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Micro-CT Evaluation of the Remaining Endosequence BC Filling Materials and Dentinal Microcracks after Retreatment with D-Race and R-Endo Systems

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ABSTRACT

Objective: To analyze the remaining EndoSequence BC filling materials and microcrack using micro-computed tomography after retreatment with D-Race and R-Endo systems.

Method: The canals of thirty mandibular single-rooted and single-canal premolar teeth were shaped and obturated with EndoSequence BC point and EndoSequence BC sealer. The samples were assigned into two groups and scanned with micro-computed tomography. Then, the canal filling materials were removed with D-Race and R-Endo systems. After all roots were re-scanned, all images were evaluated for the remaining EndoSequence BC filling materials and microcrack. Also, retreatment time was recorded.

Results: The remaining filling material in the R-Endo group was greater than the D-Race group. Both systems caused new cracks formation. However, no significant difference was noticed among them. The D-Race group needed significantly less time in comparison to the R-Endo group.

Conclusion: D-Race system was faster and more efficient compared with R-Endo system. D-Race and R-Endo files caused new cracks on the canal walls.
Keywords: D-Race, Endosequence BC sealer, microcracks, micro-computed tomography, retreatment.

1. INTRODUCTION

When primer root canal treatment fails, non-surgical retreatment is the first alternative to eradicate microorganisms in the endodontic system (1). In the case of retreatment, it is very important to fully remove the root filling materials from the canal walls to perform disinfection, re-shaping, and refilling effectively (2).

Numerous nickel-titanium rotary systems have been manufactured for retreatment procedures, such as D-Race (FKG Dentaire, La Chaux-de-Fonds, Switzerland) and R-Endo (Micro-Mega, Besancon, France) systems. D-Race system is composed of 2 files, DR1 (15mm, 30/.10) and DR2 (25 mm, 25/.04), with alternating cutting edges and triangular cross-section. DR1 file has a cutting tip that enhances penetration of the instrument into the filling material while the tip of DR2 instrument is inactive (3). R-Endo system comprises 4 instruments with inactive tips: Re (15 mm, 25/.12), R1 (15mm, 25/.08), R2 (19mm, 25/.06), and R3 (23mm, 25/.04). These files are characterized by a triangular cross-section and 3 equally spaced cutting edges (4).

Various endodontic applications including root canal instrumentation, root canal obturation, post-placement, and retreatment process can cause microcracks in root dentin (5-7). The retreatment case is a more challenging and more time-consuming procedure in comparison with primer endodontic therapy. Since more dentin tissue is removed from canal walls, more microcracks might occur during this procedure (7,8).

The removal of canal obturation materials and microcracks could be evaluated by radiographic assessment (9,10), sectioning of roots (4,11) and micro-computed tomography (micro-CT) (3,12). However, micro-CT provides more reliable information as it allows three-dimensional imaging (13). There are no available research utilizing micro-CT when comparing the effect of D-Race and R-Endo files on the remaining filling materials and microcrack formation. Therefore, this research aimed to assess the remnant filling material and dentinal cracks on the canal walls after the removal of EndoSequence BC root filling materials (Brasseler,

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Savannah, GA, USA) with D-Race and R-Endo systems using micro-CT. The null hypothesis was that there was no statistically significant difference in remaining filling material and microcrack formation between D-Race and R-Endo.

2. METHODS

G*Power program revealed that at least nine teeth per group were required under the conditions of this study (α=0.05, 1-β=0.8). After ethics committee approval (protocol no: 2019-284), straight, single-rooted human mandibular premolars without previous root fillings, root fractures or immature apices were collected. The periapical radiographs of samples were taken buccolingually and mesiodistally to examine canal configuration. As a result of this evaluation, thirty teeth with a single canal were chosen.

