ORIGINAL ARTICLE

INFLUENCE OF INSTRUMENTATION KINEMATICS ON ROOT CANAL SYSTEM PREPARATION: A SYSTEMATIC REVIEW OF STUDIES USING MICRO-COMPUTED TOMOGRAPHY

INFLUÊNCIA DA CINEMÁTICA DE INSTRUMENTAÇÃO NO PREPARO DO SISTEMA DE CANAIS RADICULARES: UMA REVISÃO SISTEMÁTICA DE ESTUDOS POR MICROTOMOGRAFIA COMPUTADORIZADA

Augusto Julio Munoz[1], Jefferson José de Carvalho Marion[2], Amanda Falcão[3], Daniel Rodrigo Herrera[4]

ABSTRACT

The aim of this study was to perform a systematic review of studies that evaluated by micro-computed tomography (micro-CT) the untouched areas of the root canal after preparation with rotary and reciprocating kinematics. Electronic search was carried out in LILACS, PubMed (MedLine), Science Direct, Cochrane, Scopus and Web of Science databases. An additional search for gray literature was performed on Google Scholar, OpenGrey, and ProQuest. The search covered studies in English, Portuguese and Spanish, with no restriction on publication time. Additionally, manual searches were carried out in the reference list of the included articles. *In vitro* studies that evaluated the percentage of untouched areas after root canal preparation, comparing rotary and reciprocating kinematics using micro-CT were selected. In total, 11 studies were selected for qualitative/quantitative analysis. One of them showed that the Reciproc (reciprocating) system has a lower percentage of untouched canal walls in lower incisors than the BioRace (rotary) system. Another study showed no significant differences between the Reciproc, WaveOne reciprocating systems and the BioRace system in mesial canals of mandibular molars. No differences were observed between ProTaper Next, ProTaper Universal (rotary) and WaveOne. A single study showed differences between kinematics, XP-Endo Shaper (rotary) showed a higher percentage of touched areas when compared to TRUShape (rotary) and WaveOne Gold. The evaluated studies showed that none of the instrumentation systems, regardless of kinematics, was able to completely touch the root canal walls.

Keywords: Endodontics, Root Canal Preparation, X-Ray Microtomography.

RESUMO

O objetivo deste estudo foi realizar uma revisão sistemática dos estudos que avaliaram por microtomografia computadorizada (micro-CT) as áreas não tocadas do canal radicular após o preparo com cinemática rotatória e reciprocante. Foram utilizadas estratégias eletrônicas de busca nas bases LILACS, PubMed (MedLine), Science Direct, Cochrane, Scopus e Web of Science. Uma busca adicional por literatura cinzenta foi realizada no Google Scholar, OpenGrey e ProQuest. A busca abrangeu estudos em inglês, português e espanhol, sem restrição ao tempo de publicação. Adicionalmente, realizou-se pesquisas manuais na lista de referências dos artigos incluídos. Foram selecionados os estudos *in vitro* que avaliaram por micro-CT a porcentagem de áreas não tocadas após o preparo do canal radicular, comparando as cinemáticas rotatória e reciprocante. No total, 11 estudos foram selecionados para análise qualitativa/quantitativa. Um deles mostrou que o sistema Reciproc (reciprocante) tem uma porcentagem menor de paredes não tocadas do canal em incisivos inferiores que o sistema BioRace (rotatório). Outro estudo não mostrou diferenças significativas entre os sistemas reciprocantes Reciproc, WaveOne e o sistema BioRace em canais mesiais de molares inferiores. Não foram observadas diferenças entre ProTaper Next, ProTaper Universal (rotatórios) e WaveOne. Um único estudo apresentou diferenças entre cinemáticas, XP--Endo Shaper (rotatório) mostrou maior porcentagem de áreas tocadas quando comparado com TRUShape (rotatório) e WaveOne Gold. Os estudos avaliados mostraram que nenhum dos sistemas de instrumentação, independente da cinemática, foi capaz de tocar completamente as paredes dos canais radiculares.

