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A systematic review: effect of hand, rotary and reciprocating instrumentation on endodontic postoperative pain

Una revisione sistematica: effetto della strumentazione manuale, meccanica con movimento di rotazione continua e reciprocante sul dolore postoperatorio endodontico

KEYWORDS
Endodontics, Postoperative pain, Systematic review, Root canal preparation, Root canal therapy

PAROLE CHIAVE
Endodonzia, dolore postoperatorio, revisione sistematica, preparazione del canale radicolare, terapia canalare

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Abstract

Aim: *This systematic review evaluated the influence of hand, rotary and reciprocating instrumentation on endodontic postoperative pain.*
Methodology: *A protocol was registered on PROSPERO. Electronic searches were conducted in MEDLINE, ISI Web of Science, Scopus and ClinicalTrials.gov. Articles were selected according to the following criteria: randomized clinical trials with patients undergoing endodontic treatment in permanent teeth, comparing instrumentation techniques with different kinematics (hand/rotary/reciprocating) and their effect on postoperative pain incidence, intensity or duration. Data on analgesic intake was also recorded. Risk of bias was evaluated and the GRADE framework was applied to assess the quality of evidence.*
Results: *Twelve studies and 1,659 patients were included in this review. Five studies compared hand instrumentation vs. engine-driven (rotary and/or reciprocating) systems. In three studies, postoperative pain results were worse with hand instruments than with engine-driven systems. In the other two studies, pain results for hand and engine-driven techniques were similar. Seven studies and a dataset from one of the five previous studies were included in the comparison of rotary vs. reciprocating systems, with contrasting results. Postoperative pain results were worse with reciprocating systems in four studies, with rotary systems in two studies and equivalent in other two studies. Data on analgesic intake were controversial. GRADE showed low quality of evidence.*
Conclusions: *Hand instrumentation presented unfavourable postoperative pain results when compared to engine-driven systems. The comparison of rotary and reciprocating systems generate contrasting results. Given the low quality of evidence and conflicting findings, results should be considered with caution and further well-designed randomized clinical trials on the matter are encouraged.*

Obiettivi: *questa revisione sistematica ha valutato l'influenza della strumentazione manuale, rotante e reciprocante sul dolore postoperatorio endodontico.*
Metodologia: *è stato registrato un protocollo su PROSPERO. Le ricerche elettroniche sono state condotte su MEDLINE, ISI Web of Science, Scopus e ClinicalTrials.gov. Gli articoli sono stati selezionati in base ai seguenti criteri: studi clinici randomizzati con pazienti sottoposti a trattamento endodontico in denti permanenti, confrontando tecniche di strumentazione con cinematiche diverse (manuale/rotante/reciprocante) e il loro effetto sull'incidenza, intensità o durata del dolore postoperatorio. Sono stati anche registrati i dati sull'assunzione di analgesici. È stato valutato il rischio di parzialità e il quadro GRADE è stato applicato per valutare la qualità delle prove.*
Risultati: *dodici studi e 1.659 pazienti sono stati inclusi in questa revisione. Cinque studi hanno confrontato la strumentazione manuale con quella meccanica (rotante e/o reciprocante). Tre articoli hanno mostrato peggiori risultati del dolore postoperatorio per la preparazione manuale e due non hanno riscontrato differenze. Sette studi e un set di dati di uno dei cinque precedenti studi sono stati inclusi nel confronto tra sistemi rotanti e reciprocanti, con risultati contrastanti. Quattro articoli mostravano risultati di dolore postoperatorio peggiori per strumenti reciprocanti, due per gli strumenti rotanti e due non hanno riscontrato differenze. I dati sull'assunzione di analgesici sono stati controversi. Il GRADE ha mostrato una scarsa qualità delle prove.*
Conclusioni: *la strumentazione manuale ha presentato risultati di dolore postoperatorio sfavorevoli rispetto ai sistemi meccanici. La comparazione tra gli strumenti reciprocanti e rotanti ha generato risultati contrastanti. Data la bassa qualità delle evidenze e i risultati contrastanti, i risultati dovrebbero essere considerati con cautela e sono incoraggiati ulteriori studi clinici randomizzati ben progettati sull'argomento.*

