

Histological evaluation of the cleaning effectiveness of two reciprocating single-file systems in severely curved root canals: Reciproc versus WaveOne

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ABSTRACT

Objective: The aim of this study was to evaluate the cleaning effectiveness achieved with two reciprocating single-file systems in severely curved root canals: Reciproc and WaveOne. **Materials and Methods:** Twenty-five mesial roots of mandibular molars were randomly separated into two groups, according to the instrumentation system used. The negative control group consisted of five specimens that were not instrumented. The mesial canals (buccal and lingual) in Reciproc Group were instrumented with file R25 and the WaveOne group with the Primary file. The samples were submitted to histological processing and analyzed under a digital microscope. **Results:** The WaveOne group presented a larger amount of debris than the Reciproc Group, however, without statistically significant difference ($P > 0.05$). A larger amount of debris in the control group was observed, with statistically significant difference to Reciproc and WaveOne groups ($P < 0.05$). **Conclusions:** The two reciprocating single-file instrumentation systems presented similar effectiveness for root canal cleaning.

Key words: Cleaning, reciprocating single-file system, reciprocating motion

INTRODUCTION

Several advances in the techniques for the root canal systems instrumentation have been obtained from the development of nickel-titanium instruments (NiTi), the main properties of these being their superelasticity, flexibility, and shape memory effect.^[1] These properties have allowed the development of rotary instruments with a variety of tapers, making biomechanical preparation faster than manual instrumentation.^[2,3]

The use of reciprocating motion may be considered as a recent innovation in mechanized root canal instrumentation; with its differentiated kinematics being described as a oscillatory movement in which the instrument turns in the clockwise direction, and then counter-clockwise before completing a full 360° rotation cycle.^[4,5] Thus, the stress promoted on the instrument is diminished, thereby considerably reducing its risk of fracture and increasing its lifespan.^[6,7] Furthermore, the instruments are made of a special metal alloy, denominated M-Wire, which

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undergoes alternate cycles of cold and heat during manufacture, which provides a significant increase in their flexibility and mechanical strength.^[7]

Among the instruments that are used in a reciprocating movement during biomechanical preparation, the Reciproc and WaveOne systems are the most widely used.^[8] These systems are sold in a presterilized condition and are for a single use, being discarded after instrumentation, which reduce the risk of cross-contamination and instrument fractures.^[4] In addition, they have advantages in comparison with conventional rotary systems, as they allow biomechanical preparation to be performed four times faster due to the use of a single instrument.^[6-8]

Both systems are composed of three instruments; and perform three cycles of 120° until they complete a 360° rotation. The files of the Reciproc system are the R25 (red - 25.08), R40 (black - 40.06) and R50 (yellow - 50.05), with the first two being indicated for constricted or curved canals, and the latter for normal and wide canals.^[9] These files have an "S"-shaped cross section, and when activated by the motor, they perform a 150° rotation in the counter-clockwise direction (cutting direction) and 30° in the clockwise direction, at a speed of approximately 300 rpm.^[5,7,10]

On the other hand, the files of the WaveOne system have a convex triangular cross section in the coronal part and a modified convex triangular part at the tip, being denominated Small (yellow - 21.06), used in thin canals, Primary (red - 25.08), indicated for the majority of canals, and Large (black - 40.08), used in wide canals.^[11] Their angle of rotation in the cutting direction (counter-clockwise direction) is 170° and in the relief direction (clockwise direction) of 50°, developing an approximate speed of 350 rpm.^[5,7,10]

However, few studies have reported the cleaning effectiveness of these new systems since the use of only one instrument could compromise the removal of debris from inside the root canals. Therefore, the aim of this study was to compare the cleaning effectiveness, by means of histological analysis, of these two motor driven systems with reciprocating movement kinematics in canals with an accentuated curvature. The null hypothesis tested was there would be no difference between the systems with regard to their cleaning effectiveness.

MATERIALS AND METHODS

Teeth selection

To perform this study, 25 freshly extracted human mandibular molar teeth, with prior approval from the Research Ethics Committee (Protocol No. 120.956), and according to Helsinki Declaration principles, were selected. The teeth presented fully formed root apices, minimum length of 16 mm, two mesial canals with distinct foramen, 30° angle of curvature and radius of curvature ≤10 mm.

