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ORIGINAL ARTICLE

Canal shaping of different single-file systems in curved root canals

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KEYWORDS
canal curvature;
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Abstract *Background/Purpose:* This study compared maintenance of canal anatomy, occurrence of apical transportation, and working time observed after instrumentation with One Shape New Generation rotary system (Micro-Mega), with those observed after instrumentation with Reciproc (VDW) and WaveOne (Dentsply-Maillefer) reciprocating systems.
Materials and methods: The mesial canals of 45 mandibular molars (curvature angles between 35° and 45°) were selected. Specimens were randomly divided into three groups, and canal preparations were performed using One Shape, Reciproc, or WaveOne systems (size #25). A digital double radiographic technique was used to determine apical transportation and change in angle of curvature. Also, working time and instrument failures were recorded. Data were statistically analyzed.
Results: During preparation, no file fractured. No statistically significant differences were found among groups. No system showed a significantly faster preparation time than others ($P > 0.05$). All instruments maintained the original canal curvature well and were safe to use.
Conclusion: Both continuous rotary instrument and reciprocating systems did not have any influence on the presence of apical transportation or caused an alteration in angle of canal curvature.

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Introduction

A new idea was lately realized for nickel-titanium (NiTi) rotary instruments: it consists of using just one instrument with different working motions with the aim to prepare root canals.[1–4] Diverse single-file systems have been promoted with the ability to prepare root canals with just one instrument. The recently introduced NiTi files Reciproc (VDW, Munich, Germany) and WaveOne (Dentsply Maillefer, Ballaigues, Switzerland) 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 based on increased flexibility of the instruments and on improvement of resistance to cyclic fatigue.[5] These files must be used in a reciprocal motion that requires special automated devices. Reciproc files are available in sizes 25—0.8, 40—0.6, and 50—0.5, and WaveOne are available in sizes 21—0.6, 25—0.8, and 40—0.8. The reciprocation working movement lies in a counterclockwise (cutting direction) and a clockwise movement (instrument release), whilst the counterclockwise cutting direction angle is greater than the instrument release one. Because the angle of counterclockwise is greater than the angle of clockwise, it is expressed that the instrument continually progress in the direction of the root canal apex. The One-Shape New Generation file by Micro-Mega (Besancon Cedex, France) is another single-file system, but used in continuous clockwise rotation; in addition to the size 25—0.6, there are Apical files in sizes 30—0.6 and 37—0.6. These instruments, having an innovative design, with three diverse cross-sectional areas above the entire length of the working part do not have a fixed pitch and a noncutting safety tip.[6] The design features of Reciproc, WaveOne,[3] and OneShape have been previously described in detail.[6] Some data are present in literature on the shaping ability of these systems,[2,6] but a comparative evaluation in canals with curvatures of over 35° is still missing.

Therefore, the aim of the present study was to compare the shaping ability of WaveOne, Reciproc, and OneShape single-file systems in severely curved root canals of extracted human molar teeth. The null hypothesis tested was that there is no difference among different single-file systems regarding canal straightening, apical transportation, or preparation time when preparing severely curved root canals.

Materials and methods

Specimen preparation

Forty-five human mandibular molars with curved mesial canals extracted for periodontal reasons were stored in a 0.2% thymol solution until use. The crown and distal root of each tooth were removed approximately at the level of the cementoenamel junction with a diamond rotary cutting instrument mounted on a high-speed handpiece with water-spray cooling, to obtain a mesiobuccal root canal measuring 12 mm in length. Confirmation of foraminal patency was performed with a #08 or #10 stainless steel manual K-type file. To avoid any bias caused by differences in the initial width, all the canals that before any instrumentation could be easily negotiated up to the apex with a #15 (or wider) file, were not included in the study. Accordingly, 45 roots were selected, and the working length was determined by subtracting 1 mm from the length at which a #10 file tip extruded apically.

