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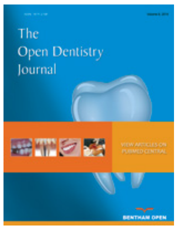

RESEARCH ARTICLE

Cleaning Effectiveness of a Reciprocating Single-file and a Conventional Rotary Instrumentation System

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Abstract:

Objective:

To compare cleaning effectiveness by histological analysis of a reciprocating single-file system with ProTaper rotary instruments during the preparation of curved root canals in extracted teeth.

Methods:

A total of 40 root canals with curvatures ranging between 20 - 40 degrees were divided into two groups of 20 canals. Canals were prepared to the following apical sizes: Reciproc size 25 (n=20); ProTaper: F2 (n=20). The normal distribution of data was tested by the Kolmogorov-Smirnov test and the values obtained for the test (Mann-Whitney U test, $P < .05$) were statistically analyzed using the GraphPad InStat for the Mac OS software (GraphPad Software, La Jolla, CA, USA).

Results:

There were no significant differences in remaining debris ($P > .05$) between the two groups.

Conclusion:

The application of reciprocating motion during instrumentation did not result in increased debris when compared with continuous rotation motion, even in the apical part of curved canals. Both instruments resulted in debris in the canal lumen, irrespective of the movement kinematics applied.

Keywords: Curved canals, Debris, Reciprocating motion, Rotary, Root canal system.

INTRODUCTION

Effective cleaning and shaping of the root canal system are essential for the biological and mechanical objectives of root canal treatment [1]. This can be achieved using a proper chemo-mechanical preparation [2, 3] and is thus essential for successful endodontic treatment. However, currently no instrument can predictably clean the entire root canal system [4, 5], and especially in the apical portion of the root canals, the cleaning efficiency is limited [6 - 9].

The nickel-titanium (NiTi) files Reciproc (VDW, Munich, Germany) are claimed to be able to completely prepare and clean root canals with only one instrument. These files are made of a special NiTi alloy called M-Wire, which is created by an innovative thermal-treatment process. The benefits of this M-Wire NiTi are increased flexibility of the instruments and improved resistance to cyclic fatigue [10]. The reciprocating motion is based on the technique of balanced forces [11], relieves stress on the instrument, and therefore, reduces the risk of cyclic fatigue caused by tension

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and compression [12, 13]. For every 3 cycles, the instrument makes a complete 360° turn [1]. In general, reciprocating root canal preparation is an advancement of the balanced force technique that allows shaping of even severely curved canals to larger apical diameters, using hand instruments [11]. The manufacturer does not strictly recommend creating a glide path when using reciprocating instrumentation. These single instrument systems are clinically interesting because they are easier to use, cause less fatigue to the operator, and avoid cross-contamination [14, 15]. In addition, they significantly reduce working time when compared with multiple instrument systems [1, 15 - 17]. Reciproc files have a continuous taper over the first 3 mm of their working part followed by a decreasing taper until the shaft. An S-shaped cross-section is used for the entire working part of the instruments. Reciproc instruments have sharp cutting edges. The design features of ProTaper have been described in detail in previous articles [18].

It is necessary to compare these single-file systems with well-known rotary NiTi systems, in order to assess the properties of reciprocating files. ProTaper is the rotary NiTi system used as control in the present investigation. These files have been evaluated in numerous investigations, with some even concerning the cleaning of even curved root canals [8, 19 - 22]. Therefore, the aim of this investigation was to compare the cleaning efficacy (residual debris) after preparation of curved root canals in extracted human molar teeth using the single-file system Reciproc in comparison with the rotary ProTaper system.

The null hypotheses tested were that there is no difference between the reciprocating single-file system and the rotary NiTi system as regards their cleaning ability in severely curved root canals.

MATERIALS AND METHODS

Tooth Selection

A total of 40 extracted human mandibular molar teeth with at least one curved root were selected. These teeth were donated by the Tooth Bank of the School of Dentistry of the State University of Amazonas, with prior approval from the Ethics Committee of the institution (Protocol No. 2012/0119). The selected teeth had not undergone previous endodontic treatment, had fully formed roots with minimum length of 16 mm, two mesial canals with distinct foramina, closed apex, root curvature angle ranging between 20 - 40 degrees, and curvature radius ≤ 10 mm (Table **1**) (according to Schneider 1971 and Pruett *et al*. 1997) [23, 24].

