

SYSTEMATIC REVIEW

Apical debris extrusion and potential risk of endodontic flare-up: correlation with rotating and reciprocating instruments used in daily clinical practice

ABSTRACT

Aim: During the mechanical and chemical preparation of root canals with reciprocating and rotating instruments, an accidental extrusion of debris beyond the dental apex can be generated. The Nickel-Titanium instruments have drastically improved the clinical procedures and the quality of endodontic treatment. The term flare-up is commonly used to indicate a clinical condition in which pain and swelling of the oral mucosa and soft facial tissues are observed following root canal therapy of a dental element.

Materials and methods: After raising the PICO question, the research was carried out following PRISMA guidelines. The search engines used were: Pubmed (Medline), EBSCO and Cochrane Library. Randomized controlled trials (RCT) and in vitro studies were included. The research focus was on articles related to the debris extrusion during root shaping with rotary and reciprocating endodontic instruments.

Results: Through the application of inclusion and exclusion criteria, 17 articles were selected. The Jadad Scale was used to evaluate the quality of the papers. In the modern literature, conflicting data have emerged regarding the apical extrusion of debris using the two instrumentation techniques taken into consideration. There are no studies that analyze the possible relationship between the apical extrusion and the design of the tip shape of the endodontic instrument; the connection between shaping techniques and the appearance of flare ups should also be investigated.

Conclusions: The apical extrusion of debris occurs both with the reciprocating technique and with continuous rotation instruments. Specifically, regarding the ProTaper, Mtwo, Reciproc, WaveOne and Hyflex, there are discordant results in the literature. The ProTaper Universal cause a greater extrusion, compared to the reciprocating ones, while the ProTaper Next are related with a smaller extrusion. In this condition, there is no difference between WaveOne and Reciproc. The association between flare-up and debris extrusion during the shaping phase must be demonstrated with in vivo clinical research. Further studies are needed in the future.

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Introduction

Endodontic Flare-up: Definition and Etiology

The term flare-up is commonly used to indicate a clinical condition in which pain and swelling of the oral mucosa and soft facial tissues are observed after a root canal therapy of a dental element (1).

It can occur over a period of time that ranges from a few hours to a few days after starting or completing the endodontic treatment; generally, a flare-up episode leads the patient to request an unscheduled check-up appointment, due to the urgency. Common symptoms, such as spontaneous pain, while chewing or beating, and swelling are associated with a transient decrease of the quality of life (1, 2).

In the contemporary scientific literature, various factors have been reported that can possibly influence the appearance of the flare-up: number of clinical sessions necessary to complete the endodontic treatment, intracanal medications, age and gender of the patient, shaping technique, cleaning of the canals and tools used, extrusion of debris beyond dental apex, diagnosis of previous pathology at the pulp and periapical level, and, finally, the microbiological component (3-6). Some medications such as Aceclofenac 200 mg could be preferred as an oral analgesic premedication, before primary root canal treatment in patients with moderate to severe preoperative pain, for efficient management of post-instrumentation pain (7), while there is no clear evidence supporting that preoperative ibuprofen is better than other drugs in reducing the intensity of postendodontic pain (8).

Therefore, during endodontic treatment, there are clinical situations in which an alteration of the balance between the defense of the host and the aggression of microorganisms is observed, with the consequent formation of acute periapical inflammation (4). Sodium hypochlorite (NaOCl) and chlorhexidine (CLX) are two of the irrigating agents that have shown an important antibacterial activity and they contribute to the incidence's reduction

of flare-ups (5). Ethylenediaminetetraacetic acid (EDTA) is effective as a rinse to remove the smear layer in the root canal (9).

Rotating and Reciprocating Endodontic Instrument

An accidental extrusion of debris beyond the dental apex can be generated during the mechanical and chemical preparation of root canals with reciprocating and rotating instruments. In most cases, from a clinical point of view, post-operative pain might affect the patient. The debris is basically represented by dentin, necrotic tissue, remaining pulp tissue, microorganisms or irrigating agents which, pushed beyond the apical foramen, cause irritation of the periapical structures (10).

The Nickel-Titanium instruments have drastically improved the clinical procedures and the quality of endodontic treatment. The reciprocating movement consists in alternating clockwise and counterclockwise rotations, with a different amplitude of the cutting angle (6-16).

The advantage of reciprocating instruments is that they have increased resistance to cyclic fatigue and are disposable for each treatment, lowering the risk of cross-infection and possible fractures (16). ProTaper files (Dentsply Maillefer, Ballaigues, Switzerland) are rotating instruments characterized by a variable taper that allows progressive preparation in a vertical and horizontal direction; they have a triangular section with three convex cutting angles (11-13).

Mtwo files (Sweden & Martina) have a helical section with cutting blades parallel to the axis of the instrument and a non-active tip. The basic series (standard set) of Mtwo rotary files includes four instruments with variable tip sizes ranging from no. 10 to no. 25, tapers ranging from .04 to .06-.07 and two lengths: 21 and 25 mm. Also file tips range in size from 30, 35, 40 and tapers of 0.5, 0.4 and 0.7 are available (12). OneShape instruments are single files designed for root canal shaping, elaborated by Micro Mega, with a diameter of 25 and single use for patient; they reduce the risk of cross-infection and the timing of



treatment (17). RaCe instruments are rotary files. They have exclusive advantages including a patented alternating cutting edge/non-screw in design, electropolished finish, and triangular cross section. These features maximize flexibility, cutting efficiency/debris removal and safety (12).

Revo-S are rotary files with an asymmetrical cross-section that provides less stress on the instrument. The canal axis has 3 cutting edges located on 3 different radiuses. The smaller section allows more flexibility and offers a better ability to negotiate curves. The asymmetrical cross-section increases the available volume for upward debris elimination (12, 18).

Neolix (Châtres-la-Forêt, France) is a newly introduced NiTi rotary system with full rotary motion that consist of one C1 file for coronal enlargement and three A1 files (with tip size range of #20, #25 and # 40) allowing for canal shaping down to the apex (19).

WaveOne (Maillefer, Switzerland) are reciprocating instruments that come in three dimensions, *21.06, *25.08 and *40.08 (constant taper) and they require a special micromotor (12, 13).

Reciproc files (Dentsply) comes in three sizes, *25.08, *40.05, *50.04, S-shaped section, regressive taper in the first 3 mm at the tip; they shape similar to Mtwo and they are used with reciprocating movement and require a special micromotor (12-14).

Hyflex files (Coltene-Whaledent, Switzerland) are characterized by an important control of shape memory and elasticity during shaping (12, 13).

Systematic Review Tool. PICO Question.

The PICO question (Population, Intervention, Comparison, Overcome) aims to investigate the correlation between reciprocating and rotating endodontic instruments and the apical extrusion of debris during the shaping phase of the root canal treatment that could lead to the appearance of postoperative flare-ups.

P: Patients undergoing endodontic therapy with rotary instruments (ProTaper, Mtwo, OneShape).

I: formation of debris during the canal shaping phase.

C: Patients undergoing endodontic therapy with reciprocating instruments (WaveOne, Reciproc, Hyflex).

