Reciprocating Root Canal Technique Induces Greater Debris Accumulation Than a Continuous Rotary Technique as Assessed by 3-Dimensional Micro–Computed Tomography

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Abstract

Introduction: The ability of single-file, reciprocating instruments to remove inorganic debris is uncertain. By using micro–computed tomography (microCT), this study compared the 3-dimensional distribution, quantity, and density of remaining inorganic debris in the mesial root of mandibular molars after instrumentation. A single reciprocating file was compared with a multifile rotary instrumentation technique. **Methods:** Teeth were selected for instrumentation using reciprocating or rotary instruments (n = 19). Teeth were scanned using microCT before and after instrumentation. Through shape recognition and superimposition image analysis techniques, remaining inorganic tissue debris was identified, quantified, and visualized 3-dimensionally, mapping debris to its location. The use of a density phantom enabled the debris density to be calculated, giving a measure of compactness. **Results:** After single-file instrumentation, an average of 19.5% debris remained in the canal compared with 10.6% with the multifile technique (P = .01) and at an average density of 1.60 g/m^3 compared with 1.55 g/m^3 for the multifile system (P > .05). Isthmuses, protrusions, and irregularities in the canal wall were repeatedly seen at the locations of debris accumulation. **Conclusions:** In canals with a high prevalence of isthmuses and protrusions, using multifile rotary systems may be preferred over reciprocating files because it can yield cleaner canals with less debris accumulation. *(J Endod 2013;39:1067–1070)*

Key Words

Debris, micro–computed tomography, reciprocate movement, root canal preparation

Since the introduction of a single-file root canal preparation technique (1), the technique has increased in popularity with the introduction of commercial systems that use this concept including Reciproc (VDW, Munich, Germany) and WaveOne (Dentsply Maillefer, Ballaigues, Switzerland). The use of only 1 file is achieved through a reciprocating motion (2). A forward counterclockwise rotation is used to cut dentine, and a subsequent shorter clockwise rotation prevents the file from locking into the canal wall, which would result in extended cyclic fatigue. Single-file systems are clinically appealing because they are easier to apply and more cost-effective than multifile approaches (2).

Research findings have generally been favorable toward a single-file, reciprocating motion, with most studies reporting a decreased preparation time (3–6), increased cyclic fatigue life (2, 7, 8), and a shaping ability similar to that of multifile systems when applied in a variety of canal types (4–6, 9, 10). However, the quality of the debridement process is controversial. For example, De-Deus et al (11) reported significantly greater debris accumulation using the single-file reciprocating F2 technique compared with the ProTaper series (Dentsply Maillefer) in single-rooted lower incisors. In contrast, Burklein et al (5) reported significantly less debris accumulation when comparing the same instruments in curved single-rooted teeth.

Previous investigators have relied on 2-dimensional (2D) cross-sectioning imaging techniques including scanning electron microscopy, radiographs, and optical microscopy (5, 11). Given the importance of debris removal and the clinical and research interest in single-file systems, the purpose of this study was to investigate using a 3-dimensional (3D) analytic approach on the inorganic tissue remaining in mandibular molars after instrumentation. Debris was fully quantified and visualized 3-dimensionally by using micro–computed tomography (microCT), a noninvasive and nondestructive methodology that does not require mechanical cross-sectioning (12). The methodology used was an improved version of previous methodology, enabling debris to be quantified in newly created canal space (12–14). This was combined with density measurements to provide insights into how debris is packed. The null hypothesis was that there was no difference in the accumulation and density of inorganic debris between the single-file reciprocating WaveOne and the multifile rotary ProTaper approach for canal preparation.

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Materials and Methods

Tooth Selection and Preparation

Mandibular molar teeth were obtained from the School of Dentistry's collection of extracted teeth. Teeth were preserved at −20°C before use and subsequently stored in a 0.1% thymol humid environment to maintain hydration (15). Ethical approval was obtained (consent no: 09/H0405/33, BBC CLRN RM&G Consortium Trusts, UK).