Table 1. Mean values of angle and radius of curvature.

	Angle	Radius of curvature
Reciproc	33,86	12,29
ProTaper	31,71	11,79

No statistically significant difference was found between groups (ANOVA test - $P>0.05$).
n=20

Preparation of Specimens

Standardized radiographs were taken prior to instrumentation, using a digital sensor (Kodak RVG 5100, Carestream Health Inc., Stuttgart, Germany) and X-ray equipment (Spectro 70 X, Dabi Atlante, Ribeirão Preto, SP, Brazil).

The tooth was placed in a radiographic mount made of silicone-based impression material (Clonage, Nova DFL, RJ, Brazil) to maintain a constant position. The X-ray tube, and thus the central X-ray beam, was aligned perpendicular to the root canal. The exposure time (0.12 s; 70 kV, 7 mA) was the same for all radiographs with a constant source-to-film distance of 50 cm and an object-to-film distance of 5 mm. The degree and the radius of canal curvature were determined using a computerized digital image-processing system [25]. Only teeth whose radii of curvature ranged between curvature radius ≤ 10 mm, and whose angles of curvature ranged between 20° and 40° were included. The homogeneity of the two groups with respect to the aforementioned parameters was assessed using analysis of variance (ANOVA) and post hoc Student-Newman-Keuls test.

Each tooth was decoronated close to the cemento-enamel junction to standardize to average length of 16 mm, which was measured with a digital caliper (Digimess, São Paulo, SP, Brazil). To separate the mesial root from the molar, diamond disks (KG Sorensen, São Paulo, Brazil) were used. Only the mesial root canals were instrumented.

Coronal access was completed using diamond burs, and the canals were controlled for apical patency with a root canal instrument of size 10 (Dentsply- Maillefer, Ballaigues, Switzerland). Only teeth with intact root apices, and whose root canal width near the apex was approximately compatible with a size 15 instrument, were included. This was checked with manual files size 15 (Dentsply- Maillefer, Ballaigues, Switzerland). Thus, it was possible to visually confirm the presence of independent foramina and determine the working length, which was established after withdrawal of file 1 mm short of the apical foramen.

Root Canal Instrumentation

In the Reciproc group, a R25 Reciproc file having a size 25 at the tip and a taper of 0.08 over the first 3 mm was used in a reciprocating, slow in-and-out pecking motion according to the manufacturer's instructions. The flutes of the instrument were cleaned after three in-and-out movements (pecks). These instruments were used only once and discarded after instrumentation of each specimen. The motor used during instrumentation was the VDW Silver Reciproc (VDW) with a contra-angle 6:1 reduction (SN S 12345, Sirona Dental Systems GmbH, Bensheim, Germany), torque-limited, and using the pre-programmed reciprocating motion for the Reciproc at Reciprocation All function.

In the ProTaper Universal group instruments were used in a modified crown-down movement, according to the manufacturer's instructions. The instruments S1 (Taper 0.02-0.11, size 17), S2 (Taper 0.04-0.115, size 20) were used in "brushing motion", F1 (Taper 0.055-0.07, size 20) and F2 (Taper 0.055-0.08, size 25) were then passively introduced with in-and-out movements in the apical direction until reaching the working length. Once the instrument had negotiated to the end of the canal and had rotated freely, it was removed. An electrically-driven motor (X-Smart, Dentsply/Maillefer, Ballaigues, Switzerland) with auto-reverse function mode was used to prepare the specimens of this group. A torque of 3 Ncm, 300 rpm was used for S1 and S2 instrument; and 2 Ncm and speed of 300 rpm for F1 and F2 instruments.

