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SYSTEMATIC REVIEW

Reciprocating and Rotatory NiTi Instruments Used for Root Canal Preparation of Primary Teeth: A Systematic Review and Meta-Analysis

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ABSTRACT

Objective: To compare the root canal preparation of primary teeth with reciprocating and rotary NiTi instruments. **Material and Methods:** Electronic databases (PubMed/MEDLINE, Web of Science, TRIP, Lilacs, Embase, and Scopus) were systematically searched until October 2020. *In vitro* studies comparing the cleaning ability, debris extrusion, file deformation, or working time of rotary and reciprocating NiTi instruments in primary teeth were evaluated. Two reviewers independently selected the studies, extracted the data, and assessed the risk of bias. Meta-analyses were conducted using a random-effects model to calculate pooled mean differences between reciprocating and rotary NiTi instruments considering the outcomes: working time (minutes) and debris extrusion (milligrams). Statistical analyses were performed using RevMan 5.3 at a significance level of 5%. **Results:** From 4,417 potentially relevant studies, 10 were included in the systematic review, and 8 considered in the meta-analyses. There was no significant difference between reciprocating and rotary NiTi instruments considering debris extrusion [3 data sets; effect size: -0.11 (-0.25–0.04); p=0.15] and working time [6 data sets; effect size: -0.37 (-0.98–0.24); p=0.24]. The heterogeneity found was moderate to high. The risk of bias was low in most studies (50.0% of all items across studies). **Conclusion:** There is no scientific evidence showing superiority of reciprocating or rotary NiTi instruments used for root canal preparation in primary teeth.

Keywords: Root Canal Preparation; Systematic Review; Tooth, Deciduous.

Introduction

The main objective of endodontic treatment is to maintain the integrity of the primary teeth with irreversibly infected or necrotic pulp due to caries or trauma [1]. The maintenance of primary teeth has a positive impact on oral functions and prevents alterations in chronology and eruption sequence of permanent teeth [2]. In addition, the biomechanical preparation has a critical role in the treatment success since the cleaning and shaping of the root canals aid in the removal of the infected pulp tissue, provide access for irrigating solutions to reach the apical third of root, and further allow adequate obturation of the prepared root canals [3].

Hand instrumentation is still considered as the principal choice of cleaning and shaping of the primary root canals; however, its use has been associated with the possibility of perforations, dentin compaction, ledge formation, and instrument fracture [4]. On the other hand, mechanical instrumentation presents better results than hand instrumentation, resulting in more centered preparations and a smaller number of lateral perforations and canal transportation [5]. Moreover, mechanical instrumentation minimizes the clinical time, which is a very interesting aspect to consider for pediatric patients [6].

Rotary and reciprocating nickel-titanium (NiTi) instruments are commercially available for mechanical root canal preparation. Rotary NiTi instruments are designed to be used in continuous rotary motion at different speeds and torque according to the NiTi alloy, heat treatment, and tip and taper of the instrument [7]. In 2007, the concept of reciprocating motion was presented [8]. This kinematic aimed to reduce the cyclic fatigue of NiTi instruments by means of intermittent clockwise and counterclockwise rotation. Thenceforth, reciprocating instruments have been developed and improved for root canal preparations, showing higher cyclic fatigue resistance than rotatory NiTi instruments [8].

The scientific literature reveals a lack of clinical trials comparing both kinematics, especially for treatment of primary teeth. Pooled *in vitro* data may provide more useful information for pediatric dentists to choose any rotary or reciprocating system for endodontic treatment in primary teeth. As efficient canal preparation is an important step to successful endodontic treatment, different outcomes should be considered, such as cleaning efficacy, debris extrusion, file deformation, and working time.

Therefore, this systematic review aimed to compare the root canal preparation of primary teeth with rotary and reciprocating NiTi instruments.

Material and Methods

The protocol was registered in the PROSPERO database (Registration number CRD42020152505) and this study was reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [9]. Furthermore, this study has followed the CRIS guidelines for *in vitro* studies, as discussed in the concept note [10].

Focused PICOS Question

The following research question was formulated to address the literature and outline the search strategy: Is there a difference between the rotary and reciprocating NiTi instruments for root canal preparation of primary teeth considering the cleaning ability, debris extrusion, file deformation or working time?