Anatomic images were acquired by microCT (Skyscan 1172; e2v technologies plc, Chelmsford, UK), and biological variation was minimized by selecting teeth with complete isthmuses as described by Weller et al (16). Teeth having continuous isthmuses were divided into 2 groups consisting of at least 19 teeth per group, which underwent the same treatment procedure. The first group was instrumented using the WaveOne and the second with the ProTaper universal series. Lengths of the canals were measured from the anatomic images using CTAn (e2v technologies plc). Mesial canals were identified and negotiated to length by a clinician who had no prior knowledge of the canal morphology. All teeth were accessed using a 501 diamond bur (Dentsply, Addlestone, UK) and prepared to length using a crown-down technique. A glide path was established to size 15. Teeth were irrigated with 6% aqueous sodium hypochlorite (Vista Dental, Racine, WI) with a 27-G needle (Monoject; Tyco Healthcare, UK Ltd, Gosport, UK). After preparation, teeth were rescanned by microCT, and debris was quantified by an image analyst with no prior knowledge of each treatment group.

Rotary and Reciprocating Instrumentation

For the rotary group, canals were prepared using ProTaper files from Dentsply. Canals were shaped to length with Shapers 1 and 2 files and continued with Finishers 1 and 2 to ½ mm and 1 mm short of the working length. One milliliter of irrigant was applied immediately after creation of a glide path and shaping with each file. For the reciprocating instrumentation group, canals were shaped with a WaveOne Primary file (Dentsply) to two thirds of the length and finally to the full length. One milliliter of irrigant was applied after creation of the glide path and 2 mL after each usage of the Primary file.

Image Acquisition and Analysis

Teeth were scanned and analyzed using microCT as described by Robinson et al (12). Entire lengths of teeth were scanned at 89 kV, 110 μA, at an isotropic resolution of 13.6 μm. Teeth were scanned both before and after instrumentation. Original canal space occupied by dentine after instrumentation was identified using a co-registration approach, and debris in newly created canal space was identified by its shape through mathematic morphology. Co-registration was performed with 3D Slicer 3.6 (available from http://www.slicer.org/) and the other steps in Matlab 7.8.0.347 (The MathWorks, Cambridge, UK). Debris was calculated as a percentage of total debris remaining in the canal after instrumentation.

Hydroxyapatite phantoms of 1.21, 1.29, 1.40, and 1.56 g/m^3 were synthesized as described by Mobasherpour et al (17). They were then used to obtain a calibration curve having an r^2 value of 0.955. Debris was identified as previously, and the average voxel density was calculated.

Statistical Analysis

Normality plots and a Lilliefors test indicated that the 2 datasets of debris accumulation each followed a normal distribution. The Levene test indicated that the variances were unequal, and, therefore, a 2-sample t test for unequal variances was used to test for statistical significance of debris accumulation. Because debris density data did not follow a normal distribution, a nonparametric test was used.

Results

The reciprocating instrument left an additional 8.9% debris in the canals, which was statistically significant compared with the continuous rotary instrument (P = .01, Fig. 1). Debris accumulated in these teeth at an average density of 1.60 g/m^3 compared with 1.55 g/m^3 for the reciprocating multifile system (P > .05). 3D representative debris maps display accumulation (Fig. 2) and visually agree with the quantitative results (Fig. 1). The majority of the debris was detected in uninstrumented regions of the teeth including protrusions in the canal wall