In both groups, root canals were irrigated with 40 ml of distilled water using a disposable plastic syringe (Ultradent Products Inc., South Jordan, UT, USA) and white NaviTip needle (Ultradent Products Inc.) at 3 mm short of the working length. Distilled water was used so that only the mechanical action of the instrument could be observed without any chemical interference during the process. At the end of instrumentation, the excess of solution was aspirated with the Capillary Tip (Ultradent Products Inc.) and the specimens were stored in a sterile 100 ml receptacle at a temperature of 5°C. Moreover, in both groups, apical preparation was standardized with an instrument compatible with #25 gauge (0.25 mm), *i.e.*, Reciproc R25 (VDW) and F2 instruments (Dentsply/Maillefer) for the Group Reciproc and Group ProTaper, respectively.

One operator completed all root canal preparations. The remaining debris areas were analyzed statistically using the analysis of variance (ANOVA) and post hoc Student-Newman-Keuls test ($P < .05$).

Histological Processing

To analyze the cleaning capacity of the systems tested, the specimens were submitted to histological processing. First, the specimens were dehydrated in a series of ascending grades of alcohol (70%, 90%, 95% and 100%) and then immersed in xylene for diaphanization and subsequent paraffinization.

Roots were split longitudinally, prepared for optical light microscope examination (Eclipse E 600, Nikon, Tokyo, Japan) at 40 X magnification.

The cleanliness of each root canal was evaluated in different areas (apical, middle and coronal third), as detailed in the sequence. Five-µm thick semi-serial sections of the apical third of each sample were made to obtain 12 sections per specimen, resulting in a total of 480 sections, which were subsequently stained with hematoxylin and eosin (HE). The images related to the sections were analyzed using the Corel Photo-Paint X4 software program (TM Corel Corporation, Ottawa, Ontario, Canada). For this purpose, an integration grid containing 300 points (15 x 20) with dimensions of 3.0 x 3.0 mm was generated by the software, superimposed on each image; considering the area occupied by the root canal and the number of points present within the limits of the canal lumen (clean area with debris) (Fig. **1**). After counting the points present in the clean and the dirty area points of each root canal area, the percentage of points with debris (dentin chips, pulp remnants and particles loosely attached to the canal wall) was calculated to determine the percentage of dirt left by each system. This percentage was calculated by a simple rule of three. A single, blinded observer performed the counting.

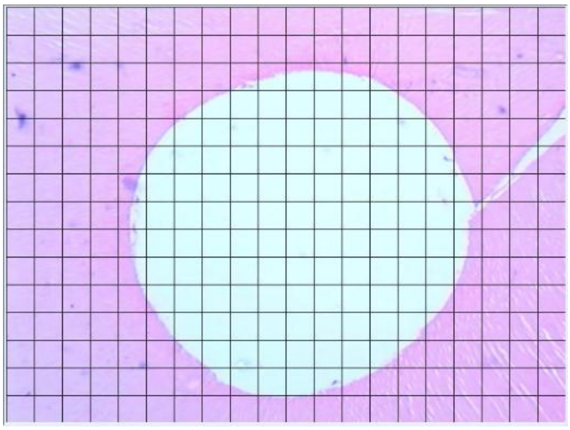

Fig. (1). Positioned integration grid over the images, making it possible to calculate the total area of the apical third of the canal of the specimens.

Statistical Analysis

The normal distribution of data was tested by the Kolmogorov-Smirnov test and the values obtained for the test (Mann-Whitney U test, $P < .05$) were statistically analyzed using the GraphPad InStat for the Mac OS software program (GraphPad Software, La Jolla, CA, USA).

RESULTS

The mean values of debris in percentage (%) in the canal lumen are shown in Table **2**.

Table 2. Mean values (%) and standard deviation (SD) of the amount of remaining debris after instrumentation in the apical third of the root canal.

	Reciproc	ProTaper
Remaining debris	5.40 ± 4.37	5.11 ± 5.20

No statistically significant difference was found between groups (Mann-Whitney U test - P>0.05).
n=20

The application of reciprocating motion during instrumentation did not result in increased debris formation when compared with continuous rotational motion, even in the apical part of curved canals. Both instruments resulted in debris in the canal lumen, irrespective of the movement kinematics applied.

In both groups it was possible to observe the presence of debris in the isthmus area, and irregularities in the canal lumen, which proves that some areas had not been touched by the instruments during biomechanical preparation. The Group Reciproc did not produce significantly more debris than the Group ProTaper ($P > .05$). Figs. (**2-4**) show debris removal promoted by the two instrumentation systems.

