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Original article

Micro CT pilot evaluation of removability of two endodontic sealers

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Abstract

Purpose: This study compared the removability of AH Plus and EndoSequence BC sealers using *in vitro* micro-computed tomography.
Methods: Ten single-canal, extracted human teeth were cleaned and shaped with ProTaper NEXT rotary files to size X5 (50/0.06) (Dentsply-Sirona). Canals were obturated with a single cone gutta-percha and either AH Plus (Dentsply-Sirona) (Group A) or EndoSequence BC (Brasseler) (Group B). ProTaper Universal Retreatment files (Dentsply-Sirona) were used to remove obturation materials after 90 days at 37°C/100% humidity. Each tooth was scanned using micro-computed tomography (SkyScan 1272; Bruker) at an isotropic resolution of 6 μm from which the percent of material removed was calculated. Two-sample *t*-tests and one-way ANOVA were used for analysis.
Results: The percent removal of materials in the coronal third was 92.9% ± 7.3% (Group A) and 93.2% ± 6.1% (Group B). Removal in the middle third was 94.9% ± 8.5% (Group A) and 96.5% ± 6.1% (Group B). Apical third removal was 76.2% ± 27.9% (Group A) and 70.1% ± 30.8% (Group B). No statistically significant differences were determined between the two sealers or among the sectional thirds within each group ($P > 0.05$).
Conclusion: AH Plus and EndoSequence BC sealers exhibit the same removability at all canal levels of 70% to 96%, with better removal coronally.

Keywords; endodontic retreatment, endodontic sealer, epoxy resin, tricalcium silicate, x-ray micro-computed tomography

Introduction

Endodontic treatment is considered a predictable procedure; however, a multifactorial failure rate of 14-16% has been reported [1]. Endodontic retreatment is often recommended after failure of the primary non-surgical root canal treatment (NSRCT). Caution is paramount in endodontic retreatment because re-accessing the root canal system places the tooth at greater risk for iatrogenic injury [2]. Retreatments are often successful but suffer from higher failure compared to initial NSRCTs [1]. Successful retreatment requires removing the previous obturation materials, such as gutta-percha (GP) and sealer, followed by disinfection of the root canal system [3].

Many methods of removing GP and sealer during endodontic retreatment have been evaluated [4]. The preferred retreatment technique is instrumentation with files combined with organic solvents to remove the GP and sealer used in the primary NSRCT [5]. The removability of a sealer is important for endodontic retreatment [6] because residual sealer makes up most of the material on canal walls after reinstrumentation. Current endodontic sealers, such as AH Plus (Dentsply-Sirona, Johnson City, TN, USA) and EndoSequence BC (Brasseler, Savannah, GA, USA), provide excellent three-dimensional sealing of canals and irregularities [7]; however, high bond strength to canal walls can lead to higher residue during retreatment [8]. AH Plus is an epoxy resin-based sealer regarded as a gold standard for sealers [9,10]. EndoSequence BC sealer, a calcium silicate cement-based sealer, has biocompatibility and high flowability [9,10]. However, limited information exists on the removability of EndoSequence BC or other tricalcium silicate-based sealers [11]. The present study evaluated the removability of AH Plus and EndoSequence BC sealers using micro-computed tomography (micro-CT).

Materials and Methods

Sample selection

Ten anterior, single-canal extracted human teeth, without evidence of fracture or cavitation, were selected. (University of New England, IRB#: 121515-014 not human subject research). The crowns of the teeth were removed with a diamond disk (Keystone industries, Gibbstown, NJ, USA), and the working length (WL) was determined by the use of size 10 K-file, 1 mm short of the radiograph apex on the WL radiograph.