O: debris extrusion beyond dental apex and the related potential risk of causing flare-ups.

Justification of the Systematic Review

In the modern scientific literature, there are systematic reviews that analyze the connection between apical extrusion of debris, flare-up and the type of endodontic instruments used during the root canal shaping phase. The need to develop this study arises from the desire to update and deepen the subject in the light of the numerous studies published in the last decade, between 2011 and 2021.

Compared to the recent systematic reviews, new articles have been included which provide a detailed reading key on the analyzed topic and satisfy the pre-established criteria of inclusion. Furthermore, in the literature there are diametrically opposed and contrasting results regarding the subject (20, 21).

Therefore, the main goal of the systematic review is to analyze the contemporary studies in a global and rational way and try to provide guidelines to be applied in daily clinical life.

Materials and Methods

The systematic review was reported following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and it was performed applying meticulously the Handbook Cochrane recommendations (22, 23). The study has been previously registered on PROSPERO platform with code number (341112).

Search Strategy

The systematic review was conducted between 1 July 2021 and January 2022. The primary sources were selected through the use of search engines, such as Pubmed (Medline), EBSCO and Cochrane Library. Alternative sources, such as opengray literature, Google Scholar and bibliograph-

ic indexes of previous systematic reviews, related to the topic, have been consulted. A last research for a partial records update was performed on 6 June 2022. The Boolean operators used are “AND” and “OR”.

Different types of keywords were used based on the analyzed context:

- Group 1: (Apical debris OR detritus extrusion OR apical extrusion OR debris extrusion OR flare up);
- Group 2: (WaveOne OR Reciproc OR Hyflex OR reciprocating OR reciprocating file);
- Group 3: (ProTaper OR Mtwo OR One-Shape OR rotary instrument OR rotary file).

The terms of group 1 and group 2, and those of group 1 with group 3 were combined; in both cases the Boolean operator AND was used (table 1).

The NOT operator was not taken into consideration during the research phase.

Articles Selection

Prior to the process of selecting scientific articles for carrying out the systematic review, the inclusion and exclusion criteria were determined.

Inclusion criteria:

- Randomized controlled studies, cohort studies, case-control studies, cross-sectional studies, in vitro studies.
- Patients with endodontic treatment performed through the use of rotating and reciprocating systems.
- Studies that analyze dental elements belonging to the permanent dentition.
- In vivo studies in which endodontic treatments were performed with appropriate isolation (rubber dam).
- In vivo studies in which root canal irrigation protocols with NaOCl or CLX and EDTA were applied.
- Articles in English.

Exclusion criteria:

- Animal studies, clinical cases, systematic reviews, meta-analyses.
- Studies not available with full text.
- Studies in which no distinction is made between reciprocating and rotating systems.
- Studies analyzing endodontic therapies in temporal dentition.

- Studies with endodontic therapies without rubber dam isolation.
- Studies with endodontic treatments carried out using only manual technique.
- Studies without the control group.
- Studies in which dental elements are characterized by the presence of open apex, cracks or micro fractures, root caries.

In the research phase of the scientific articles, no time restrictions were applied regarding the dates of publication of the sources.

Data Collection

Three operators (F.A.V, A.S, F.Z) independently managed the research and screening of the sources, applying the previously described inclusion and exclusion criteria. The results were compared and extracted; in case of discrepancies, a Senior Author (C.P) was consulted in order to find a fair and thoughtful compromise. The data were collected by compiling tables of results. No metaanalysis or statistical investigations were expected for this study.

Evaluation of the Quality of the Studies

The qualitative evaluation (table 2) of the selected articles was carried out using established indices depending on the type of study.

In the case of Randomized Clinical Trials (RCT) various Scales can be used, including that of Delphi, Jadad and Yates. Many quality assessment tools exist in the literature; however, none cover all the critical aspects of in vitro studies (24).

Some of them could be adapted and applied to evaluate and assess the quality of in vitro studies (24).

The Jadad Scale has demonstrated the best evidence of validity and has been used in over 15,000 scientific studies published in the literature. It mainly focuses on the adequacy of randomization, double blindness and loss of patients' follow up (25).

The final score, assigned through points, can vary between 0 and 5; an article is considered valid, from a qualitative



Table 1
Search String on Pubmed (Medline)

<p>Group 1 AND Group 2</p>	<p>((("apical"(All Fields) OR "apically"(All Fields) OR "apicals"(All Fields) OR "apices"(All Fields)) AND "debris"(All Fields)) OR ("detritus"(All Fields) AND ("extrusion"(All Fields) OR "extrusions"(All Fields))) OR ((("apical"(All Fields) OR "apically"(All Fields) OR "apicals"(All Fields) OR "apices"(All Fields)) AND ("extrusion"(All Fields) OR "extrusions"(All Fields))) OR ("debris"(All Fields) AND ("extrusion"(All Fields) OR "extrusions"(All Fields))) OR ((("flare"(All Fields) OR "flares"(All Fields)) AND "up"(All Fields))) AND ("WaveOne"(All Fields) OR ("reciproc"(All Fields) OR "reciprocal"(All Fields) OR "reciprocity"(All Fields) OR "reciprocally"(All Fields) OR "reciprocals"(All Fields) OR "reciprocate"(All Fields) OR "reciprocated"(All Fields) OR "reciprocates"(All Fields) OR "reciprocating"(All Fields) OR "reciprocation"(All Fields) OR "reciprocations"(All Fields) OR "reciprocator"(All Fields) OR "reciprocators"(All Fields) OR "reciprocities"(All Fields) OR "reciprocity"(All Fields)) OR "Hyflex"(All Fields) OR ("reciproc"(All Fields) OR "reciprocal"(All Fields) OR "reciprocity"(All Fields) OR "reciprocally"(All Fields) OR "reciprocals"(All Fields) OR "reciprocate"(All Fields) OR "reciprocated"(All Fields) OR "reciprocates"(All Fields) OR "reciprocating"(All Fields) OR "reciprocation"(All Fields) OR "reciprocations"(All Fields) OR "reciprocator"(All Fields) OR "reciprocators"(All Fields) OR "reciprocities"(All Fields) OR "reciprocity"(All Fields)) OR ((("reciproc"(All Fields) OR "reciprocal"(All Fields) OR "reciprocity"(All Fields) OR "reciprocally"(All Fields) OR "reciprocals"(All Fields) OR "reciprocate"(All Fields) OR "reciprocated"(All Fields) OR "reciprocates"(All Fields) OR "reciprocating"(All Fields) OR "reciprocation"(All Fields) OR "reciprocations"(All Fields) OR "reciprocator"(All Fields) OR "reciprocators"(All Fields) OR "reciprocities"(All Fields) OR "reciprocity"(All Fields)) AND ("filing"(MeSH Terms) OR "filing"(All Fields) OR "file"(All Fields))))</p>
<p>Group 1 AND Group 3</p>	<p>((("apical"(All Fields) OR "apically"(All Fields) OR "apicals"(All Fields) OR "apices"(All Fields)) AND "debris"(All Fields)) OR ("detritus"(All Fields) AND ("extrusion"(All Fields) OR "extrusions"(All Fields))) OR ((("apical"(All Fields) OR "apically"(All Fields) OR "apicals"(All Fields) OR "apices"(All Fields)) AND ("extrusion"(All Fields) OR "extrusions"(All Fields))) OR ("debris"(All Fields) AND ("extrusion"(All Fields) OR "extrusions"(All Fields))) OR ((("flare"(All Fields) OR "flares"(All Fields)) AND "up"(All Fields))) AND ("protaper"(All Fields) OR "protapers"(All Fields) OR "Mtwo"(All Fields) OR "OneShape"(All Fields) OR ((("rotaries"(All Fields) OR "rotary"(All Fields)) AND ("instrument"(All Fields) OR "instrument s"(All Fields) OR "instrumentation"(MeSH Subheading) OR "instrumentation"(All Fields) OR "instruments"(All Fields) OR "instrumented"(All Fields) OR "instrumenting"(All Fields))) OR ((("rotaries"(All Fields) OR "rotary"(All Fields)) AND ("filing"(MeSH Terms) OR "filing"(All Fields) OR "file"(All Fields))))</p>