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Introduction

Pain associated with endodontic therapy is widely feared by patients (1) and has been extensively investigated (2-7). The prevalence of postoperative pain and flare-up as reported in the literature ranges from 3 to 58% (8). Such unpleasant experience results from a complex multifactorial process, being influenced by inherent aspects of the patient, the tooth to be treated and interventions of the dental operator (9). Several prior endodontic studies have attempted to correlate postoperative pain to intraoperative factors as irrigating solution (10), instrumentation technique (11), intracanal dressing (12), number of visits (8) and obturation technique (13). Extrusion of root canal contents into the periradicular tissues causes inflammation and may be related to postoperative pain (14, 15). The amount of extruded debris and neuropeptides released in the periodontal ligament differ between instrumentation techniques (16) and it has been indicated as a reason why there are differences in postoperative pain experienced by patients. Rotary nickel-titanium (NiTi) systems led to a reduction in debris extrusion when compared to hand stainless-steel instruments (17, 18). NiTi allowed safe and efficient engine-driven systems for cleaning and shaping root canals, especially those with curvatures (19). There is clinical and experimental evidence that such systems reduce the occurrence of operative errors such as deviation and apical transportation due to their remarkable flexibility (20, 21).
Recently, a tendency to greater debris extrusion with NiTi single-file reciprocating systems compared to NiTi multiple-file rotary systems has been reported (16, 22). Continuous rotation movement may improve coronal transportation of dentine chips and infected debris by acting like a screw conveyer (23). However, the development of reciprocating instruments brought potential advantages: increased fatigue life (24), reduced number of instruments, lower cost, shorter preparation time (11), better shaping ability (25) and elimination of cross-contamination associated with single-use instruments.
Controversial findings have been described in two recent systematic reviews of in vitro studies regarding the influence of instrumentation techniques on debris extrusion (16, 22). Moreover, results could change in a clinical situation due to the presence of periapical tissues, which act as a natural barrier providing physical back-pressure (26), thus preventing apical extrusion. Contrasting results are also observed in clinical trials addressing postoperative pain (11, 27-29). In this context, the aim of this study was to systematically review the literature to determine the influence of hand, rotary and reciprocating instrumentation techniques on postoperative pain in patients submitted to endodontic treatment in permanent teeth.

Materials and Methods

A review protocol was registered on PROSPERO (CRD 42016036587). This systematic review was carried out and reported according to recommended guidelines (30, 31). Two research questions were formulated according to a PICOS (population, intervention, comparison, outcome, and study type) framework, considering randomized clinical trials, RCTs. 1) In patients receiving endodontic treatment in permanent teeth, do engine-driven instrumentation techniques using NiTi systems induce equivalent postoperative pain compared to hand preparation using stainless-steel instruments? 2) In patients receiving endodontic treatment in permanent teeth, considering engine-driven NiTi instrumentation, do reciprocating systems induce equivalent postoperative pain compared to rotary systems?

Eligibility criteria
RCTs with patients undergoing endodontic treatment in permanent teeth that compared instrumentation techniques with different kinematics (hand stainless-steel instruments vs. engine-driven NiTi systems or rotary vs. reciprocating engine-driven NiTi systems) and their effect on postoperative pain incidence, intensity

or duration were included in this review. There was no age limit and all pain scales were considered. Observational studies, reviews, case reports, case series, in vitro studies and those without pain measurement outcomes were excluded. Also, RCTs comparing two instrumentation techniques with the same kinematics (e.g. two rotary systems) were excluded.

