=0.0002; b) SMD: 0.37; 95% CI: 0.15 to 0.58; P=0.0010]. There was no significant difference in the incidence of pain, and the incidence of mild, moderate and severe pain (P>0.05). **Conclusion:** The meta-analysis results revealed that rotary system were the instrument of choice as they had lower intensity of postoperative pain. Further controlled studies are advocated to provide clarification for intensity/incidence of postoperative pain in endodontic treatment with mechanized instruments.

Keywords: Endodontics; Endodontic Files; Meta-Analysis; Postoperative Pain; Systematic Review

Introduction

The sensation of discomfort after the endodontic intervention, also known as postoperative pain, continues to be a common complication (1.9% to 48%) and does not seem to be directly related to the state of pulp health or periradicular condition [1]. Although more common in the first 24 h after the endodontic procedure [2], postoperative pain has a multifactorial origin with a negative experience that has become a significant cause of treatment rejection. However, the extrusion of debris has been suggested as one of the main problems associated with postoperative pain [3-5]. Regardless of canal preparation technique, manual or engine-driven, instrumentation always results in some degree of debris extrusion [6, 7].

Engine-driven instruments can be either rotary or reciprocating. Single-file reciprocating systems offered new perspectives for root canal preparation, but there is uncertainty about the incidence of postoperative pain [8]. According to De-Deus *et al.* [9], single-file reciprocating instrumentation with the WaveOne (Dentsply Maillefer, Ballaigues, Switzerland) and Reciproc systems (VDW GmbH, Munich, Germany) extruded significantly more debris than rotary instrumentation with the ProTaper Universal system (Dentsply Maillefer, Ballaigues, Switzerland). However, in a clinical trial, Relvas *et al*. [10] found no differences in the frequency of postoperative pain between the reciprocating (Reciproc) and rotary techniques (ProTaper Universal; Dentsply Maillefer, Ballaigues, Switzerland). They suggested that the extrusion of debris is similar to the systems evaluated.

It is important to note that previous systematic reviews with similar objectives as used in this study were found during our searches [11-13]. However, differences are observed in the number of databases used, the period of search, type and number of included studies in the meta-analysis [11-13]. Contradictory results were observed, with two systematic reviews favorable to rotary kinematics [11, 12] and one showing more favorable results to the reciprocating system [13].

Simplification of the endodontic technique is an obvious need. The kinematics of root canal preparation might be related to the presence of postoperative pain. Although some clinical trials have investigated the causes of postoperative pain, there is no clinical consensus regarding the results found [13, 14]. In the current study we included more studies than the previous reviews on the same topic; this systematic review and meta-analysis aimed to compare the incidence and intensity of postoperative pain after endodontic instrumentation with reciprocating and rotary systems. The null hypothesis is that no difference exists in the incidence and intensity of postoperative pain between reciprocating and rotary kinematics.

Table 1. Search Strategy for the PubMed/MEDLINE, Scopus and Web of Science databases

Database	Search Strategy
PUBMED	#1 AND #2-Search (((((((((((reciprocating system) OR reciprocating file) OR reciprocating) OR alternating movement) OR reciprocating instrument) OR alternate motion) OR reciprocating movement) OR reciprocating motion) OR reciprocating instrumentation))) AND ((((((((((rotary system) OR rotary file) OR rotary instrument) OR endodontic rotary file) OR continuous movement) OR continuous motion) OR rotary movement) OR rotary motion) OR rotary instrumentation) OR continuous rotation) Filters: Publication date from 2008/01/01 to 2020/06/30
	#2-Search (((((((((rotary system) OR rotary file) OR rotary instrument) OR endodontic rotary file) OR continuous movement) OR continuous motion) OR rotary movement) OR rotary motion) OR rotary instrumentation) OR continuous rotation)
	#1-Search (((((((((reciprocating system) OR reciprocating file) OR reciprocating) OR alternating movement) OR reciprocating instrument) OR alternate motion) OR reciprocating movement) OR reciprocating motion) OR reciprocating instrumentation)
SCOPUS	#1 AND #2 ((TITLE-ABS-KEY (reciprocating AND system) OR TITLE-ABS-KEY (reciprocating AND file) OR TITLE-ABS-KEY (reciprocating) OR TITLE-ABS-KEY (alternating AND movement) OR TITLE-ABS-KEY (reciprocating AND instrument) OR TITLE-ABS-KEY (alternate AND motion) OR TITLE-ABS-KEY (reciprocating AND movement) OR TITLE-ABS-KEY (reciprocating AND motion) OR TITLE-ABS-KEY (reciprocating AND instrumentation))) AND ((TITLE-ABS-KEY (rotary AND system) OR TITLE-ABS-KEY (rotary AND file) OR TITLE-ABS-KEY (rotary AND instrument) OR TITLE-ABS-KEY (endodontic AND rotary AND file) OR TITLE-ABS-KEY (continuous AND movement) OR TITLE-ABS-KEY (continuous AND motion) OR TITLE-ABS-KEY (rotary AND movement) OR TITLE-ABS-KEY (rotary AND motion) OR TITLE-ABS-KEY (rotary AND instrumentation) OR TITLE-ABS-KEY (continuous AND rotation)) Filters: 2008/01/01 to 2020/06/30
	#2 (TITLE-ABS-KEY (rotary AND system) OR TITLE-ABS-KEY (rotary AND file) OR TITLE-ABS-KEY (rotary AND instrument) OR TITLE-ABS-KEY (endodontic AND rotary AND file) OR TITLE-ABS-KEY (continuous AND movement) OR TITLE-ABS-KEY (continuous AND motion) OR TITLE-ABS-KEY (rotary AND movement) OR TITLE-ABS-KEY (rotary AND motion) OR TITLE-ABS-KEY (rotary AND instrumentation) OR TITLE-ABS-KEY (continuous AND rotation))
	#1 (TITLE-ABS-KEY (reciprocating AND system) OR TITLE-ABS-KEY (reciprocating AND file) OR TITLE-ABS-KEY (reciprocating) OR TITLE-ABS-KEY (alternating AND movement) OR TITLE-ABS-KEY (reciprocating AND instrument) OR TITLE-ABS-KEY (alternate AND motion) OR TITLE-ABS-KEY (reciprocating AND movement) OR TITLE-ABS-KEY (reciprocating AND motion) OR TITLE-ABS-KEY (reciprocating AND instrumentation))
WEB OF SCIENCE	#1 AND #2 Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI Allotted time=2008-2020
	#2 TS=(rotary system) OR TS=(rotary file) OR TS=(rotary instrument) OR TS=(endodontic rotary file) OR TS=(continuous movement) OR TS=(continuous motion) OR TS=(rotary movement) OR TS=(rotary motion) OR TS=(rotary instrumentation) OR TS=(continuous rotation) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI Allotted time=Every year
	#1 TS=(reciprocating system) OR TS=(reciprocating file) OR TS=(reciprocating) OR TS=(alternating movement) OR TS=(reciprocating instrument) OR TS=(alternate motion) OR TS=(reciprocating movement) OR TS=(reciprocating motion) OR TS=(reciprocating instrumentation) Indexes=SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, ESCI Allotted time=Every year