point of view, when the score is equal to or greater than 3. The bias risk is low when the score is 4-5, moderate when the scores is 3 and high when the score is between 0-2 (25).

In the first three questions, relating to randomization, double blind and follow up, 1 point is assigned respectively if the article satisfies the requirements of the Scale, 0 points otherwise. In the fourth and fifth questions, relating to the adequacy of randomization and blindness, in case of a positive outcome a point (+1) will be assigned, otherwise a point (-1) will be removed. Randomization is the only system that increases the probability of an equal, balanced and uniform distribution of the variables that affect a search result.

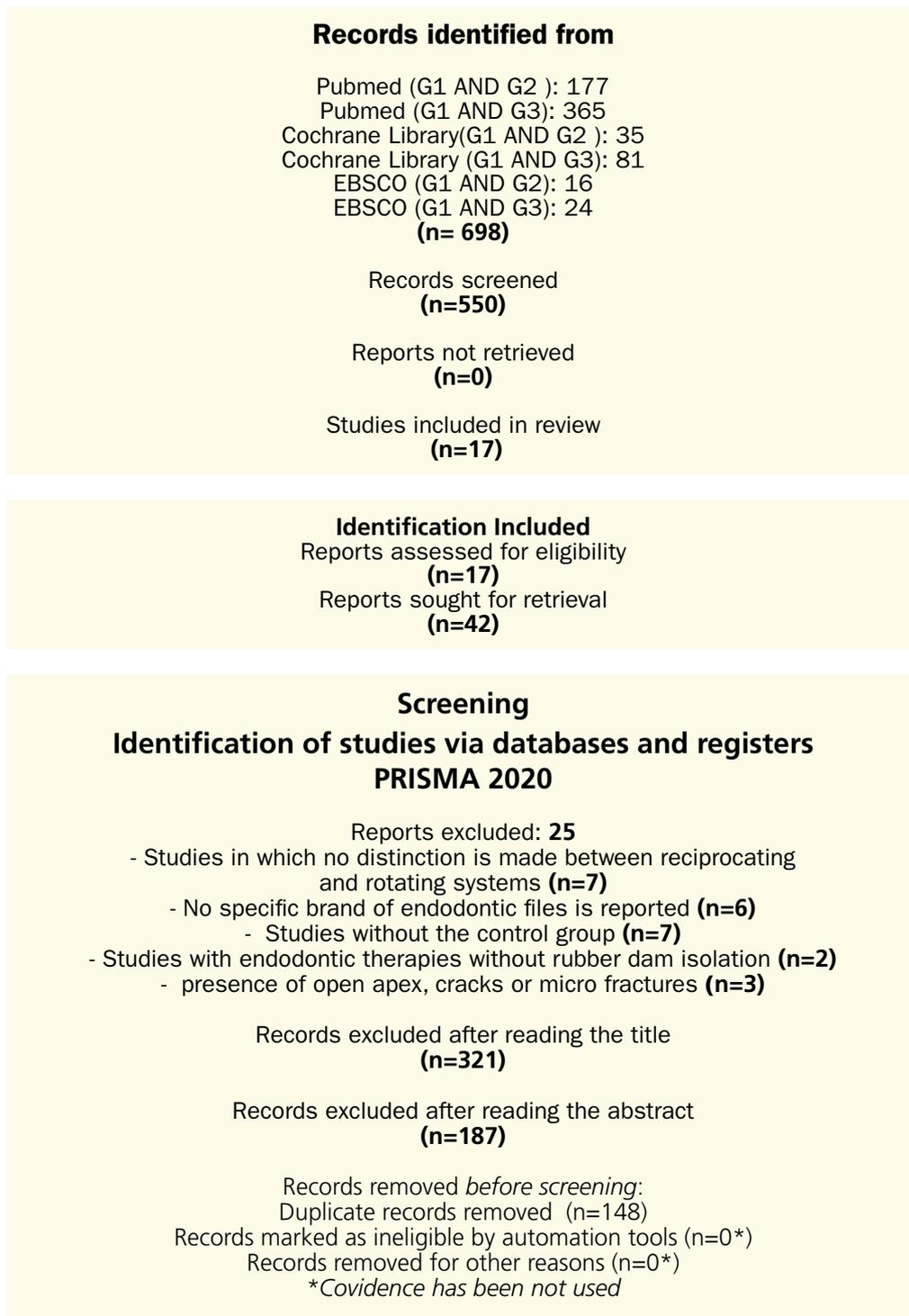
Furthermore, it is believed that the loss or absence of patients' follow up can alter the validity of a study when it is greater than 20% (25).

Results

Search and Selection

Using the MeSH and non-MeSH terms and applying the search strategy previously described, a total of 698 articles were selected through search engines, such as Pubmed (Medline), EBSCO and Cochrane Library (Figure 1). Through Pubmed search, combining group 1 and group 2 terms, 177 articles were obtained, while 365 articles were selected by creating a search string between group 1 and group 3. The search through the Cochrane Library led to a total of 81 articles with the combination of group 1 AND group 3 and 35 articles with the combination of group 1 AND group 2. The search through the EBSCO led to a total of 24 articles with the combination of group 1 AND group 3 and 16 articles with the combination of group 1 AND group 2. Once the duplicates have been eliminated, the first identification phase ends with a total

Figure 1
Flowchart.



of 550 articles. Duplicates have been removed using the “Systematic Review Assistant-Deduplication Module” (26), a specific tool developed in 2013. During the screening phase, 321 articles were deleted after reading the title, while 187 were ex-

cluded after reading the abstract. Therefore, the previously described inclusion and exclusion criteria were applied to a total of 42 full-text articles potentially relevant to the development of the review. The methodological criteria for eligibility