Palavras-chave: Endodontia, Preparo de Canal Radicular, Microtomografia por Raio-X

[1] Undergraduate student, Dental School of the Federal University of Mato Grosso do Sul (UFMS), Campo Grande/MS - Brazil.
[2] Professor at Dental School of the Federal University of Mato Grosso do Sul (UFMS), Campo Grande/MS - Brazil.
[3] Dental Surgeon, Escola de Saúde da Marinha, Brazilian Navy, Rio de Janeiro - RJ - Brazil.
[4] Professor at Dental School of the Federal Fluminense University, Niteroi - RJ - Brazil.

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INTRODUCTION

The chemical-mechanical preparation of the root canal is an important step in endodontic treatment. Its objective is the complete removal of the remaining pulp tissue, microorganisms, and infected dentin; as well as the modeling of the root canal system (RCS), through the mechanical action of endodontic instruments and the chemical action of auxiliary chemical substances, providing adequate conditions for filling and sealing (1).

Several nickel-titanium (NiTi) instrumentation systems are developed to optimize mechanical instrumentation with differences in design, alloy heat treatment and instrumentation kinematics (2- 4). Available systems, regardless of their kinematics, do not achieve complete RCS debridement, leaving large areas of untouched walls (5-7). Bacteria located in these areas have the potential to remain dormant and be responsible for persistent periapical inflammation (1,8).

Two-dimensional (2D) radiographic images from different directions and serial slice methods were commonly used to compare the modeling capabilities of different instrumentation systems. However, limitations in reproduction and the invasive nature of sample sections have been described as major disadvantages (9,10). Advances in diagnostic imaging procedures are at the forefront of dental research and find in micro-computed tomography (micro-CT) a non-invasive, high-resolution imaging technology capable of overcoming the limitations of 2D and slice analysis (11-14).

The technology provided by micro-CT makes it possible to reproduce and reconstruct the root canal system three-dimensionally (3D) (15), being widely used in endodontic research to assess the modeling capacity of the instruments (11). Knowledge of the properties and modeling capabilities of rotary and reciprocating instruments is essential to help professionals selecting the most appropriate instrument for each clinical situation.

Thus, the aim of this study was to perform a systematic review focused on studies that used micro-CT analysis in the assessment of untouched canal areas after preparation with continuous rotary and reciprocating kinematics. The null hypothesis to be tested is that there is no significant difference in the percentage of untouched areas after preparation with continuous rotary and reciprocating kinematics.

MATERIAL ANDMETHODS

Protocol and Registration

This systematic review was performed according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (16,17). The study is registered in the International prospective register of systematicreviews(PROSPERO)(CRD42022326086).

PICO

The research question was designed based on the PICO principles: Population (*in vitro* studies evaluating, by micro-CT, the percentage of untouched areas after root canal preparation); Intervention (root canal preparation); Comparison (instrumentation kinematics – rotary and reciprocating); Result (percentage of untouched areas). The research question was finally defined as follows: In micro- CT analysis, does the instrumentation kinematics influence the percentage of untouched areas after root canal preparation?

Inclusion Criteria

Inclusion criteria consisted of *in vitro* studies that evaluated, using micro-CT, the percentage of untouched areas after root canal preparation, comparing rotary and reciprocating kinematics. It covered studies in English, Portuguese, and Spanish, without restriction in terms of publication time.

Exclusion Criteria

The following exclusion criteria were applied: 1) Studies without micro-CT evaluation; 2) Studies that did not compare the two kinematics; 3) Animal studies; 4) Reviews, letters, conference summaries, personal opinions, case reports; and 5) Full text not available.

Information source and search strategy

Electronic search strategies were used in LILACS, PubMed (MedLine), Science Direct, Cochrane, Scopus and Web of Science databases. An additional search for gray literature was performed on Google Scholar, OpenGrey, and ProQuest. In addition, manual searches were performed on the reference list of included articles.

Selection of studies

The selection process was carried out in two phases. In phase one, two reviewers (A.J.M. and D.R.H.) independently selected titles and abstracts from all identified references. Studies that did not meet the eligibility criteria were excluded. In phase two, the same two reviewers applied the eligibility criteria to the full text of the studies. A third reviewer (J.J.M.) was consulted in the event of a disagreement not resolved by a consensus discussion.