Keeping the #10 file inside the canal, a series of radiographs were taken following the methodology of Iqbal et al.[7] Adobe Photoshop CS5 software (Adobe Systems Inc., San Jose, CA, USA) was used to enhance the edges of the initial and final instrumentation radiographs.[8] The angle and the radius of the canal curvature were determined according to the method previously described[8] by using a computerized digital image processing system (AutoCAD 2006; Autodesk Inc., San Rafael, CA, USA). The roots whose angles of curvature ranged between 35° and 45° were included in this study and randomly divided into three groups with 15 canals each. There was no need to perform thermal cycling of specimens.[9] The homogeneity of the groups with respect to the aforementioned two parameters was assessed using analysis of variance (Table 1). The roots were embedded in a jig constructed with autopolymerizing acrylic resin (Technovit 4000; Heraeus Kulzer, Wehrheim, Germany) so that they could be removed for preparation and later reinserted in a predetermined position for the purpose of comparing the images taken before and after preparation using standardized radiographic imaging.[10] To allow accurate superimposition of the pre- and postoperative images, the head of the X-ray tube was fitted to a cylinder-shaped apparatus so as to remain stationary and at a constant distance from the digital sensor used to acquire all of the images. The acrylic jig containing the root was then positioned at the center of the sensor so as to align perfectly with a square-shaped guide previously designed on the sensor, thus allowing the jig to be accurately repositioned during the experimental procedure.

Root canal instrumentation

The working length was established with a size 10 K file, using 5% sodium hypochlorite (Ogna; Muggiò, Milan, Italy) as irrigant, which was introduced into each canal until the file tip became visible at the major foramen under stereomicroscope (SOM 32; Karl Kaps GmbH & Co. KG, Asslar/Wetzlar, Germany) magnification. Subsequently, the file was withdrawn until the tip was tangential to the major foramen. The rubber stop was adjusted to the nearest flat anatomic landmark on the tooth, which was

Table 1 Characteristics of curved root canals ($n = 15$ teeth per group).

Group	Curvature (°)			Radius (mm)		
	Mean (SD)	Min	Max	Mean (SD)	Min	Max
WO	40.2 (3.39)	35	45	6.25 (1.17)	4.4	8.1
RE	40.6 (3.44)	35	45	6.21 (0.87)	4.2	7.5
OS	39.8 (3.76)	35	45	6.52 (1.11)	4.7	8.7
P	0.825			0.687		

OS = OneShape ; RE = Reciproc; WO = WaveOne.

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chosen as a reference for the measurement of the root canal. The distance between the file tip and the rubber stop was measured under the same magnification with a millimeter ruler. Then, 1 mm was subtracted from this measurement, and the resulting value was taken as the working length. A single operator, in accordance with the manufacturers' recommendations, performed instrumentation. Primary WaveOne files and Reciproc R25 instruments were operated in a reciprocating motion powered by a torque-limited electric motor (WaveOne Motor; Dentsply Maillefer) using preset adjustments, whilst OneShape instruments (size 25, taper 0.06) were operated in continuous rotation motion using an electric motor with a rotational speed of 400 rpm (MM Control; Micro-Mega). All instruments were used in a slow in-and-out pecking motion with amplitude of about 3 mm. The flutes of the instruments were cleaned after three in-and-out movements (pecks) and the root canal was flushed with 2 mL of a 5% NaOCl solution using a 30-gauge needle (NaviTip; Ultradent, South Jordan, UT, USA) that was inserted as deeply as possible into the canal without binding. Apical patency was maintained using a size 10 K file. Once the rotary instrument had negotiated to the end of the canal and had rotated freely, it was removed. Each instrument was used in four canals and then discarded.

Assessment of root canal preparation

After performing the preparations, the roots were repositioned in a predetermined position in the acrylic jig, and postoperative radiographs were taken with a #25 stainless steel manual file inside the canal. The digital radiographs were saved in JPG format and imported into Adobe Photoshop CS5 software (Adobe Systems Inc.). The images of the pre- and postinstrumentation radiographs were superimposed to compare the differences between pre- and postinstrumentation canal geometry (Figure 1). The images were then transferred to AutoCAD 2006 software (Autodesk Inc.) to measure the distance between the central axes at working length. The digital radiographs were taken in the same apparatus for the whole sample, and the data were stored in an optical magnetic disk. The evaluated parameters assessed by a blinded endodontist with research experience were change in angle of canal curvature, apical transportation, and working time. This last parameter was calculated starting through the insertion of the first file until the end of the instrumentation, including total active instrumentation, cleaning of the flutes of the instruments, and irrigation, whilst the time required to place and adjust the rubber stops to working length was not included. The number of fractured instruments was also recorded.