Table 2
Evaluation of the Quality of the Included Articles

Authors/Year	Randomization	Double Blind	Follow up	Appropriate Randomisation	Appropriate Blinding	Total score Article Quality Bias Risk
Relvas et al. 2016 (10)	YES	YES	YES	YES	NR	4/5 Low
Shokraneh et al. 2017 (11)	YES	YES	YES	YES	NR	4/5 Low
Surakanti et al. 2014 (13)	YES	YES	YES	NR	NR	3/5 Moderate
Kherlakian et al. 2016 (14)	YES	YES	YES	YES	NR	4/5 Low
Çiçek et al. 2016 (20)	YES	YES	YES	YES	NR	4/5 Low
Neelakantan et al. 2015 (27)	YES	YES	YES	NR	YES	4/5 Low
Bürklein et al. 2013 (28)	YES	YES	YES	NR	NR	3/5 Moderate
Vivekanandhan et al. 2016 (29)	YES	YES	YES	NR	NR	3/5 Moderate
Eliasz et al. 2020 (30)	YES	NO	NO	YES	NR	2/5 High
Yılmaz et al. 2017 (31)	YES	YES	YES	NR	NR	3/5 Moderate
De-Deus et al. 2015 (32)	YES	YES	YES	YES	NR	4/5 Low
Küçükylmaz et al. 2014 (33)	NO	YES	YES	NR	NR	2/5 High
El Khodary et al. 2019 (34)	YES	YES	YES	NR	NR	3/5 Moderate
Labbaf et al. 2017 (35)	YES	YES	YES	NR	NR	3/5 Moderate
Shahi et al. 2016 (36)	YES	YES	YES	YES	NR	4/5 Low
Ozsu et al. 2014 (37)	YES	YES	YES	NR	NR	3/5 Moderate
Silva et al. 2014 (38)	YES	YES	NO	YES	NR	3/5 Moderate

NR: No Reported. In the total score section, the green color indicates a good scientific validity of the article ($=or>3$); the red color is associated with a limited validity.

determine the definitive inclusion of 17 articles, which will subsequently be subjected to quality assessment using determined indices and from which the data will be extracted.

Graphic Representation of the Research Results

The explanatory table of the articles used for carrying out the systematic review is shown below. The first author is reported for each study; the year of publication; the country of

origin; the Journal (Impact Factor correlated) where the paper has been published; the research size sample; which can be referred to the number of patients or dental elements treated; the endodontic instruments considered in the article; the type of movement, that is rotating or reciprocating; data collection; the clinical diagnosis that led the authors to perform root canal therapy or if they are in vitro studies, and finally, the clinical and statistically significant data reported in the selected articles.

Table 3A

Results Table: studies on patients

Authors/ Year Country	Journal Impact Factor (IF) 2021-2022	Sample size	Endodontic Instruments	Data Collectio Methodology	Preoperative Diagnosis	Relevant Conclusions Reported
Relvas et al. 2016 (10) Brazil	Clinical Oral Investigations IF: 3.573	78 mandibular molars	Protaper Reciproc	Questionnaire to evaluate the Verbal Rating Scale	Asymptomatic pulp necrosis	No significant difference between the two techniques regarding post- operative pain and flare-up
Shokraneh et al. 2017 (11) Iran	Clinical Oral Investigations IF: 3.573	96 patients	Protaper Universal WaveOne Manuals	Questionnaire to evaluate the Visual Analogue Scale	Pulp necrosis with periapical lesion	The group of patients treated with the reciprocating system reported less post-operative pain. No flare up
Kherlakian et al. 2016 (14) Brazil	Journal of Endodontics IF: 4.171	210 patients	ProTaper WaveOne Reciproc	Questionnaire to evaluate the Visual Analogue Scale	Vital dental elements. Root canal treatment performed due to prosthetic reasons	No difference between the instruments analyzed regarding post-operative pain and the need for analgesic therapy
Çiçek et al. 2016 (20) Turkey	Journal of Applied Oral Science IF: 2.698	90 patients	ProTaper WaveOne	Questionnaire to evaluate the Visual Analogue Scale	Asymptomatic, necrotic teeth with radiographic periapical lesion	There is no significant difference between the two techniques in terms of post- operative pain
Neelakantan et al. 2015 (27) India	Clinical Oral Investigations IF: 3.573	624 patients	OneShape Reciproc	Questionnaire, the Mann-Whitney Scale and chi-squared test	Symptomatic irreversible pulpitis	The reciprocating technique is associated with a lower intensity and duration of post- operative pain than the rotating one
Shahi et al. 2016 (36) Iran	Iranian Endodontic Journal IF: 1.13	78 mandibular molars	ProTaper RaCe	Questionnaire to evaluate the Visual Analogue Scale	Irreversible pulpitis without radiographic periapical lesions	No significant difference between the two groups regarding the extrusion of debris

Interpretation of the results

The results obtained show discrepancy in the data collected. The articles included in the systematic review are 17. Of these, 11 are in vitro studies (13, 28-35, 37, 38) and 6 randomized controlled trials (10, 11, 14, 20, 27, 36). The time

span covered by the research is approximately 8 years, being the oldest article dating back to 2013 (28) and the most current one to 2020 (30). From a geographical and epidemiological point of view, four articles are from Brazil (23,5%), four from Turkey (23,5%), three



from Iran (17,5%) and India (17,5%), one from Poland (6%), Germany (6%) and Egypt (6%). Several Journals have been consulted during data collection; the one with greater impact factor was Journal of Clinical Medicine (30), the lower one was Iranian Endodontic Journal (34, 35); one Journal has no impact factor reported (34). The sample size in RCT varies from 624 (27) to 90 patients (20). In vitro studies, the greater size was 90 (31), the lower was 45 teeth (33). One article analyzes incisor (31), four articles are focused on premolars (13, 33, 37, 38) and four are about molars (28, 32, 34, 35). One articles do not differentiate between dental elements (30) and one analyze monoradicular teeth (29).

In RCT, four articles employ questionnaire to evaluate the Visual Analogue Scale (11, 14, 20, 36), one the Verbal Rating Scale (10) and one the Mann-Whitney Scale (27).

The reason why a root canal therapy was performed was pulp necrosis (10, 11, 20), irreversible pulpitis (27, 36) and prostodontic reasons (21).

Except for one study where analysis of CBCT sections has been used to determine debris apical extrusion (30), all in vitro studies have been developed using extracted teeth and measuring the weight difference of Eppendorf tubes (13, 29-31, 33-35, 37) or specific vials (28, 32, 38) before and after the root canal treatment.

Discussion

The main goal of the systematic review was to investigate the possible correlation between the debris extrusion beyond the dental apex and the manifestation of the postoperative flare-up depending on whether the root canal shaping was performed using rotary or reciprocating endodontic instruments. After the analysis of the data (Table 3A, 3B), it was evident that the reciprocating and rotating techniques are associated with apical extrusion of debris. In the study by Relvas et al (10), no differences in postoperative pain are reported

between the two techniques, while Shokraneh et al (11) report that the intensity and duration of pain is reduced in those cases where root canal therapy was performed with reciprocating instruments. In both cases, no post-treatment flare up episodes are reported.

Therefore, In modern scientific literature, conflicting data emerge regarding the topic in question; Kherlakian et al (14) and Çiçek et al (20) reported, as in the case of Relvas et al (10), that there is no difference between the instruments analyzed regarding post-operative pain and the need for analgesic therapy once the treatment is completed, contrary to what is reported by Neelakantan (27), where the shaping with reciprocating is related to a lower intensity and duration of postoperative pain compared to that with rotating ones.