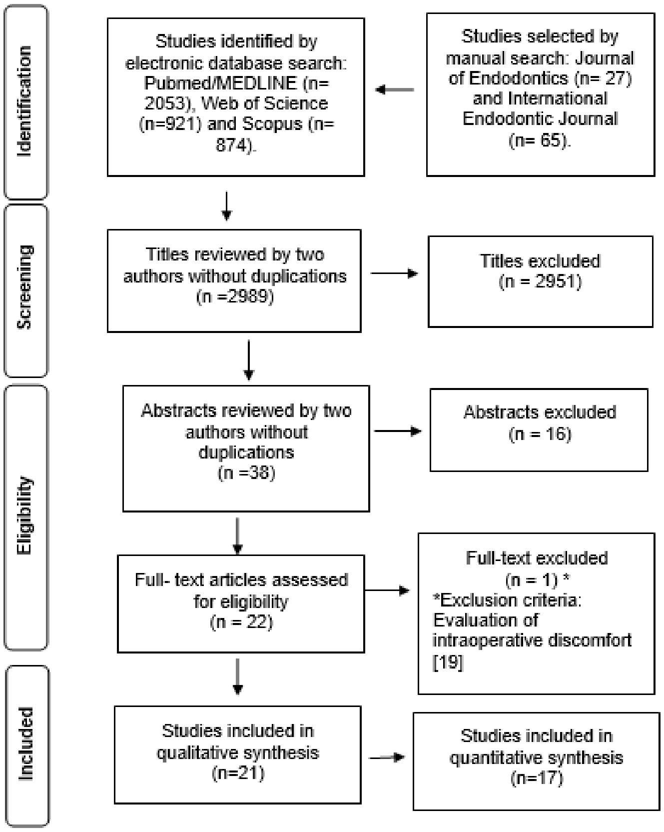

Figure 1. Flow diagram of the article selection process

Materials and Methods

Protocol and registry

This review was performed following the recommendations of the Cochrane Collaboration for systematic reviews [15] and is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement [16]. The study is registered in PROSPERO under registration number CRD42017071582.

Eligibility criteria

The PICO components were defined as follow: *Population*; patients requiring endodontic treatment (primary or secondary), *Intervention and Comparison*, endodontic instrumentation with reciprocating versus rotary systems, and *Outcome*, postoperative pain.

The criteria for inclusion were randomized clinical trials (RCTs) evaluating and comparing postoperative pain after the use of reciprocating and rotary kinematics; it was evaluated according to the pain level (mild, moderate, or severe). We excluded prospective studies without randomization, retrospective studies, case reports, reviews, *in vitro* and *ex vivo* studies, and studies evaluating postoperative pain after the use of only one of the systems without direct comparison with the other.

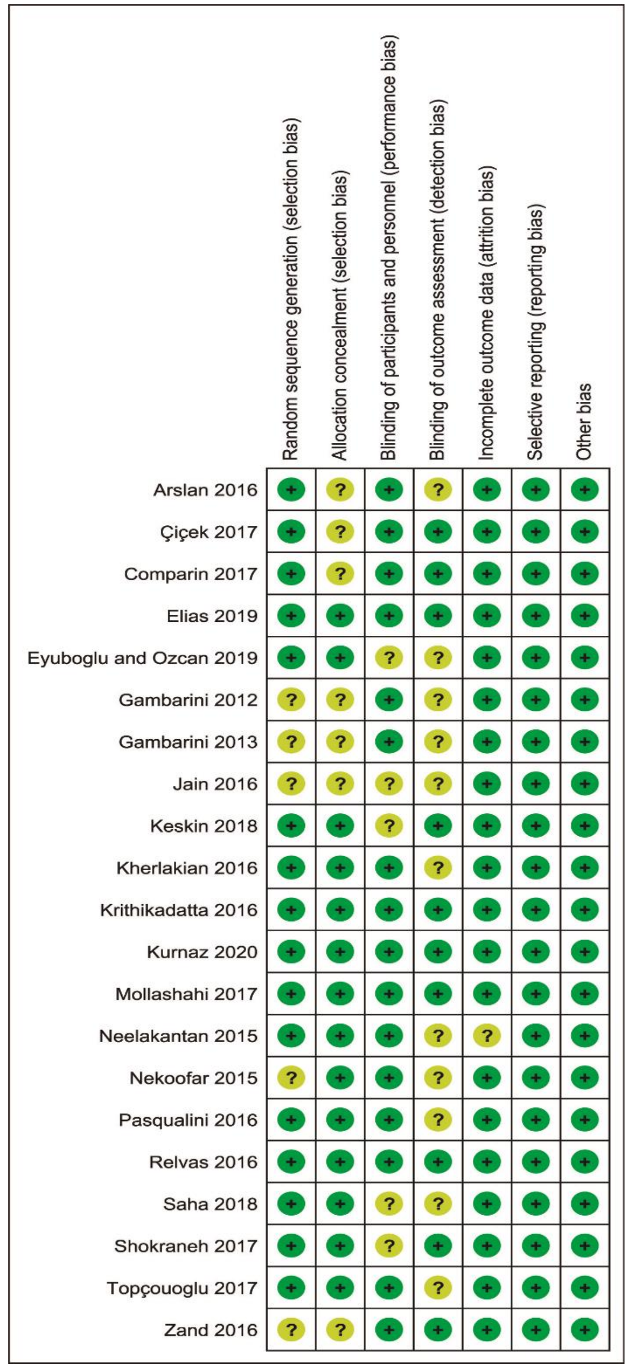

Figure 2. Risk of bias of the included studies using the Cochrane risk of bias tool; + as low risk of bias;? as unclear risk of bias.

Before the literature search, the research question of the present study was elaborated: “Does instrumentation with the reciprocating system cause more postoperative pain than instrumentation with the rotary system?” The primary outcome to be evaluated was the intensity and incidence of postoperative pain caused by instrumentation with reciprocating and rotary systems.

Table 2. Clinical characteristics of endodontic treatments in the included studies

Author	Diagnosis	Presence of pre-op pain	Tooth type	Systems	Irrigant	Working length
Arslan ***et al.*** **[17]**	NS	Yes	Molars	Reciproc in various kinematics	1.25% NaOCl	NS
Comparin ***et al.*** **[18]**	Endodontic Retreatment (asymptomatic and symptomatic AP)	Yes	All	Reciproc and Mtwo	2.5% NaOCl	1 mm
Çiçek ***et al.*** **[19]**	Asymptomatic pulp necrosis with periapical lesion	No	Mandibular teeth with single straight root canal	Hand files, WO , and PTN	5.25% NaOCl+ 2% Chlorhexidine	0.5 mm
Elias ***et al.*** **[20]**	Symptomatic irreversible pulpitis	Yes	Mandibular premolars	Reciproc and OSh	2.5% NaOCl	0.5 mm
Eyboglu and Özcan [21]	Endodontic Retreatment (Asymptomatic AP)	No	All	OS, Revo S and WO	2.5% NaOCl	0.5 mm
Gambarini ***et al.*** **[22]**	pulp necrosis	Yes	Premolars/ molars	TF, TF adaptive (reciprocating-rotary) and WO	5% NaOCl	NS
Gambarini ***et al.*** **[23]**	pulp necrosis	Yes	Premolars/ molars	TF and Reciproc	5% NaOCl	NS
Jain ***et al.*** **[24]**	Symptomatic irreversible pulpitis	No	Maxillary/ mandibular molar	WO, OS and SAF	5.25% NaOCl	NS
Kherlakian ***et al.*** **[5]**	Vital pulps (prosthetic purposes)	No	Premolars and Molars	PTN, WO, and Reciproc	2.5% NaOCl	0.5 mm
Keskin ***et al.*** **[25]**	Asymptomatic/ symptomatic irreversible pulpitis or Asymptomatic/ symptomatic AP	No	Maxillary and mandibular teeth	R-Pilot, ProGlider and stainless-steel K-files	5.25% NaOCl	NS
Krithikadatta ***et al.*** **[26]**	Asymptomatic, symptomatic irreversible pulpitis or pulp necrosis	Yes	Premolars/ Molars	WO, PTU and Mtwo	5% NaOCl+2% Chlorhexidine	Apex
Kurnaz [27]	Asymptomatic AP	No	single root canal teeth	PTN and WO	2,5% NaOCl	0 mm
Mollashahi ***et al.*** **[28]**	Symptomatic irreversible pulpitis	Yes	Molar	OS, Reciproc and K-file	2.5% NaOCl	0.5 mm
Neelakantan and Sharma [29]	Symptomatic irreversible pulpitis	Yes	Mandibular molars	Reciproc and OS	3% NaOCl	NS
Nekoofar ***et al.*** **[30]**	Irreversible pulpitis	No	Premolar and Molars	WO and PTU	2% Chlorhexidine	0.5 mm
Pasqualini ***et al.*** **[31]**	Asymptomatic, symptomatic irreversible pulpitis/ pulp necrosis	Yes	All	PTU and WO	5% NaOCl	Apex
Relvas ***et al.*** **[10]**	pulp necrosis	No	Mandibular molars	Reciproc and PTU	2.5 % NaOCl	0.5 mm
Shokraneh ***et al.*** **[32]**	Necrotic pulps and periapical lesion	No	Mandibular molars	WO, PTU and stainless steel K-files	5.25% NaOCl	1 mm
Saha ***et al*** **[33]**	Symptomatic irreversible pulpitis with/without AP with no periapical lesion	No	Maxillary/ mandibular premolars and molars	PTN, SAF and WO	5.25% NaOCl	NS
Topçuoğlu ***et al.*** **[34]**	Endodontic Retreatment (Asymptomatic AP)	No	Upper incisor teeth	Reciproc, PTU Retreatment and Hand file	2.5% NaOCl	1 mm
Zand ***et al.*** **[35]**	pulp necrosis	No	Mandibular molars	Race and Reciproc	2.5% NaOCl, 17% EDTA in gel-form and normal saline	NS

