Micro–computed Tomography versus the Cross-sectioning Method to Evaluate Dentin Defects Induced by Different Mechanized Instrumentation Techniques

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Abstract

Introduction: The objective of this study was to compare the methods of micro–computed tomography (micro-CT) and cross-sectioning followed by stereomicroscopy in assessing dentinal defects after instrumentation with different mechanized systems. **Methods:** Forty mesial roots of mandibular molars were scanned and divided into 4 groups (n = 10): Group R, Reciproc; Group PTN, ProTaper Next; Group WOG, WaveOne Gold; Group PDL, ProDesign Logic. After instrumentation, the roots were once again submitted to a micro-CT scan, and then sectioned at 3, 6, and 9 mm from the apex, and assessed for the presence of complete and incomplete dentinal defects under a stereomicroscope. The nonparametric Kruskal-Wallis, Friedman, and Wilcoxon tests were used in the statistical analysis. The study used a significance level of 5%. **Results:** The total number of defects observed by cross-sectioning followed by stereomicroscopy was significantly higher than that observed by micro-CT, in all of the experimental groups ($P \leq .05$). All of the defects identified in the postoperative period were already present in the corresponding preoperative period. There was no significant difference among the instrumentation systems as to the median numbers of defects, for either cross-sectioning followed by stereomicroscopy or micro-CT, at all the root levels ($P > .05$). In the micro-CT analysis, no significant difference was found between the median numbers of pre- and postinstrumentation defects, regardless of the instrumentation system ($P > .05$). **Conclusion:** None of the evaluated instrumentation systems led to the formation of new dentin defects. All of the defects identified in the stereomicroscopic analysis were already present before instrumentation, or were absent at both time points in the micro-CT analysis, indicating that the formation of new defects resulted from the sectioning procedure performed before stereomicroscopy and not from instrumentation. *(J Endod 2017;■:1–6)*

Key Words

Dental instruments, endodontics, evaluation methods, X-ray computed tomography

Significance

None of the evaluated mechanized instrumentation systems led to the formation of new dentin defects. All of the defects identified in the cross-sectional analysis were already present before instrumentation, or were absent at both time points in the micro-CT analysis.

Mechanized nickel-titanium instrumentation systems were incorporated into endodontic treatments, adding benefits such as simplification, optimization, and preservation of the original canal shape (1, 2). Thus, systems with different concepts were developed using instruments with different cross-sections and kinematics, as well as improved metal alloys (M-Wire and "controlled memory"), to ensure greater resistance to fatigue and greater flexibility (3, 4).

Recent studies, however, have shown that mechanized endodontic instrumentation can potentially cause dentinal defects (5–7). A method frequently used for the direct analysis of dentin defects after instrumentation is root cross-sectioning. However, in addition to causing the specimen to become unusable after analysis, this method provides only a 2-dimensional view, which may compromise correct interpretation of the results. Micro–computed tomography (micro-CT), on the other hand, is a noninvasive method that allows assessing the specimen in 3 dimensions, with the additional advantage of not rendering the specimen unusable, thus allowing it to be used in successive analyses at the different treatment stages (8).

The objectives of this study were to compare the methods of micro-CT and root cross-sectioning in evaluating complete (CDD) and incomplete dentin defects (IDD) after endodontic instrumentation with the Reciproc, ProTaper Next, WaveOne Gold, and ProDesign Logic systems, and also to compare these systems with regard to the number of dentin defects induced by their use. The null hypotheses tested were (1) that there is no difference between the micro-CT and cross-sectioning methods in terms of their ability to

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enable the observation of dentinal defects, (2) that there is no difference between the instrumentation systems in terms of the number of induced defects, and (3) that the use of the instrumentation systems tested does not result in the formation of dentinal defects in mesial canals of mandibular molars.

Materials and Methods

Selection of Teeth

This study was approved by the local Research Ethics Committee (protocol no. 1.676.753). The specimens used were expressly donated by the patients who were treated by one of the authors (C.P.S.) and who were indicated for tooth extraction owing to advanced periodontal disease. The teeth were placed in distilled water at the time of extraction and stored in the institutional biorepository for a maximum period of 3 months.

Forty mesial roots of first and second mandibular molars were used. The inclusion criteria were fully formed roots, roots with independent foramina, curvatures between 10° and 30° (9), and an initial foramen diameter corresponding to a #15 K-type file (Dentsply Maillefer, Ballaigues, Switzerland). The exclusion criteria were teeth with calcifications; dilacerations; pathologic internal, external, or apical root resorption; internal or external perforations in the furcation region; root caries; root cracks visible under a stereomicroscope at ×8 magnification; and previous endodontic treatment.

The sample size of 10 specimens per group provided a test power of 80%, with a type I error probability of 0.05, for an effect size of 0.70, as calculated by G * Power 3.1.9.2 software (Heinrich-Heine-Universität in Düsseldorf, Düsseldorf, Germany).

