Computed Micro-Tomographic Evaluation of Glide Path with Nickel-Titanium Rotary PathFile in Maxillary First Molars Curved Canals

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Abstract

Introduction: X-ray computed micro-tomography scanning allows high-resolution 3-dimensional imaging of small objects. In this study, micro-CT scanning was used to compare the ability of manual and mechanical glide path to maintain the original root canal anatomy. **Methods:** Eight extracted upper first permanent molars were scanned at the TOMOLAB station at ELETTRA Synchrotron Light Laboratory in Trieste, Italy, with a microfocus cone-beam geometry system. A total of 2,400 projections on 360° have been acquired at 100 kV and 80 μA, with a focal spot size of 8 μm. Buccal root canals of each specimen (n = 16) were randomly assigned to PathFile (P) or stainless-steel K-file (K) to perform glide path at the full working length. Specimens were then microscanned at the apical level (A) and at the point of the maximum curvature level (C) for post-treatment analyses. Curvatures of root canals were classified as moderate (≤35°) or severe (≥40°). The ratio of diameter ratios (RDRs) and the ratio of cross-sectional areas (RAs) were assessed. For each level of analysis (A and C), 2 balanced 2-way factorial analyses of variance ($P < .05$) were performed to evaluate the significance of the instrument factor and of canal curvature factor as well as the interactions of the factors both with RDRs and RAs. **Results:** Specimens in the K group had a mean curvature of 35.4° ± 11.5°; those in the P group had a curvature of 38° ± 9.9°. The instrument factor (P and K) was extremely significant ($P < .001$) for both the RDR and RA parameters, regardless of the point of analysis. **Conclusions:** Micro-CT scanning confirmed that NiTi rotary PathFile instruments preserve the original canal anatomy and cause less canal aberrations. *(J Endod 2012;38:389–393)*

Key Words

Computed micro-tomography scanning, glide path, nickel-titanium, nickel-titanium rotary instrumentation, PathFile

Nickel-titanium (NiTi) rotary instruments reduce operator fatigue, the time required for shaping, and the risk of procedural errors associated with root canal instrumentation (1, 2). Superelasticity properties enable NiTi rotary files to be placed in curved canals exerting less lateral forces on the canal walls and maintaining the original canal shape (3, 4). NiTi rotary tools have unique design properties in terms of cross-sectional shape, taper, tip, and the number and angle of flutes. These properties improve the shaping process without creating canal aberrations, particularly in narrow and severely curved canals (2). Preserving root canal anatomy represents a major issue difficult to overcome. Despite this, several studies showed that shaping outcomes with NiTi rotary instruments are generally predictable (5, 6). Coronal enlargement and manual or mechanical preflaring to create a glide path was shown to be the first step for a safer use of NiTi rotary instrumentation because it prevents fractures of torsion instruments and shaping aberrations (7–9). Recently, NiTi rotary PathFiles (PFs) (Dentsply Maillefer, Ballaigues, Switzerland) were introduced to improve mechanical glide path (7, 10). These instruments are more capable of maintaining the original canal anatomy and cause less aberrations and modifications of canal curvature compared with manual preflaring performed with stainless-steel K-files (KFs) (7). Of note, clinician's expertise did not appear to have a significant impact on outcome (7). A number of techniques were used to evaluate endodontic instrumentation (3), such as plastic models (11), histological sections (12), scanning electron microscopic studies (13), serial sectioning with Bramante technique (14), radiographic comparisons (15), and silicon impressions of instrumented canals (16). X-ray micro–computed tomography (CT) scanners are based on cone-beam geometry and are optimized to obtain nondestructive high-resolution (from 1 to 10s of micrometers) 3-dimensional (3D) imaging of small objects. The main component of this scanner is the microfocus x-ray source featuring a spot size of <50 μm (usually only a few microns). Differently from the medical CT scan, the specimen is mounted on a high-precision rotation stage and revolves around its own axis, whereas the x-ray source and the detector are steady. The 3D reconstruction of the data is usually based on the Feldkamp algorithm (17). The micro-CT scan has recently emerged as a powerful

