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ORIGINAL RESEARCH ARTICLE

Micro-CT Evaluation of Centering Ability and Canal Transportation of Protaper Ultimate and RevoS+ Rotary File Systems in Simulated Curved Canals

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Abstract

Purpose: A successful root canal preparation is to remove infected tissue and to obturate the canal three-dimensionally. The present study aimed to evaluate the centering ability of Protaper Ultimate and RevoS+ rotary file systems in curved canals of printed mandibular first molars by using micro-computed tomography (micro-CT).
Materials and Methods: In this study, 16 mandibular molar teeth were printed from resin with 45° mesial root curvature. The instrumentation procedure was performed according to the specified groups, either Protaper Ultimate or RevoS+. The pre-and post-preparation images were repositioned in all three spatial planes by DataViewer. All images were imported into the CTAn software for the calculation of the centering ability and transportation values.
Results: The results showed no significant differences between the Protaper Ultimate and RevoS+ groups in terms of the centering ratio in the most inclined part of the canal. There were also no significant differences between the groups in canal transportation. ($p>0.05$)
Conclusions: Protaper Ultimate and RevoS+ rotary file systems showed similar ability in centering ratio and canal transportation in curved canals from printed mandibular molars. This study reported that both systems provide a safe preparation in clinically curved root canals.

Key words: centering ratio; root canal preparation; simulated canals; transportation

Introduction

The major principle of successful root canal preparation is the full removal of infected pulp and dentin tissue in order to obturate the canal three-dimensionally. In the past 20 years, nickel-titanium (Ni-Ti) instruments have become popular tools in the advance of the endodontic field.[1] Various strategies have been developed, including different cross-section designs, thermomechanical heat treatment, and improvements of metallurgical properties in the production of Ni-Ti rotary endodontic file systems.[2] With the widespread use of Ni-Ti technology in modern endodontics; clinicians have focused on a more compatible and precise approach to the original root canal anatomy in canal shaping. Protaper Ultimate was introduced by Dentsply Sirona as the last-generation Protaper rotary file system, and it was developed to increase flexibility and provide greater resistance to cyclic fatigue. In this system, SX [SX 020.003v], Slider [016.002v], Shaper [020.004v], F1 [020.007v], F2 [025.008v], F3 [030.009v], files are available.[3]

GenENDO by Micro-Mega company produced RevoS+ rotary file system, with a fixed apical size of 25, and designed with a distinctly asymmetrical cross-section aimed at reducing stress on the instrument.[4] Electropolishing and heat treatment are applied to the Ni-Ti instrument, respectively. This file system includes the following shaping instruments: SC1+[25, 0.06], an instrument used to prepare the coronal and middle of the canal; SC2+[25, 0.04] is an instrument used at working length; and SU+[25, 0.06] is an instrument used in working length that summarizes the action of the previous two instruments.[5] However little is known about its working performance, especially from a perspective of in vivo through a three dimensional precision analysis.

Not only the type of endodontic file system and instrumentation techniques but also root canal morphology and degree of inclination

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Figure 1. 3D-printed tooth model after preparing mesial root canals

play an important role in canal preparation. Therefore, the mechanical preparation of narrow and curved root canals is a challenge for clinicians during routine endodontic treatment procedures. [6] Any change or deviation in the canal path can result in undesirable ledge and zip formation, strip perforation, or transportation. Moreover, some canal surfaces remain uninstrumented by the file, resulting in the accumulation of microorganisms. [7]

With developing technology, it is clinically valuable to evaluate instruments that allow root canal preparation faithful to the canal anatomy. The capacity to maintain a center position within the root canal is referred to as an instrument's centering ability. Thanks to the instrument's centering, symmetrical preparation is carried out. [8] Thus, it is possible to evaluate the rotary file systems for safe preparation. [9] Therefore, the purpose of this study was to compare the centering ability and canal transportation of Protaper Ultimate and RevoS+ rotary file systems in printed mandibular molars by using micro-CT.