NS: not stated; AP: apical periodontitis; OS: one shape; WO: wave one; PTN protaper next; TF: Twisted File; SAF: Self Adjusting File; PTU: ProTaper Universal; Pre-op, preoperative

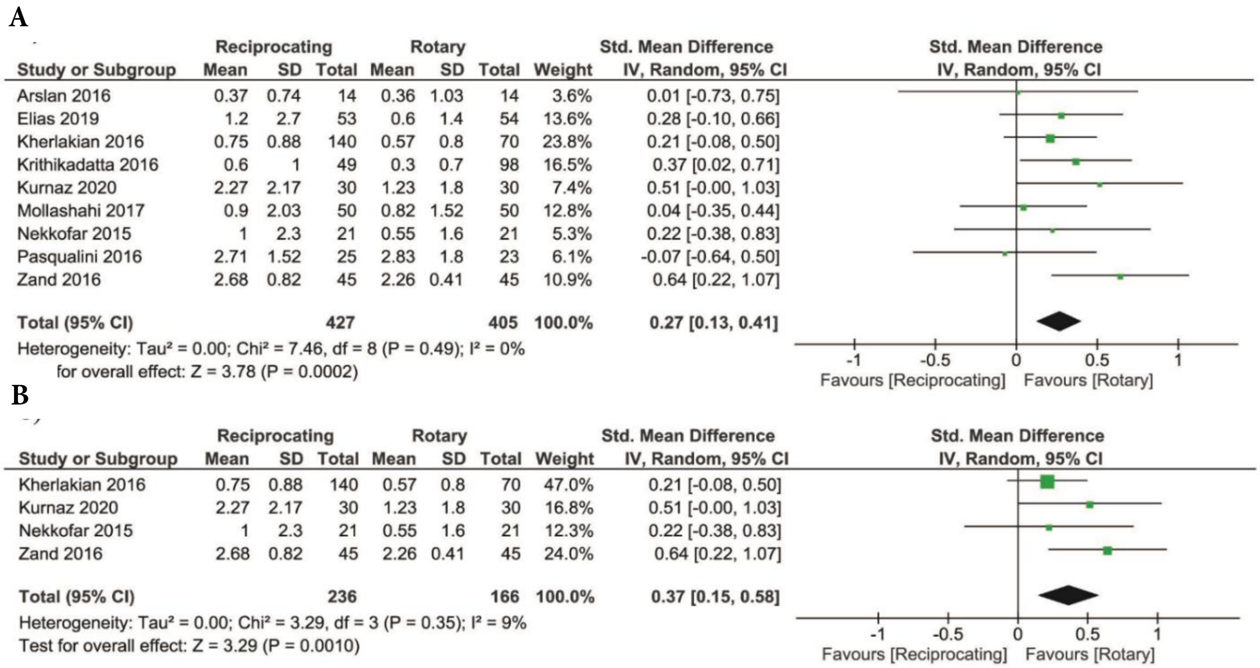

Figure 3. *A)* Forest plot of the intensity of postoperative pain in the first 24 h after instrumentation with reciprocating and rotary systems; *B)* Forest plot of the intensity of postoperative pain in the first 24 h after instrumentation with reciprocating and rotary systems without studies included patients with preoperative pain

Information sources

A comprehensive electronic literature search comprising articles published from January 2008 to June 2020 was performed. The search was started in 2008 because of the introduction of reciprocating motion in that year. The following electronic databases were searched: MEDLINE/PubMed, Scopus, and Web of Science. Also, manual searches of two high-impact endodontic journals comprising the last 6 months were performed: International Endodontic Journal (IEJ) and Journal of Endodontics (JOE). The electronic search was restricted to articles published in English.

Search strategy

The search strategies used controlled vocabulary keywords and related synonyms for each group of intervention and comparison, combined within each concept by the Boolean operator 'OR'. This approach allowed to retrieve articles containing any of the terms. Sets of terms for both groups were constructed and combined by the Boolean operator 'AND'. This step permits to retrieve articles that contain at least one of the terms of each group of intervention and comparison. The search strategies are summarized in Table 1.

Selection of the studies and data collection

Two independent researchers (M.T.S. and S.M.B.) evaluated and selected potential studies for inclusion by reading the titles and then the abstracts and applying the previously established inclusion criteria. Next, the full text of the selected articles was read.

The following data were extracted from the selected studies: author and year, type of study, presence or absence of blinding, sample size, diagnosis, presence of preoperative pain, prescription of analgesics, tooth treated, number of sessions, working length used, type of irrigant, instrumentation system, method of assessing postoperative pain,time intervals and outcomes of each study (Tables 2 and 3).

Evaluation of the quality of the included studies

The Cochrane Collaboration "risk of bias "tool was used to assess the quality of the selected studies [15]. A critical analysis was done individually for each aspect of bias risk, divided into seven domains: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other bias. Each domain was classified as a low risk of bias, unclear risk of bias, or high risk of bias.

The extraction of the qualitative and quantitative data, as well as assessment of the risk of bias, was performed by two independent researchers (M.T.S. and S.M.B.) Disagreements between evaluators were resolved through discussion.

