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ORIGINAL ARTICLE

Comparison of the shaping abilities of three nickel–titanium instrumentation systems using micro-computed tomography

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Abstract *Background/purpose:* The purpose of this study was to compare the canal transportation (CTR) and centering ratio (CR) of ProFile (PF), Twisted File (TF), and WaveOne (WO) nickel-titanium instrument systems and evaluate canal volume (CV) and surface area (SA) using micro-computed tomography (CT).
Materials and methods: Eighteen extracted human mandibular molars with two separate mesial canals were selected. The specimens were randomly divided into three groups of six teeth. Therefore, twelve root canals were allocated for each group ($n = 12$): group 1, PF(#30/.06); group 2, TF(#30/.06); group 3, WO (primary) instrument systems. Working lengths were determined 0.5 mm short of the apical foramen. Specimens were scanned before and after root canal preparation. Scanned images were reconstructed and the effects of root canal preparation on the CV and SA were evaluated. Pre- and post-instrumentation cross-sectional images of 1, 3, 5, and 7 mm from the anatomical apex were obtained and the CTR and CR were compared. The data were analyzed by the Kruskal-Wallis test and linear mixed model with Bonferroni's correction. A $P < 0.05$ was considered to be significant.
Results: Postoperative canals were larger and had greater SA, although these changes were not statistically significant ($P > 0.05$). At any levels (1-, 3-, 5-, and 7-mm), no significant difference was found in the amount of CTR among the groups ($P > 0.05$). At the 1-, 3-,

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and 7-mm levels there was no significant difference in the CR among the groups ($P > 0.05$). However, at the 5-mm level, WO group showed significantly smaller CR than PF group ($P < 0.05$).
Conclusion: Within the limitations of this study, WO showed smaller CR than PF, which imply that careful use of WO in curved canals is recommended.

Introduction

Cleaning and shaping of the root canal is one of the major procedures of endodontic treatment.[1] When curvatures are present, root canal preparation becomes more difficult, and there is a tendency to divert the prepared canal away from the original axis.[2,3] In the glossary of endodontic terms of the American Association of Endodontists,[4] root canal transportation is defined as "removal of canal wall structure on the outside curve in the apical half of the canal due to the tendency of files to restore themselves to their original linear shape during canal preparation; may lead to ledge formation and possible perforation". The preservation of the original canal shape and the lack of canal transportations are associated with sealing efficiency[5] and reduced weakening of the tooth structure.[6] The introduction of nickel–titanium (NiTi) rotary instrumentation has not only enabled easier and faster preparation of the root canal system but has also provided consistent, predictable, and reproducible shaping with considerably less iatrogenic damage.[7]

Recently, a new generation of the NiTi rotary instrument with higher flexibility and greater cutting efficiency has been introduced: the Twisted Files (TF) (SybronEndo, Orange, CA, USA). The manufacturer claims that R-phase heat treatment, surface conditioning and twisting of the metal significantly increases instrument resistance to cyclic fatigue and provides greater flexibility, maintaining the original canal center and minimizing canal transportation even in severely curved root canals.[8] Freire et al[9] found that at 3 mm and 4 mm from the anatomical apex, the TF system had lower levels of apical transportation and better centering ability than the EndoSequence (Brasseler, Savannah, GA, USA) system. The more recently introduced single-file NiTi system, WaveOne (WO) (Dentsply Maillefer, Ballaigues, Switzerland) is claimed to be able to completely prepare root canals with only one instrument. The system is designed to be used with a dedicated reciprocating motion motor, which might decrease the impact of cyclic fatigue on the NiTi rotary instrument, compared with rotational motion.[10] The files are made of a special NiTi alloy called M-Wire that is created by an innovative thermal treatment process. The benefits of this M-Wire NiTi are increased flexibility of instruments and improved resistance to cyclic fatigue.[11] Bürklein et al[12] have shown that root canal shaping with the WO instrument can be performed with a good centering ability in regularly curved canals of extracted teeth.

Micro-computed tomography (micro-CT) is particularly useful for studies on endodontic instrumentation because it allows two-dimensional (2D) and three-dimensional (3D) evaluation of root canal geometry and quantitative measurements of dentin removal from the canal walls. Indeed, a number of studies have used micro-CT-based imaging to look at the effects of various instrumentation efficiencies and techniques.[13,14]

The purpose of this study was to compare the amount of transportation and centering abilities of PF (Dentsply Maillefer), TF, and WO NiTi instrumentation systems and quantitatively evaluate canal volume and surface area produced by each system using micro-CT.

Materials and methods

Eighteen human mandibular molars with two separate mesial root canals were used. To facilitate the experimental set-up of micro-CT scanning, a mounting zig was prepared for the precise repositioning of the teeth. The occlusal surfaces of the teeth were ground flat and perpendicular to the long axis by a diamond disc. Then, the teeth were placed in the center of the object stage (13 mm in diameter and 2 mm in height) with the occlusal surface towards the floor. After pouring acrylic resin mixture (Ortho-Jet Powder and Liquid; Lang Dental, Wheeling, IL, USA) into the object stage, the teeth with mounting zigs were immersed in hot water. After 10 minutes, excess of acrylic resin was trimmed out. Thereafter, the access cavities were prepared, and mesial canals were localized and explored with a size 10 K-flexofile (Dentsply Maillefer), which was inserted into the canals until the tip was just visible at the apical foramen. Radiographs were taken in a mesio-distal projection to confirm the presence of two separate canals. Radiographs in the bucco-lingual direction were also taken to determine the root canal curvature. According to the Schneider method, only canals with a curvature between 10° and 20° were used.[15] Individual working lengths (WLs) were calculated 0.5 mm short of the apical foramen, ranging from 13 mm to 17 mm.

Specimens were randomly assigned to three groups ($n = 12$).

Group 1 (PF)

A glide path was established by using a size 10 and 15 K-flexofile. The canals were prepared in a crown-down fashion by an electric motor (Endo-Mate DT, NSK, Tokyo, Japan) with 2.0N cm of torque at 300 rounds per minute (RPM). A size 25/0.06 PF was used to two-thirds of the WL. The instrument was withdrawn when resistance was felt, and then followed by a size 30/0.06 PF to the same length.