Initial root canal treatment

The roots of the teeth were cleaned and shaped with ProTaper NEXT rotary files (PTN; Dentsply-Sirona) with a ProMark torque-limited electric motor (Dentsply-Sirona) to size X5 (50/0.06), following the manufacturer's instructions, along with EndoGel root canal file lubricating gel (Jordco, Hillsboro, OR, USA), which contains ethylenediaminetetraacetic acid (EDTA). Irrigation was performed with 5 mL of 3% NaOCl between files. The canals were thoroughly dried with matching ProTaper NEXT absorbent points (Dentsply-Sirona). The prepared teeth were randomly divided into two groups ($n = 5$) and obturated using the single cone technique with size X5 GP points (50/0.06; Dentsply-Sirona) and one of the two endodontic sealers (Table 1) [10,12,13]. The GP was seared off at the cementoenamel junction. The obturated teeth were stored individually for 90 days at 37°C and 100% humidity incubator in 1.5-mL polyethylene tubes (VWR, Radnor, PA, USA).

Removal of obturated materials

Obturated materials were removed from root canals using ProTaper Universal Retreatment rotary files (PTR; Dentsply-Sirona) and the ProMark electric motor. The PTR system includes three files with various tapers and diameters at the tip (D1: 30/0.09; D2; 25/0.08; and D3:20/0.07). D1 has a cutting tip to facilitate penetration into obturation material. D2 and D3 have non-cutting tips to remove the obturating material from the middle and apical thirds, respectively [14]. No organic solvent was used to dissolve the GP. Removal was judged complete when the working length was reached, and no filling material was seen when the D3 file was removed under magnification. A single operator executed all instrumentation to eliminate intra-operator variability.

Scanning

Each tooth was scanned before (at 90 days after obturation) and after the removal of obturated materials using micro-computed tomography (micro-CT; SkyScan 1272; Bruker, Billerica, MA, USA) at 6 μm voxel size, 90 kVp, 110 μA, with 0.5 mm aluminum and 0.038 mm copper filters. All datasets were exported in the Digital Imaging and Communications in Medicine (DICOM) file format. The GP and sealer volume were measured using image analyzer software (CTAn v.1.18.40+; Bruker). Each specimen was divided into coronal, middle, and apical thirds, measured from the

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Table 1 Endodontic sealers used in this study

Type	Product name (manufacturer, country)		Composition	Lot number	Working time	Setting time
Epoxy resin	AH Plus (Dentsply-Sirona, Johnson City, TN, USA)	paste A	bisphenol A epoxy resin, zirconium oxide, bisphenol F epoxy resin, calcium tungstate, iron oxide, silica	#0000119047	4 h	8.3 h
		paste B	N,N-dibenzyl-5-oxanonadiamin-1,9, amantiameamine, tricyclodecane-diamine, calcium tungstate, zirconium oxide			
Tricalcium silicate cement	EndoSequence BC (Brasseler, Savannah, GA, USA)	single paste	zirconium oxide, calcium silicates, calcium phosphate, calcium hydroxide, filler, thickening agents	#(10)16002SP	>24 h	2.7 h[†]

[†]in a water bath at 37°C

Table 2 Average gutta-percha (GP) length (mm) with standard deviations (SD)

Group: sealer	GP length (mm)	SD	Coefficient of variation
A: AH Plus	11.3	1.4	0.1
B: EndoSequence BC	12.1	1.1	0.1

Coefficient of variation is computed by dividing SD by total GP length.

Table 3 Average total canal volume (mm^3) by sealer group with standard deviations (SD)

Group: sealer	Sectional third	Total canal volume (mm^3)	SD	Coefficient of variation
A: AH Plus	coronal	5.9	2.6	0.4
	middle	3.1	1.1	0.3
	apical	1.5	0.4	0.3
	total	10.5	2.8	0.3
B: EndoSequence BC	coronal	3.7	0.5	0.1
	middle	2.6	0.5	0.2
	apical	1.2	0.4	0.3
	total	7.4	0.8	0.1

Total canal volumes are presented per sealer group and by sectional third, which are defined as equal thirds of GP length.
Coefficient of variation is computed by dividing SD by total canal volume.

Table 4 Average percent removal of gutta-percha (GP) and sealer with standard deviations (SD)

Group: sealer	Sectional third	GP + sealer percent (%)	SD	Coefficient of variation
A: AH Plus	coronal	92.9	7.3	0.1
	middle	94.9	8.5	0.1
	apical	76.2	27.9	0.4
B: EndoSequence BC	coronal	93.2	6.1	0.1
	middle	96.5	6.1	0.1
	apical	70.1	30.8	0.4

100% is complete removal of the obturation materials. Coefficient of variation is computed by dividing SD by GP + sealer percent (%).

cementoenamel junction to the most apical part of the GP cone. Material volumes were calculated for each sectional third, creating three material volumes per tooth.