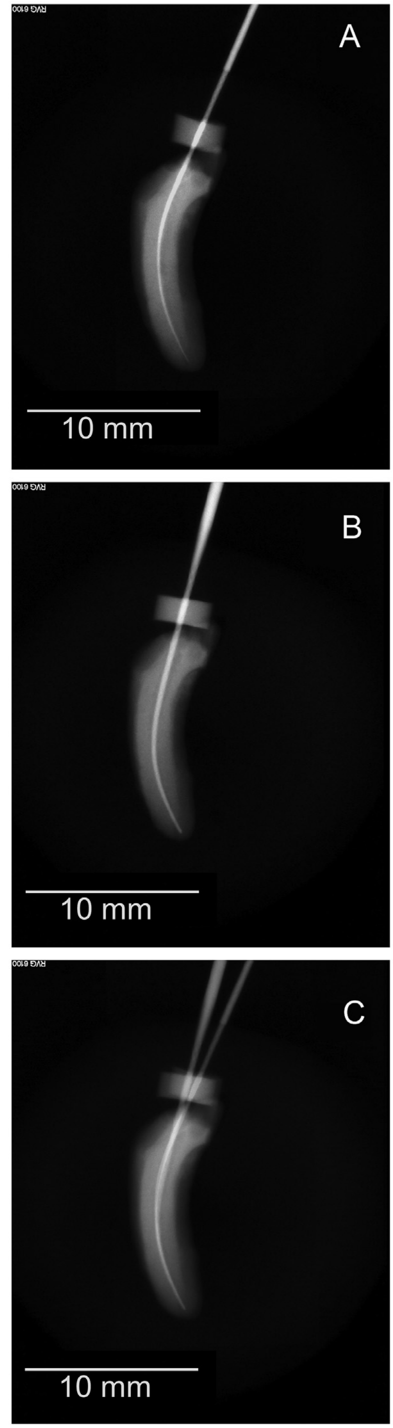

Figure 1 The radiographs at working length of (A) pre- and (B) postinstrumentation, (C) superimposed to compare the differences between pre- and postinstrumentation canal geometry.

Statistical analysis

Mean and standard deviations were determined for each group, and three different one-way analysis of variance tests were used to assess the significance of the factor under investigation (instrumentation system) on the three measured variables (change of the angle of canal curvature, apical transportation, and working time). The Shapiro-Wilk test was employed to assess the normal distribution of data in each group. The level of statistical significance was set at $P < 0.05$. All statistical analyses were performed by using the SPSS 15.0 software (SPSS Inc., Chicago, IL, USA).

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Results

No teeth were lost as a result of instrument fracture. No rotary instrument appeared deformed after preparing four canals. Mean and standard deviation values are shown in Table 2. No significant differences were found regarding canal straightening, apical transportation, or preparation time when preparing severely curved root canals (Table 2).

Discussion

The present study aimed to compare the maintenance of canal anatomy, the occurrence of apical transportation, and the working time of three single-file systems having different design features and using different working motions in curved root canals. The canal anatomy conservation is extremely significant considering the fact that the root canal enlargement is able to have an additional impact on tooth weakening, and also makes the restored tooth more susceptible to be fractured in the presence of fiber posts.[11–14] The results of the present study failed to demonstrate any influence of the file system used on the parameters "change of angle of curvature" and "apical transportation". Once the preparation was finished, a considerable part of the foramens kept their same initial prepreparation position, and the shape of the prepared canals maintained the same central axes existing before the performance of preparations, although with expanded lateral dimensions, due to the uniform use aroused by the instruments employed in the canal walls.