Table 1

Search strategy used in the Medline database

Search string #1	"Root Canal Preparation"[Mesh] OR "Root Canal Preparation" OR "Canal Preparation, Root" OR "Canal Preparations, Root" OR "Preparation, Root Canal" OR "Preparations, Root Canal" OR "Root Canal Preparations" OR "Root Canal Instrumentation" OR "Hand File" OR "Hand Stainless Steel" OR "Rotary" OR "Rotary File" OR "Rotary Instrument" OR "Rotary Nickel Titanium" OR "Rotary NiTi" OR "Reciprocating File" OR "Reciprocating Instrument" OR "Reciprocating Nickel-Titanium" OR "Reciprocating NiTi"
Search string #2	"Pain"[Mesh] OR "Pain" OR "Pain, Burning" OR "Burning Pain" OR "Burning Pains" OR "Pains, Burning" OR "Suffering, Physical" OR "Physical Suffering" OR "Physical Sufferings" OR "Sufferings, Physical" OR "Pain, Migratory" OR "Migratory Pain" OR "Migratory Pains" OR "Pains, Migratory" OR "Pain, Radiating" OR "Pains, Radiating" OR "Radiating Pain" OR "Radiating Pains" OR "Pain, Splitting" OR "Pains, Splitting" OR "Splitting Pain" OR "Splitting Pains" OR "Ache" OR "Aches" OR "Pain, Crushing" OR "Crushing Pain" OR "Crushing Pains" OR "Pains, Crushing" OR "Pain, Postoperative"[Mesh] OR "Pain, Postoperative" OR "Postoperative Pain" OR "Postoperative Pains" OR "Symptom Flare Up"[Mesh] OR "Symptom Flare Up" OR "Flare Up, Symptom" OR "Flare Ups, Symptom" OR "Symptom Flare Ups" OR "Symptom Flaring Up" OR "Flaring Up, Symptom" OR "Flaring Ups, Symptom" OR "Symptom Flaring Ups" OR "Acute Symptom Flare" OR "Acute Symptom Flares" OR "Flare, Acute Symptom" OR "Flares, Acute Symptom" OR "Symptom Flare, Acute" OR "Symptom Flares, Acute" OR "Symptom Flareup" OR "Flareup, Symptom" OR "Flareups, Symptom" OR "Symptom Flareups" OR "Symptom Flare-up" OR "Flare-up, Symptom" OR "Flare-ups, Symptom" OR "Symptom Flare-ups"
Search string #3	((randomized controlled trial[pt] OR controlled clinical trial[pt] OR randomized controlled trials[mh] OR random allocation[mh] OR double-blind method[mh] OR single-blind method[mh] OR clinical trial[pt] OR clinical trials[mh] OR ("clinical trial"[tw]) OR ((singl*[tw] OR doubl*[tw] OR trebl*[tw] OR tripl*[tw]) OR (mask*[tw] OR blind*[tw])) OR ("latin square"[tw]) OR placebos[mh] OR placebo*[tw] OR random*[tw] OR research design[mh:noexp] OR follow-up studies[mh] OR prospective studies[mh] OR cross-over studies[mh] OR control*[tw] OR prospectiv*[tw] OR volunteer*[tw]) NOT (animal[mh] NOT human[mh]))
Search string #4	#1 AND #2 #1 AND #2 AND #3
Limits	English language and Custom date range (1985-2017)

Search methodology

Searches were conducted in three electronic databases (Medline, ISI Web of Science and Scopus), with English language restriction, from 1985 to 2017. Additional search was performed at www.clinicaltrials.gov to identify finished studies that were not yet published. The last search was carried out in May 2017. The search strategy used in the Medline database via PubMed engine search is described in Table 1. Search words were adjusted for each database. The references of all eligible documents were also hand-searched.

Duplicate search results were excluded (EndNote X7 program, Thompson Reuters, New York, USA) and two independent researchers (A.R.S. and R.D.M.) identified the content of articles first by reviewing titles and abstracts, and the presence of the selection criteria listed above. The articles were classified as: i) include, ii) exclude or iii) uncertain. Full publications of included and uncertain articles were obtained for verification of eligibility by the same two reviewers. Any discrepancies between evaluators were resolved by discussion or by a third party (R.S.O.). In papers with missing information or data, authors were contacted by e-mail.

Data collection process

A standardized scheme was created for data collection, which was conducted by the same two reviewers. The following data were extracted.

- Publication details: author and year of publication.
- General characteristics of the study: age and gender of patients, sample size, group of teeth, pulp and periapical condition, number of operators as well as their clinical experience, number of treatment sessions, irrigating solution, and instrumentation technique (hand, rotatory and/or reciprocating).
- Pain-related information: period of evaluation, pain scale, analgesic drug, analgesic intake and pain results regarding incidence, intensity and/or duration of pain.