The teeth were kept in 0.5% chloramine solution at 4°C for 48 h for the disinfection, and next, washed in running water for 24 h. After this, the teeth were individually submitted to orthoradial radiograph taken, using a digital sensor (Kodak RVG 5100, Carestream Health Inc., Stuttgart, Germany) and X-ray equipment (Spectro 70X, Dabi Atlante, Ribeirão Preto, SP, Brazil) with exposure time of 0.4 s and object-film distance of 10 cm.

After obtaining the radiographic images, these were digitized, and with the aid of the AutoCAD 2012 software (Autodesk, San Rafael, CA, USA) measurements were taken of the angle (in degrees) and of the radius of curvature (in mm) of the mesial root of each tooth. In order to measure the angle of curvature of the root, the Schneider method was followed,^[12] by tracing a line (w) parallel to the long axis of the root as from the canal opening orifices, and another (x) that began in the apical foramen and ended at the intersection with the first line, at the point where the curvature of the root began. The acute angle (α) formed by these two lines determined its degree of curvature. According to Pruett *et al.*,^[13] there is a point A and a point B on the lines w and x where the curvature of the canal begins and ends, respectively. These points are tangential to a circle whose radius (r), in millimeters determines the radius of the curvature of the canal. The center of the circle is defined by the meeting of the straight lines y and z, which originate at points A and B and are traced perpendicularly to the lines w and x, respectively [Figure 1].

Biomechanical preparation

Coronal opening was performed with a spherical diamond coated bur No. 1015 (KG Sorensen, São Paulo, SP, Brazil), coupled at high speed device (Silent - MRS 350, Dabi Atlante, Ribeirão Preto, SP, Brazil) under constant water cooling. The crowns of the teeth were partially sectioned with a diamond disc (KG Sorensen)

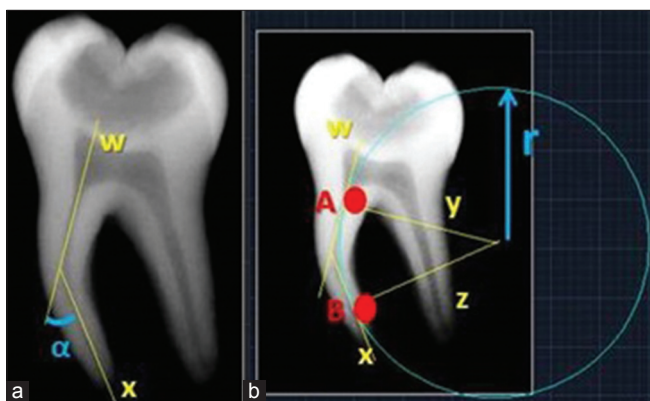


Figure 1: (a) Calculation of the angle of curvature (α) of the mesial root (b) determination of the radius of curvature (r) of the mesial root

close to the amelocement junction, to standardize the mean length of the mesial root (both canals-buccal and lingual) at 16 mm.

The working length was determined by inserting a K-type file #10 (Dentsply/Maillefer Ballaigues, Switzerland) in the apical direction until its tip was visualized; and withdrawn 1 mm short of the apical foramen.

With the purpose of keeping the teeth in the same position during biomechanical preparation, a matrix (2.0 cm \times 2.0 cm \times 2.0 cm) made of condensation silicone (Perfil Denso, Vigodent, Rio de Janeiro, RJ, Brazil), coupled to an acrylic base was used. After manipulating the silicone, the roots were inserted with the buccal surface parallel to one of the matrix surfaces, leaving only the entrances of the mesial canals out of the silicone. After silicone polymerization, the root/matrix sets were removed from the acrylic base; and the 25 silicone blocks containing the canals were randomly assigned into two experimental groups, which were submitted to instrumentation ($n = 20$), and one group, considered the negative control ($n = 10$), in which the canals were not instrumented.