After inclusion of studies, if the necessary data were not found, efforts were made to contact the authors to retrieve unpublished data.

Risk of bias in individual studies

During data extraction and quality assessment, any disagreements between reviewers were resolved through discussion and, if necessary, by involving a third author. For each aspect of the quality assessment, the risk of bias was scored based on Cochrane criteria [The Cochrane Handbook for Systematic Reviews of Interventions version 5.1.0 (http://handbook.cochrane.org)] adapted to the nature of the studies *in vitro*. The judgment for each record was "yes", indicating a low risk of bias, "no" indicating high risk of bias, and "unclear", indicating lack of information or uncertainty about the potential for bias.

If one or more criteria were not met, the study was scored as "high risk of bias". When the study was judged "unclear" in its key domains, attempts were made to contact the authors and obtain more information to define "low" or "high" risk.

Studies with similar interventions and outcomes would be considered for quantitative synthesis through meta-analysis. However, due to substantial heterogeneity among the included studies, the meta-analysis was not performed.

RESULTS

Selection of studies

Ninety-six studies remained after removing duplicates. Of these, 85 were discarded after applying the exclusion criteria based on reading the title and abstract. In the end, 11 studies met the requirements — as shown in the flow diagram (Fig. 1) — and had their full texts analyzed. No additional studies were added after manually searching the references of these studies. It was not necessary to discuss with the third reviewer to resolve disagreements, as the two initial reviewers agreed on the included studies.

Data extraction

A data extraction worksheet was created with the following information: first author, year of publication, country of affiliation of the first author, sample size, tooth type, canal curvature, resolution used in micro-CT, instrumentation systems used and percentage of untouched area (Table 1).

Qualitative assessment of included studies

The overall bias and biases obtained due to the randomization process, selection of reported outcome, standardization of root anatomy, and operator variability are shown in Figure 2. An frustating attempt was made to contact the corresponding author of Yuan and Yang, 2018 (18) and clarify operator variability. The study was considered "unclear" in the general assessment (Fig. 2).

Evaluated properties and results

The percentage of untouched areas during instrumentation was evaluated in this systematic review and is presented in Table 1. It was not possible to establish the influence of heat treatment on the modeling capacity of the different systems used in the evaluated studies.

DISCUSSION

Root canal instrumentation aims to eliminate compromised pulp tissue, microbial irritants and create ideal room for efficient irrigation, intracanal medication application and subsequent filling (8). Unprepared canal areas can compromise the disinfection of the root canal system and allow the maintenance of the infectious process, leading to endodontic failure (1,8).

The initial objective of this review included quantitative synthesis in the data to compare the effectiveness of the two kinematics in the modeling ability of root canals, but this was not possible due to the significant heterogeneity among the studies, involving the type of tooth examined, canal curvature, instrument design, and final instrumentation size, for example.

Through the qualitative evaluation of the included studies, it was possible to accept the proposed null hypothesis that there is no significant difference in the percentage of untouched areas after preparation with continuous rotary and reciprocating kinematics.

In the qualitative evaluation of the process of standardization of the initial root anatomy, the possibility of previous pairing by micro-CT of the specimens in the studies was considered relevantly positive (19-21). Micro-CT provides detailed information on roots and canals before instrumentation, proving to be effective in studying modeling after root preparation (20-23). Thus, only studies that used micro-CT were included in this systematic review.

Root canal instrumentation can result in large areas of untouched walls, regardless of the kinematics used during instrumentation (21,22). One study showed that the Reciproc (reciprocating) system has a lower percentage of untouched canal walls in mandibular incisors when compared to the BioRace (rotary) system, which could be explained by the taper and design of the instrument (21). Another study showed no significant differences between the Reciproc and WaveOne reciprocating systems and the BioRace system in mesial root canals of mandibular molars (24). Likewise, Zhao *et al.* did not observe any difference between ProTaper Next, ProTaper Universal (rotary) and WaveOne (25).