- Population: Human primary teeth

- Intervention: Reciprocating NiTi instruments
- Comparison: Rotary NiTi instruments
- Outcomes: Cleaning ability, debris extrusion, file deformation or working time
- Study Design: *in vitro* studies

Data Sources and Search Strategy

A comprehensive literature search was undertaken through PubMed/MEDLINE, Web of Science, Turning Research Into Practice (TRIP), Lilacs, Embase, and Scopus databases to identify studies related to the research question and published up to October 2020. The search was conducted with no publication year or language restrictions. Initially, the subject search used a combination of controlled vocabulary and text words based on the search strategy in the PubMed/MEDLINE database. Then, the search strategy was adapted for other databases (Supplementary appendix). The results of searching the various databases were cross-checked to find and remove duplicates.

The inclusion criterion was *in vitro* studies that evaluated reciprocating and rotary NiTi instruments for root canal preparation in primary teeth. The exclusion criteria were: 1) did not consider debris extrusion, working time, file deformation or cleaning ability as outcomes; 2) did not use the same irrigating solution during root canal preparation with both instruments.

Search Steps: Screening and Selection

Step 1: Titles and abstracts were independently reviewed by two authors (L.L.B and M.M.S.) and selected for further review if they met the inclusion criterion. The inter-examiner agreement (Kappa = 1.00) calculation indicated excellent agreement.

Step 2: Full-text articles of studies selected in the previous step were retrieved and independently reviewed by two authors (L.L.B and M.M.S.) based on exclusion criteria. The reference list of all articles selected in this step was examined and the full texts of potentially interesting studies for the research question were evaluated.

Any disagreement in either step was first resolved by discussion between the reviewers (L.L.B and M.M.S.). A third author (C. P. C.) was consulted if discrepancies remained.

Data Extraction

Both reviewers independently collected the data from the eligible studies. Thus, the following data were systematically extracted from each paper: publication details (authors, year, country and language), sample characteristics (teeth type, sample size - number and type of root canals), methodology (rotary or reciprocating NiTi instruments - commercial names and manufacturers, number of instruments for system and protocol, irrigation solution for instrumentation, number of operators and evaluators), and outcome's information.

Assessment of the Risk of Bias

The reviewers also independently assessed the risk of bias according to the Cochrane Handbook for Systematic Reviews of Interventions [11], based on following criteria: randomization of teeth, description of sample size calculation, rotary and reciprocating NiTi instruments used according to the manufacturer's

instructions, root canal preparation performed by a single operator and blinding of the examiner. The studies were evaluated by rating each domain as having low, high, or unclear risk of bias (no information or uncertainty over the potential for bias). Disagreements between the reviewers were resolved by consensus for the final risk of bias classification.

Data Analysis

Meta-analyses were conducted using a random-effects model to calculate pooled mean differences between reciprocating and rotary NiTi instruments considering the working time (minutes) and debris extrusion (milligrams). The working time was measured with a digital chronometer and included the time taken for instrumentation, instrument change (when necessary), shaping, and irrigation of the root canals. Apically extruded debris and irrigant were collected, dried, and weighed using Eppendorf tube. The net weight of the dry debris was calculated by subtracting the weight of the empty Eppendorf tube from the total weight. The analyses were conducted with Review Manager Software (RevMan version 5.3 software, Cochrane Collaboration, Copenhagen, Denmark, 2014), considering a p-value < 0.05 as statistically significant (Z-test). In addition, statistical heterogeneity among studies was assessed via the Cochran Q test and inconsistency (I^2).

A descriptive analysis was performed for cleaning ability and file deformation. Four studies [12-15] considered cleaning ability as an outcome, but the measure unit varied among them. In addition, only one study [14] evaluated the file deformation using both NiTi instruments.

Results

The search strategy identified 4,417 potentially relevant studies, removing duplicates. After screening the titles and abstracts, 10 studies were assessed for more detailed information. None study was excluded after a full-text review. Therefore, 10 *in vitro* studies were included in this systematic review. Figure 1 presents a flowchart of the study selection process and the reasons for exclusions.