Table 3. Methodological characteristics and main results of the included studies

Author	Sample Size	Method of assessing post-op pain	Time intervals	Outcomes of each study
Arslan *et al.* [17]	Group 1: (150º CCW–30º CW): *n*=14 Group 2: (270º CCW–30ºCW): *n*=14 Group 3: (360º CCW–30º CW): *n*=14 Group 4: (continuous rotation): *n*=14	Visual Analogue Scale	1, 3, 5, and 7 days	Continuous rotation resulted in more post-op pain at day 1 than in reciprocating groups
Comparin *et al.* [18]	Group 1: (R): *n*=32 Group 2: (Mtwo retreatment)=33	Verbal Rating Scale	24, 48 and 72 h.	The same effect of reciprocating and continuous rotary system regarding the incidence, intensity, and duration of post-op pain
Çiçek *et al.* [19]	Group 1: (Modified step-back technique using stainless-steel hand files): *n*=30 Group 2: (WO): *n*=30 Group 3: (PTN): *n*=30	Pain Intensity Scale	12, 24, and 48 h.	The modified step-back technique produced less pain compared to the rotary and reciprocal techniques
Elias *et al.* [20]	Group 1: (R): *n*=54 Group 2: (OS): *n*=54	Numerical Rating Scale	6, 12, 24, 48 and 72 h	Continuous rotary instruments were accompanied by a significantly lower incidence of pain at 12 and 24 h postoperatively compared to reciprocation
Eyuboglu and Özcan [21]	Group 1: (OS): *n*=33 Group 2: (Revo S): *n*=33 Group 3: (WO): *n*=33	Verbal Rating Scale	6, 12, 18, 24, 48 and 72 h, 7 days, and 1 month	The WO system was associated with the highest post-op pain intensity values
Gambarini *et al.* [22]	Group 1: (rotary crown-down technique using TF): *n*=30 Group 2: (WO): *n*=30 Group 3: (TF adaptative - reciprocation/continuos rotation): *n*=30	Visual Analogue Scale	3 days	A reciprocating single-file technique showed more significant inflammatory response and pain than a rotary nickel-titanium crown down instrumentation technique (TF)
Gambarini *et al.* [23]	Group 1: (Crown-down technique using TF): *n*=30 Group 2: (R): *n*=30	Visual Analogue Scale	3 days	For patients who developed no pain, the TF instrumentation technique showed significantly better results. For patients with severe pain, the incidence of symptoms was significantly higher with the reciproc technique
Jain *et al.* [24]	Group 1: (WO): *n*= 47 Group 2: (OS): *n*=47 Group 3: (SAF): *n*=47	Functional Pain Scale	24, 48, 72h and 7 days	Patients treated with the SAF system were associated with significantly less post-op pain
Kherlakian *et al.* [5]	Group 1: (PTN): *n*=70 Group 2: (WO): *n*=70 Group 3: (R): *n*=70	Visual Analogue Scale	24 , 48, 72h, and 7 days	The reciprocating and the continuous rotary system were same for the incidence of post-op pain

Keskin *et al.* [25]	Group 1: (stainless-steel K-files): *n*=80 Group 2: (ProGlider): *n*=80 Group 3: (R-Pilot): *n*=80	Visual Analogue Scale	6, 12, 18, 24, 48 and 72 h	Preparation of glide paths with rotating or reciprocating NiTi instruments was associated with less post-op pain levels and incidence compared to manual glide path preparation with no significant difference between rotating and reciprocating instruments
Krithikadatta *et al.* [26]	Group 1: (WO): *n*=49 Group 2: (PTU): *n*=49 Group 3: (Mtwo): *n*=50	Visual Analogue Scale	2, 4, 6, 12, 24, 36 and 48 h	Patients treated with WO files experienced more pain compared to the other files
Kurnaz [27]	Group 1: (PTN): *n*=30 Group 2: (WO): *n*=30	Visual Analogue Scale	during first 7 days	Post-op pain was significantly higher in the WO group than in the PTN group during the first 2 days of follow-up
Mollashahi *et al.* [28]	Group 1: (OS): *n*=50 Group 2: (R): *n*=50 Group 3: (stainless steel K-files): *n*=50	Visual Analogue Scale	6, 12, 24, 48 and 72 h	The instrumentation kinematics (single-file reciprocating or single-file rotary) had no impact on the intensity of post-op pain
Neelakantan & Sharma [29]	Group 1: (R): *n*=605 Group 2: (OS): *n*=605	Visual Analogue Scale	until 7 days	Reciproc showed significantly less intensity and duration of post-op pain compared to O S
Nekoofar *et al.* [30]	Group 1: (WO): *n*=21 Group 2: (PTU): *n*=21	Numerical Rating Scale	6, 12, 18, 24, 48 and 72 h	Lower post-op pain with PTU rotary instruments than the WO reciprocating single-file technique
Pasqualini *et al.* [31]	Group 1: (PTU): *n*=23 Group 2: (WO): *n*=24	Visual Analogue Scale	until 7 days	Reciprocating instrumentation affected post-op quality greater extent than rotary instrumentation
Relvas *et al.* [10]	Group 1: (PTU): *n*=39 Group 2: (R): *n*=39	Verbal Rating Scale	24, 72 h and 7 days	The occurrence of post-op pain was low and similar between the reciprocating and rotary techniques
Shokraneh *et al.* [32]	Group 1: (WO): *n*=32 Group 2: (PTU): *n*=31 Group 3: (stainless steel K-files): *n*=30	Visual Analogue Scale	6, 12, 18, 24, 48 and 72 h	Postop-op pain was significantly lower with the WO file than the PT U and hand files
Saha *et al.* [33]	Group 1: (PTN): *n*=70 Group 2: (SAF): *n*=70 Group 3: (WOG): *n*=70	Visual Analogue Scale	24, 48, 72 h and 7 days	SAF system may prove to be a better system compared with PTN and WOG as it produces minimal postop-op pain
Topçuoğlu *et al.* [34]	Group 1: (R): *n*=45 Group 2: (PTUR): *n*=45 Group 3: (Hand File): *n*=45	Visual Analogue Scale	6, 12, 24, 48 and 72 h, 7 days, and 10 days	Manual files caused more significant post-op pain after non-surgical endodontic retreatment compared to the ProTaper retreatment and R files
Zand *et al.* [35]	Group 1: (Race): *n*=45 Group 2: (R): *n*=45	Visual Analogue Scale	4, 12, 24, 48, 72h and 1 week	RaCe files resulted in less severe post-op pain compared to R files

Post-op: postoperative; VAS: visual analogue scale; RCT: randomized controlled trials; VRS: verbal rating scale; NRS: numerical rating scale; R: reciprocating; WO: wave one; PTN: OS: one shape; PTUR: WOG: SAF: CW: clock-wise