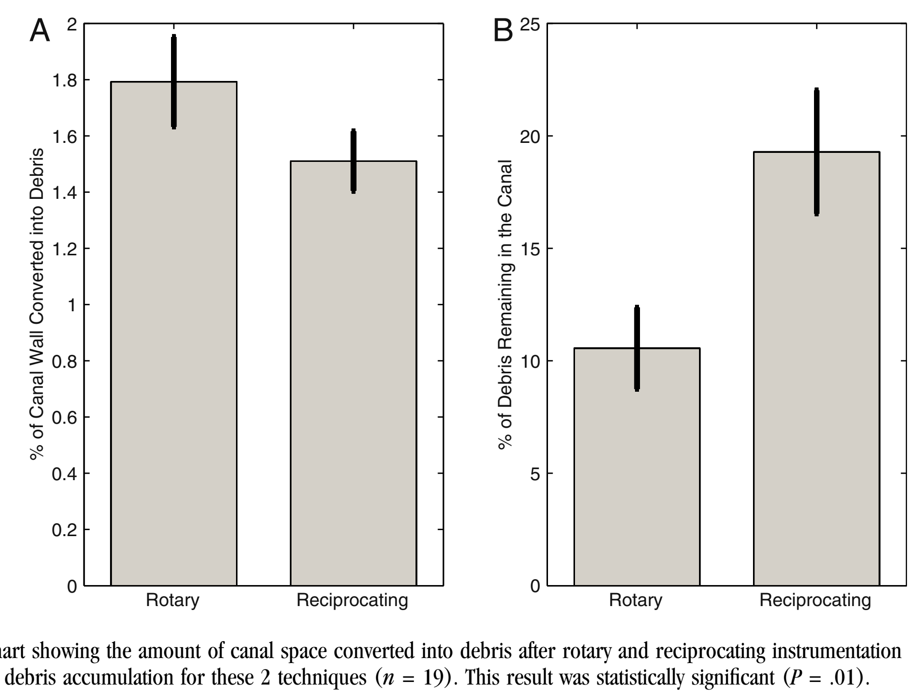

Figure 1. (*A*) A bar chart showing the amount of canal space converted into debris after rotary and reciprocating instrumentation (n = 19). (*B*) A bar chart showing the percentage debris accumulation for these 2 techniques (n = 19). This result was statistically significant (P = .01).

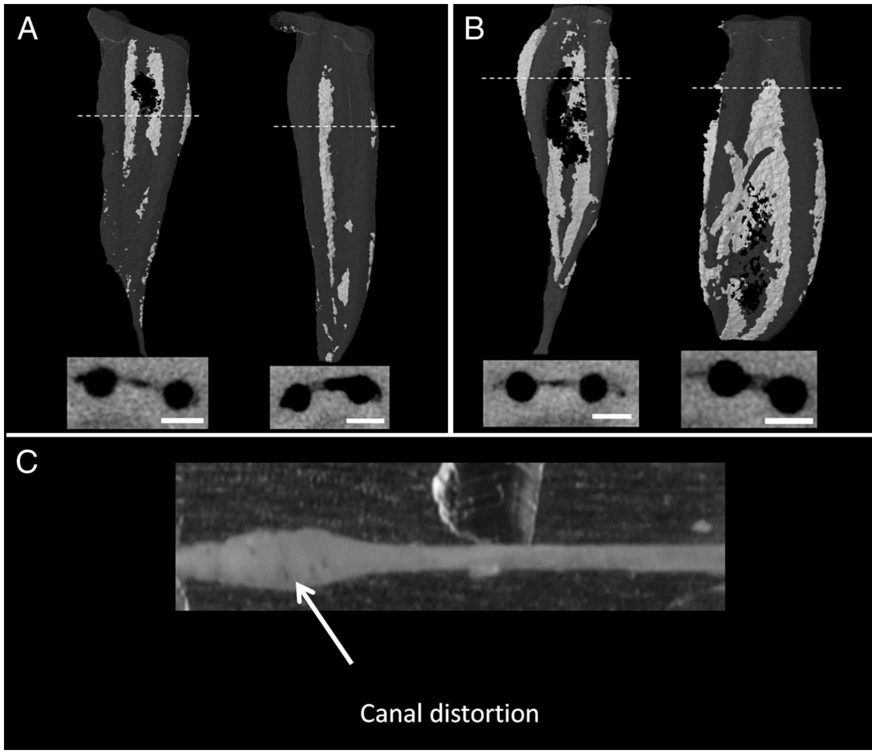

Figure 2. (*A* and *B*) Representative images of the 3D models show the location of debris within canals. The canal space is shaded gray and the debris white. A corresponding transverse slice is a microCT reconstructed image, and the white dotted line shows its approximate location in the model. Canals instrumented with (*A*) rotary and (*B*) reciprocating files are shown. Scale bars represent 1000 μm. (*C*) Photograph of a silicone model and a corresponding microCT slice at the location of the dotted line. Debris was pushed into the channel by use of a wire until it had been compacted at a similar density to that in native teeth.

and isthmuses (Fig. 2). Rotary and reciprocating instruments both converted similar amounts of canal wall to debris ($P > .05$, Fig. 1).