The instruments of the tested systems were activated by a Sirona handpiece (SN S 12345, Sirona Dental Systems GmbH, Bensheim, Germany), with 6:1 reduction, coupled to a VDW Silver Reciproc motor (VDW GmbH, Munich, Germany).

The roots in the Reciproc Group were instrumented only with file R25 (25.08/21 mm-VDW GmbH), with the Reciproc ALL function predetermined by the motor. Three movements of the instruments were made with slight apical pressure until the working length was attained. The first movement corresponded to preparation of the cervical third;

the second to preparation of the middle third, and the third, to preparation of the apical third. Between one movement and the other, the instrument was cleaned with sterile gauze and the canal irrigated with 1 ml of 2.5% NaOCl solution (Cloro Rio 2.5%, Indústria Farmacêutica Rioquímica LTDA, São José do Rio Preto, SP, Brazil), introduced at 3 mm short of the apex, with the NaviTip irrigation tip coupled to a syringe (Ultradent Products Inc., South Jordan, UT, USA).

In the WaveOne Group, only the Primary instrument (25.08/21 mm - Dentsply/Maillefer) was used, driven by the same motor fitted for the WaveOne ALL function. In the same mode as used in the previous group, the specimens were instrumented with the same three movements in the direction to the apex, instrument cleaning and irrigation with 1 ml of 2.5% NaOCl solution between one movement and the next, until the working length was attained. After instrumentation in both groups (Reciproc and WaveOne), the canals were irrigated with 2 ml of 2.5% NaOCl solution, following completion of the instrumentation. Biomechanical preparation was performed by only one professional in order to standardize the procedure. Whereas, the specimens of the negative control group were not instrumented.

Histological processing

After biomechanical preparation, the specimens were fixed in 4% buffered formalin solution for 48 h, washed in running water for 1 h, and immersed in Morse solution for approximately 4 weeks for decalcification, with periodic changes of solution every 2 days. On the conclusion of the decalcification process, the roots were cut perpendicularly to their long axis at 5 mm from anatomical apex, to perform the histotechnical processing. The root apices were washed in running water, dehydrated in ascending grades of alcohol (70%, 90%, 95%, and 100%) and diaphanized in xylol for embedment in liquid paraffin at approximately 60°C. Semi-serial cuts 5- μ m thick were made (15 semi-serial sections of each specimen) and were stained with hematoxylin and eosin.

The histological cuts were analyzed under a digital Dino-Lite Plus AM313T microscope (AnMo Electronics Corporation, New Taipei City, Taiwan) at 60 \times and 230 \times magnifications. The images with reference to the cuts were recorded as a tagged image file format and submitted to evaluation using the Dino Capture 2.0 software (AnMo Electronics Corporation, New Taipei City, Taiwan). An integration grid containing 588

points (0.9 cm × 0.9 cm), generated by the software was overlapped on each image obtained; thus allowing the points present in the root canal to be counted [Figure 2]. The area occupied by the canal was considered the total number of points present within the limits of the root canal lumen, without concern about establishing its absolute value since the isthmus region was not considered. After counting the clean points and those that presented the debris, the percentage of the points with debris in the cross-section of the root canal was calculated to determine the cleaning effectiveness of each system. Before images analysis, any identification of the groups was omitted, allowing blinded evaluation by a single and duly trained observer.

Statistical analysis

The normal distribution of data was tested by the Shapiro-Wilks test and the values obtained (Kruskal-Wallis, the Dunn multiple comparisons test, $P < 0.05$) were analyzed using the GraphPad InStat for Mac OS software (GraphPad Software, La Jolla, CA, USA).

RESULTS

The mean values of debris, in percentage (%) in the root canal lumen, may be seen in Table 1. In both groups submitted to instrumentation, it was possible to observe the presence of debris in the root canal lumen. The WaveOne group presented larger amount of debris than the Reciproc Group, however, without statistically significant difference ($P > 0.05$). Whereas, specimens in the control group, in which no instrumentation was performed, a larger amount of debris was observed with statistically significant difference from the Reciproc and WaveOne Groups ($P < 0.05$). Figures 3-5 present the debris removal by the two instrumentation systems and the negative control group.