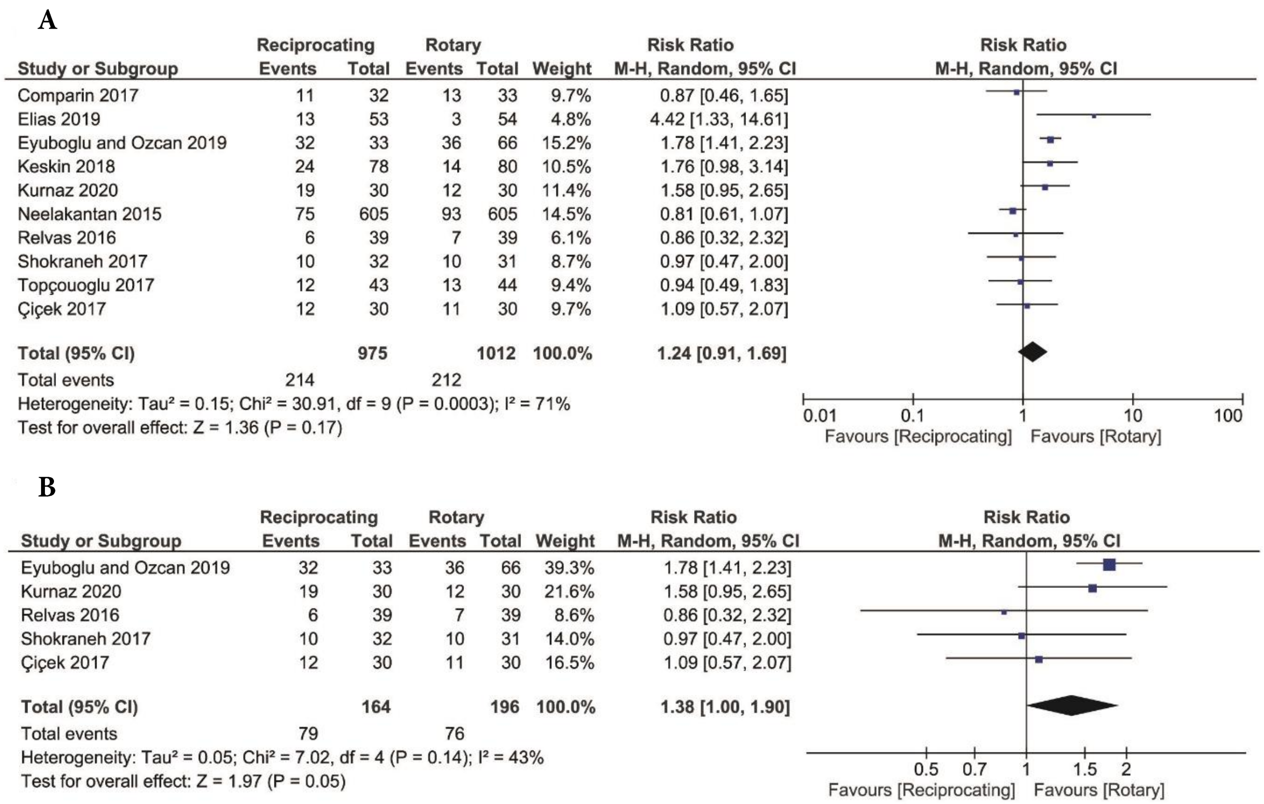

Figure 4*. A*) Forest plot of the incidence of postoperative pain in the first 24 h after instrumentation with reciprocating and rotary systems; *B*) Forest plot of the incidence of postoperative pain in the first 24 h after instrumentation with reciprocating and rotary systems without studies included patients with preoperative pain

Summary measures and synthesis of results

The extracted data were analyzed with the Review Manager 5.3 software (RevMan 5, The Cochrane Collaboration, Copenhagen, Denmark). The data of the eligible studies were reported as continuous quantitative or ordinal qualitative variables. The intensity of postoperative pain was reported as continuous variables, by means and standard deviations. The incidence and subgroups of pain levels (mild, moderate, and severe) were reported as ordinal variables, according to the pain assessment scales used.

For the pain intensity, the standardized mean difference (SMD) with 95% confidence interval (CI) was calculated using the Inverse Variance (IV) method. For the incidence of postoperative pain, the relative risk (RR) with 95% CI was calculated using the Mantel-Haenszel (M-H) method. The random-effects model was used for all meta-analyses. The I^2 statistic was used to evaluate the percent variation among studies due to heterogeneity, with 0% to 40% corresponding to might not be important heterogeneity, 30% to 60% may represent moderate heterogeneity, 50% to 90% may represent substantial heterogeneity and 75% to 100% considerable heterogeneity [15]. The level of significance was set at $P<0.05$.

The articles were divided into studies that used continuous variables (mean pain intensity and standard deviation) and the ones that used dichotomized ordinal variables (presence or absence of pain).

Additional analysis

Additionally, a subgroup meta-analysis was performed according to the incidence of the level of pain (mild, moderate, and severe). All meta-analysis was performed again, excluding the studies with preoperative pain, as they could be a potential source of bias.

The kappa coefficient was used to evaluate the agreement between researchers in selecting the abstracts [36].

Results

Selection of the studies

The initial search of the databases identified 3940 articles, including 2053 in PubMed/MEDLINE, 921 in Web of Science, 874 in Scopus, 27 in JOE, and 65 in IEJ. After reading the titles, 37 articles were selected. Following the application of the inclusion

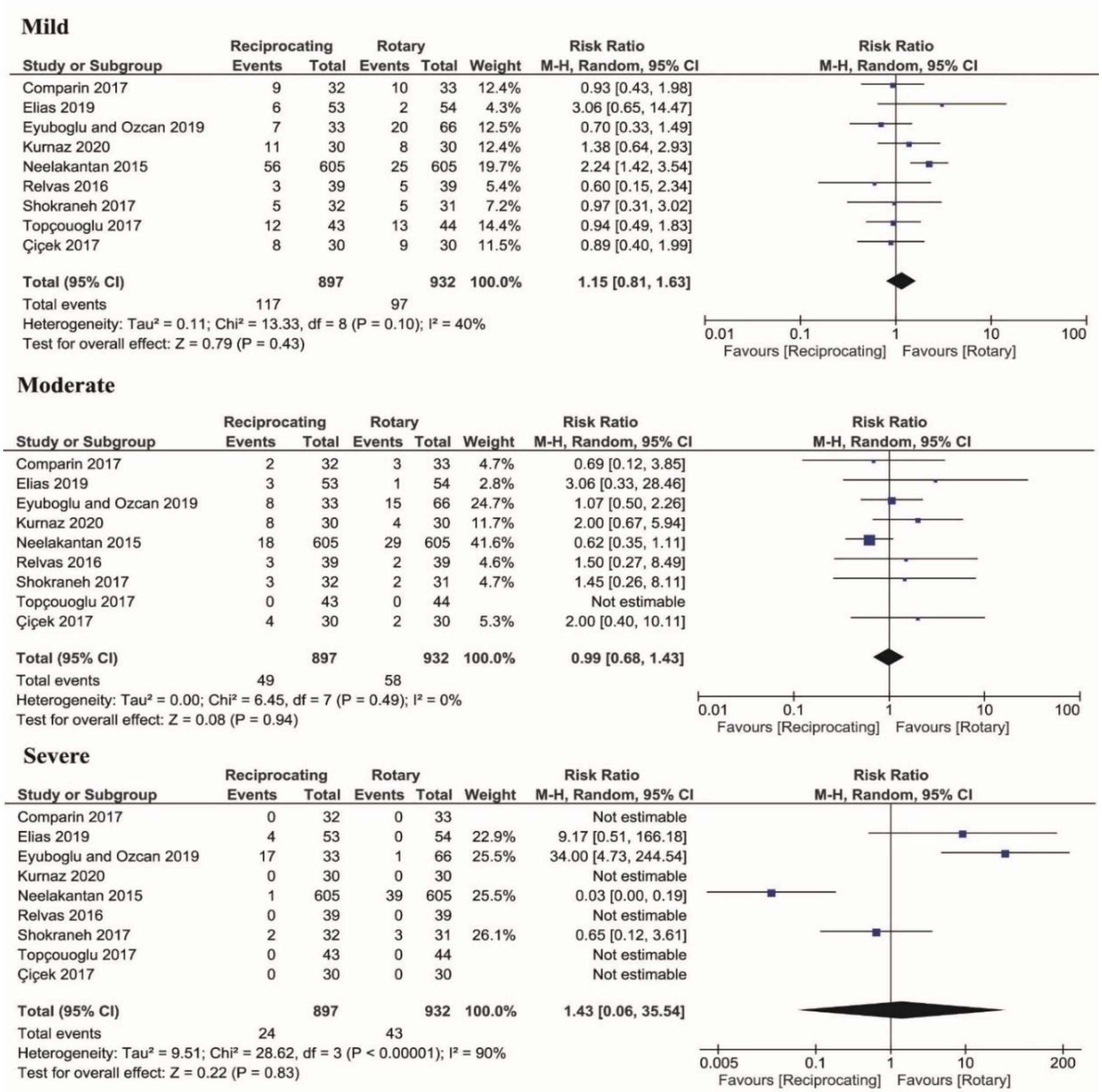

Figure 5. Forest plot of the incidence of mild, moderate and severe postoperative pain in the first 24 h after instrumentation with reciprocating and rotary systems

criteria and according to the research question, 22 articles had the abstracts read. The full text of these articles was read and only one whose objective was to evaluate the intraoperative discomfort of patients during root canal instrumentation was excluded [37]. Thus, 21 articles were included in the systematic review [5, 10, 17-35] and 17 studies were eligible for the meta-analysis [5, 10, 17-21, 25-32, 34, 35]. The PRISMA flow diagram showing the complete selection process and inclusion of the articles is illustrated in Figure 1.