Statistical analysis

Shapiro-Wilk tests were conducted to investigate the normality of the data. Shapiro-Wilk tests showed the normality of the data ($P > 0.05$). Levene tests were done to examine the equality of variances among study groups. Levene tests showed that the variances were not significantly different among study groups ($P > 0.05$). Two-sample *t*-tests and ANOVA tests were used based on the normality of the data and equality of variances among study groups.

Two-sample *t*-tests were performed to determine if significant differences were present in GP length and total canal volume between AH Plus and EndoSequence BC sealers and the apical, middle, and apical levels after removal. ANOVA tests were performed to calculate if significant differences existed in removability among the sectional thirds within each group. When statistical significance was detected in ANOVA tests, Tukey's *post-hoc* tests were performed to identify pairs of groups with significant differences. Statistical significance was defined using $\alpha = 0.05$.

Results

Tables 2 and 3 show GP length (about 12 mm), the calculated total canal volumes (7.4 and 10.5 mm^3), and each sectional third for both groups (1.2 to 5.9 mm^3). The data is presented as the average and the standard deviations (SD). No significant differences were found in total GP length ($P = 0.35$) or total canal volume ($P = 0.15$) between the sealers. Percent removal was calculated using the following equation:

$$\left(1 - \frac{\text{Volume of material after removal}}{\text{Volume of material before removal}}\right) \times 100\% = \text{Percent removal of material}$$

The average percent removal of GP and sealer is shown with their respective standard deviations (Table 4).

Representative cross-sections from the coronal, middle, and apical thirds of three teeth filled with a single-cone technique using AH Plus and EndoSequence BC sealer before and after removal are shown (Fig. 1). Qualitatively, the presence of lateral canals and other canal irregularities in anatomy were noted within each group.

No statistically significant difference in removability existed between the two sealers at the coronal ($P = 0.95$), middle ($P = 0.74$), and apical thirds ($P = 0.75$) because of the large standard deviations. The percent removal of material was lowest in the apical third (Table 4), ranging from

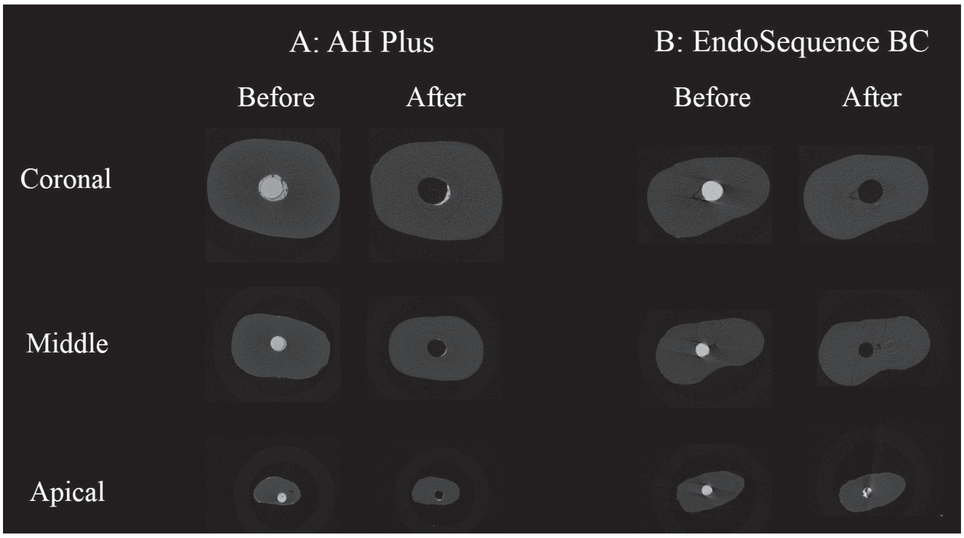

Fig. 1 Representative cross-sections from the coronal, middle, and apical thirds of teeth filled with a single-cone technique using AH Plus and EndoSequence BC sealer, before and after removal

70.1% to 76.2%, whereas the coronal and middle removal was 92.9% to 96.5%.