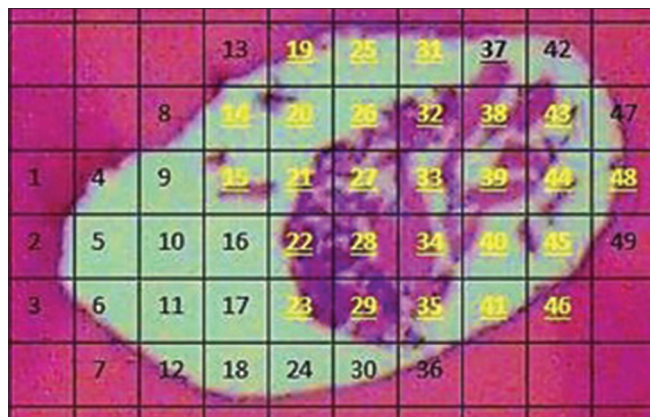


Figure 2: Integration grid overlapped on image at 230x. The yellow points indicate presence of debris (H and E)

DISCUSSION

The aim of this study was to compare the cleaning effectiveness of two single-file instrumentation systems with reciprocating movement kinematics. Based on the results obtained, it can be affirmed that the tested hypothesis was accepted since the two systems evaluated presented a similar behavior with regard to cleaning effectiveness.

In spite of the complex and variable anatomy of root canal systems, in the present study, standardization criteria were used to guarantee comparability among the groups. The first of these was the exact determination of the degree of curvature of the mesial roots, by selecting teeth with a 30° angle of curvature, considered severely.^[12] Whereas, the radius of curvature adopted (≤ 10 mm) represents how abruptly a specific angle of curvature occurs when the canal deviates from the straight line; that is, the smaller the radius of the circle traced, the more accentuated is the curvature of the root canal.^[13] However, because they are independent measurements, the canals may present equal angulations with different radii.

Table 1: Mean values (%) and SD of the amount of debris remaining after instrumentation in the apical third of the root canal

Control group	Reciproc group	Waveone group
61.76±6.51 ^a	25.35±7.06 ^b	28.96±13.21 ^b

Different lower case letters in line indicate statistically significant difference among groups. Dunn's multiple comparisons test categories with the same letter are not statistically different from each other ($P < 0.05$). Kruskal-Wallis, Dunn's multiple comparisons test- $P > 0.05$. $P = 0.07$. SD: Standard deviation, ^{a,b,c}= P value=0.07

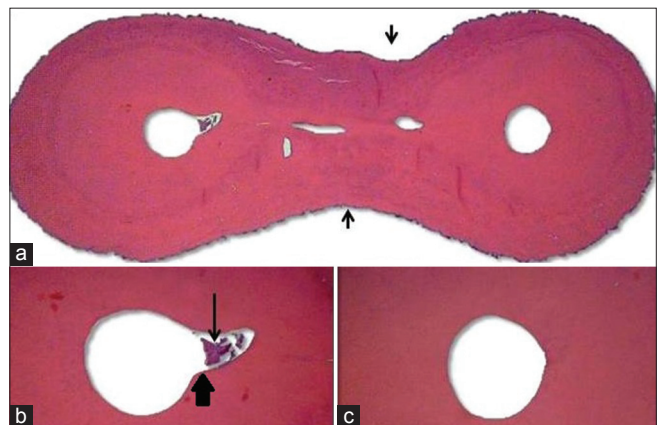


Figure 3: Representative image of the cross-section at the apical area from specimen of Reciproc Group (a) panoramic view of the histological cut at lower magnification (60x), showing two distinct canals (mesiobuccal and mesiolingual), with flattening of the mesial root (arrows) (b) Canal presenting flattening area and presence of debris (smaller arrow). Note the limit area of the instrument action (larger arrow) (c) Canal with circular configuration (230x) and absence of debris (H and E)