Paque et al. (2011) did not find differences when the ProTaper system was used in rotary or reciprocating

TABLE 1. CHARACTERISTICS OF THE STUDIES INCLUDED IN THE SYSTEMATIC REVIEW

Number	Author / Country	Tooth	Sample number	Curvature (grade)	Micro-CT Resolution (µm)	Groups	Untouched area (%)
1	Poly et al. (2021)/Brazil	Distal root of lower molars	30 (10 per group)	10 to 20	21.00	WaveOne Gold, TRUShape, XP-Endo Shaper	11.50 / 12.40 / 5.30
2	Da Silva et al. (2021)/Brazil	Lower premolars	33 (11 per group)	Not Available	22.00	TRUShape, Reciproc Blue R40, ProTaper Universal	39.80 / 45.40 / 47.90
3	Medeiros et al. (2021)/Brazil	Lower canines	30 (15 per group)	10 to 20	12.10	WaveOne Gold, Mtwo	7.96 / 10.18
4	Zuolo et al. (2018)/Brazil	Lower incisives	40 (10 per group)	Straight (<5)	14.25	BioRaCe, Reciproc, Self Adjusting File, TRUShape	32.38 / 18.95 / 16.08/ 19.20
5	Yuan & Yang (2018)/China	Mesial root of lower molars	20 (10 per group)	20 to 35	36.00	WaveOne, ProTaper Next	34.32 / 29.21
6	Espir et al. (2018)/Brazil	Lower incisives	54 (18 per group)	Not Available	17.42	Reciproc, Unicone, Mtwo	17.30 / 30.00 / 23.15
7	Guimaraes et al. (2017)/Brazil	Lower premolars	26 (13 per group)	Severe curvatures were excluded	19.9	TRUShape, Reciproc	24.00 / 30.00
8	De-Deus et al. (2015)/Brazil	Mesial root of lower molars	30 (10 per group)	10 to 20	14.16	Reciproc, WaveOne, BioRaCe	36-42 / 34-48 /42-47 (.25-.40)
9	Busquim et al. (2015)/Brazil	Distal root of lower molars	30 (15 per group)	<20	11.88	Reciproc R40, BioRaCe	15.12 / 9.73
10	Zhao et al. (2014)/China	Lower molars	36 (12 per group)	25-35 mesiovestibular canals / 15-25 mesiolingual canals / 5-20 distal canals	30.00	ProTaper Next, ProTaper Universal, WaveOne	41.50-36.90-55.30 / 41.40-38.40-56.30 / 39.60-35.30-52.10 (MV-ML-D)
11	Paqué et al. (2011)/Swissland	Mesial root of first lower molars	50 (25 per group)	20 to 40	20.00	ProTaper Universal rotary / A reciprocating PTU file	18.70 / 16.20