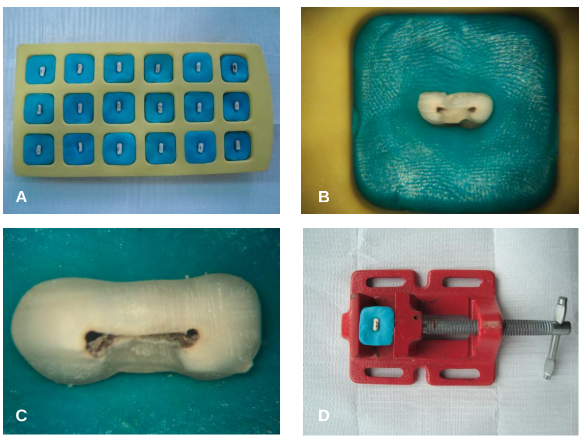

Fig. (2). (A). Specimens grouped into silicon blocks; **(B).** Magnification of the specimen with an increase of 8 X; **(C).** Magnification the specimen with 16 X; **(D).** Test specimens placed in a bench vise to instrumentation. For magnifying images was used microscope operative Alliance (São Carlos, São Paulo, Brazil).

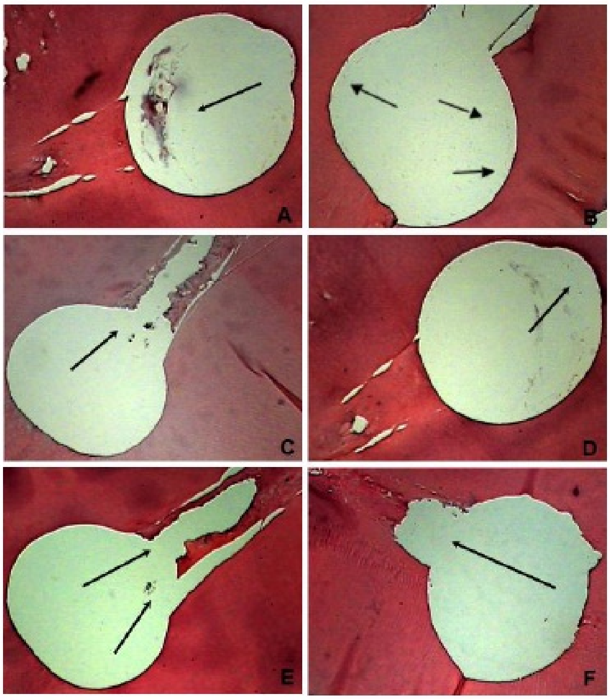

Fig. (3). Representative image of cleaning promoted by the Reciproc instrumentation system (Reciproc Group). **(A).** Debris present in the canal lumen (arrow); **(B).** Area cleaned by instrumentation (arrow); **(C).** Debris in the isthmus region (arrow); **(D).** modification of anatomy of canal lumen after instrumentation (arrow); **(E).** and **(F).** Isthmus region with presence of debris (arrow). HE - 40 X.