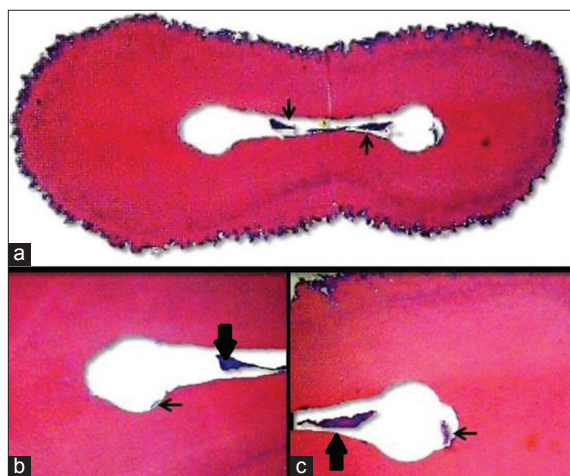


Figure 4: Representative image of the cross-section at the apical area from specimen of WaveOne Group (a) panoramic view of the histological cut at lower magnification (60×), showing the isthmus area between the canals, with presence of debris (arrows) (b and c) canals at greater magnification (×230) showing evidence of debris in the root canal lumen (smaller arrows) and in the isthmus area (larger arrows) (H and E)

Therefore, with the standards adopted, the teeth could simulate clinical situations that represent difficulty in performing endodontic treatment.^[14,15]

The action of endodontic instruments against dentinal walls results in the main root canal with a progressively conical shape, however, at all times respecting its original anatomy.^[16] With the reciprocating movement proposed by Yared,^[4] the use of one single instrument for cleaning and shaping the root canal system has led to a new paradigm. Biomechanical preparation is performed starting with the gradual entry of the instruments (R25 and primary), using a crown-down technique.^[4,9]

In the present study, the instruments R25 (Reciproc) and Primary (WaveOne) were used, since the manufacturers recommended the use of these instruments in canals with accentuated curvature, since manual instruments would not be capable of passively reaching the working length in these cases.^[8] Furthermore, according to the manufacturers' instructions, the instruments were discarded after biomechanical preparation, since their use is recommended in one single tooth; that is, for the preparation of 3 or 4 canals in the case of molars. However, Park *et al.*^[17] have reported, by means of scanning electron microscopy, that instruments of the Reciproc and WaveOne systems may be used in approximately 5 canals without significant alterations occurring on their surface, suggesting the possibility of reusing the instruments.

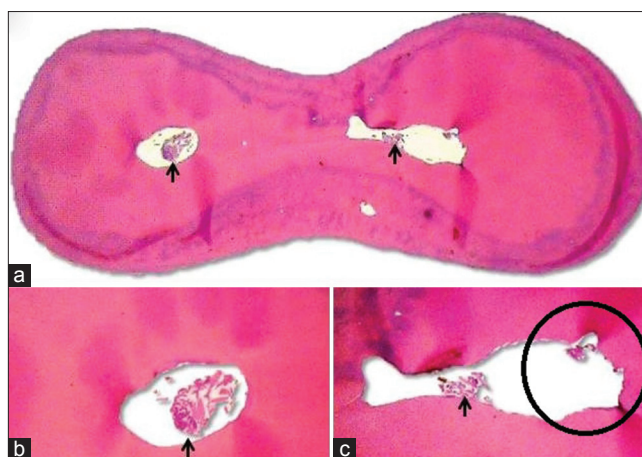


Figure 5: Representative image of the cross-section at the apical level from specimen of the control group. Smaller and greater magnification of the canals, highlighting the large amount of debris (arrows) (c) Irregular walls of noninstrumented canals (indication) (H and E)

Considering the main objective of this study, only NaOCl solution, at the concentration of 2.5% was used after each gradual entry of the instruments, to avoid the influence of different irrigant solutions. NaOCl is the solution of first choice for performing endodontic treatment because, in addition to the mechanical flushing action of debris from within the root canal system, it promotes the dissolution of organic tissue.^[18] Moreover, so that there would be no alterations in the result of the cleaning effectiveness due to the use of NaOCl, the amount of solution used and the depth of irrigation were standardized in the two groups submitted to instrumentation.