The kappa coefficient was applied to the selection of the abstracts. The test result was 94% (kappa=0.94), indicating a high level of agreement between researchers.

Characterization of the studies

The 21 studies selected were analyzed qualitatively (Table 2). A total of 3429 endodontic treatments were performed and 2816 patients were evaluated. Only one of the studies used a split-mouth design [29]. Sample size calculation was not reported in four studies [10, 19, 22, 23].

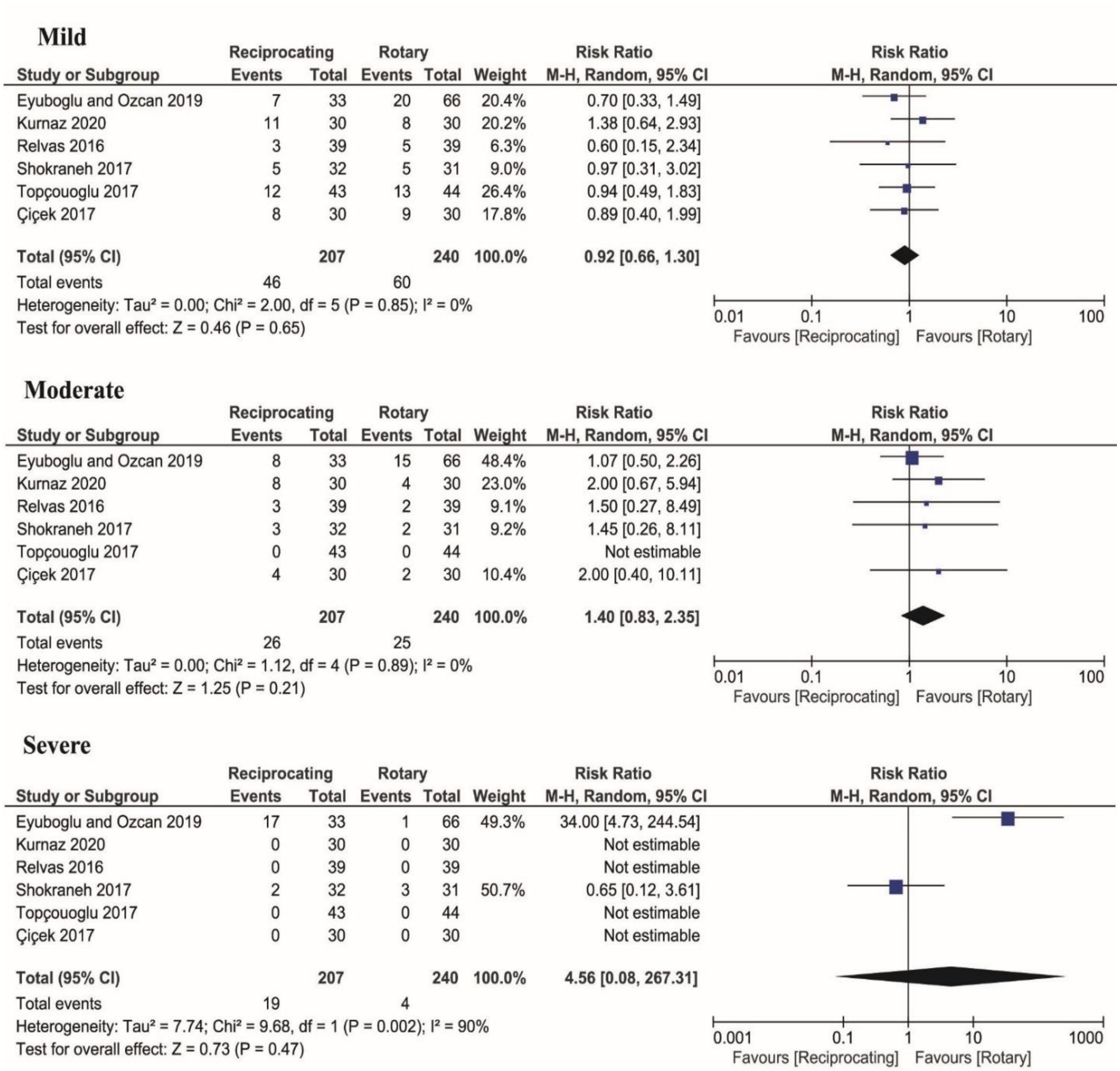

Figure 6. Forest plot of the incidence of mild, moderate and severe postoperative pain in the first 24 h after instrumentation with reciprocating and rotary systems without studies included patients with preoperative pain

In most articles (*n*=19), endodontic treatment was performed in a single session [5, 10, 18-29, 31-33, 35]. Only two articles reported that root canal filling occurred in a second session [30, 34]. In one study, root canal filling was not performed and only an intracanal medication applied for the evaluation of postoperative pain [26]. During the intervention, the working length varied between studies: at the apex (*n*=3) [26, 27, 31], 0.5 mm from the apex (*n*=7) [5, 10, 19-21, 28, 30, 38, 39] 1 mm from the apex (*n*=3) [18, 32, 34]. The other included studies did not report the working length [17, 19, 21-25, 29, 33, 35]. Regarding the irrigant used during instrumentation, 18 studies chose NaOCl with concentrations varying from 1.25% to 5.25%, with a 2.5% concentration being the most frequently used [5, 10, 28, 34]. One article used only 2% chlorhexidine throughout endodontic treatment [30].

The methods of assessing postoperative pain comprised of different scales. Most studies (*n*=13) used a Visual Analogue Scale (VAS) [5, 10, 17, 22, 23, 25, 27-34], but other methods such Verbal Rating Scale (VRS) [10, 18], Numerical Rating Scale (NRS) [20, 30], Pain Intensity Scale (PIS) [19], Functional

Pain Scale (FPS) [24] and Four Level Verbal Rating Scale (FLVR) [21] were also used.

The time intervals between endodontic treatment and the evaluation of postoperative pain varied widely among studies, ranging from 2 h to 10 days after treatment. However, most studies (n=16) included a 24 h interval for postoperative pain assessment [5, 10, 17-21, 24-26, 28, 30, 32-35].

Concerning the use of medication, nine studies only recommended the rescue medication in the event of pain [5, 18, 22-25, 33, 35]. Two studies reported medication use immediately after the endodontic intervention [30, 32]; two reported a prescription for unrestricted use [29, 31]; five reported prescriptions only in the event of severe pain [17, 20, 21, 26, 27, 34]; and two did not report the recommendation of medication use [10, 19]. In eight articles, analgesic consumption was used as a measure of the intensity of postoperative pain [5, 17, 18, 29-32, 34].

Regarding previous pain experience, nine studies did not exclude patients with preoperative pain [17, 18, 20, 22, 23, 28, 29, 31, 34]. Nine included studies reported irreversible pulpitis [20, 24-26, 28-31, 33], 9 pulp necrosis [10, 19, 22, 23, 25, 26, 31, 32, 35], 4 asymptomatic and/or symptomatic apical periodontitis [18, 21, 27, 34] as the diagnosis.