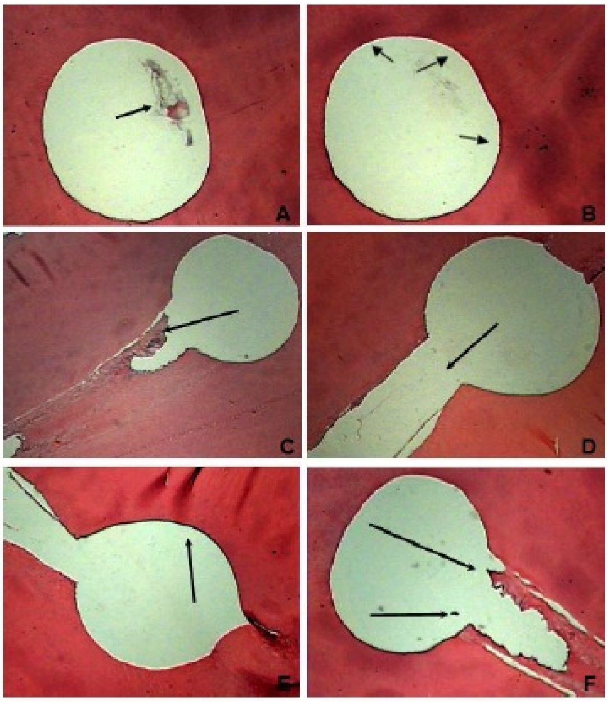

Fig. (4). Representative image of cleaning promoted by rotary instrumentation with the ProTaper system. **(A).** Debris present in the canal lumen (arrow); **(B).** Area cleaned by instrumentation (arrow); **(C).** Debris in the isthmus region (arrow); **(D).** Isthmus region without debris (arrow); **(E).** Canal lumen without presence of debris (arrow); **(F).** Presence of debris in the isthmus region (arrow). HE - 40 X.

DISCUSSION

The aim of this study was to assess and compare the cleaning efficiency of the single-file reciprocating instrument Reciproc with the established rotary ProTaper Universal system in curved root canals of extracted human molar teeth. The removal of vital and/or necrotic pulp tissue, infected dentin and dentin debris to eliminate most of the microorganisms from the root canal system is still one of the most important objectives during root canal instrumentation [26]. In this *in vitro* investigation, the ability to achieve some of these objectives was examined in severely curved root canals, involving the single-file system Reciproc and ProTaper rotary NiTi instruments.

Previous studies have assessed ProTaper instruments with regard to the preparation of curved root canals [27, 28], instrumentation of round and oval root canals [29] and the amount of apically extruded debris [12]. For the single-file system, the Reciproc R25 reciprocating file was selected for this investigation. This file was used in accordance with the manufacturer's recommendations, as these sizes are designated for narrow and curved canals. The reciprocating instrument selected has a tip diameter equivalent to a size 25. It must be taken into consideration that for the ProTaper Group, the final instrument used for canal preparation had a tip diameter equivalent to a size 25 (ProTaper F2).

The complex anatomy of the root canal system, with respect to the number, variation and shape, suggests that particular attention is required, because in regions of root flattening or isthmus, the disinfection, cleaning and shaping processes become hampered. In the literature, these regions are considered inaccessible areas [30]. Due to this peculiarity, the mesial roots of mandibular molars were selected, because of their root flattening and presence of isthmus. Despite the variations in the morphology of natural teeth, several attempts have been made in the present study to ensure comparability of the two experimental groups.

In the present study, 40 mesial roots of extracted human mandibular molars, which had 2 separate mesial root canals and separate foramina, were used. This choice was intended to eliminate the variables found in the root canals of different groups of teeth, and to ensure sample homogeneity. Therefore, teeth in both groups were balanced with respect to the apical diameter and length (distance between apex and cemento-enamel junction) of the root canal, and based on the initial radiograph, the teeth were also balanced with respect to the angle and the radius of canal curvature. The curvatures of all root canals ranged between 20° and 40° and the radii ranged between 3.1 and 10.6 mm. It is noteworthy that this group of teeth presents anatomical peculiarities and characteristics that difficulty in instrumentation of root canals with curvatures [9, 31 - 33].

During the present study, no instrument fractured. All instruments were used to enlarge one curved canal [34, 35].

Many efforts to increase the efficiency and safety of NiTi rotary instruments have been invented such as surface engineering (implantation or electropolishing), improvements in the manufacturing processes, microstructure control (*e.g.* heat treatment or innovative manufacturing techniques) or the use of new alloys [36]. In 2007, a new NiTi alloy (M-Wire; Dentsply Tulsa Dental Specialties, Tulsa, OK, USA) was developed. The M-Wire alloy is said to have an increased torsional resistance of up to 400% compared with martensitic NiTi and enables complete preparation of even severely curved root canals [37 - 40].

Among the systems using NiTi instruments, the Universal ProTaper system is one of the most popular systems. Its main features are the convex triangular cross-section, absence of radial guide, inactive tip and multiple tapers [22, 41]. All these features allow the instrument to be guided through the trajectory of the root canal; increasing cutting capacity and reducing advancement of the instrument in the apical direction, thereby reducing the screwing-in effect [42]. Due to these characteristics, this type of rotary system was used for comparison with the Reciproc system in this study.