During the histological analysis, it was found that there were several configurations of the root canal systems, in spite of standardization as regards the severity of curvature of the roots used. In the cases of ribbon-shaped canals, or those with the presence of isthmus, the area with debris was larger than it was in those with a circular format.^[14] Circular canals provide a greater area of contact of the NiTi instruments, which have a cylindrical format and act in a centralized mode.^[19]

Bürklein *et al.*,^[8] when evaluating the cleaning effectiveness of the same systems by means of scanning electron microscopy, found that the Reciproc system promoted greater debris removal than the WaveOne system, in the apical third. This fact may be explained by the difference in cross-section of the instruments. While the S-shaped cross-section in the Reciproc instruments provides the presence of deeper grooves, which favors debris removal, the convex triangular

format in the WaveOne instruments creates thick metal core with shallow grooves and lower debris removal effectiveness.^[20] In addition, the systems have different amplitudes of cutting movement, being 150° for Reciproc and 170° for WaveOne. Although recent studies have demonstrated that there is no difference in the percentage increase in area after instrumentation with the R25 and Primary files,^[21,22] when one associates the wider angle of advance in the cutting direction (counter-clockwise) of the WaveOne system with the lower depths of its grooves, this may explain the inferior performance in regard to debris removal during instrumentation.

Nevertheless, this behavior was not observed in the present study since both systems presented similar effectiveness with regard to the cleaning effectiveness in the apical third of the root canal. In the study of Bürklein *et al.*,^[8] the action of these instruments was evaluated in the three root thirds, and only in the apical third was there significant difference as regards cleaning effectiveness. In the present study, the authors choose to evaluate only the apical third, as it is known that the cleanliness of root canal systems diminishes as the instrument advances from the cervical into the apical direction,^[23,24] making the results more relevant. However, the authors believe that further studies must be conducted to elucidate these facts.

These single-file systems are clinically more attractive, because they allow a significant reduction in the time of their application when compared with multiple instrument systems.^[6,20,25] However, the reduction in operative time when single-file systems are used significantly diminish the time of irrigation and chemical debridement of root canal systems.^[8] This situation must be compensated with the use of larger volumes of irrigant solution and its activation to promote the chemical dissolution of debris and promote adequate disinfection of the root canal system.^[8] It is known that a lower amount of debris accumulates when the canal is irrigated more frequently.^[2]

Despite the limitations of this *in vitro* study, it may be concluded that the Reciproc and WaveOne systems have similar cleaning effectiveness in the apical third of severely curved root canals. However, further studies are needed to clarify the mechanisms involved in improving the cleaning effectiveness of the root canal system.