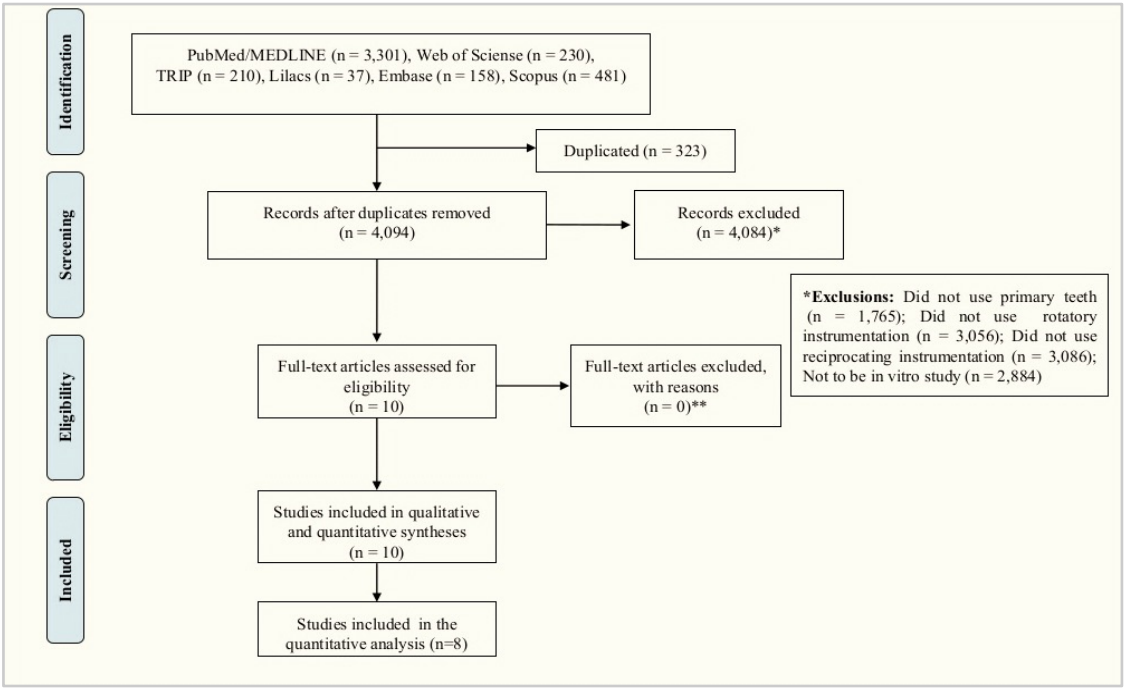

Figure 1. Flowchart of study selection according to PRISMA statement.

Characteristics of the Included Studies

All studies were published in English and conducted in Brazil [13,15,16], India [12,17,18], Iran [14], Syria [19], and Turkey [20,21] and were reported between 2014 and 2020. Moreover, the studies included anterior or posterior human primary teeth. ProTaper [12,13,15,18-20] (Dentsply Maillefer, Ballaigues, Switzerland) and Wave-One (Dentsply Maillefer, Ballaigues, Switzerland) [12,13,15,17,19] systems were the most tested rotary and reciprocating instruments, respectively. A more detailed summary of the selected studies is shown in Table 1.

Table 1. Main characteristics of the *in vitro* selected studies for systematic review.

Study	Country	Type of Teeth and Root Canals	Number of Root Canals	Rotary System / Reciprocating System Protocol	Number of Instruments per System Rotary System / Reciprocating System	Chemical Preparation	Number of Operators	Number of Examiners	Outcome (s) of the Studies	Outcome (s) Considered in the Systematic Review
Alnassar et al. 2019 [19]	Syria	Molars/Distal	16	ProTaper (Dentsply Maillefer, Ballaigues, Switzerland) / Wave-One (Dentsply Maillefer, Ballaigues, Switzerland) The root canals were prepared using a manual #10 K-file (Dentsply Maillefer) to verify their patency. - ProTaper system: X1 (size 17, taper 0.04) and X2 (size 25, taper 0.06). - Wave-One system: one file (21/06) was used with a reciprocal motion.	2 / 1	Distilled water (5mL)	1	1	Extrusion debris	Extrusion debris
Barasuol et al. 2020 [16]	Brazil	Molars / all canals	27	ProDesign Logic (Easy Dental Equipment, Belo Horizonte, Brazil) / Reciproc (VDW, Munich, Germany). The root canal length was measured using an adjusted file. - ProDesign was used with the motor (size 25.01) and ProDesign Logic file (size 25.06) in continuous rotation. - Reciproc file: R25 (size 25.08) was used with the motor in reciprocating motion.	2 / 1	Sodium hypochlorite (20 mL)	1	Not reported	Working time Shaping ability	Working time
Gungor and Kustarci 2016 [21]	Turkey	Maxillary molars / Mesiobuccal	15	Twist file Adaptive (SybronEndo, Orange, CA, USA / Reciproc (VDW, Munich, Germany)	2 / 1	Bidistilled water (6 mL)	1	1	Debris extrusion	Debris extrusion