Comparin et al (39), analyzing the Mtwo and Reciproc systems, did not report differences in the incidence, intensity and duration of postoperative pain with time intervals at 24-48-72 hours. Similar data have been described by Keskin et al (40), where there are no differences regarding postoperative pain in those cases where a glide path is performed with a rotating or reciprocating system. Pasqualini et al (41), in their randomized clinical study, focusing on ProTaper and WaveOne, demonstrated that the reciprocating system is associated with greater discomfort in the immediate post-operative period and in cases of previous periapical inflammation compared to the rotating one. Also in the meta-analysis of randomized clinical trials performed by Hou et al (42), rotary systems are associated with a lower incidence of postoperative pain than reciprocating instruments.

In relation to the extrusion of debris beyond the dental apex depending on the technique used, conflicting data emerged. In the study by Surakanti et al (13), WaveOne instruments, when compared with ProTaper and Hyflex, lead to a greater accumulation of debris beyond apex with the risk of originating post-treatment inflammatory reactions. Vivekanandhan

Table 3B
Results Table: in vitro studies

Authors/ Year Country	Journal Impact Factor (IF) 2021-2022	Sample size	Endodontic Instruments	Data Collection Methodology	Preoperative Diagnosis	Relevant Conclusions Reported
Surakanti et al. 2014 (13) India	Journal of Conservative Dentistry IF: 4.146	60 mandibular premolars	ProTaper Hyflex WaveOne	Eppendorf tubes and pre/post treatment weight measurement	In vitro study Extracted elements	More debris extrusion with Waveone instruments than ProTaper and Hyflex
Bürklein et al. 2013 (28) Germany	International Endodontic Journal IF: 5.264	80 mandibular central incisors	Reciproc Mtwo F360 OneShape	Specific vials whose weight was measured before and after the instrumentation	In vitro study Extracted elements	Greater debris extrusion in the Reciproc group
Vivekanandhan et al. 2016 (29) India	Journal of Conservative Dentistry IF: 4.146	60 monoradicular teeth	ProTaper Universal WaveOne Revo-S	Eppendorf tubes and pre/post treatment weight measurement	In vitro study Extracted elements	No difference between ProTaper and WaveOne regarding the extrusion of debris; minor in the case of Revo-S files
Eliasz et al. 2020 (30) Poland	Journal of Clinical Medicine IF: 5.583	60 dental elements	ProTaper Next WaveOne	CBCT sections of a specific area of the root compared before/after shaping	In vitro study Extracted elements	Greater transport of debris beyond the apex with ProTaper Next; WaveOne ensure a more conservative and retentive preparation
Yilmaz et al. 2017 (31) Turkey	Journal of Endodontics IF: 4.171	90 upper central incisors	ProTaper Next Reciproc Twisted Files adaptive	Eppendorf tubes and pre/post treatment weight measurement	In vitro study Extracted elements	Greater extrusion of debris beyond apex with Reciproc compared with ProTaper Next
De-Deus et al. 2015 (32) Brazil	Clinical Oral Investigations IF: 3.573	80 mesial root of mandibular molars	ProTaper Universal WaveOne Reciproc Manuals	Specific vials whose weight was measured before and after the instrumentation	In vitro study Extracted elements	Greater apical extrusion in the ProTaper group compared to the reciprocating group. No difference between the Reciproc e WaveOne
Küçükyılmaz et al. 2014 (33) Turkey	Brazilian Oral Research. IF: 1.633	45 mandibular premolars	ProTaper Reciproc OneShape	Eppendorf tubes and pre/post treatment weight measurement	In vitro study Extracted elements	Greater extrusion of debris and irrigation solution in the Reciproc group compared to the rotating group
El Khodary et al. 2019 (34) Egypt	Egyptian Dental Journal IF: No reported	63 mandibular molars	ProTaper Next Hyflex	Eppendorf tubes and pre/post treatment weight measurement	In vitro study Extracted elements	No significant difference between the three systems regarding extrusion of debris beyond apex



Table 3B
Results Table: in vitro studies

Labfaf et al. 2017(35) Iran	Iranian Endodontic Journal IF: 1.13	60 mesiobuccal root of upper molar	Protaper Universal Hyflex Reciproc Neolix	Eppendorf tubes and pre/post treatment weight measurement	In vitro study Extracted elements	Hyflex files are associated with less extrusion of debris during the root canal shaping phase; the Reciproc instead cause a greater escape of debris beyond the apex
Ozsu et al. 2014 (37) Turkey	European Journal of Dentistry IF: 3.04	56 mandibular premolars	ProTaper Universal ProTaper Next WaveOne	Eppendorf tubes and pre/post treatment weight measurement	In vitro study Extracted elements	ProTaper Universal have a greater extrusion of debris than the Next and the reciprocating technique
Silva et al. 2014 (38) Brazil	Journal of Endodontics IF: 4.171	45 mandibular premolars	ProTaper Universal WaveOne Reciproc	Specific vials whose weight was measured before and after the instrumentation	In vitro study Extracted elements	No difference between the two reciprocating systems regarding the extrusion of debris; it's greater in case of ProTaper Universal.

et al (29), on the other hand, do not report any differences between ProTaper Universal and WaveOne. The largest apical discharge of debris with the reciprocating technique is also reported by Bürklein et (28), in the specific case of the Reciproc compared to OneShape and Mtwo, by Yilmaz et al (31), which analyzes the ProTaper Next and Reciproc and by Küçükylmaz (33), where in addition to that of debris, there is also a greater extrusion of irrigating agents in the case of Reciproc compared to ProTaper and OneShape.

Eliasz et al (30), in contrast to the authors previously cited, demonstrate in their study that ProTaper Next cause greater extrusion than WaveOne, due to the more conservative and retentive root canal shaping capacity of the reciprocating instruments.

Nevares et al (43), show in their study that there is not difference between ProTaper Next and Reciproc regarding apical extrusion of debris in severely curved canals. Both in the De-Deus (42) and Ozsu (37) study, the ProTaper Universal are attributable to a greater apical extrusion when compared with ProTaper Next

and the Waveone (37) and the Reciproc and the WaveOne (32).

Furthermore, it's important to highlight that there are no differences in potential extrusion between WaveOne and Reciproc (32), as also reported by Silva et al (38). On the other hand, Nevares et al (44) demonstrate the Reciproc files produced significantly more debris than WaveOne ($p < 0.05$), and both systems produced a greater apical extrusion of debris than HyFlex CM ($p < 0.001$).

The WaveOne Gold system, regarding debris extrusion, outperformed also TRUShape and TruNatomy files in Roshdy et al study (45). Similar results to Silva (38) were also described by Tinoco et al (46), who reported, in an ex vivo study, the extrusion of *Enterococcus Faecalis* with WaveOne, Reciproc and BioRacer files; in this case the apical extrusion is greater with a rotating system (BioRacer) and there is no difference between the two reciprocating ones.