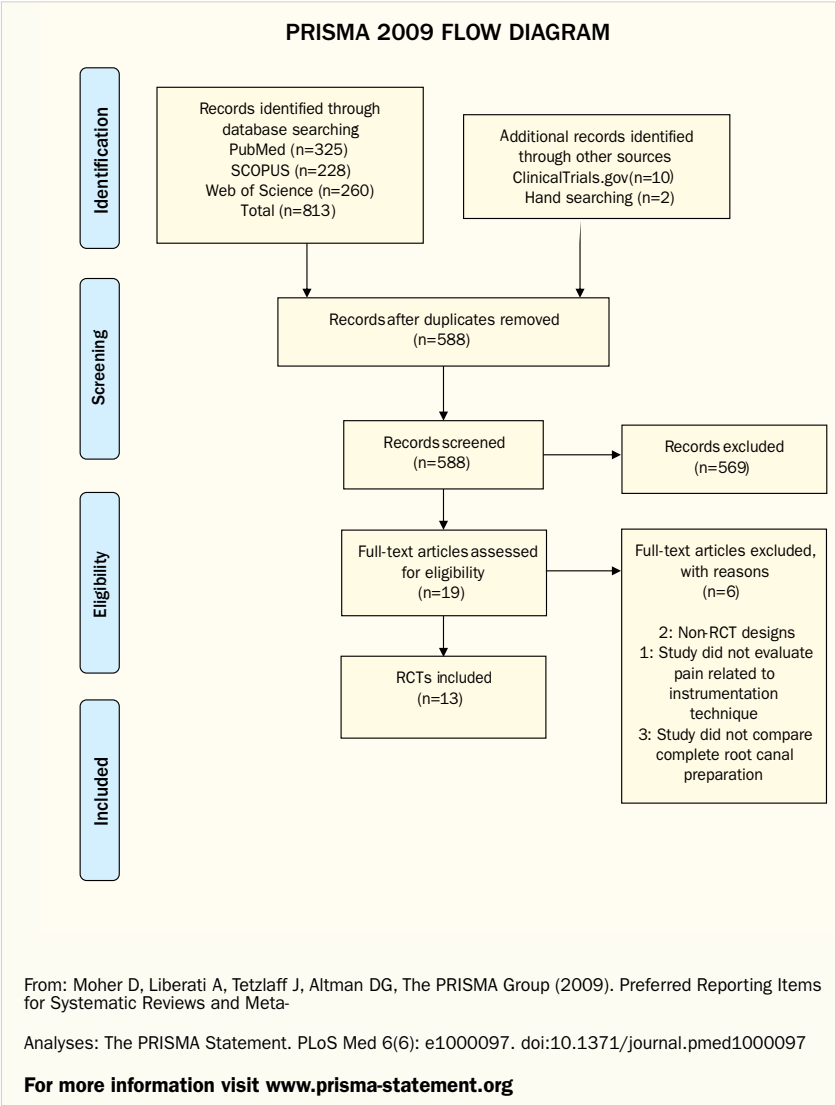

Figure 1
Flow diagram of the study according to the PRISMA Statement.

Risk of bias

The risk of bias of included studies was assessed using the Cochrane risk of bias tool (30) considering the judgment of random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data and selective reporting. The assessment was performed by the same two reviewers independently and verified by a third researcher using the Review Manager Software Version 5.3 (The Cochrane Collaboration, London, UK). Publication bias was not statistically assessed, though searches for unpublished studies were performed to minimize the publication bias.

Quality of the body of evidence

The Grading of Recommendations, Assessment, Development and Evaluation (GRADE) framework for systematic reviews was applied to the included trials to assign an overall outcome-specific rating for within-study risk of bias (methodological quality), directness of evidence, heterogeneity, precision of effect estimates and risk of publication bias (32). The assessment was performed by one reviewer and discussed with other two researchers to generate a score.

Data synthesis

Considerable heterogeneity was verified in the selected studies regarding demographic characteristics of patients, endodontic diagnosis, technical procedures, pain scales and pain assessment periods. Also, the e-mails sent regarding missing data/information received no reply. Thus, meta-analysis was considered inappropriate and data were summarized descriptively.

Results

The flowchart for the selection of eligible studies is shown in Figure 1. Initial electronic searches identified 702 studies. The screening of titles and abstracts resulted in 14 manuscripts and two additional papers were found by hand-searching. Four papers were excluded after full-text reading since two studies used non-RCT designs (33, 34); one study did not evaluate pain related to instrumentation technique (35); and one study compared hand and rotary techniques for glide-path procedure, not for complete root canal preparation (36). Ten studies registered at www.clinicaltrials.gov were found, eight in progress and two completed investigations. Of these, one did not provide conclusive data (no statistical analysis) and the other was included in the review (29).

In total 12 studies and 1,659 patients aged between 14 and 73 years old were included in this review (Table 2). Five studies were included in the comparison of hand vs. engine-driven (rotary and/or reciprocating) instrumentation techniques (29, 37-40). Other seven studies (11, 27, 41-45) and a

Table 2

General characteristics of the studies included in the review (N 12)