				The root canal length was measured using a manual #10 K-file. - Twist file Adaptive: SM1 (20/0.04) and SM2 (25/0.06). - Reciproc: R25 Reciproc file (size 25) with a taper of 0.08.						
Jeevanandan and Thomas 2018 [18]	India	Mandibular molars / Mesiolingual	20	ProTaper (Dentsply Maillefer, Ballaigues, Switzerland) / TEP-ER 10 (NSK, Nakanishi, Japan) - ProTaper system: the single file was used till the working length. - TEP-ER 10: 15 NiTi K- file to No.30 NiTi- K- flex file, which was coupled with NSK Endodontic contra-angle with reciprocating motion.	1 / 2	Saline solution + EDTA	1	Not reported	Working time Volumetric analysis	Working time
Katge et al. 2014 [12]	India	Molars / Not reported	30	ProTaper (Dentsply Maillefer, Ballaigues, Switzerland) / Wave-One (Denstply Maillefer, Ballaigues, Switzerland) The root canals were prepared using a manual #10 K-file (Dentsply Maillefer) to verify their patency. - ProTaper system: SX and S2 file were inserted untill the working length. - Wave-One system: Small file (6% taper).	2 / 1	Saline solution (5 mL)	1	1	Working time Cleaning ability	Working time Cleaning ability
Kucukyilmaz et al. 2015 [20]	Turkey	Canines / Single	15	ProTaper (Dentsply Maillefer, Ballaigues, Switzerland) / Reciproc (VDW, Munich, Germany) The root canal length was measured using a manual #15 K-file (Dentsply, Maillefer, Ballaigues, Switzerland) - ProTaper system: S1, S2, F1, F2. - Reciproc system: R25 Reciproc file (size 25) with a taper of 0.08 over the first 3 mm was used.	4 / 1	Bidistilled water (4 mL)	1	2	Working time Debris extrusion	Working time Debris extrusion
Pinheiro et al. 2016 [13]	Brazil	Molars / all canals	20	ProTaper (Dentsply Maillefer, Ballaigues, Switzerland) / Wave-One (Dentsply Maillefer, Ballaigues, Switzerland) The root canals were prepared using a manual #10 K-file (Dentsply	4 / 3	Sodium hypochlorite (4 mL - ProTaper, 1mL - Wave-One)	1	Not reported	Cleaning ability Working time	Cleaning ability Working time

				Maillefer) to verify their patency. - ProTaper system: S1, S2 with brushing motion and F1, F2 files with back-and-forth motions. - Wave-One system: small with 0.06 taper; primary and large with 0.08 taper.						
Prabhakar et al. 2016 [17]	India	Molars, Incisors and Canines/ Not reported	28	One Shape (Micromega, Cedex, France) / Wave-One (Dentsply Maillefer, Ballaigues, Switzerland) The root canal length was measured using a manual #10 K-file. - Wave-One: single-file - One-Shape: single-file	1 / 1	Sodium hypochlorite	Not reported	Not reported	Working time Dentin thickness Centering ability Canal transportation	Working time
Ramazani et al. 2016 [14]	Iran	Mandibular molars / Mesiobuccal	16	Mtwo Files (VDW GmbH, Munich, Germany) / Reciproc (VDW GmbH, Munich, Germany) - Mtwo Files: 10/0.04, 15/0.05, 20/0.06 and 25/0.06. - Reciproc system: Reciproc file (size 25) with a taper of 0.08.	4 / 1	Sodium hypochlorite (5mL)	1	1	Cleaning ability File deformation Working time Shaping ability	Cleaning ability File deformation Working time
Silva et al. 2018 [15]	Brazil	Incisors and Canines / all canals	12	ProTaper (Dentsply Maillefer, Ballaigues, Switzerland) / Wave-One (Dentsply Maillefer, Ballaigues, Switzerland) The root canal length was measured using manual #10 and #20 K-files (Dentsply Maillefer, Ballaigues, Switzerland) - Protaper: 40/0.06 - Wave-One: 40/0.08	1 / 1	Sodium hypochlorite (2 mL)	1	2	Cleaning ability	Cleaning ability