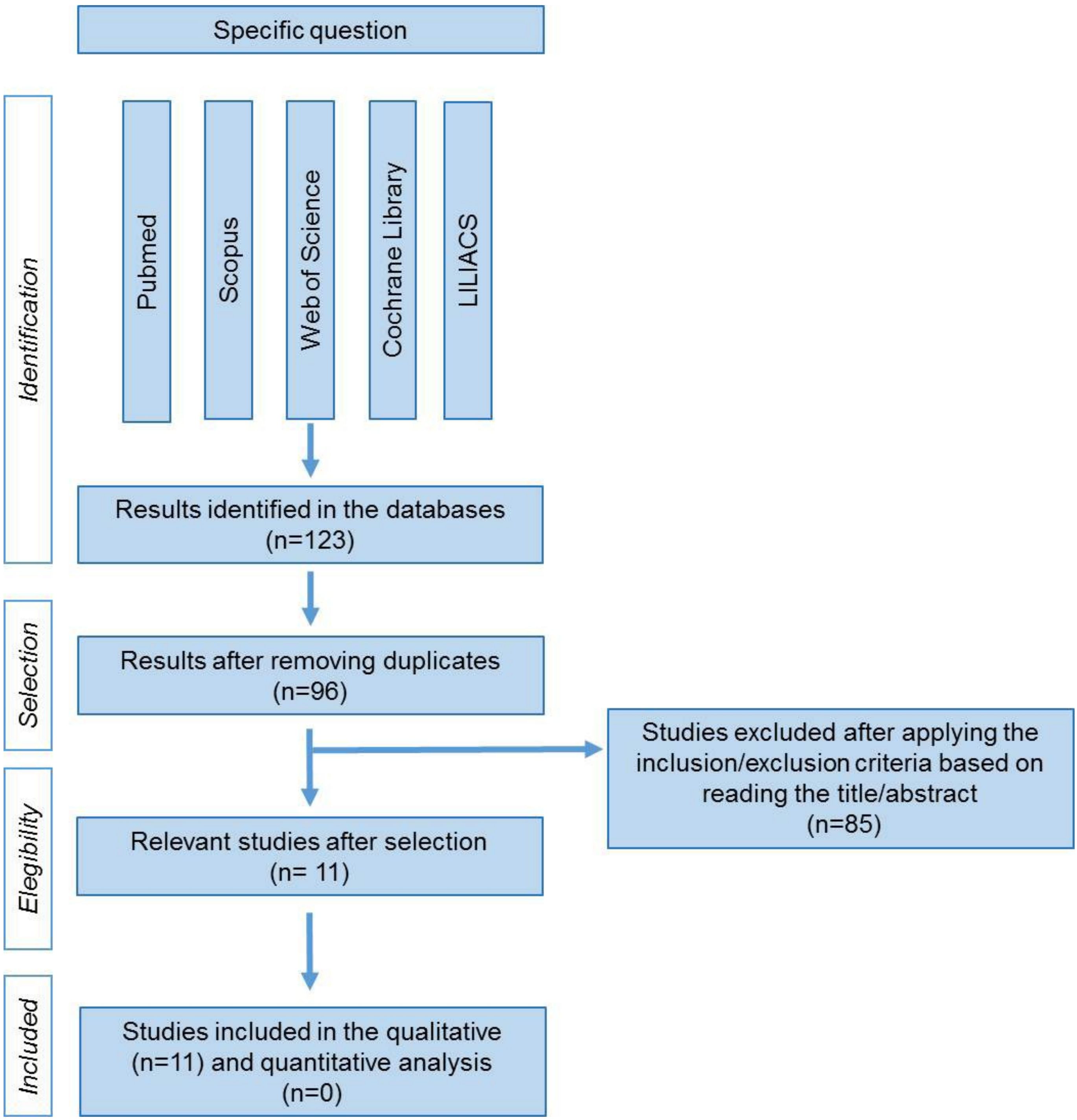

Figure 1. *Flowchart of the study selection.*

	Randomization	Reported result	Root anatomy standardization	Operator variability	General
Poly 2021	+	+	+	+	+
da Silva 2021	+	+	+	+	+
Medeiros 2021	+	+	+	+	+
Zuolo 2018	+	+	+	+	+
Yuan and Yang 2018	+	+	+	?	?
Espir 2018	+	+	-	+	-
Guimaraes 2017	-	+	+	+	-
De-Deus 2015	+	+	+	+	+
Busquim 2015	+	+	+	+	+
Zhao 2014	+	+	+	+	+
Paqué 2011	+	+	+	+	+

Figure 2. Analysis of risk of bias in included studies.

kinematics (26). Another study compared the Unicone reciprocating system with Reciproc R40 and MTwo (rotary) files; the results showed a greater amount of untouched areas in the Unicone system (22).

The TRUshape (rotary) system has fewer untouched areas (24%) in lower premolars compared to the Reciproc instrument (30%), justified by Guimarães *et al.* (2017) for the modeling created by the "S"-shaped rotary instrument that would facilitate instrumentation in flattened canals (19). On the other hand, the TRUShape system showed no differences with the WaveOne Gold system (reciprocal), also in flat canals. However, they were less effective in shaping the canal when compared with the XP-Endo Shaper (rotary) system (27).

Da Silva et al. (2021) also tested the TRUShape system, comparing it with the Reciproc Blue (reciprocating) system and the ProTaper Universal system, without observing significant differences in modeling capability (28). The authors justify the similar performance of the Reciproc Blue system in the fact that these instruments undergo a blue heat treatment in the manufacturing process, which increases their flexibility when compared to the Reciproc M-wire instrument, enhancing their ability to better follow the root canal anatomy, reaching a higher percentage of instrumented area (28).