No statistically significant differences were found in percent removal among the coronal, middle, and apical thirds for AH Plus (P = 0.22) or EndoSequence BC (P = 0.86).

Discussion

Micro-CT is non-destructive and can be used to obtain data sets for image analysis, preserving the teeth for further evaluation [15]. Micro-CT is becoming widely used to assess root filling quality *in vitro*, but it is limited in its inability to detect debris embedded in the dentinal tubules [16]. A single cone approach was used for cleaning, shaping, and obturating the teeth, which is a popular clinical technique for AH Plus and EndoSequence BC sealers, and suitable for micro-CT [17,18]. The favorable filling quality of EndoSequence BC and other tricalcium silicate sealers achieved a 90.9% success rate [18]. Huang et al. [17] reported that AH Plus had more voids at all root levels when compared to EndoSequence BC sealer by the single cone technique.

Removal of obturated materials was done after 90-day incubation to simulate a clinical timescale, longer than other studies (one to six weeks) [16,19-23]. NiTi rotary retreatment files were used to achieve conservative and uniform instrumentation with a short working time, like other retreatment studies [15,19,21,22,24]. The PTR system was chosen to be consistent with other studies that used it for standardized retreatment procedures [14,15,20,22,23,25-28]. Monguilhott et al. found that PTR files removed more filling material in the apical region than in the coronal and apical regions [23]. Huang et al. described how PTR files (D1, D2, and D3) extruded approximately 0.4 mg of debris apically when used without solvent [25]. In their study, Huang et al. employ PTR files (D1, D2, and D3) to ensure uniform instrumentation among the teeth [25]. The residual filling material may be attributed to ovate canal shape, which PTR files cannot easily access [19]. Additional apical enlargement could decrease the apical sealer residue by either hand or rotary files [29]. Ultrasonic activation of irrigants with an irrisonic tip is also a viable method to improve material removal in the apical and middle thirds, where branching and finer canals are present [16].

This study found GP and sealer could not be removed completely. Removal evaluations of AH Plus versus EndoSequence BC (or other tricalcium silicate sealers) have proven equivocal across the research. In some studies, more EndoSequence BC sealer remained after removal of obturated materials than AH Plus, especially in the coronal third [11,28,30]. These studies [11,28,30] attribute this difference to the fact that EndoSequence BC has the potential to penetrate dentinal tubules, leave intratubular tags, and adhere to canal walls [9,27,31-34]. Studies comparable to those mentioned in the previous sentences [9,11,27,28,30-34] have found the opposite [35,36]. The removability of AH Plus and GP after cold lateral obturation was between 89% and 99% in some studies [20-22], while Ma et al. reported a 96% removal of GP and iRoot SP sealer [19]; the iRoot SP sealer is identical to EndoSequence BC sealer [10]. The current study shows that the removal of GP and sealer is from 70% to 96%, depending on the root section. Furthermore, no differences were found in the removability between AH Plus and EndoSequence BC sealers, which agrees with the studies by Uzunoglu et al. and Kim et al. [11,37].

Sealer removability may depend on the sealer's adhesion to dentine [26]. Sealers can adhere to canal walls and penetrate dentinal tubules, making detection and removal complicated [6,19]. The dentinal adherence of AH Plus and EndoSequence BC sealers has been previously reported to be equal [38]. More material remained in the apical third in this study, but unlike other studies, no significant differences in residual sealer were found among sectional thirds for AH Plus and EndoSequence BC sealer [37,39,40]. Although the groups were randomized, the sample size of five teeth caused uneven allocation of specimens with lateral canals and anatomical irregularities. Future studies with larger sample sizes could further investigate these variabilities in anatomy that influenced the removability of GP and sealer.

In conclusion, within the parameters of this experiment, AH Plus and EndoSequence BC sealers in endodontically treated teeth could be removed equally using the PTR files, although residual sealer remained. AH Plus and EndoSequence BC sealers showed no significant difference in removability across their sectional thirds, although removal was less effective apically.

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Conflict of interest
The authors declare no conflict of interest.

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