Assessment of the Risk of Bias

The final assessment of the risk of bias in the included studies is summarized in Table 2. Risk of bias was low in most studies (50.0% of all items across studies). Only two studies [14,16] described the method used to generate the random sequence and also two studies [16,20] reported the sample size calculation. Most studies reported that NiTi instruments were used according to the manufacturer's instructions and that a single operator performed the root canal preparation. Four studies [13,16-18] were scored as unclear risk of bias regarding blinding of the examiner because they did not report who performed the evaluations.

Table 2. Assessment of the risk of bias of the selected studies.

Study	Randomization of Teeth	Sample Size Calculation	Kinematics Systems Used according to the Manufacturer's Instructions	Root Canals Preparation Performed by a Single Operator	Blinding of the Examiner
Alnassar et al. [19]	Unclear	High	Low	Low	Low
Barasuol et al. [16]	Low	Low	Low	Low	Unclear
Gungor and Kustarci [21]	Unclear	High	Low	Low	Low
Jeevanandan and Thomas [18]	Unclear	High	Unclear	Low	Unclear
Katge et al. [12]	Unclear	High	Low	Low	Low
Kucukyilmaz et al. [20]	Unclear	Low	Low	Low	Low
Pinheiro et al. [13]	Unclear	High	Unclear	Low	Unclear
Prabhakar et al. [17]	High	High	Low	Unclear	Unclear
Ramazani et al. [14]	Low	Unclear	Unclear	Low	Low
Silva et al. [15]	Unclear	High	Low	Low	Low

Meta-analyses

From the 10 studies included in the systematic review, 8 studies were included in the meta-analyses. A meta-analysis for debris extrusion was performed with 3 data sets [19-21], while a meta-analysis for working time was performed with 6 data sets [12-14,16,18,20]. There was no difference between reciprocating and rotary NiTi instruments considering debris extrusion [effect size: -0.11 (-0.25–0.04); p=0.15] (Figure 2) neither working time [effect size: -0.37 (-0.98–0.24); p=0.24] (Figure 3). The heterogeneity was found to be moderate (I^2=59%) and high (I^2=99%), respectively.

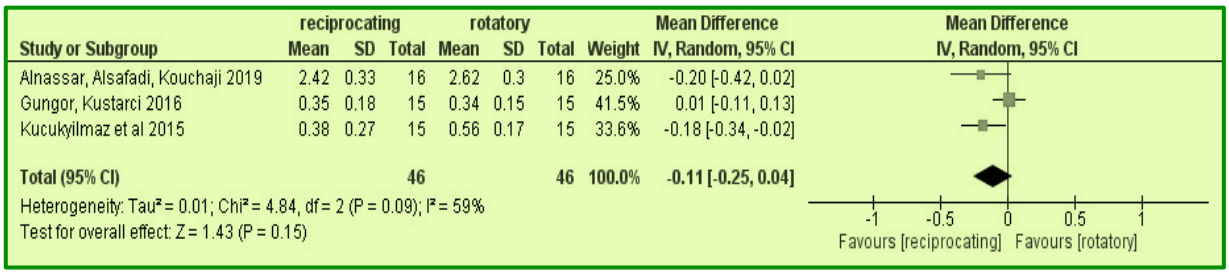

Figure 2. Meta-analysis considering debris extrusion (milligrams) as outcome.