Medeiros et al. (2021) compared the MTwo system with the WaveOne Gold system without observing significant differences in canal preparation. Nevertheless, when the final 5mm was evaluated, the WaveOne Gold system showed lower apical transport (28). The authors explain this result also by the heat treatment of the reciprocating system, which gives memory control to the instrument (29).

It is important to standardize the diameter and taper of the final instrument when comparing the shaping ability of different instruments (30). The data obtained showed different instrumentation protocols, regardless of kinematics. The differences between the untouched areas of the root canal system after instrumentation in rotary or reciprocating kinematics is still controversial, requiring further studies with greater control of the variables, reducing the heterogeneity of the various parameters in question (thermal treatment of NiTi alloy, cross-section of the instrument, diameter, taper, etc.), allowing a quantitative synthesis of the data.

CONCLUSION

The evaluated studies that used micro-CT showed that none of the instrumentation systems, regardless of kinematics, was able to completely touch the root canal walls.

The authors declare no conflicts of interest.

Corresponding Author:
Daniel R. Herrera
Rua Mario Santos Braga, 28 - Centro,
Niterói - RJ, 24020-140 - Brazil
danielherrera@id.uff.br

REFERENCES

1. Gomes BPFA, Herrera DR. Etiologic role of root canal infection in apical periodontitis and its relationship with clinical symptomatology. Braz Oral Res. 2018 Oct 18;32(suppl 1):e69.
2. Marzouk AM, Ghoneim AG. Computed tomographic evaluation of canal shape instrumented by different kinematics rotary nickel-titanium systems. J Endod. 2013 Jul;39(7):906-9.
3. Zhao D. Shen Y. Peng B, Hasapasalo M. Root Canal preparation of mandibular molars with 3 nickel-titanium rotary instruments: a micro-computed tomographic study. J Endod. 2014 Nov;40(11):1860-4.
4. Thompson SA, Dummer PM. Shaping ability of ProFile .04 Taper Series 29 rotary nickel-titanium instruments in simulated root canals Part 1. Int Endod J. 1997 Jan;30(1):1-7.
5. Yared GM, Bou Dagher FE, Machtou P. Influence of rotational speed, torque and operator´s proficiency on ProFile failures. Int Endod J. 2001 Jan;34(1):47-53.
6. Da Silva Limoeiro AG, Dos Santos AH, De Martin AS, et al. Micro-computed tomographic evaluation of 2 nickel-titanium instrument systems in shaping root Canals. J Endod. 2016 Mar;42(3):496-9.
7. Brasil SC, Marceliano-Alves MF, Marques ML, et al. Canal transportation, unprepared áreas, and dentin removal after preparation with BT-Race and ProTaper Next Systems. J Endod. 2017 Oct;43(10):1683-7.
8. Vera J, Siqueira Jr JF , Ricucci D, et al. One- versus two-visit endodontic treatment of teeth with apical periodontitis: a histobacteriologic study. J Endod. 2012 Aug;38(8):1040-52.
9. Bramante C, Berbert A, Borges R. A methodology for evaluation of root canal instrumentation. J Endod. 1987 May;13(5):243-5.
10. Shivashankar MB, Niranjan NT, Jayasheel A, Kenchanagoudra MG. Computed Tomography Evaluation of Canal Transportation and Volumetric Changes in Root Canal Dentin of Curved Canals Using Mtwo, ProTaper and ProTaper Next Rotary System-An In-vitro Study. J Clin Diagn Res. 2016 Nov;10(11):ZC10-ZC14.
11. Versiani MA, Carvalho KKT, Mazzi-Chaves JF, Souza-Neto MD. Micro-computed tomographic evaluation of the shaping ability of XP-endo Shaper, iRace, and EdgeFile systems in long oval shaped canals. J Endod. 2018 Mar;44(3):489-95.
12. Metzger Z, Zary R, Cohen R, Tperovich E, Paqué F. The quality of root canal preparation and root canal obturation in canals treated with rotary versus self-adjusting files: a three-dimensional micro-computed tomographic study. J Endod. 2010 Sep;36(9):1569-73.
13. Moura-Netto C, Palo RM, Pinto LF, Mello-Moura AC, Daltoe , Wilhelmsen NS. CT study of the performance

of reciprocating and oscillatory motions in flattened root canal areas. Braz Oral Res. 2015;29:1-6.