Author	Year	Age*	Gender (female %)	N (patients)	N (teeth)	Group of teeth	Pulpal/periapical condition	N (operators)	Experience	N (sessions)	Irrigant	Instrumentation technique
Al-Jabreen (37)	2002	18 to 55	n.i.	91	105 35 each	Maxillary central incisors	Pulp necrosis	n.i.	n.i.	1	2.6% NaOCl	HAND (step-back) vs. ROT 1 (Profile 04) vs. ROT 2 (Profile GT)
Ahmed *et al.* (38)	2012	14 to 60	n.i.	102	102 51 each	Single-rooted teeth	Symptomatic irreversible pulpitis and/or acute apical periodontitis	n.i.	n.i.	1	2.5% NaOCl	HAND (step-back) vs. ROT (ProTaper)
Nekoofar *et al.* (11)	2015	15 to 55 40 ROT 38 REC	52.4% ROT 52.4% REC	42	42 21 each	Premolars and molars	Asymptomatic irreversible pulpitis	1	n.i.	2	2% CHX 17% EDTA	ROT (ProTaper) vs. REC (WaveOne)
Neelakantan *et al.* (41)	2015	25 to 40 31 mean	49.6% ROT 49.6% REC	605	1210 605 each	Mandibular molars	Symptomatic irreversible pulpitis	2	Endo-dontists	1	3% NaOCl 17% EDTA	ROT (OneShape) vs. REC (Reciproc)
Kashefinejad *et al.* (39)	2016	17 to 52 30.8 HAND 32.5 for ROT	n.i.	53	60 30 each	Single-rooted teeth	Symptomatic irreversible pulpitis	n.i.	n.i.	1	Normal saline	HAND (step-back) vs. ROT (Mtwo)
Kherlakian *et al.* (42)	2016	19 to 73 47 mean	62.8% ROT 65.7% REC 1 61.4% REC 2	210	210 70 each	Premolars and molars	Vital pulp	5	Endo-dontists	1	2.5% NaOCl 17% EDTA	ROT (ProTaper Next) vs. REC 1 (WaveOne) vs. REC 2 (Reciproc)
Krithikadatta *et al.* (43)	2016	18 to 55	46.9% ROT 1 51% ROT 2 61.2% REC NSD	152	152 49 ROT 1 50 ROT 2 49 REC	Premolars and molars	Asymptomatic or symptomatic irreversible pulpitis or pulp necrosis with or without apical periodontitis	4	Final year post-graduate students	2	5% NaOCl 17% EDTA final flush 2% CHX	ROT 1 (ProTaper Next) vs. ROT 2 (Mtwo) vs. REC (WaveOne)
Zand *et al.* (45)	2016	19 to 59 33.22 ROT 33.73 REC NSD	60% ROT 48.9% REC NSD	90	90 45 each	Mandibular molars	Asymptomatic pulp necrosis	n.i.	n.i.	1	2.5% NaOCl 17% EDTA	ROT (RaCe) vs. REC (Reciproc)
Talebzadeh *et al.* (40)	2016	Over 18	n.i.	96	96 48 each	Mandibular molars	Asymptomatic irreversible pulpitis	1	n.i.	1	5% NaOCl	HAND (step-back) vs. ROT (RaCe)
Pasqualini *et al.* (44)	2016	25%-16 to 30 33%-31 to 45 42%-46 to 60	50%	47	47 23 ROT 24 REC	Single or multi-rooted	Asymptomatic or symptomatic irreversible pulpitis or pulp necrosis	1	Endodontist	1	5% NaOCl 10% EDTA	ROT (ProTaper) vs. REC (WaveOne)

Relvas *et al.* (27)	2016	18 to 64 25.9 ROT 25.8 for REC	Only men	78	78 39 each	Mandibular molars	Asymptomatic pulp necrosis	1	Endodontist	1	2.5% NaOCl 17% EDTA	ROT (ProTaper) vs. REC (Reciproc)
Shokraneh *et al.* (29)	2017	20 to 45 31.7 HAND 29.6 ROT 30.3 REC NSD	50% HAND 51.6% ROT 46.9% REC NSD	93	93 30 HAND 31 ROT 32 REC	Mandibular molars	Asymptomatic pulp necrosis and apical periodontitis	1	Endodontist	1	5.25% NaOCl 17% EDTA	HAND (crown-down) vs. ROT (ProTaper) vs. REC (WaveOne)

Studies are listed in chronological publication order.

**Age range and mean per group (if informed).*

CHX: chlorhexidine; EDTA: ethylenediamine tetraacetic acid; HAND: hand group; NaOCl: sodium hypochlorite; n.i.: not informed; NSD: no significant difference between groups; REC: reciprocating group; ROT: rotary group (continuous rotation motion).

Figure 2
Risk of bias evaluation: (+) low; (?) unclear. Studies are listed in alphabetical order by the Review Manager Software.