Discussion

Although single-file reciprocating systems have been shown to offer advantages over multifile rotary systems, this study shows a statistically significant shortcoming, which may have previously been overlooked by clinicians and researchers. With the single-file system, greater amounts of debris were packed laterally in isthmuses and protrusions, and this may be a clinically significant finding because this debris may harbor bacteria (18, 19), which are capable of reinfecting the tooth. Although density in debris was not statistically different between the techniques, debris was densely packed into the canals. To show how densely packed debris is in a canal, Figure 2 demonstrates how a canal model is distorted after an attempt to reproduce this density in a 200-μm silicone canal model. The debris may be so tightly packed with rotary motion that it is difficult to achieve a greater amount of packing with the reciprocating approach. Data from this study are in agreement with De-Deus et al (11) who compared reciprocating and rotary techniques on a single-rooted canal. Burklein et al (5) showed that rotary ProTaper instrumentation resulted in greater debris and acknowledged the reason for this might be that the ProTaper technique created more debris initially. Burklein et al used the ProTaper F3, whereas this study used the ProTaper F2. Both ProTaper F2 and WaveOne Primary have a similar profile; both have an 8% taper and a 0.25-mm tip and, therefore, create a similar amount of debris as shown in Figure 1. Further work is necessary to identify the reasons for a greater volumetric packing although they are likely to be multifactorial. For instance, the continuous forward motion of the rotary file enables constant exit of debris up the flute of the file; however, each backward motion of the reciprocating file might provide the opportunity for debris to build up in protrusions and isthmus areas. In addition, the reciprocating motion of the file may not allow the blade to cut into the dentine as cleanly, resulting in a burnishing-type effect (20, 21) and pushing debris into recesses and isthmuses. Differences also exist in how the rotary and reciprocating files prepare canals. The rotary shaper files cut mostly in the coronal two thirds, whereas the rotary finishers cut mostly in the apical third. However, the reciprocating file continues to cut along its length, with file engagement increasing as canal penetration continues. Thus, when the tip reaches the apical two thirds, the coronal part is still being shaped. Consequently, the file may work against itself in extracting debris from the tooth. It is also worth noting that the rotary group was irrigated more frequently although the same volume of irrigant was used in both groups. Debris may have less opportunity to accumulate in a tooth that is more frequently irrigated.

Apart from an improved understanding and optimization of instrumentation, debris might be more effectively managed by postinstrumentation methods such as ultrasonic cleaning, which showed superior debris removal in large lateral canals (22, 23). Future work might enable optimization of this approach for problematic regions.

Debris accumulation has been assessed using a number of different methods including optical microscopy, scanning electron microscopy, radiology, and weight loss (5, 11, 24). The greatest benefit of using microCT compared with other techniques is that it is nondestructive. The same sample can be repeatedly scanned and treated, enabling differences to be truly visualized and quantified.

Unlike techniques that are restricted to a certain focal plane or field of view, microCT is capable of imaging the entire canal 3-dimensionally at high resolution, giving a greater comprehensive picture of where differences are. Because the tooth readily attenuates an x-ray beam, high-energy x-rays must be used. High-energy x-rays provide poor soft-tissue contrast, and, consequently, microCT is limited to analyzing inorganic material.

Conclusions

Because reciprocating motion was shown to leave more debris, the null hypothesis is rejected. The study underlines the importance of managing debris in root canal preparation through instrumentation and irrigation, particularly when using a reciprocating file. In canals with a high prevalence of isthmuses and protrusions, using multifile rotary systems may be preferred over reciprocating files because it can yield cleaner canals with less debris accumulation. Results also highlight the need for instrumentation protocols that reduce debris buildup; however, this is challenging in view of the compactness of the debris.

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The authors deny any conflicts of interest related to this study.

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