14. Peters OA, Schönenberger K, Laib A. Effects of four Ni-Ti preparation techniques on root canal geometry assessed by micro computed tomography. Int Endod J. 2001 Apr;34(3):221-30.
15. Peters OA, Laib A, Rüegsegger P, Barbakow F. Three-dimensional analysis of root canal geometry by high-resolution computed tomography. J Dent Res. 2000 Jun;79(6):1405-9.
16. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. J Clin Epidemiol. 2009 Oct;62(10):1006-12.
17. Shamseer L, Moher D, Clarke M, et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. BMJ. 2015 Jan 2;350:g7647.
18. Yuan G, Yang G. Comparative evaluation of the shaping ability of single-file system versus multi-file system in severely curved root canals. J Dent Sci. 2018 Mar;13(1):37-42.
19. Guimarães LS, Gomes CC, Marceliano-Alves MF, Cunha RS, Provenzano JC, Siqueira JF. Preparation of oval-shaped canals with TRUShape and Reciproc systems: a micro–computed tomography study using contralateral premolars. J Endod. 2017 Jun;43(6):1018-22.
20. Busquim S, Cunha RS, Freire L, Gavini G, Machado ME, Santos M. A micro-computed tomography evaluation of long-oval canal preparation using reciprocating or rotary systems. Int Endod J. 2015 Oct;48(10):1001-6.
21. Zuolo ML, Zaia AA, Belladonna FG, et al. Micro-CT assessment of the shaping ability of four root canal instrumentation systems in oval-shaped canals. Int Endod J. 2018 May;51(5):564-71.
22. Espir CG, Nascimento-Mendes CA, Guerreiro-Tanomaru JM, Cavenago BC, Hungaro Duarte MA, Tanomaru-Filho M. Shaping ability of rotary or reciprocating systems for oval root canal preparation: a micro-computed tomography study. Clin Oral Investig. 2018 Dec;22(9):3189-94.
23. Versiani MA, Leoni GB, Steier L, et al. Micro–computed tomography study of oval-shaped canals prepared with the Self-adjusting File, Reciproc, WaveOne, and ProTaper Universal systems. J Endod. 2013 Aug;39(8):1060-6.
24. De-Deus G, Belladonna FG, Silva EJ, et al. Micro-CT evaluation of non-instrumented canal areas with different enlargements performed by NiTi systems. Braz Dent J. Nov-Dec 2015;26(6):624-9
25. Zhao D, Shen Y, Peng B, Haapasalo M. Root canal preparation of mandibular molars with 3 nickel-titanium rotary instruments: a micro–computed tomographic study. J Endod. 2014 Nov;40(11):1860-4.
26. Paqué F, Zehnder M, De-Deus G. Microtomography-based comparison of reciprocating single-file F2 ProTaper technique versus rotary full sequence. J Endod. 2011 Oct;37(10):1394-7.
27. Poly A, Marques F, Moura Sassone L, Karabucak B. The shaping ability of WaveOne Gold, TRUShape and XP-endo Shaper systems in oval-shaped distal canals of mandibular molars: A microcomputed tomographic analysis. Int Endod J. 2021 Dec;54(12):2300-6.
28. da Silva EJNL, de Moura SG, de Lima CO, et al. Shaping ability and apical debris extrusion after root canal preparation with rotary or reciprocating instruments: a micro-CT study. Restor Dent Endod. 2021 Feb 25;46(2):e16.
29. Medeiros TC, Lima CO, Barbosa AFA, et al. Shaping ability of reciprocating and rotary systems in oval-shaped root canals: a microcomputed tomography study. Acta Odontol Latinoam. 2021 Dec 31;34(3):282-288.
30. Paqué F, Musch U, Hülsmann M. Comparison of root canal preparation using RaCe and ProTaper rotary Ni-Ti instruments. Int Endod J. 2005 Jan;38(1):8-16.