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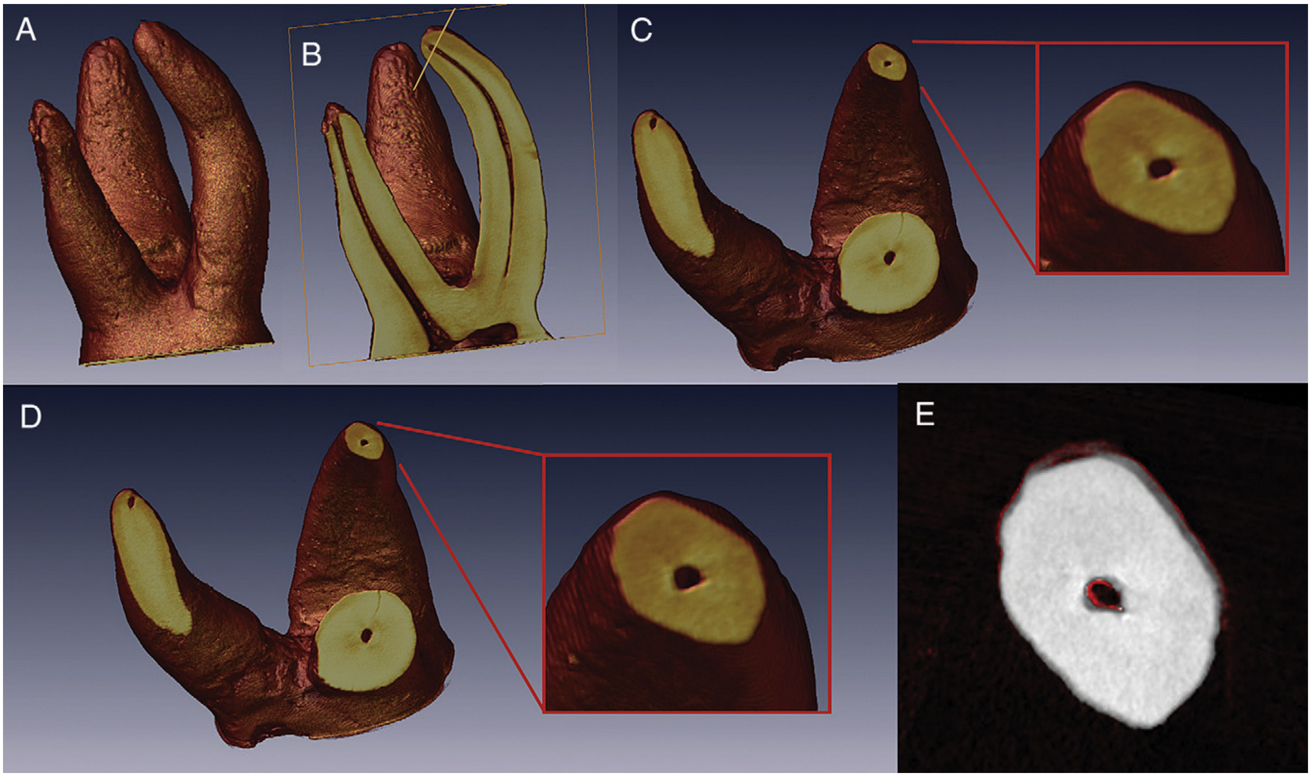

Figure 1. (*A*) A 3D reconstruction of a specimen. (*B*) The root canal path with selection of the cutting plane. (*C*) The cutting plane orthogonal to the canal axis in the pretreatment specimen. (*D*) The same cutting plane in the post-treatment specimen. (*E*) Image matching of the 2 radiologic sections, according to the previously selected cutting plane, shows the difference of the canal diameters between the pre- (*red*) and post-treatment (*gray*) specimens.

tool for the evaluation of root canal morphology. This noninvasive technique allows a detailed 3D evaluation of the effects of canal preparation on anatomy (18). It also allows the superimposition of 3D renderings of preoperative and postoperative canal system with a high resolution. In this study, we aimed to compare the ability of the manual and mechanical glide path to maintain the original root canal anatomy by using the micro-CT technique.

Materials and Methods

Eight extracted upper first permanent molars with a fully formed apex that had not undergone prior endodontic treatment were used. After debriding the root surface, specimens were immersed in a 5% solution of NaOCl (Niclor 5; OGNA, Muggiò, Italy) for 1 hour and then stored in saline solution.

Micro-CT Analysis

Specimens were mounted on a stable support and then scanned at the TOMOLAB station (19) at ELETTRA Synchrotron Light Laboratory in Trieste, Italy. The system is based on a cone-beam geometry with the following characteristics: (1) a sealed tungsten microfocus x-ray tube, with a focal spot size ranging from 5 to 40 μm, an energy ranging from 40 to 130 kV, and a maximum current of 300 microA and (2) a water-cooled charge-coupled device (CCD) camera with a large field of view (49.9 mm $\times$ 33.2 mm) and a small pixel size (12.5 $\times$ 12.5 μm). A total number of 2,400 projections on 360° at 100 kV and 80 μA, a focal spot size of 8 μm, with a focus-object and focus-detector distance of 110 mm and 300 mm, respectively, in a timeframe of 2 hours 32 minutes for each specimen was acquired.

Axial images were reconstructed by means of Cobra 7.2 software (Exxim, Pleasanton, CA) and subsequently elaborated for artifacts removal using PORE3D (20), a software developed at the ELETTRA research center. High-resolution raw 16-bit images were converted to an 8-bit TIFF file format; the whole stack gives a volume of around 1,000 $\times$ 1,000 $\times$ 1,000 isotropic voxels featuring a 9.2-μm side length. Each image stack was first equalized by ImageJ 1.43u 64 bit (a freeware software by the National Institutes of Health, Bethesda, MD) and then processed by Amira 5.3.3 64 bit edition (Visage Imaging, Richmond, Australia) for volume registration and cutting plane selection. The registration algorithm was based on the mean square difference between the gray values of the 2 image sets. The alignment steps have been set to 0.9 μm with a tolerance of 0.0001 units on the voxel intensity.

Each root canal path was studied dynamically by examining both high-resolution 3D rendering and orthogonal cross-sections. Root sections orthogonal to the canal axis were set at 2 different levels: at 1 mm from the canal apex (A) and at the point of maximum curvature (C). The cutting plane orientation was the same for both the pre- and post-treatment samples. This axial sections have been imported in TIFF format and analyzed with ImageJ to measure area, perimeter, and diameters (major and minor, orthogonal to one another) by using an automatic thresholding algorithm to avoid manual errors. Measurements were performed twice by the same operator (intraobserver control) and once by another operator (interobserver control).

Specimen Preparation

After access cavity preparation, the working length (WL) was established under microscopic vision (OPMI Pro Ergo; Carl Zeiss,