Assessment of risk of bias

Three studies did not describe the random sequence generation [22, 23, 30]. As for the randomization method, coin tossing [19], random number table [28] and drawing lots [5] were mentioned in one study each. Shuffling envelopes was described in five studies [21, 25, 26, 29, 34] and random number generation using software was used in eight other studies [10, 17, 18, 20, 27, 31-33]. Five studies were unclear about the method of allocation concealment [17-19, 22, 23], and only one study was not clear about incomplete outcome data [29]. Five studies were unclear regarding blinding of participants and personnel [21, 24, 25, 32, 33]. Eleven studies were unclear about blinding of outcome assessment [5, 17, 21-24, 29-31, 33, 34]. All studies had a low risk of bias for selective reporting and other biases (Figure 2).

Meta-analysis

The meta-analysis of this study was performed in two steps. In the first step (a), all studies that included postoperative pain in the first 24 h were evaluated. Fourteen of the 18 studies were selected. Two articles were excluded from the meta-analysis because they did not include the selected 24 h interval [22, 23], and the other two articles were excluded because they did not include data that could be compared to the other studies [24, 35].

Even though all studies evaluated the intensity of the pain, an overall comparison of the results was not possible due to the different nature of the variables. Therefore, the articles were divided into studies that used continuous variables (mean pain intensity and standard deviation) and the ones that used dichotomized ordinal variables (presence or absence of pain). When continuous variables were given, studies that used the mean pain intensity VAS, the number of subjects per score is not known [5, 17, 26, 28, 30, 31]. When ordinal variables were given, a further subgroup meta-analysis was done according to the level of pain (mild, moderate, and severe). Since the number of subjects in each pain score was given, the incidence of pain could then be analyzed [10, 18-21, 27, 29, 32, 34].

In the second step (b), a meta-analysis was performed excluding the studies with preoperative pain as it could be a potential source of bias (n=8).

Postoperative pain intensity showed a statistically significant difference (P<0.05), favoring the rotary system [(a) SMD: 0.27; 95% CI: 0.13 to 0.41; P=0.0002 (P=0.49; I^2=0%)] such when studies with preoperative pain were excluded [(b) SMD: 0.37; 95% CI: 0.15 to 0.58; P=0.0010 (P=0.35; I^2=9%] (Figure 3).

Meta-analysis of the incidence of postoperative pain revealed no significant difference (P>0.05) in both steps of the meta-analysis (a and b) between the reciprocating and rotary instrumentation systems [(a) RR: 1.24; 95% CI: 0.91 to 1.69; (P=0.0003; I^2=71%); (b) RR: 1.38; 95% CI: 1.00 to 1.90; P=0.14; I^2=43%)] (Figure 4). In the first step (a), there was also no significant difference (P>0.05) between the mild [RR: 1.15; 95% CI: 0.81 to 1.63; (P=0.10; I^2=40%)], moderate [RR: 0.99; 95% CI: 0.68 to 1.43; (P=0.49; I^2=0%)], and severe postoperative pain [RR: 1.43; 95% CI: 0.06 to 35.54; (P<0.00001; I^2=90%)] (Figure 5). In the second step (b), meta-analysis of the incidence revealed no significant difference (P>0.05) for mild [RR: 0.92; 95% CI: 0.66 to 1.30; (P=0.85; I^2=0%)], moderate [RR: 1.40; 95% CI: 0.83 to 2.35; (P=0.89; I^2=0%)] and severe postoperative pain [RR: 4.56; 95% CI: 0.08 to 267.31; P=0.002; I^2=90%] (Figure 6).

Substantial heterogeneity was observed for meta-analysis performed for postoperative pain incidence with all studies included (a) (P=0.0003; I^2=71%). However, when studies with preoperative pain were excluded, this heterogeneity was trivial (Figure 4).

Considerable heterogeneity was observed for meta-analysis performed for severe subgroup in the first step (a) (P<0.00001; I^2=%) and in the second step (b) (P=0.002; I^2=90%) (Figure 5 and 6).

Discussion

The null hypothesis that no difference exists between reciprocating and rotary kinematics regarding the incidence and intensity of postoperative pain was partially rejected. When studies using an ordinal variable to assess the incidence of pain were compared, the results showed no statistically significant difference. On the other hand, evaluation of studies using continuous variables to determine the intensity of pain revealed a significant difference in postoperative pain, favoring the rotary system.

The extrusion of debris and the presence of remnant microorganisms in the root canal are fundamental factors that can explain the relationship between instrumentation systems and postoperative pain. Caviedes-Bucheli *et al.* [40] suggested that debris' extrusion is a significant causative agent of inflammatory responses after instrumentation. The authors also demonstrated that the use of different instrumentation systems could result in variable quantities of debris that trigger the neuropeptides' expression. These neuropeptides are released from C-type nerve fibers present in the periodontal ligament when stimulated by the extrusion of irritants from the root canal, causing inflammation [41].

In vitro studies have compared the extrusion of debris between reciprocating and rotary instrumentation systems [6, 38, 42-46]. The conclusion is that all techniques produce some degree of debris extrusion during the canals' chemical-mechanical preparation. According to the results of the current meta-analysis, rotary systems cause less intense postoperative pain than reciprocating systems. The kinematics of continuous rotation may improve debris removal, increasing the capacity of removal through the crown by acting like a screw conveyor, which results in less apical extrusion [6]. On the other hand, in reciprocation, the movement is unequal (greater rotation angle high in the direction of the cut and smaller in the disengaging direction) and acts as a piston, increasing the incidence of apical extrusion [47]. However, Koçak *et al.* [48] and Üstün *et al.* [39] reported better performance of reciprocating files regarding debris extrusion. No consensus exists regarding the kinematics. Other factors such as the cross-section and design of the instrument, tip/taper, flexibility, alloy type, file sequence, and cutting efficiency, could influence the extrusion [8].

In a systematic review, Caviedes-Bucheli *et al.* [8] have evaluated the influence of two rotary-file (ProTaper Universal and Mtwo) and two single-file (WaveOne and Reciproc) systems on the apical extrusion of debris and its biological relationship with symptomatic apical periodontitis. This study included 9 laboratory studies that evaluated debris extrusion, in which 4 of them were included in their meta-analysis. Additionally, two in vivo studies that evaluated the expression of neuropeptides were analyzed. Despite the limited evidence due to the small number of studies, it seems that the inflammatory response is influenced by the type of movement and instrument design. The number of instruments does not seem to influence an inflammatory reaction.

Another factor that could influence postoperative pain is the defined working length. The working length was not standardized in the studies selected for the present review. This fact should be taken into consideration since it can influence the amount of apically extruded debris and microorganisms [40]. Surakanti *et al.* [49] and Myers and Montgomery [50] demonstrated that a working length of 1 mm from the apical foramen significantly reduces the extrusion of debris and consequently causes less postoperative pain. Furthermore, the mechanical stress of instrumentation and chemical irritation from the irrigants in treatment with a working length of 0.5 mm can intensify the patient's discomfort [14, 40]. However, a recently published meta-analysis concluded that apical patency maintenance during routine endodontic treatment was not associated with an increase in the incidence of postoperative pain [51].

Sodium hypochlorite (NaOCl) is the irrigant of choice for root canal treatment because of its high antibacterial activity [52, 53]. However, the incidence of postoperative pain may be influenced by the NaOCl concentration chosen. Higher concentrations dissolve a more considerable amount of organic tissue and are, therefore more cytotoxic [54]. No consensus exists about the ideal concentration of NaOCl for root canal treatment. An *in vitro* study demonstrated that 5.25% NaOCl promoted higher apical extrusion of debris than 2.5% [55]. On the other hand, the results of a clinical trial showed that 5.25% NaOCl triggered significantly less postoperative pain than 2.5% [56]. Studies found in the literature that evaluated postoperative pain [29, 56, 57], used 2.5%, 5.25% or even higher NaOCl concentrations. In the present review, 95% of the selected articles used NaOCl as irrigant at concentrations ranging from 1.25% to 5.25%.