Material and Methods

In this in vitro study, 16 mandibular molar teeth were printed from resin, with simulated 45° curved mesial root canals containing a radiopaque substance that simulates pulp tissue. A 3D molar tooth model was designed in Cura Slicing Software (Ultimaker, Netherlands) and produced with Stereolithography (SLA) printing. This study was performed with 32 mesial root canals according to G*Power analysis (n=16). All samples were scanned with a micro-CT device (Bruker Micro-CT SkyScan 1275, Kontich, Belgium) for initial scanning. The sample was fixed with orthodontic wax and irradiated with an X-ray source of the device at 40 kVp, 250 mA beam current, no filter, 24.7 µm pixel size, 0.2 rotation. The scanning was carried out in 360°. Other settings and parameters of the device were made under the manufacturer's recommendation. The micro-CT sections were examined in the Data Viewer program. Then, all samples were divided into two groups.

The working length in the mesio-buccal and mesio-lingual canals was measured after the micro-CT scan until it could be seen through the apical foramen using a #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland). Each canal's working length was calculated by taking this measurement and deducting 1mm. Root canal preparation was performed according to the manufacturer's instructions in specified groups.

- Group 1: Root canal preparation with Protaper Ultimate
- Group 2: Root canal preparation with RevoS+

5.25% sodium hypochlorite irrigation solution was used during the preparation. Finally, 5 mL of distilled water was used to irrigate the canals. After irrigation, the canals were dried with paper cones. A single endodontist performed all the experimental procedures. Figure 1 shows the 3D model after the canal preparations.

After instrumentation, all samples were placed in the holder of the micro-CT device according to the groups and re-scanned for the second time using the parameters specified in the initial scanning. The raw images were reconstructed after the second scan with the NRecon software (ver. 1.6.10.4, Bruker, X-ray, Belgium). Two-dimensional 1024 slices were obtained from each sample. Using the DataViewer software, the pre- and post-preparation photos were moved in all three spatial planes. These images were imported into the CTAn (version 1.20.3.0, Bruker X-ray Kontich, Belgium) software to calculate the centering ability and canal transportation. Figure 2 shows the teeth in DataViewer software and the distance calculated from the software.

The centering ratio was calculated according to certain formulas eq1: (m1 ¬ m2)/(d1 ¬ d2) or eq2: (d1 ¬ d2)/ (m1 ¬ m2) as previously suggested by Gambill et al. [10] If the value obtained is 1, it means excellent centering ability, and 0 indicates the poor centering ability of the instrument. The canal transportation values were calculated with the following formula eq3: (m1¬ m2) ¬ (d1 ¬ d2) [11].Figure 3 shows the distances from the canal and margin using equations 1, 2, and 3. All distances were measured at the most inclined level of root canals.

Table 1. Centering ratio values of rotary file systems

	N	Mean	Std. Deviation	Std. Error Mean	Sig. p=0.67
Protaper Ultimate	16	0.298	0.100	0.0250	
RevoS+	16	0.385	0.154	0.0386	

Table 2. Transportation values of rotary file systems

	N	Mean	Std. Deviation	Std. Error Mean	Sig. p=0.73
Protaper Ultimate	16	0.430	0.124	0.0439	
RevoS+	16	0.320	0.101	0.0360	

Statistical Analysis

SPSS program (The IBM SPSS Inc., Chicago, USA) version 26.0, was used to conduct all statistical analyses. An independent t-test was used to evaluate the homogeneity of the data and to compare the centering ratio of the groups.

Results

According to the results obtained, no significant difference was observed between the Protaper Ultimate and RevoS+ groups in terms of the centering ratio in the most inclined part of the canals. (p>0.05) Besides, there were no significant differences between the groups in terms of canal transportation. (p>0.05) Table 1 and Table 2 shows the results for centering ratio and transportation values for file systems. Figure 4 shows the representative micro-CT images after canal preparations.

Discussion

The American Association of Endodontists has identified excessive root canal curvature as a risk factor that could influence the course of treatment. [12,13] To provide effective canal shaping and disinfection in the endodontic treatment of curved canals, it is necessary to control factors such as the choice of file systems and root canal