In Labfaf's study (35), the HyFlex prove to be the best instruments when considering the apical extrusion, while the Reciproc, contrary to what other authors reported (32, 37, 38), cause a greater



leakage than the ProTaper Universal. El Khodary et al (34), in the analysis of Hyflex and ProTaper Next, and Shahi et al. (36), in the study by ProTaper and RaCe, found no statistically significant differences in terms of extrusion of debris beyond dental apex. The data are in contrast with what described by Capar et al. (47), where in an in vitro study reports that ProTaper Next cause less debris extrusion when compared with Hyflex reciprocating files. The articles considered for carrying out the systematic review did not report data concerning the possible correlation between debris extrusion and flare-up (10, 11, 14, 20, 27). The possible causes of flare ups, reported in the literature, can be associated with: root canal preparation and obturation up to the apical end and not the apical constriction (48), the presence of severe preoperative pain (49), presence of *Fusobacterium Nucleatum* (50), presence of radiolucent periapical lesion prior to the treatment (51-53), asymptomatic irreversible pulpitis in female patients (54) and number of visits necessary to complete the endodontic treatment (55). The main limitation of the systematic review is correlated to the presence of in vitro studies, which have, in certain cases, less scientific validity than clinical studies on patients. There are no studies in the literature that analyze the possible relationship of the extrusion of debris with the design of the tip of the endodontic instrument. In addition, other variables, such as the initial anatomy of the tooth, the number of roots and the instrumentation technique (single, multi-file) have not yet been considered. However, de Oliveira Escocio et al. (56) reported in their randomized clinical trial that the working length did not influence endodontic postoperative pain in case of pulp necrosis. Regarding the data collection method, the main current method to study the amount of debris in vitro is through specific microbalances that measure the difference in weight of the vials before and after the endodontic instrumentation. It is necessary that in

the future further studies be carried out both in vivo and in the laboratory, with a strict control of the bias; the aim is to determine the possible correlation between the extruded debris following root canal shaping with reciprocating and rotating techniques and the phenomenon of post endodontic flare up.

The final goal, that is proposed, is to be able to control all those factors, which depend on the operator and the instruments used, in order to minimize pain and discomfort in the endodontic post-treatment phase.

Conclusions

The apical extrusion of debris occurs both with the reciprocating technique and with continuous rotation instruments. Specifically, regarding the ProTaper, Mtwo, Reciproc, WaveOne and Hyflex, there are discordant results in the literature. The ProTaper Universal cause a greater extrusion, compared to the reciprocating ones, while the ProTaper Next are related with a lower extrusion. In this clinical condition, there is no difference between WaveOne and Reciproc. The association between flare up and debris extrusion during the shaping phase must be demonstrated with in vivo clinical research. Further studies are needed in the future.

Clinical Relevance

The clinical relevance of apical debris extrusion, observed with both reciprocating and rotating instruments, varies among analysed NiTi. Validation of the correlation between debris extrusion and flare-ups during shaping necessitates future in vivo clinical research.

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Conflict of Interest

The authors declare that there is no conflict of interest in the article.



References

- Sipavičiūtė E, Manelienė R. Pain and flare-up after endodontic treatment procedures. *Stomatologija, Baltic Dental and Maxillofacial Journal*. 2014;16(1):25-30. PMID: 24824057.
- Yu VS, Messer HH, Yee R, Shen L. Incidence and impact of painful exacerbations in a cohort with post-treatment persistent endodontic lesions. *J Endod*. 2012 Jan;38(1):41-6. doi: 10.1016/j.joen.2011.10.006. Epub 2011 Nov 17. PMID: 22152618.
- Alves Vde O. Endodontic flare-ups: a prospective study. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod*. 2010 Nov;110(5):e68-72. doi: 10.1016/j.tripleo.2010.05.014. Epub 2010 Sep 1. PMID: 20813556.
- Siqueira JF Jr. Microbial causes of endodontic flare-ups. *Int Endod J*. 2003 Jul;36(7):453-63. doi: 10.1046/j.1365-2591.2003.00671.x. PMID: 12823700.
- Onay EO, Ungor M, Yazici AC. The evaluation of endodontic flare-ups and their relationship to various risk factors. *BMC Oral Health* 2015; 142. <https://doi.org/10.1186/s12903-015-0135-2>.
- Spinelli A, Zamparini F, Lenzi J, Gandolfi M.G, Prati C. Clinical Evaluation of a Novel Premixed Tricalcium Silicate Containing Bioceramic Sealer Used with Warm Carrier-Based Technique: A 12-Month Prospective Pilot Study. *Appl. Sci*. 2023, 13, 11835. <https://doi.org/10.3390/app132111835>.
- Sundaramurthy JL, Natanasabapathy V, Mahendran K, Narasimhan S, Raghu S, Cherian AR, Vaanjay M, Krithikadatta J. Efficiency of Immediate and Controlled release of Aceclofenac on Post-instrumentation Pain in Root Canal Treatment - A Triple Blind Randomized Controlled Trial. *Eur Endod J*. 2023 Mar;8(2):125-132. doi: 10.14744/eej.2022.40469. PMID: 37010203; PMCID: PMC10098434.
- De Geus JL, Wambier LM, Boing TF, Loguercio AD, Reis A. Effects of Ibuprofen Compared to Other Pre-medication Drugs on the Risk and Intensity of Postendodontic Pain: A Systematic Review. *Eur Endod J*. 2018 Oct 9;3(3):123-133. doi: 10.14744/eej.2018.83803. PMID: 32161868; PMCID: PMC7006579.
- Haapasalo M, Shen Y, Wang Z, Gao Y. Irrigation in endodontics. *Br Dent J*. 2014 Mar;216(6):299-303. doi: 10.1038/sj.bdj.2014.204. PMID: 24651335
- Relvas JB, Bastos MM, Marques AA, Garrido AD, Sponchiado EC Jr. Assessment of postoperative pain after reciprocating or rotary NiTi instrumentation of root canals: a randomized, controlled clinical trial. *Clin Oral Investig*. 2016 Nov;20(8):1987-1993. doi: 10.1007/s00784-015-1692-0.
- Shokraneh A, Ajami M, Farhadi N, Hosseini M, Rohani B. Postoperative endodontic pain of three different instrumentation techniques in asymptomatic necrotic mandibular molars with periapical lesion: a prospective, randomized, double-blind clinical trial. *Clin Oral Investig*. 2017 Jan;21(1):413-8. doi: 10.1007/s00784-016-1807-2.
- Berutti Elio, Gagliani Massimo. *Manuale di Endodonzia*. Milano: Edra, 2021.
- Surakanti JR, Venkata RC, Vemisetty HK, Dandolu RK, Jaya NK, Thota S. Comparative evaluation of apically extruded debris during root canal preparation using ProTaper™, Hyflex™ and Waveone™ rotary systems. *J Conserv Dent*. 2014 Mar;17(2):129-32. doi: 10.4103/0972-0707.128045. PMID: 24778507; PMCID: PMC4001267.
- Kherlakian D, Cunha RS, Ehrhardt IC, Zuolo ML, Kishen A, da Silveira Bueno CE. Comparison of the Incidence of Postoperative Pain after Using 2 Reciprocating Systems and a Continuous Rotary System: A Prospective Randomized Clinical Trial. *J Endod*. 2016 Feb;42(2):171-6. doi: 10.1016/j.joen.2015.10.011. Epub 2015 Nov 29. PMID: 26614017.
- Laurindoa FV, de Figueiredoa JA. Reciprocating versus Rotary instruments: a review. *Rev Odonto Cienc*. 2016; 31(3): 135-139.
- Yared G. Canal preparation using only one Ni-Ti rotary instrument: preliminary observations. *Int Endod J*. 2008 Apr;41(4):339-44. doi: 10.1111/j.1365-2591.2007.01351.x. Epub 2007 Dec 12. PMID: 18081803.
- Azizi A, Prati C, Schiavon F, Fitzgibbon RM, Pirani C, Iacono F, Pelliccioni GA, Spinelli A, Zamparini F, Puddu P, Bolelli G, Generali L. In-Depth Metallurgical and Microstructural Analysis of Oneshape and Heat Treated Onecurve Instruments. *Eur Endod J*. 2021 Apr;6(1):90-97. doi: 10.14744/eej.2021.63634. Epub 2021 Mar 23. PMID: 33762534; PMCID: PMC8056813.
- Afreen L, Chandra R, Jain J, Mehrotra A. Comparative evaluation of removal of smear layer using newer rotary endodontic files: A scanning electron microscope study. *J Conserv Dent*. 2021 Nov-Dec;24(6):616-621. doi: 10.4103/jcd.jcd_92_21
- Forghani M, Hezarjaribi M, Teimouri H. Comparison of the shaping characteristics of Neolix and Protaper Universal systems in preparation of severely curved simulated canals. *J Clin Exp Dent*. 2017 Apr 1;9(4):e556-e559. doi: 10.4317/jced.53476.
- Çiçek E, Koçak MM, Koçak S, Saam BC, Türker SA. Postoperative pain intensity after using different instrumentation techniques: a randomized clinical study. *J Appl Oral Sci*. 2017 Jan-Feb;25(1):20-26. doi: 10.1590/1678-77572016-0138.
- Martins CM, De Souza Batista VE, Andolfatto Souza AC, Andrada AC, Mori GG, Gomes Filho JE. Reciprocating kinematics leads to lower incidences of postoperative pain than rotary kinematics after endodontic treatment: A systematic review and meta-analysis of randomized controlled trial. *J Conserv Dent*. 2019 Jul-Aug;22(4):320-331. doi: 10.4103/JCD.JCD_439_18.
- Moher D, Shamseer L, Clarke M, Ghersi D, Liberati A, Patticrew M et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Systematic Reviews* 2015 4:1.
- Cumpston M, Li T, Page MJ, Chandler J, Welch VA, Higgins JPT, Thomas J. Updated guidance for trusted systematic reviews: a new edition of the Cochrane Handbook for Systematic Reviews of Interventions. *Cochrane Database of Systematic Reviews* 2019, Issue 10 Art. No: ED000142. DOI: 10.1002/14651858.ED000142.
- Tran, L., Tam, D.N.H., Elshafay, A. et al. Quality assessment tools used in systematic reviews of in vitro studies: A systematic review. *BMC Med Res Methodol* 21, 101 (2021). <https://doi.org/10.1186/s12874-021-01295-w>.