2.1. Root Canal Shaping and Obturation

A single experienced investigator conducted all treatments. Tooth crowns were removed to acquire a uniform sample length. The working length of root canals was adjusted to 0.5 mm shorter from the apex. Each canal was shaped with EndoSequence Xpress files (Brasseler, Savannah, GA, USA) up to a size 35/.04. The instruments were used at 500 rpm/2 Ncm using an endodontic motor (E-connect S Endomotor; Eighteeth, Jiangsu Province, China). The canals were rinsed with 5 mL of 5.25% NaOCl following each file. After the shaping process, final irrigation procedure was accomplished using 5 mL of 17% EDTA and saline. Then, each canal was obturated with EndoSequence BC points (35/.04 and accessory gutta-percha) and EndoSequence BC sealer using the cold lateral compaction method. Following temporary sealing of the canal orifices (Coltosol; Coltene-Whaledent, Langenau, Germany), quality of the canal obturation was affirmed using a periapical radiograph. Each specimen was stored in an incubator at 37°C and 100% humidity for two weeks to complete the setting of EndoSequence BC sealer.

2.2. Micro-CT Scanning

After obturation procedure, each specimen was scanned using micro-CT (SkyScan 1172; Bruker-microCT, Kontich, Belgium) at 100 kV, 100 µA, 13.7 µm isotropic resolution, 180° rotation around the vertical axis, 2.450 ms camera exposure time, frame averaging of 2, with an aluminum and copper filter. The images were reconstructed using NRecon v.1.6.3 (Bruker-microCT) with a beam hardening correction of 65%, a smoothing of 3, and an attenuation coefficient range of 0 to 0.23. The reconstructed images were imported to the CTAn software (v.1.13, Bruker-microCT) for three-dimensional analysis. In each sample, the volume of the filling material (mm^3) was measured for the whole root canal and also for all root canal thirds. Micro-CT evaluation was performed by another experienced and blinded investigator.

After the roots were randomly assigned into 2 groups (n=15), the volume of the root canal filling was statistically analyzed using the Mann-Whitney U test and no significant difference was found between the groups ($p > .05$). This result showed that the specimens were homogeneously distributed.

2.3. Retreatment Procedure

D-Race group: D-Race system includes DR1 (15mm, 30/.10) and DR2 (25 mm, 25/.04) rotary files. DR1 instrument was used at the coronal third of the canals. The canal filling in the remaining part of the canal was removed using DR2 instruments. DR1 and DR2 were operated at 1000 rpm/1.5 Ncm and 600 rpm/1.5 Ncm, respectively.

R-Endo group: R-Endo system includes Re (15 mm, 25/.12), R1 (15mm, 25/.08), R2 (19mm, 25/.06) and R3 (23mm, 25/.04) rotary files. Re rotary files were used in the canal orifice; R1 instruments were used at the coronal third of the root canals, R2 files (19mm, 25/.06) in the middle third and R3 files to the working length. All R-Endo rotary files were operated at 300 rpm/1.2 Ncm.

The new instruments were used for retreatment of each tooth. All retreatment files were used in an up-and-down motion with brushing movements. The canals were rinsed with 2 mL of 5.25% NaOCl following each rotary file.

2.4. Retreatment Time

The time needed to remove the canal filling was noted in minutes using a stopwatch, excluding change of instruments and irrigation time. The timing commenced with the insertion of the initial retreatment instrument into the canal entrance and concluded when the last retreatment file, which reached the working length, was entirely removed from the canal.

2.5. Remaining Root Filling Material

Each sample was re-scanned at the initial micro-CT scanning parameters after the retreatment process. The volume of the remaining filling material was measured and the percentage of the remaining filling material was calculated for the whole root canal and also for all root canal thirds.

2.6. Dentinal Microcrack

The reconstructed images were imported to the DataViewer program (version 1.5.1, Bruker microCT). The transverse cross-sectional images obtained from all scans after obturation and retreatment procedures were examined simultaneously by 2 blinded endodontists with more than 5 years of experience. Any lines extending from the external root surface to dentin or from the root canal lumen to dentin were described as the dentinal microcrack. In case of disagreement, the sections were evaluated until the observers agreed. The microcrack distribution was represented as a percentage.