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REFERENCES

1. Versiani MA, Leoni GB, Steier L, De-Deus G, Tassani S, Pécora JD, *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;39:1060-6.
2. Marchesan MA, Arruda MP, Silva-Sousa YT, Saquy PC, Pecora JD, Sousa-Neto MD. Morphometrical analysis of cleaning capacity using nickel-titanium rotary instrumentation associated with irrigating solutions in mesio-distal flattened root canals. *J Appl Oral Sci* 2003;11:55-9.
3. Johnson E, Lloyd A, Kuttler S, Namerow K. Comparison between a novel nickel-titanium alloy and 508 nitinol on the cyclic fatigue life of ProFile 25/04 rotary instruments. *J Endod* 2008;34:1406-9.
4. Yared G. Canal preparation using only one Ni-Ti rotary instrument: Preliminary observations. *Int Endod J* 2008;41:339-44.
5. Pedullà E, Grande NM, Plotino G, Gambarini G, Rapisarda E. Influence of continuous or reciprocating motion on cyclic fatigue resistance of 4 different nickel-titanium rotary instruments. *J Endod* 2013;39:258-61.
6. Gavini G, Caldeira CL, Akisue E, Candeiro GT, Kawakami DA. Resistance to flexural fatigue of Reciproc R25 files under continuous rotation and reciprocating movement. *J Endod* 2012;38:684-7.
7. Kim HC, Kwak SW, Cheung GS, Ko DH, Chung SM, Lee W. Cyclic fatigue and torsional resistance of two new nickel-titanium instruments used in reciprocation motion: Reciproc versus WaveOne. *J Endod* 2012;38:541-4.
8. Bürklein S, Hinschitzka K, Dammaschke T, Schäfer E. Shaping ability and cleaning effectiveness of two single-file systems in severely curved root canals of extracted teeth: Reciproc and WaveOne versus Mtwo and ProTaper. *Int Endod J* 2012;45:449-61.
9. Yared G. Canal Preparation with Only One Reciprocating Instrument Without Prior Hand Filing: A New Concept. Available from: http://www.vdw-reciproc.de/images/stories/pdf/GY_Artikel_en_WEB.pdf. [Last accessed on 2011 Dec 09].
10. Arias A, Perez-Higueras JJ, de la Macorra JC. Differences in cyclic fatigue resistance at apical and coronal levels of Reciproc and WaveOne new files. *J Endod* 2012;38:1244-8.
11. Lim YJ, Park SJ, Kim HC, Min KS. Comparison of the centering ability of Wave-One and Reciproc nickel-titanium instruments in simulated curved canals. *Restor Dent Endod* 2013;38:21-5.
12. Schneider SW. A comparison of canal preparations in straight and curved root canals. *Oral Surg Oral Med Oral Pathol* 1971;32:271-5.
13. Pruett JP, Clement DJ, Carnes DL Jr. Cyclic fatigue testing of nickel-titanium endodontic instruments. *J Endod* 1997;23:77-85.
14. Gonçalves LC, Sponchiado-Junior EC, Marques AA, Frota MF, Garcia Lda F. Morphometrical analysis of cleaning capacity of a hybrid instrumentation in mesial flattened root canals. *Aust Endod J* 2010;36:1-6.
15. da Frota MF, Filho IB, Berbert FL, Sponchiado EC Jr, Marques AA, Garcia Lda F. Cleaning capacity promoted by motor-driven or manual instrumentation using ProTaper Universal system: Histological analysis. *J Conserv Dent* 2013;16:79-82.
16. Paqué F, Musch U, Hülsmann M. Comparison of root canal preparation using RaCe and ProTaper rotary Ni-Ti instruments. *Int Endod J* 2005;38:8-16.
17. Park SK, Kim YJ, Shon WJ, You SY, Moon YM, Kim HC, *et al.* Clinical efficiency and reusability of the reciprocating nickel-titanium instruments according to the root canal anatomy. *Scanning* 2013;36:246-51.
18. Baratto-Filho F, Leonardi DP, Zielak JC, Vanni JR, Sayão-Maia SM, Sousa-Neto MD. Influence of ProTaper finishing files and sodium hypochlorite on cleaning and shaping of mandibular central incisors – A histological analysis. *J Appl Oral Sci* 2009;17:229-33.
19. Taha NA, Ozawa T, Messer HH. Comparison of three techniques for preparing oval-shaped root canals. *J Endod* 2010;36:532-5.
20. Pedullà E, Grande NM, Plotino G, Palermo F, Gambarini G, Rapisarda E. Cyclic fatigue resistance of two reciprocating nickel-titanium instruments after immersion in sodium hypochlorite. *Int Endod J* 2013;46:155-9.
21. Yoo YS, Cho YB. A comparison of the shaping ability of reciprocating NiTi instruments in simulated curved canals. *Restor Dent Endod* 2012;37:220-7.
22. Saleh AM, Tavanafar S, Vakili-Gilani P, Al Sammerraie NJ, Rashid F. Influence of operator's experience level on lifespan of the WaveOne Primary file in extracted teeth. *Restor Dent Endod* 2013;38:222-6.

23. Fornari VJ, Silva-Sousa YT, Vanni JR, Pécora JD, Versiani MA, Sousa-Neto MD. Histological evaluation of the effectiveness of increased apical enlargement for cleaning the apical third of curved canals. *Int Endod J* 2010;43:988-94.
24. Arvaniti IS, Khabbaz MG. Influence of root canal taper on its cleanliness: A scanning electron microscopic study. *J Endod* 2011;37:871-4.
25. Bürklein S, Schäfer E. Apically extruded debris with reciprocating single-file and full-sequence rotary instrumentation systems. *J Endod* 2012;38:850-2.

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