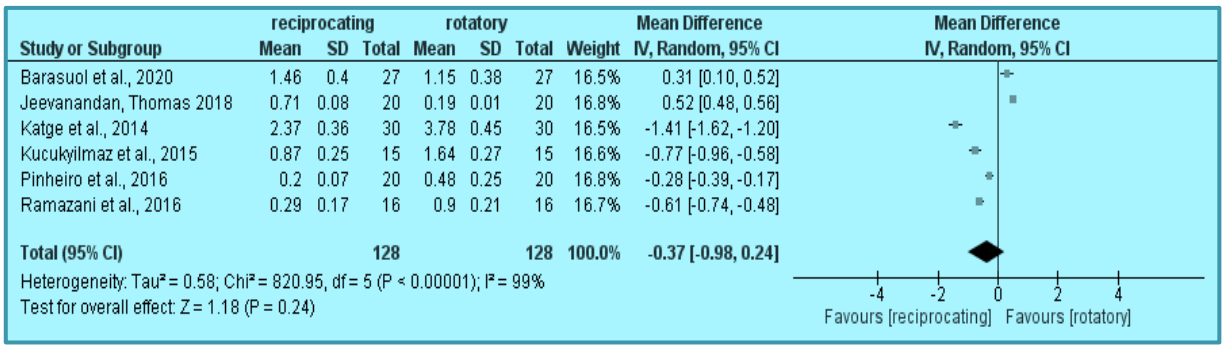

Figure 3. Meta-analysis considering working time (minutes) as outcome.

Descriptive Analysis

Four studies [12-15] evaluated the cleaning ability of the root canals after implementing both kinematics. Two studies [12,14] performed the evaluation using a stereomicroscope based on the following scores: score 0: thorough ink removal, score 1: nearly thorough ink removal (remains of ink detected), score 2: partial ink removal (India ink remained in some areas), and score 3: no ink removal (a considerable amount of ink remained). Katge et al. [12] found that the reciprocating instrument (Wave-One) promoted better cleaning in the coronal and middle thirds of the root canals when compared to rotatory system (ProTaper). On the other hand, Ramazani et al. [14] did not find a difference between the reciprocating (Reciproc) and rotary (Mtwo) NiTi instruments.

Silva et al. [15] evaluated the cleaning ability of the root canals based on the presence of a smear layer following the scores: score 1: open dentinal tubules, without debris; score 2: open dentinal tubules, with debris covering less than 50% of the area; score 3: open dentinal tubules, with debris covering more than 50% of the area; and score 4: covered dentinal tubules and debris in 100% of the examined area. A greater cleaning ability for the reciprocating instrument (Wave-One) was only found in the coronal third when compared to ProTaper. Pinheiro et al. [13] evaluated the cleaning ability for Enterococcus Faecalis from root canals. There was no significant difference between the rotatory and the reciprocating NiTi instruments in the cleaning ability.

Ramazani et al. [14] also evaluated the file deformation when using Mtwo and Reciproc instruments as outcome. The files were examined under microscopic after each use and no instrument deformation or fracture was observed.

For the working time outcome, Prabhakar et al. [17] found that reciprocating instrument (Wave-One) resulted in a lower working time when compared to rotatory system (One-Shape).

Discussion

This is the first systematic review that compared the root canal preparation of primary teeth with reciprocating and rotary kinematics systems considering different outcomes such as cleaning ability, debris extrusion, file deformation or working time. The scientific literature has demonstrated that the use of NiTi instruments requires a shorter working time than hand files [6,22]. This factor is important in pediatric dentistry because it enables faster procedures while maintaining safety and quality, reducing fatigue of the patient and the professional [23]. The root canal preparation time is dependent on the technique and the operator's experience, as well as the number and type of instruments used. Three reciprocating kinematics (Wave One, Reciproc, and hand NiTi K-files under reciprocating motion) and four rotary systems (ProTaper, Twist File Adaptive, One Shape and Mtwo) were tested in the included studies. Normally, only one NiTi reciprocating instrument is used to prepare the root canal, while multiple rotary instruments must be used sequentially according to the manufacturer's instructions and trademark. The results of most included studies favored the reciprocating kinematics, and are generally recommended fewer instruments for the canal preparation when compared to rotary systems [13]. Pooled data showed no difference between the kinematics (rotary or reciprocating) considering working time. This may be explained due to few number of studies included.