After endodontic access, a #10 K-type file (Dentsply Maillefer) was inserted into the mesiobuccal and mesiolingual canals until its tip was visible at the apical foramen. A silicone stop was fitted at the tip of the corresponding cusp to obtain the initial measurement of the specimen. The occlusal surface was abraded with a double-sided diamond disc no. 7013 (KG Sorensen, Barueri, SP, Brazil), coupled to a straight handpiece and micromotor operated at low speed and under refrigeration, to establish a standard specimen length of 18 mm. The working length for instrumentation was established 1 mm short of the apical foramen (10).

The distal root of the specimen was then sectioned under refrigeration with double-sided diamond disk no. 7020 (KG Sorensen) and then discarded. The surface of the mesial root was scaled with periodontal curettes (SS White Artigos Dentários Ltda., Rio de Janeiro, RJ, Brazil), and its surface was once again submitted to analysis under a stereomicroscope (Stemi 508; Carl Zeiss, Jena, Germany), at ×8 magnification. Specimens that showed evident fracture lines or cracks were excluded from the sample. The specimens were then stored in a 0.1% thymol solution for 24 hours for disinfection, and subsequently kept in distilled water until the instrumentation procedures were initiated (6).

Acquisition of Preinstrumentation Micro-CT Images

Initial scanning of all the specimens was performed individually with an X-ray microtomograph (SkyScan 1176; Bruker, Kontich, Belgium) operating at 80 KV and 310 μA, and performed by 360° rotation with a rotation step of 0.5°, to produce images with a voxel size of 17.42 μm. The selected filter was copper plus aluminum, and the average time taken to complete the scanning process of each specimen was 21 minutes and 41 seconds.

After image acquisition and projection in 2 dimensions, the cross-sections were reconstructed with NRecon v.1.6.9 software (Bruker) using the modified Feldkamp cone-beam reconstruction algorithm, with beam-hardening correction of 40% and ring artifact correction = 10, resulting in 800 to 900 cross-sections per specimen (11).

Root Canal Preparation

Before chemomechanical preparation, the roots were coated with hydrophilic vinyl polysiloxane impression material (Express XT, Neuss, Germany), and embedded in acrylic resin to form a flask system simulating the bone and periodontal ligament, leaving the most apical 2 mm of the specimen exposed (12). Specimens were randomly assigned (www.random.org) to 4 groups (n = 10), and the relative uniformity of root angulation in the different specimen groups was confirmed by the Kruskal-Wallis test (P = .0993). The canals were then instrumented by the same experienced operator and the following experimental groups were formed.

Group R. The R25 instrument (25/0.08) of the Reciproc system (VDW GmbH, Munich, Germany) was used in reciprocating motion, according to a sequence of 3 in-and-out movements with an average amplitude of 3 mm in the cervical, middle, and apical levels, until reaching the working length.

Group PTN. The instruments of the ProTaper Next system (Dentsply Maillefer) were used in rotary motion at 300 rpm and applying a torque of 2 Ncm. The X1 instrument (17/0.04) was initially used for cervical preparation, and then the X1 and X2 (25/0.06) instruments were applied up to the working length using in-and-out movements.

Group WOG. The Primary instrument (25/0.07) of the WaveOne Gold System (Dentsply Maillefer) was used in a manner similar to that described for Group R.

Group PDL. The instruments of the ProDesign Logic system (Easy Equipamentos Odontológicos, Belo Horizonte, MG, Brazil) were used in a rotary motion. The 25/0.01 instrument was used at 350 rpm and 1 Ncm torque, applying slow and gentle in-and-out movements until achieving foraminal patency, and then the 25/0.06 instrument was used until reaching the working length with in-and-out movements, at 950 rpm and 4 Ncm torque.

The X-Smart Plus motor (Dentsply Maillefer) was used in all systems. Both the speed (rpm) and torque (Ncm) settings, as well as the kinematics applied to the instruments followed the recommendations of the respective manufacturers. Each instrument was used in 4 canals (13) and then discarded.

Patency was checked at each instrument change with a #10 K-type file (Dentsply Maillefer). Irrigation was performed with 2.5% sodium hypochlorite (NaOCl) at each instrument change or, in the case of the reciprocating system, after every 3 movements of entry and exit. Irrigation was performed with a 10-mL disposable hypodermic syringe and 30-gauge needle (Ultradent, South Jordan, UT). After the chemomechanical preparation, the canals were irrigated with 5 mL of 17% ethylenediaminetetraacetic acid (EDTA) for 1 minute, followed by a final irrigation with 5 mL of 2.5% NaOCl, for a total 40 mL of NaOCl solution per canal. Afterward, final aspiration was performed with a capillary tip (Ultradent), followed by drying of the canals with absorbent paper points (Dentsply Maillefer).

Evaluation of Pre- and Postinstrumentation Micro-CT Images

After the specimen was removed from the experimental flask, a new micro-CT scan and reconstruction of the tomographic image was performed following the same protocol as that of the initial scan.

Pre- and postinstrumentation images were geometrically aligned using the DataViewer program (version 1.5.1; Bruker). The cross-sections of the recorded images were then visualized using CTAn software (version 1.14.4; Bruker). The volume of interest of each specimen extended from the furcation region to the apex of the mesial root.