	Random sequence generation (selection bias)	Allocation concealment (Selection bias	Blinding of participants and personnel (performance bias)	Blinding of oucome assessment (detection bias)	Incomplete outcome data (attrition bias9	Selective reporting (reporting bias)
Ahmed et al. 2016	+	+	?	?	?	?
Al-Jabreen 2012	?	?	?	?	?	?
KashefineJad et al. 2016	+	?	+	?	?	+
Kherlaklan et al. 2016	+	+	?	?	?	?
Krithkadata et al. 2016	+	+	+	+	+	?
Neelakantan et al. 2015	+	+	?	?	+	?
Nekoofar et al. 2015	?	+	?	?	?	+
Pasqualini et al. 2016	+	+	?	?	+	?
Relvas et al. 2016	+	+	+	+	?	+
Saha et al. 2018	+	+	?	?	?	?
Shokraneh et al. 2016	+	?	?	+	+	+
Talebzadeh et al. 2016	?	?	+	+	+	+
Zand et al. 2016	?	?	+	+	?	+

dataset from one (29) of the five previous studies were included in the comparison of rotary vs. reciprocating systems.

A wide range of pain incidence was observed in the included studies, considering periods of two hours to seven days: 11.4% (37) to 96.7% in hand instrumentation; 0% (37) to 54.8% (29) in rotary instrumentation and 0% (27) to 43.7% (29) in reciprocating instrumentation. Pain intensity or severity was not summarized due to the different pain scales used in the included studies (Table 3). Nevertheless, the highest postoperative pain levels were recorded in the early stages after root canal treatment, especially within the first 24h (11, 27, 29, 40, 42, 43, 45).

Pain-related data of studies comparing hand and engine-driven instrumentation are described in Table 3. In three studies postoperative pain results were worse with hand instruments than with engine-driven systems (29, 37, 39). In the other two studies pain results for hand and engine-driven techniques were similar (38, 40). Three studies evaluated analgesic intake by patients; in two of these investigations the analgesic intake was higher when using hand instruments in comparison to engine-driven systems (29, 30), while the other study showed similar results (40).

Pain-related data of studies comparing rotary and reciprocating instrumentation are also shown in Table 3. The eight included studies revealed contrasting find-

Table 3

Pain-related information in the studies comparing hand vs. engine-driven instrumentation techniques (N=5) and studies comparing rotatory vs. reciprocating instrumentation techniques (N=8)

Author	Year	Period of evaluation	Pain scale	Analgesic drug	Analgesic intake	Pain results
Hand vs. engine-driven techniques						
Al-Jabreen (37)	2002	48 h, 7 days	Categorical	n.i.	n.i.	Pain incidence: HAND>ROT
Ahmed et. al. (38)	2012	48 h	VAS (0-10)	1 mg Paracetamol	n.i.	Pain incidence: HAND=ROT
Kashefinejad et al. (39)	2016	4, 8, 12, 24 h	VAS (0-10)	max. 3,200 mg/ day Ibuprofen	HAND>ROT	Pain incidence/ intensity: HAND>ROT
Talebzadeh et al. (40)	2016	4, 8, 12, 24, 48 h, 7 days	VAS (0-100)	400 mg Ibuprofen	HAND=ROT	Pain intensity: HAND=ROT
Shokraneh et al. (29)	2017	6, 12, 18, 24, 48, 72 h	Heft-Parket VAS (0-170)	400 mg Ibuprofen	HAND> ROT/REC	Pain intensity: HAND>ROT/REC
Rotary vs. reciprocating techniques						
Nekoofar et al. (11)	2015	6, 12, 18, 24, 48, 72 h	NRS (0-10)	400 mg Ibuprofen (+325 mg Paracetamol)	ROT<REC	Pain intensity/duration: ROT<REC
Neelakantan & Sharma (41)	2015	Up to 7 days	Modified VAS (0-10)	400 mg Ibuprofen	ROT>REC	Pain incidence/ intensity/duration: ROT>REC
Kherlakian et al. (42)	2016	24, 48, 72 h, 7 days	VAS (0-100)	400 mg Ibuprofen	ROT=REC	Pain intensity: ROT=REC
Krithikadatta et al. (43)	2016	2, 4, 6, 8, 12, 24, 36, 48 h	VAS (0-10)	400 mg Ibuprofen	n.i.	Pain intensity: ROT<REC
Zand et al. (45)	2016	4, 12, 24, 48, 72 h, 7 days	VAS (0-100)	n.i.	n.i.	Pain intensity: ROT<REC
Pasqualini et al. (44)	2016	7 days	VAS (0-10)	Optional analgesics	ROT=REC	Pain intensity: ROT<REC
Relvas et al. (27)	2016	24, 72 h, 7 days	VRS	n.i.	n.i.	Pain incidence/ intensity: ROT=REC
Shokraneh et al. (29)	2017	6, 12, 18, 24, 48, 72 h	Heft-Parket VAS (0-170)	400 mg Ibuprofen	ROT=REC	Pain intensity: ROT>REC (first 18 h)

Studies are listed in chronological publication order.

