Accuracy of Cone-beam Computed Tomography in Measuring Dentin Thickness and Its Potential of Predicting the Remaining Dentin Thickness after Removing Fractured Instruments

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Abstract

Introduction: The purpose of this study was to evaluate the accuracy of cone-beam computed tomographic (CBCT) to measure dentin thickness and its potential of predicting the remaining dentin thickness after the removal of fractured instrument fragments. **Methods:** Twenty-three human mandibular molars were selected, and 4-mm portions of #25/.06 taper K3 files (SybronEndo, Orange, CA) were fractured in mesial canals. The teeth were then scanned using a micro–computed tomographic (micro-CT) system and a CBCT unit. Dentin thickness was measured and compared between both micro-CT and CBCT images to study the accuracy of CBCT readings. Then, the process of removing the fragments was simulated in CBCT images using the MeVisLab package (MeVis Research, Bremen, Germany); the predicted minimal remaining dentin thickness after removal was measured in different layers using VGStudio MAX software (Volume Graphics, Heidelberg, Germany). Data were compared with the actual minimal remaining dentin thickness acquired from micro-CT images, which were scanned after removing fractured instruments using the microtrepan technique. The results were analyzed statistically using intraclass correlation coefficients (ICCs) and a forecasting regression model analysis. **Results:** The ICC for the dentin thickness was 0.988. The forecasting regression model of CBCT imaging estimating dentin thickness was micro-CT imaging = 15.835 + 1.080*CBCT, R^2 = 0.963. The ICC for the remaining dentin thickness was 0.975 ($P < .001$). The forecasting regression model of CBCT imaging forecasting remaining dentin thickness was micro-CT imaging = 147.999 + 0.879*adjusted CBCT, R^2 = 0.906. **Conclusions:** The study showed that CBCT imaging could measure dentin thickness accurately. Furthermore, using CBCT images, it is reliable and feasible to forecast the remaining dentin thickness after simulated instrument removal. *(J Endod 2017;■:1–6)*

Key Words

Cone-beam computed tomographic imaging, dentin thickness, instrument fragment removal, micro–computed tomographic imaging, treatment simulation

Significance

CBCT imaging can be used to measure the dentin thickness and predict the remaining dentin thickness after removing fractured instrument fragments using the microtrepan technique. It is instructive to making clinical decisions about cases with fractured instruments.

Root canal preparation is an essential part of root canal treatment. The introduction of rotary nickel-titanium (NiTi) endodontic instruments has improved the efficacy of the process and enhanced the success rate of treatment (1). However, the fracture of rotary NiTi files remains a concern among endodontists because of the possibility of intracanal file fracture (2). Researchers have reported a frequency of rotary instrument fracture from 0.9%–5.1% depending on the study design and the brand of rotary instruments (3).

Contemporary clinical studies suggest that the prognosis for endodontic treatment is not significantly affected by the presence of a retained instrument fragment (4). However, the prognosis may be reduced when a fractured instrument compromises effective disinfection of a root canal associated with periapical pathosis.

The management of a case with a broken instrument and a retained fragment might involve an orthograde or a surgical approach. In an orthograde approach, a retained instrument fragment may be managed in the following ways:

1. By removal
2. With bypassing
3. By preparing and filling the root canal to the level of the fragment

In general, if the fragment is located in the apical third of the canal or beyond the canal curvature, clinicians usually elect to leave it *in situ* (5). If the fragment is located in the coronal two thirds of the canal or before the canal curvature, there is no consensus

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on management approaches in current practice. However, supported by favorable conditions such as techniques and sufficient devices, it would seem more prudent to remove the fragment, rather than bypassing it, so that cleaning and shaping of the root canal system could be completed effectively, especially when the tooth is strategically important (6).

In the management of separated instruments, the ultimate goal is not only to retrieve the fragment but also to preserve the integrity of the tooth (6). Minimum remaining dentin wall thickness is thought to be an important factor associated with the long-term outcome in general and issues like fracture and perforation specifically (7). Therefore, it is relevant to evaluate dentin thickness before trying to remove a fractured instrument from the root canal.

Numerous methods have been proposed for the assessment of radicular wall thickness (eg, radiographs, serial sectioning, micro–computed tomographic [micro-CT] imaging, and cone-beam computed tomographic [CBCT] imaging) (8–10). Studies revealed that a radiograph showed greater thicknesses than were actually present. Therefore, radiographs should not be considered a reliable method for this task (11).

Earlier studies included sectioning the tooth to directly measure the canal wall thickness (10). This method is destructive, and the samples cannot be used for further studies or as their own control. Recently, a nondestructive method (ie, micro-CT imaging) and simulation techniques based on micro-CT–derived data sets have been introduced to endodontic research (12). However, this method is limited to laboratory use because of high radiation doses and limited specimen size.