During preparation, irrigating solutions and debris may be extruded by the apical foramen, leading to periapical inflammation, postoperative pain and delay of periapical healing [24]. Thus, the reduction or elimination of apical extrusion of infected debris can leads to more successful treatment rates. Although all preparation methods and instruments are associated with debris extrusion, the amount of debris extrusion may vary with techniques and the design of the file systems [25]. Reciprocating NiTi instruments were developed

as a sort of mechanized balanced force technique for improving control of apically extruded debris to minimize the cyclic fatigue of the file, and prevent torsional fracture [8]. Despite that, the meta-analysis showed no difference in the debris extrusion between mechanical kinematics systems.

The heterogeneity found in the meta-analyses was moderate to high. Considering the limited number of studies and the methodological variability among them, heterogeneity is unavoidable. Four [12-15] included studies that evaluated the cleaning capacity of both kinematics. Two studies [12,14] used ink injection and clearing techniques for this purpose, one study reported the presence of a smear layer on the root canals [15], and another study [13] performed a microbiological evaluation before and after instrumentation. Thus, it was not possible to perform the meta-analysis.

One study [12] found that the reciprocating instrument (Wave-One) promoted better cleaning of the coronal and middle canal thirds when compared to continuous rotary system (ProTaper). Other study [14] did not find a significant difference between the groups (Reciproc and Mtwo). It is important to highlight that different NiTi instruments were tested in the selected studies and many aspects can interfere on the findings, such as the NiTi alloy, heat treatment, and cross-sectional design. According to the manufacturer's instructions, Wave-One must be brushed toward the canal walls, which can result in greater enlargement in the coronal third and consequently higher cleaning efficacy.

Although the primary molars uniformly exhibited buccopalatal widened canals [26], it might be inferred that the canal cross-section toward the coronal region might favor the action of both rotary and reciprocating instruments. The increasing diameter of dentinal tubules and the subsequent dentin softness toward the coronal third [27], when faced with mechanical instrumentation, may also be another contributing factor. Conversely, the presence of apical ramification may explain the insignificant difference between groups in the apical third. Enterococcus faecalis are an important cause of endodontic treatment failure, mainly because of microbial resistance after treatment [4]. Pinheiro et al. [13] found that both rotary and reciprocating instruments are effective in intracanal bacterial reduction.

Some included studies also considered shaping ability as an outcome [14,16-18], but it was not included in this review. Although this outcome is important for endodontic treatment of permanent teeth, this relevance is secondary in primary teeth. The presence of the permanent successor closes to the roots of primary teeth and physiologic root resorption difficult an accurate interpretation of the anatomy primary root canals [19].

Although a comprehensive literature search was undertaken through several databases, grey literature sources were not searched. Grey literature can reduce publication bias and facilitate a more balanced view of the evidence [28]. It has been shown that inclusion of grey literature may have an impact in situations where there are few relevant studies, or where there are questionable vested interests in the published literature [29].

Even though the risk of bias was low in most studies (50.0% of all items across studies), the lack of information about sample size calculation is an important issue that impacts on the findings, and should be carefully considered in future *in vitro* studies. Furthermore, *in vitro* results cannot be directly extrapolated to clinical situations or to the instrument kinematic, which differs from those tested. Therefore, clinical trials focused on the efficacy of reciprocating and rotary NiTi instruments for cleaning and shaping of root canals during biomechanical preparation in primary teeth would be most essential to establish their clinical relevance.

Conclusion

There is no scientific evidence showing the superiority of reciprocating or rotatory NiTi instruments used for root canal preparation in primary teeth, considering debris extrusion and working time.

Authors' Contributions

LILB	https://orcid.org/0000-0002-6482-1399	Methodology and Writing - Review and Editing.
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TLL	https://orcid.org/0000-0003-3568-5217	Conceptualization, Methodology, Formal Analysis and Writing - Original Draft.

All authors declare that they contributed to critical review of intellectual content and approval of the final version to be published.

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None.

Conflict of Interest

The authors declare no conflicts of interest.

Data Availability

The data used to support the findings of this study can be made available upon request to the corresponding author.

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