HAND: hand group; n.i.: not informed; NRS: Numerical Rating Scale; REC: reciprocating group; ROT: rotary group; VAS: Visual Analogue Scale; VRS: Verbal Rating Scale.

ings. Postoperative pain results were worse with reciprocating systems in four studies (11, 43-45) and with rotary systems in two studies (29, 41). Finally two studies found that postoperative pain is equivalent in both root canal preparation techniques (27, 42). Five studies also evaluated pain-relieving consumption. Of these, three reported that analgesic intake is similar in patients undergoing treatment with rotary and reciprocating systems (29, 42, 44). In one study (11) analgesic intake was higher in the reciprocating group, while in the other (41) it was higher in the rotary group.

Risk of bias evaluation is illustrated in Figure 2. Most studies had unclear risk of bias with regards to the following items: blinding of participants and personnel (58.3%), blinding of outcome assessment (58.3%) and incomplete outcome data (58.3%). Most studies had low risk of bias in terms of random sequence generation (66.6%) and allocation concealment (58.3%). Based on the GRADE approach, quality of evidence was classified as low because of limitations in the design, implementation and indirectness of evidence.

Discussion

This systematic review is the first to summarize and critically analyse the available information about the influence of hand, rotary and reciprocating instrumentation techniques on endodontic postoperative pain. A wide range of pain incidence was observed in the included studies. In general, the results described here were in line with those observed in the systematic review conducted by Pak and White (5), in which pain incidence in the first 24 hours was 40%, decreasing acutely thereafter, reaching 11% at seven days. Pain intensity or severity was not summarized due to the lack of consistency of pain scales used in the included studies. Still, the highest postoperative pain levels were also recorded in the early stages after root canal treatment, especially within the first 24h, as previously reported (5).

Postoperative pain has been associated with the apical extrusion of infected debris, which may occur during any hand or engine-driven instrumentation technique (17, 46, 47). Most studies in this review (29, 37, 39) and others not included herein (36, 48) showed worse postoperative pain results when hand preparation is used comparatively to rotary or reciprocating systems. It is important to note that four out of five studies included in this review (37-40) used hand instruments with a step-back approach. In the step-back or any push-pull filing technique the file acts as a plunger in the apical region and drives debris through the foramen (46), probably exacerbating inflammation and pain. On the contrary, flutes of rotary instruments tend to pull debris back towards the root canal orifice (46, 49).

Comparison of postoperative pain between rotary and reciprocating systems showed conflicting findings in this review, but reciprocation produced worse postoperative pain results, according to four studies (11, 43-45). A recent systematic review (22) found that reciprocating instruments tended to extrude more dentine debris than rotary instruments, but it also showed studies with opposite results. Another systematic review (16) demonstrated that both multiple-file rotary and single-file reciprocating systems generate apical extrusion of debris in laboratory studies and in vivo expression of neuropeptides released from C-type nerve fibres in the periodontal ligament. They supported the hypothesis that the inflammatory reaction and subsequent pain response in the apical area is not influenced by the number of files but the type of movement and instrument design characteristics, as previously suggested (23, 50). It is worth mentioning that rotary and reciprocating systems with different designs were grouped in this review to assess the effects of kinematics.

Controversially, one study with a large sample size (605 patients) showed worse pain results with rotary instrumentation in comparison to reciprocation (41). It was the only study to evaluate a single-file rotary system (OneShape, Micro-Mega, Besancon Cedex, France), while all others assessed multi-file rotary systems (Table 2). A recent meta-analysis of three studies (28) compared the postoperative pain after single-visit root canal preparation with rotary vs. reciprocating instruments and found no difference between techniques considering pain incidence. However, it is important to highlight that they found a high heterogeneity between studies (I2=87%), and a wide confidence interval (0.25-6.52) showing imprecision of the result. In two studies of the present review pain results were similar for rotary and reciprocating systems (27, 42). Aligned with these findings, Martinho et al. (51) reported that files in rotary and reciprocating motion have similar effectiveness in