Statistically, the standard deviation of observations may increase when curved specimens are used.[10] Some studies have employed standardized artificial canals in training blocks with the aim to minimize this problem.[15,16] Nevertheless, the advantage related to testing file systems in the natural dentin of extracted teeth is likely to be greater than the benefit caused by observing smaller standard deviations in simulated canals.[8,10] This is a reason why natural teeth were employed in the present study. Efforts were made in the present study to safeguard the experimental groups comparability in spite of variations in the natural teeth morphology. To realize this described above, a computerized digital image processing system was employed to determine both the angle and the radius curvature.[17] The homogeneity of the three groups with respect to the defined constraints was statistically analyzed. According to the P values obtained (Table 1), the groups were well balanced with respect to the angle and the radius of canal curvature.

Concerning canal straightening, the results for all instruments were slightly higher than those of recent studies under similar experimental conditions.[2,6] This is probably due to the fact that, in the present investigation, canals with curvatures between 35° and 45° were instrumented, whereas in the aforementioned studies, this range was rather lower in as far as canals with curvatures between 25° and 35° were prepared.

WaveOne instruments have changing cross-sections along the working part, from a concave triangular cross-section with a radial land at the tip to a neutral rake angle with a triangular convex cross-section in the middle part and near the shaft.[3] Reciproc instruments have an S-shaped cross-section and two sharp cutting edges along the whole working part.[3,18,19] OneShape instruments have a changeable three cutting-edge design located at the tip region progressively changing from three to two cutting edges in the middle part, whereas near the shaft, the instruments have two cutting edges.[6] This design, employed in continuous rotation with comparatively higher speed, permits the instruments to rapidly move into the curved root canals.

The results of this study are in agreement with several previous studies.[1,3,6,20,21] Burklein et al[3,6] reported that WaveOne, Reciproc, and OneShape maintained the original curvature of severely curved canals in extracted teeth well. Also, although Saber el al[2] reported some significant differences regarding canal straightening and apical transportation between the three single file system, they concluded that from a clinical point of view, these differences might be of no importance. For this reason, the differences relating to the type of alloys (where WaveOne and Reciproc instruments are made of M-wire alloy while OneShape is made of conventional 55-NiTi alloy), to the design features of the instruments, and last but not least, to the working motions (reciprocal motion concern WaveOne and Reciproc and continuous rotation concern OneShape), did not appear to be decisive for the characteristics analyzed in this study.

Also concerning preparation time, no clinically relevant differences have been found among the three systems tested in this study. The recorded times were higher than those of recent investigations,[2,6] probably because of the greater curvature of tested specimens with respect to those of previous studies.

All instruments were employed with the aim to enlarge four curved canals and no instrument fracture was recorded. Therefore, these files could be used for enlargement of at least four canals by means of use of the instrumentation sequence described in this study, without higher chance of fracture. This means that a molar tooth with four root canals can be prepared with only one single-file instrument.

In conclusion, the results of the present investigation failed to reject the null hypothesis: no statistically significant differences exist among the tested single-file systems regarding canal straightening, apical transportation, or

Table 2 Mean values (SD) for experimental groups.

	WO group	RE group	OS group
Changes in angle of curvature (SD)* (°)	2.71[a] (0.29)	2.92[a] (0.41)	2.70[a] (0.33)
Apical transportation (SD)* (mm)	0.11[a] (0.01)	0.09[a] (0.02)	0.10[a] (0.03)
Working time (SD)* (s)	113.42[a] (15.70)	108.79[a] (12.65)	115.37[a] (13.13)

*The same superscripted letters indicate no significant differences ($P > 0.05$).
OS = OneShape; RE = Reciproc; SD = standard deviation; WO = WaveOne.

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preparation time when preparing severely curved root canals. On the inside of the parameters of this study, both continuous rotary instrument and reciprocating systems did not have any influence on apical transportation and they did not produce negative change in the angle of canal curvature. All single-file systems tested are efficient and safe, to prepare at least four severely curved canals.

Conflicts of interest

All authors disclose any potential sources of conflict of interest.

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