The use of CBCT imaging is increasingly popular because of its higher diagnostic yield compared with apical radiographs regarding apical periodontitis (13), vertical root fractures (14), or root perforations (15). The outcome of root canal treatment may also be improved when using this imaging modality (16).

Most of the attention regarding endodontic applications of CBCT imaging has been focused on the diagnosis of periapical lesions caused by pulpal inflammation, visualization of canals, detection of internal and external resorption, and diagnosis of root fractures (17). However, so far, only recently has CBCT imaging been introduced to evaluate dentin thickness before or after the removal of a fractured instrument (18).

Therefore, the aim of this study was to evaluate the accuracy of CBCT imaging in measuring radicular dentin thickness. Moreover, the study tested the ability of CBCT-derived simulations to predict the remaining dentin thickness after removing fractured instrument fragments.

Materials and Methods

Creating Fractured Instrument Models

Twenty-three mandibular molars with a similar canal shape, size, and curvature in the mesiobuccal and mesiolingual canals were selected from a collection of extracted human teeth from a Chinese population sample based on micro-CT prescanning and 3-dimensional reconstruction. These teeth were ultrasonically cleaned and stored in 0.1% thymol solution until use. The study had been approved by the university ethics board (WCHSIRB-D-2013-171).

Standard access cavities were prepared for all teeth. To generate file fractures at predictable levels within a canal for each member of the experimental group, #25/.06 taper K3 NiTi instruments (SybronEndo, Orange, CA) were used, which were notched to a depth of half the instrument diameter at a point 4 mm from the file tip as described previously (19). The notched instruments were then placed into a randomly selected mesial canal at 250 rpm. Instrument fracture occurred approximately 5 mm apical from the canal orifice, thus creating 23 specimens with retained fragments.

Obtaining Micro-CT and CBCT Images

The specimens were sequentially scanned using a micro-CT system (μCT-50; Scanco Medical, Bassersdorf, Switzerland) with an isotropic voxel size of 30 μm and a CBCT system (3D Accuitomo; Morita, Kyoto, Japan) with an isotropic voxel size of 125 μm. Volumetric data obtained from both scanners were converted to the Digital Imaging and Communication in Medicine format for analysis.

Simulating the Removal of Fractured Instruments

First, CBCT data were imported into a framework system (MeVisLab; MeVis Research, Bremen, Germany) to provide an environment for interactively performing a virtual canal preparation. The procedure was based on a typical microtrepan bur shape to simulate the course of fractured instrument removal according to the actual condition.

Similar to our previous study (20), the work flow included the following steps:

1. Build a 3-dimensional data set from the scanned fractured instrument model CBCT image,
2. Create a virtual trepan bur (a cylinder) in the canal and set the size of the needed trepan (900-μm diameter according to the actual size),
3. Interactively place the virtual trepan bur to a proper position around the fractured instrument (1–1.5 mm apical to the coronal end) and simulate removing dentin to form a narrow parallel cylindrical space, and
4. Save the image with the cylinder for subsequent analysis (Fig. 1).

Removal of Fractured Instruments

All 23 fractured instruments were removed from the specimens using a microtrepan bur and/or microtube technique. Coronal enlargement of the canals to a smooth tapered shape in order to visualize the fragment was performed using Gates Glidden burs (#1–#3) visualized under a microscope (Pico; Carl Zeiss, Jena, Germany). Gates Glidden burs were modified by grinding the bur perpendicular to their long axis at the maximum cross-sectional diameter. A staging platform was then prepared at the coronal end of the retained instrument fragment to provide sufficient space around the instrument, which allows the introduction of the trepan bur, using modified Gates Glidden burs sequentially up to size #3. This procedure has been comprehensively described by Ruddle (21).

After creating the staging platform, the 20-G microtrepan bur (outside diameter = 0.9 mm, inside diameter = 0.6 mm; Micro-Retrieve & Repair System; Superline NIC Dental, Shenzhen,

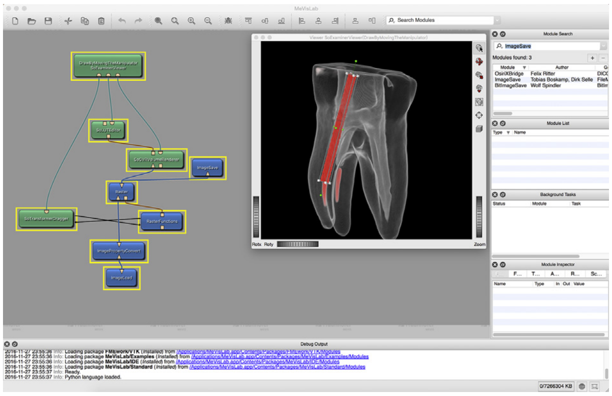

Figure 1. Simulating the removal of fractured instruments using the MeVisLab package.