- 25 Olivo SA, Macedo LG, Gadotti IC, Fuentes J, Stanton T, Magee DJ. Scales to assess the quality of randomized controlled trials: a systematic review. *Phys Ther*. 2008 Feb;88(2):156-75. doi: 10.2522/ptj.20070147. Epub 2007 Dec 11. PMID: 18073267.
- 26 Rathbone J, Carter M, Hoffmann T. et al. Better duplicate detection for systematic reviewers: evaluation of Systematic Review Assistant-Deduplication Module. *Syst Rev* 4, 6 (2015). <https://doi.org/10.1186/2046-4053-4-6>.
- 27 Neelakantan P, Sharma S. Pain after single-visit root canal treatment with two single-file systems based on different kinematics—a prospective randomized multicenter clinical study. *Clin Oral Investig*. 2015 Dec;19(9):2211-7. doi: 10.1007/s00784-015-1448-x. Epub 2015 Mar 15. PMID: 25773449.
- 28 Bürklein S, Benten S, Schäfer E. Quantitative evaluation of apically extruded debris with different single-file systems: Reciproc, F360 and OneShape versus Mtwo. *Int Endod J*. 2014 May;47(5):405-9. doi: 10.1111/iej.12161. Epub 2013 Jul 26. PMID: 23889673.
- 29 Vivekanandhan P, Subbiya A, Mitthra S, Karthick A. Comparison of apical debris extrusion of two rotary systems and one reciprocating system. *J Conserv Dent*. 2016;19(3):245-249. doi:10.4103/0972-0707.181941
- 30 Elias W, Kubiak K, Poncyłjusz W, Surdacka A. Root Canal Transportation after Root Canal Preparation with ProTaper Next, WaveOne Gold, and Twisted Files. *J Clin Med*. 2020;9(11):3661. Published 2020 Nov 14. doi:10.3390/jcm9113661
- 31 Yılmaz K, Özyürek T. Apically Extruded Debris after Retreatment Procedure with Reciproc, ProTaper Next, and Twisted File Adaptive Instruments. *J Endod*. 2017 Apr;43(4):648-651. doi: 10.1016/j.joen.2016.12.003. Epub 2017 Feb 28. PMID: 28258810.
- 32 De-Deus G, Neves A, Silva EJ, Mendonça TA, Lourenço C, Calixto C, Lima EJ. Apically extruded dentin debris by reciprocating single-file and multi-file rotary system. *Clin Oral Investig*. 2015 Mar;19(2):357-61. doi: 10.1007/s00784-014-1267-5. Epub 2014 Jun 21. PMID: 24950606.
- 33 Küçükylmaz E, Savas S, Saygılı G, Uysal B. Assessment of apically extruded debris and irrigant produced by different nickel-titanium instrument systems. *Braz Oral Res*. 2015;29:1-6. doi: 10.1590/1807-3107bor-2015.vol29.0002. Epub 2014 Nov 11. PMID: 25387860.
- 34 El Khodary, S., Roshdy, N. (2019). Influence of different rotary systems on the amount of apically extruded debris in mandibular molars (An In vitro study). *Egyptian Dental Journal*, 65(Issue 2 - April (Fixed Prosthodontics, Dental Materials, Conservative Dentistry & Endodontics)), 1663-1670. doi: 10.21608/edj.2019.72637
- 35 Labbaf H, Nazari Moghadam K, Shahab S, Mohammadi Bassir M, Fahimi MA. An In vitro Comparison of Apically Extruded Debris Using Reciproc, ProTaper Universal, Neolix and Hyflex in Curved Canals. *Iran Endod J*. 2017;12(3):307-311. doi:10.22037/iej.v12i3.13540
- 36 Shahi S, Asghari V, Rahimi S, Lotfi M, Samiei M, Yavari H, Shakouie S, Nezafati S. Postoperative Pain after Endodontic Treatment of Asymptomatic Teeth Using Rotary Instruments: A Randomized Clinical Trial. *Iran Endod J*. 2016 Winter;11(1):38-43. doi: 10.7508/iej.2016.01.008. Epub 2015 Dec 24. PMID: 26843876; PMCID: PMC4731532.
- 37 Ozsu D, Karatas E, Arslan H, Topcu MC. Quantitative evaluation of apically extruded debris during root canal instrumentation with ProTaper Universal, ProTaper Next, WaveOne, and self-adjusting file systems. *Eur J Dent*. 2014 Oct;8(4):504-508. doi: 10.4103/1305-7456.143633. PMID: 25512732; PMCID: PMC4253107.
- 38 Silva EJ, Sá L, Belladonna FG, Neves AA, Accorsi-Mendonça T, Vieira VT, De-Deus G, Moreira EJ. Reciprocating versus rotary systems for root filling removal: assessment of the apically extruded material. *J Endod*. 2014 Dec;40(12):2077-80. doi: 10.1016/j.joen.2014.09.009. Epub 2014 Oct 23. PMID: 25442728.
- 39 Comparin D, Moreira E, Souza EM, De-Deus G, Arias A, Silva EJ. Postoperative Pain after Endodontic Retreatment Using Rotary or Reciprocating Instruments: A Randomized Clinical Trial. *J Endod*. 2017 Jul;43(7):1084-1088. doi: 10.1016/j.joen.2017.02.010. Epub 2017 May 3. PMID: 28477995.
- 40 Keskin C, Sivas Yılmaz Ö, Inan U, Özdemir Ö. Postoperative pain after glide path preparation using manual, reciprocating and continuous rotary instruments: a randomized clinical trial. *Int Endod J*. 2019 May;52(5):579-587. doi: 10.1111/iej.13053. Epub 2018 Dec 31. PMID: 30536837.
- 41 Pasqualini D, Corbella S, Alovisei M, Taschieri S, Del Fabbro M, Migliaretti G, Carpegna GC, Scotti N, Berutti E. Postoperative quality of life following single-visit root canal treatment performed by rotary or reciprocating instrumentation: a randomized clinical trial. *Int Endod J*. 2016 Nov;49(11):1030-1039. doi: 10.1111/iej.12563. Epub 2015 Nov 5. PMID: 26468626.
- 42 Hou, XM, Su Z, Hou BX. Post endodontic pain following single visit root canal preparation with rotary vs reciprocating instruments: a meta-analysis of randomized clinical trials. *BMC. Oral Health*. 2017, 17, 86.
- 43 Nevaes G, Romeiro K, Albuquerque D, et al. Evaluation of Apically Extruded Debris during Root Canal Retreatment Using ProTaper Next and Reciproc in Severely Curved Canals. *Iranian Endodontic Journal*. 2017;12(3):323-328. doi:10.22037/iej.v12i3.15850
- 44 Nevaes G, Felipe X, Gominho L, Cavalcanti F, Casimiro M, Romeiro K, Alvares P, et al. "Apical Extrusion of Debris Produced during Continuous Rotating and Reciprocating Motion." *Scientific World Journal* 2015 (October 12, 2015): 1-5. doi:10.1155/2015/267264
- 45 Roshdy NN, Hassan R. Quantitative evaluation of apically extruded debris using TRUShape, TruNatomy, and WaveOne Gold in curved canals. *BDJ Open*. 2022 May 20;8(1):13. doi: 10.1038/s41405-022-00106-8. PMID: 35595771; PMCID: PMC9122899.
- 46 Tinoco JM, De-Deus G, Tinoco EM, Saavedra F,