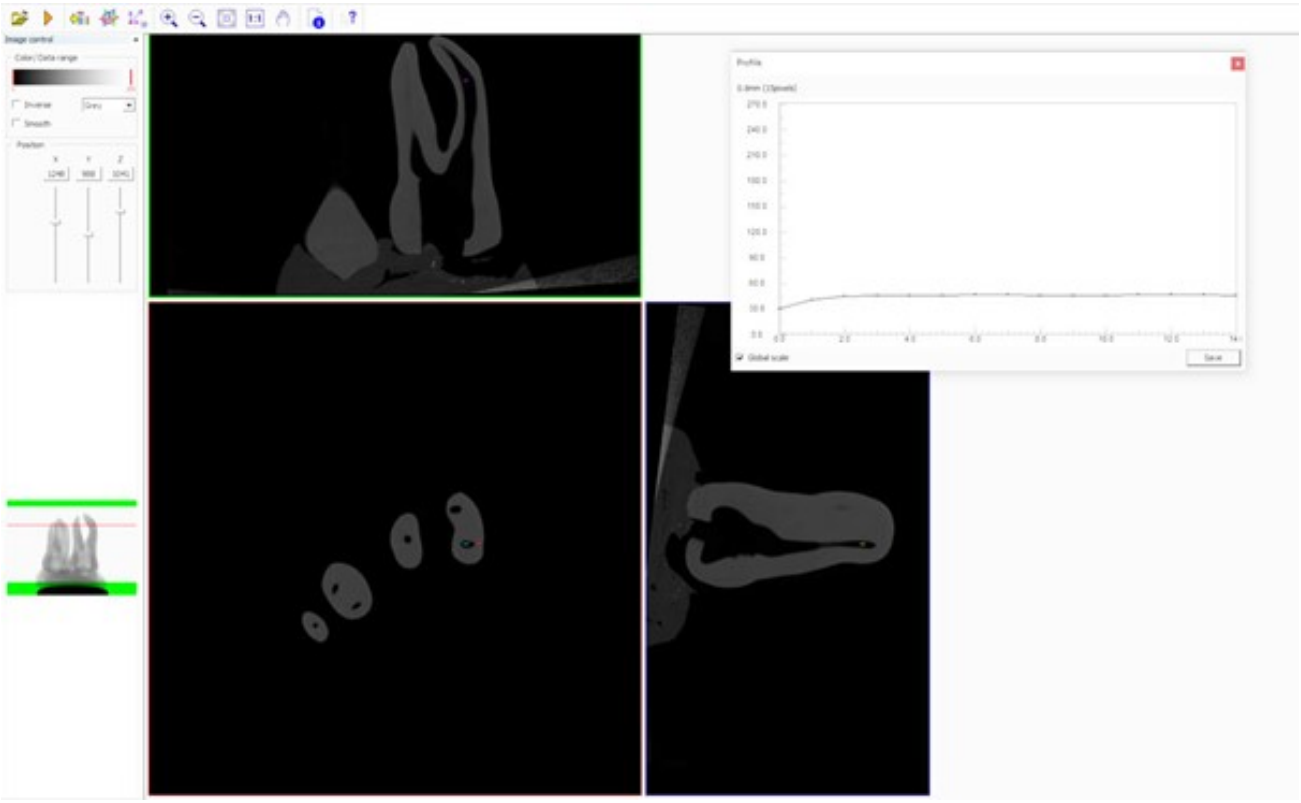

Figure 2. Examination of specimens in the DataViewer software

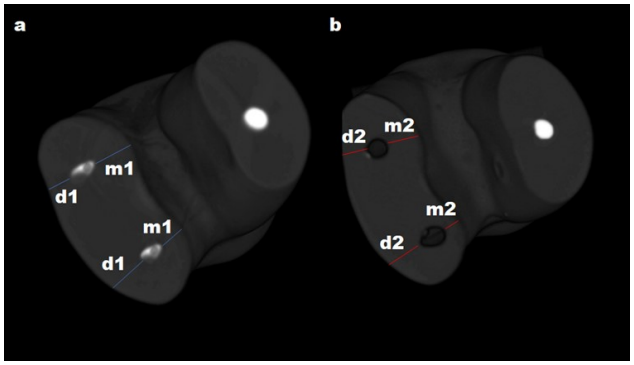

Figure 3. Determination of distances for equation:1,2,3. **a**; m1 and d1 distances **b**; m2 and d2 distances