Although the reciprocating systems with a single instrument have clear advantages over rotary systems with multiple instruments [1, 14, 16, 17], the results of the present study showed that the cleaning capacity of the two systems is similar.

Debris was used as a criterion to assess the cleaning efficiency of the different instruments in this study, because debris comprises dentin chips, residual vital or necrotic pulp tissue attached to the root canal wall, which is considered infected, and could cause reinfection of the root canal [43].

Considering the major objective of the present study (to compare the cleaning effectiveness of the different instruments), a simple irrigation protocol with only distilled water was used to avoid any influence of different irrigation solutions, as has been justified in detail in several previous studies [18, 34, 35, 44]. A standardized total volume of 40 mL was used for each specimen. According to this study, the frequency of irrigation, suction, and flooding process were revealed as predominant factors for cleaning the root canal system even without chemical properties, which proves that the physical action of the irrigation process also contributes to the cleaning process.

Histological analysis is considered a well-established method in the literature, and has been used to evaluate the cleaning ability of various endodontic instrumentation systems. In the present study, the cleaning efficiency was examined on the basis of a numerical scheme for debris evaluation, by means of histological evaluation of the coronal, the middle and the apical thirds of the canals [45, 46]. This method combines the use of a light microscope to analyze serial sections, and superimposition of a grid; making it possible to quantify the presence of dirt or debris in the root canal [31 - 33]. In both groups, partially un-instrumented areas with remaining debris were found in all canal sections. This finding has also been described by other authors [4, 5, 12, 35, 46 - 49] and is consistent with other investigations using microcomputer tomography assessment of canal shapes [4]. In another study, however, Bürklein *et al.* (2012) [1] demonstrated that continuous rotary instrumentation produces significantly more debris than the reciprocating system. A possible reason for the findings of Bürklein *et al.* (2012) [1] is probably due to the fact that the F3 ProTaper Universal instrument was the last instrument used in the canal preparation, whereas in the present study, instrumentation was performed until the F2 ProTaper Universal instrument. Furthermore, the present results confirm previous observations that cleanliness decreased from the coronal to the apical part of the root canal [4, 5, 9, 44, 47, 49]. Therefore, sufficient disinfection and copious irrigation are essential to improve root canal cleanliness [9, 47].

The similar cleaning effectiveness presented by the two systems evaluated in this study may also be attributed to the fact that the taper of the F2 ProTaper Universal instrument and Reciproc R25 is 8% in the first 3 mm and 0.25 mm at the tip, which promotes root canal shaping with similar geometrical shapes, despite the differences in cross-section [1]. In addition, the "shaper" or rotary "S" instruments of Universal ProTaper system cut the cervical and middle thirds, while the "finisher" or "F" instruments cut the apical third whereas, the entire length of the reciprocating file R25 cuts dentin [27 - 50]. Thus, when the tip reaches the two apical thirds, the coronal part still needs to be instrumented [50]. This may explain the similar cleaning capacity obtained in this study, despite the different kinematics [1].

According to the results of the present *in vitro* study, it may be concluded that reciprocating single-file system and sequence rotary instrumentation system promoted similar cleaning effectiveness in the apical third of root canals, showed relatively good cleaning ability, and can be regarded as being suitable for cleaning of even severely curved with only one instrument. However, clinically other aspects have to be taken into consideration when selecting the instrument, such as preparation time, which could decrease when using the single-file (Reciproc Group). Thus, simultaneously the time available for irrigation and chemical debridement of the root canal system is also reduced. To compensate the decreased irrigation time when using the single-file system, larger volumes of irrigant and additional activation of the irrigant seem to be advisable to improve chemical dissolution of residual debris and disinfection of the root canal system. Further investigations are warranted to asses this aspect in further detail.

CONCLUSION

Despite the limitations of the present in vitro study, it may be concluded that reciprocating single-file system and full-sequence rotary instrumentation system promoted similar cleaning effectiveness in the apical third of root canals. However, further studies are needed to clarify the mechanisms involved in improving the cleaning capacity of the root canal system.

CONFLICTS OF INTEREST

The authors confirm that this article content has no conflict of interest.

ACKNOWLEDGEMENTS

Declared none.

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