- Fidel RA, Sassone LM. Apical extrusion of bacteria when using reciprocating single-file and rotary multifile instrumentation systems. *Int Endod J.* 2014 Jun;47(6):560-6. doi: 10.1111/iej.12187. Epub 2013 Sep 24. PMID: 24111671.
- 47 Capar ID, Arslan H, Akcay M, Ertas H. An in vitro comparison of apically extruded debris and instrumentation times with ProTaper Universal, ProTaper Next, Twisted File Adaptive, and HyFlex instruments. *J Endod.* 2014 Oct;40(10):1638-41. doi: 10.1016/j.joen.2014.04.004. Epub 2014 May 27. PMID: 25260737.
- 48 Khan TA, Iqbal Z. Comparison of postobturation flare ups between two apical limit of instrumentation and obturation in root canal treatment in vivo study. *Isra Med J.* 2019; 11(1): 46-50.
- 49 Alí A, Olivieri JG, Duran-Sindreu F, Abella F, Roig M, García-Font M. Influence of preoperative pain intensity on postoperative pain after root canal treatment: A prospective clinical study. *J Dent.* 2016 Feb;45:39-42. doi: 10.1016/j.jdent.2015.12.002. Epub 2015 Dec 8. PMID: 26678517.
- 50 Chávez de Paz Villanueva LE. Fusobacterium nucleatum in endodontic flare-ups. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2002 Feb;93(2):179-83. doi: 10.1067/moe.2002.120803. PMID: 11862208
- 51 Pamboo J, Hans MK, Kumaraswamy BN, Chander S, Bhaskaran S. Incidence and factors associated with flare-ups in a post graduate programme in the indian population. *J Clin Exp Dent.* 2014 Dec 1;6(5):e514-9. doi: 10.4317/jced.51578. PMID: 25674318; PMCID: PMC4312678.
- 52 Iqbal M, Kurtz E, Kohli M. Incidence and factors related to flare-ups in a graduate endodontic programme. *Int Endod J.* 2009 Feb;42(2):99-104. doi: 10.1111/j.1365-2591.2008.01461.x. PMID: 19134037.
- 53 Tanalp J, Sunay H, Bayirli G. Cross-sectional evaluation of post-operative pain and flare-ups in endodontic treatments using a type of rotary instruments. *Acta Odontol Scand.* 2013 May-Jul;71(3-4):733-9. doi: 10.3109/00016357.2012.715199. Epub 2012 Aug 21. PMID: 22905970.
- 54 Nair M, Rahul J, Devadathan A, Mathew J. Incidence of Endodontic Flare-ups and Its Related Factors: A Retrospective Study. *J Int Soc Prev Community Dent.* 2017 Jul-Aug;7(4):175-179. doi: 10.4103/jispcd.JISPCD_61_17. Epub 2017 Jul 31. PMID: 28852632; PMCID: PMC5558250.
- 55 Onay EO, Ungor M, Yazici AC. The evaluation of endodontic flare-ups and their relationship to various risk factors. *BMC Oral Health.* 2015 Nov 14;15(1):142. doi: 10.1186/s12903-015-0135-2. PMID: 26577095; PMCID: PMC4647657.
- 56 de Oliveira Escócio, A., Kaoru Hamasakia, S., Mendes, Élide, Milaré Angelieri, B., Matta, A. C. G., de Jesus Soares, A., & Frozoni, M. (2023). Postoperative pain after foraminal enlargement in teeth with necrosis and apical periodontitis: a prospective and randomized clinical trial. *Giornale Italiano Di Endodonzia*, 37(1). <https://doi.org/10.32067/GIE.2023.37.01.01>.