Analgesic consumption should also be considered in the assessment of postoperative pain. Eight studies used this parameter to analyze pain intensity, but significant differences between groups were only observed in two studies [29, 30]. However, in the study of Nekoofar *et al.* [30], the analgesic was administered to all patients immediately after endodontic treatment not serving as a parameter since all patients received medication regardless of the presence of pain and still under the effect of anesthesia. For Neelakantan *et al.* [29], the medication was optional and would, therefore, not be a reliable parameter. Some patients could choose not to take the medication even in the presence of pain, while others may turn to its use, although they only experience minimal discomfort. Other studies that did not find a significant difference, recommended medication use only in the event of pain; it would be the safest management for subsequent pain assessment based on analgesic consumption [5, 18, 25, 34].

The cause of postoperative pain could be related to a combination of the cited factors. The incidence of postoperative pain has also been evaluated with other factors such as single or multiple session, use of antibiotics, anesthetic solution, diagnosis of the patient, and preoperative pain [5, 30, 58-60]. Other factors that influence the occurrence of postoperative pain are patient age and gender, deficient instrumentation, hyperocclusion, non-localized canals, and apical patency [22, 61]. Postoperative pain intensity also depends on the interaction between the patient's immune response, infection and damage to periapical tissues [62].

Although systematic reviews are a useful research tool, differences in the study design or the patient's experience of pain can make comparisons difficult [2]. The present review attempted to standardize the selection of study designs, minimize differences within variables, and, therefore achieve a more significant comparison. The variability of the study design parameters should be considered. Previous studies also showed variability within included studies. Sun *et al.* [11] evaluated the postoperative pain of various instruments, with different cross-sections. Their included studies had different initial pain levels. Abdulrab *et al.* [51] studied the influence of apical patency on postoperative pain. They also included teeth with different initial pain levels, vital and non-vital teeth, and different kinematics instruments (manual and rotary) and irrigants (NaOCl in different concentrations associated or not with EDTA). The exclusion of studies that included preoperative pain did not alter the results of this meta-analysis.

In the meta-analysis, the postoperative pain was evaluated over the 24 h after endodontic treatment. This period was chosen based on the systematic review of Pak & White [2] who assessed the prevalence of pain before, during and after endodontic treatment. The authors stated that the severity of postoperative pain declines progressively, decreasing by half on the first day and less than 10% after 7 days. Thus, 24 h became more relevant and was observed in 81.7% of the studies included in this review.

Though the methods for outcome assessment is variable, all the rating scales used in studies assess pain intensity. Different methods of assessing pain intensity are reported in the literature. Numerical and verbal self-assessment scales or behavioral observation scales are commonly used in clinical trials that evaluate pain after endodontic treatment [63]. However, to objectively quantify and standardize pain levels in a group of individuals is somewhat challenging [63]. The patient's experience of pain is very subjective. It is influenced by factors such as expectations, cultural and behavioral knowledge, the previous perception of the condition in other patients, physical (genetic) factors, and psychological factors [11]. The VAS is a conceptually simple and methodologically robust categorization system that is easy to manage and ensures patient discretion [64]. This scale is characterized by a continuous frequency distribution that allows statistical analysis of average pain intensity. Also, the VAS is a highly reproducible method that is not influenced by gender [65]. In this review, 66,6% of the included articles used VAS for assessing postoperative pain. However, the remaining articles applied other pain assessment scales, such as VRS (*n*=2), NRS; (*n*=2), PIS (*n*=1), FPS (*n*=1) and FLVR (*n*=1). Nevertheless, the pain assessments using different types of scales are highly correlated [63].

The meta-analysis of the intensity of postoperative pain showed significant differences between kinematics favoring rotary. On the other hand, the meta-analysis on the incidence of postoperative pain revealed no significant differences, even the pain levels (mild, moderate, and severe) were evaluated separately. Considerable heterogeneity was observed for the meta-analyses performed for the subgroup of severe postoperative pain. However, with a reduced number of studies, the I^2 statistic does not produce a reliable estimate of the between-study variance in a meta-analysis [66]. This heterogeneity can be attributed to the studies by Neelakantan *et al.* [29] and Eyuboglu and Özcan *et al.* [21], which demonstrated more divergent results. While the first study presented more favorable results to the reciprocating system, in the second, the rotational system obtained lower pain intensity values. Several aspects may be related to these differences found in the two studies such as age and gender of the included patients, type of tooth, instrumentation technique, characteristics of the instrument used and sample size [21, 29]. The type of pulp and perirradicular diagnosis and preoperative pain's presence may also be related to the discrepancies found. Neelakantan *et al.* [29] only included patients with symptomatic irreversible pulpitis with symptomatic apical periodontitis, that is, patients with severe preoperative pain, (VAS=8-10). On the other hand, Eyuboglu and Özcan *et al.* [21] selected patients that needed endodontic retreatments due to asymptomatic apical periodontitis. Our results regarding postoperative pain intensity were similar to the systematic review by Sun *et al.* [11], observing lower pain intensity for rotary systems.

For incidence, the meta-analyses of Sun *et al.* [11] and Hou *et al.* [12] suggested lower postoperative pain favoring rotary; in our study, this difference was not observed. Conversely, Martins *et al.* [13] showed that rotary increased the incidence of postoperative pain after endodontic treatment. However, when the incidence of mild, moderate, and severe postoperative pain was evaluated in 24 h, no difference was observed between the systems.

The discrepancies between these studies' conclusions are due to differences in the studies included in the meta-analyses, as well as it reflects differences in the execution of systematic reviews [11-13]. Only RCTs were included in our meta-analysis because they are a critical method for clinically evaluating materials and treatments. Controlled settings are established to achieve greater clinical credibility and reliability. Sun *et al.* [11] included prospective and retrospective studies and RCTs. In this study, meta-analyses were performed in two steps: admitting or not studies that included patients with preoperative pain. It was considered that these clinical variances might have repercussions on statistical heterogeneities. Thus, the present review allowed the selection of more recent RCTs, seeking to complement and enrich the existing knowledge.

The main limitation of the present review is inherent to the type of study, such as the quality and quantity of primary studies available in the literature [15]. Among the included studies it was possible to observe clinical variations (types of files, diagnosis, analgesic use, number of sessions, irrigation solutions, length of work, presence of preoperative pain) and methodological variations (pain assessment methods and time elapsed from the instrumentation moment to the evaluation of the outcome). Further controlled studies are necessary to clarify the incidence and intensity of postoperative pain after endodontic treatment with mechanized instruments.

Conclusion

The meta-analysis assessing the incidence of postoperative pain showed no difference between the reciprocating and rotary systems. However, the results of the meta-analysis evaluating the intensity of postoperative pain revealed findings favoring the rotary system. Further controlled studies are necessary to clarify the incidence and intensity of postoperative pain after endodontic treatment with mechanized instruments.

Conflict of Interest: 'None declared'.

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***Please cite this paper as*:** da Silveira MT, Batista SM, Mamede Veloso SR, de Oliveira NG, de Vasconcelos Carvalho M, de Melo Monteiro GQ. Effect of Reciprocating and Rotary Systems on Postoperative Pain: A Systematic Review and Meta-Analysis. Iran Endod J. 2021;16(1): 1-16. Doi: 10.22037/iej.v16i1.27944.