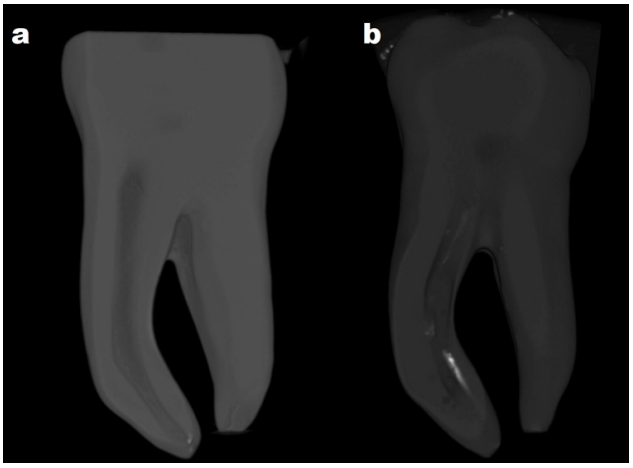

Figure 4. Micro-CT images after preparation with Protaper Ultimate b; Representative micro-CT images after preparation with RevoS+

preparation technique by the operators.

Ni-Ti rotary file systems have provided an advance that improves the quality of endodontic treatments by increasing the shaping efficiency and shortening the working time. [14] With continuous developments, the operator must select an appropriate system based on the anatomy of the root canal, the characteristics of the instrument, and self-experience in clinical practice. [15]

So far extracted human teeth have been used commonly in vitro studies. However, there are still limitations such as ethical concerns, collection, and standardization of human teeth samples with similar characteristics for in vitro examination. [16] Based on these considerations, the shaping ability of file systems has been often evaluated in replica teeth with different root canal configurations to overcome this problem. [17–19]

Resin-based printed teeth can be produced which could fully simulate the external and internal shape of the teeth in a s standard way by using 3D printing technology. This innovative approach allows the samples to be designed in various dimensions and inclination levels with features such as reproducibility and repeatability. [19]

Micro-CT as a perfect in vitro imaging modality, has provided a comprehensive understanding of morphometric parameters, including the complex anatomy of the root canal system, its apical diameter, shape, and geometry along the length of the canal. [20] The micro-CT method was therefore applied for comparisons before and after root canal preparation as well as visualization of printed teeth in our study. The danger zone, an anatomical region on the distal surface of the mesial root of the mandibular molars, is situated in the middle third of the root canal. [21] Removing more dentin from this region can often result in strip perforations in areas where curvature begins. [22] To avoid this undesirable complication, the instrument should move in accordance with the original anatomy of the root canal during preparation. The centering ratio is a measure of the instrument's ability to stay centered in the canal. [8]

Canal transportation is defined as the deviation of the root canal

from its natural axis after root canal preparation.[23] It can lead to the extrusion of debris, irrigation solutions, and filling materials in further steps of treatment,[24] which is also the reason why canal transportation was selected and analyzed. In this study, the centering ratio and canal transportation of Protaper Ultimate and RevoS+ file systems in the danger zone area was evaluated by using 3D-printed molar teeth. Protaper Ultimate and RevoS+ are brand-new endodontic file systems and there is no study evaluating their shaping ability in the literature so far as we know. However, the first versions of these files the Protaper Universal and Revo-S system were compared with the different rotary file systems in previous studies.[5,25,26] In a previous study, no significant difference was found between Revo-S, MTwo, and Protaper Universal, the first generation of the Protaper file systems in terms of centering ability.[27] Similarly, Saima et al.'s study showed no significant differences in centering ability between Protaper Universal and Revo-S at coronal, middle, and apical levels.[28] According to the study of Mao et al., while there was no apparent difference at other levels, the Protaper Next and Revo-S groups demonstrated significantly less transportation and superior centering ability than the Protaper Universal group at a distance of 1 mm from the apical foramen.[29]

Within the limitation of this study, the study was performed by using printed teeth under in-vitro conditions. However, there was a disadvantage that difference in hardness and radiopacity between dentin and resin-based material. With printing techniques, dentin-like 3D printing material can be developed in the future.

Conclusion

In cases of anatomical complexity, clinicians should consider an effective instrumentation method for endodontic treatment. The choice of instrument is a crucial step that determines the outcome of the treatment. Within the limitations of this study, Protaper Ultimate and Revo-S rotary file systems showed similar centering ratios and canal transportation values in curved canals.

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Author Contributions

All authors contributed to the study's conception and design. A.O. and A.B. performed material preparation, data collection, and analysis. A.O., B.C., and A.B. wrote the first draft of the manuscript. Y.H. and B.C. contributed to previous versions of the manuscript. All authors read and approved the final manuscript.

Conflict of Interest

The authors state that there is no conflict of interest in this study.

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