reducing endotoxins and cultivable bacteria from primarily infected root canals, which could influence postoperative pain. Gender has been suggested to play a role in pain studies (9, 52, 53) and may function as a confounding factor in studies comparing instrumentation techniques. Females have shown to experience higher levels of postoperative pain compared to males (9). In the present review, few studies reported a balanced percentage of men and women in their population (11, 29, 41-43, 45), while one study (27) included only male patients due to insufficient number of female patients during recruitment, resulting in a biased sample. Indeed, the last paper reported low pain incidence (<20%) for both rotary and reciprocating groups (27). The frequency was lower than that observed in studies including men and women (29).
Another confounding factor is the presence of preoperative pain, which may also interfere with postoperative pain (6, 53). Three studies included only symptomatic teeth (38, 39, 41), while five studies selected exclusively asymptomatic cases (11, 27, 29, 40, 45). Other studies elected assorted or undefined samples regarding preoperative pain (37, 42-44). Additionally, Krithikadatta et al. (43) observed that nonvital teeth experienced more pain compared to vital teeth across rotary and reciprocating groups, probably because the extrusion of infected necrotic tissue triggers an acute inflammatory response in the periapical area with subsequent pain (14).
The clinical experience of operators consists in another potential cause of heterogeneity between studies. Endodontists were reported in five papers (27, 29, 41, 42, 44), and final year graduate students in one paper (43), while other studies did not inform about operators' experience (11, 37-40, 45). Previous investigations reported no significant differences in postoperative pain experience after treatment performed by endodontists vs. generalists (54, 55) but patients' general satisfaction was higher after treatment by specialists (55). A positive impact of an expert operator may emerge from shorter operating time and better communication when dealing with patient stress (44, 54).

In this review only two studies (11, 43) performed endodontic treatment in two clinical sessions, with the others reporting single session. According to Attar et al. (56) patients treated with calcium hydroxide dressing vs. obturation did not differ in postoperative pain levels. Even with conflicting results in the literature, systematic reviews on the subject seem to demonstrate that the number of treatment visits does not affect postoperative pain (57-59).
Although pain symptoms have subjective nature and pain measurement represents a challenge in clinical trials (3, 5), pain scales used in the included studies have been previously validated (60). Most studies used the Visual Analogue Scale (VAS) or its variations (38-45). Other authors used the Numerical Rating Scale (NRS) (11), the Verbal Rating Scale (VRS) (27), the Heft-Parket VAS (29), and the categorical scale (37). Fortunately, endodontic pain evaluations using different types of pain scale are known to be highly correlated (56).
Analgesic intake findings usually accompanied those of postoperative pain (53), i.e., if a preparation technique showed worse pain results, it also promoted higher analgesic consumption (Table 3). This situation was not observed in two studies (29, 44). This may be related to psychological variations regarding pain tolerance and urgency to use pain killers (61). From the 12 studies included in this review, seven recommended the use of Ibuprofen in case of postoperative pain (11, 29, 39-43). Nonsteroidal anti-inflammatory drugs have been recommended as first-choice medication for postoperative pain management after endodontic therapy, especially Ibuprofen (62).
Some limitations of this review should be highlighted: 1) most studies had unclear risk of bias with regards to the blinding of participants and personnel, blinding of outcome assessment and incomplete outcome data; 2) general quality of the body of evidence was classified as low, due to limitations in the design, implementation and indirectness of evidence, limiting the extern validation; 3) meta-analysis was not presented due to the heterogeneity in the selected studies regarding demographic characteristics of patients, endodontic

diagnosis, technical procedures, pain assessment methods and periods. In this context, the present review points out some orientation regarding the influence of instrumentation techniques on endodontic postoperative pain, but also highlights the need for additional standardized and well-design clinical trials.

Conclusions

Hand instrumentation led to worse postoperative pain results when compared to engine-driven systems. Among engine-driven instruments with different kinematics, conflicting results are reported. Given the low quality of evidence and contrasting findings, results should be carefully interpreted and cannot generate strong recommendations for clinicians at this moment.

Clinical Relevance

Pain related to endodontic treatment is a concern for professionals and patients. This systematic review provides evidence about the influence of hand, rotary and reciprocating instrumentation on postoperative pain. It also approaches the quality of the included randomized clinical trials.

Conflict of interest

All authors declare that they have no conflicts of interest. In addition, all authors have read and approved the manuscript as submitted, are qualified for authorship, believe the submission represents honest work and take full responsibility for the reported findings.

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