2.7. Statistical Analysis

After using the Shapiro-Wilk test, the percentage of the remaining filling material in the groups was compared using the Mann-Whitney U and Kruskal-Wallis tests. The Mann-Whitney U test was also utilized to compare the formation of microcrack and retreatment time. The significance level was determined at .05.

Table 1. *Descriptive values of the time (minutes) needed for retreatment procedure with D-Race and R-Endo systems*

Groups	Mean ± SD	Median	Min-Max
D-Race	0.40 ± 0.09	0.37	0.2 – 0.6
R-Endo	1.25 ± 0.14	1.21	1.1 – 1.5
p	***.000***		

SD, standard deviation.

Table 2. *Means and standard deviations (± SD) of the percentage (%) values of the remaining filling material after retreatment with D-Race and R-Endo systems in the coronal, middle and apical thirds and total root canal*

	D-Race (n=15)	R-Endo (n=13)	*p*
Coronal (%)	9.67 ± 10.54	15.06 ± 20.30	*1.000*
Middle (%)	3.42 ± 5.79	30.75 ± 33.60	***.043***
Apical (%)	12.64 ±2 7.7	57.31 ± 25.8	***.001***
Total (%)	8.58 ± 17.46	34.38 ± 31.72	***.000***

3. RESULTS

3.1. Retreatment Time

The amount of time (minutes) needed for the retreatment procedure with the D-Race and R-Endo systems is shown in Table 1. The D-Race group needed significantly less time compared to the R-Endo system ($p < .05$).

3.2. Remaining Root Filling Material

The percentage values of the remaining filling material after retreatment procedures with R-Endo and D-Race systems are listed in Table 2. The representative micro-CT images from each group are seen in Figure 1. The D-Race system showed a better performance in removing filling material from the total root canal in comparison to the R-Endo system ($p < .05$). Regarding different root canal thirds, R-Endo group had significantly higher values than the D-Race group in terms of the percentage of the remaining filling material in the middle ($p < .05$) and apical ($p < .05$) third. But there was no significant difference between the groups in the coronal third ($p > .05$).

During retreatment, R3 files were fractured in two teeth and these samples were discarded from R-Endo group. There was no rotary file separation in the D-Race group. Other procedural errors such as ledge or zipping were not observed in either group.

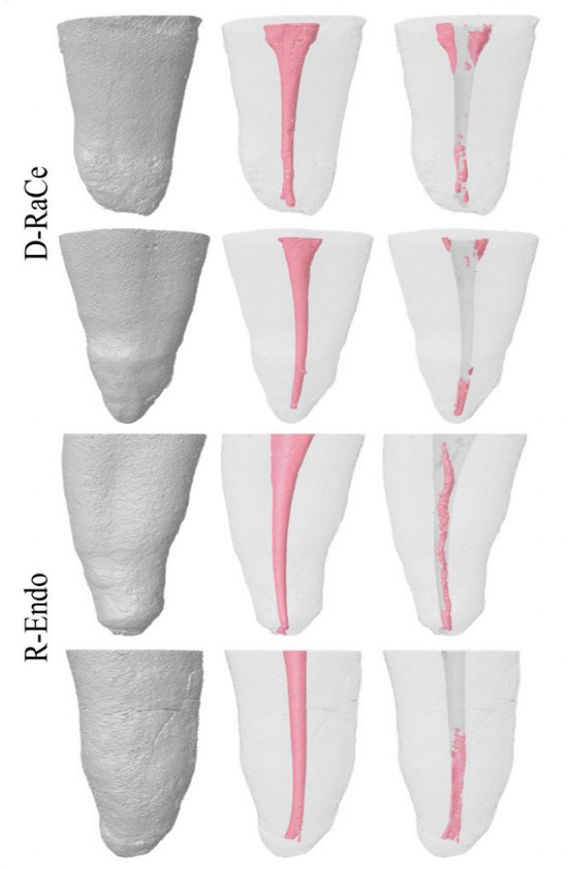

Figure 1. *The filling material in pre – and post-retreatment micro-CT images of representative samples of each group.*

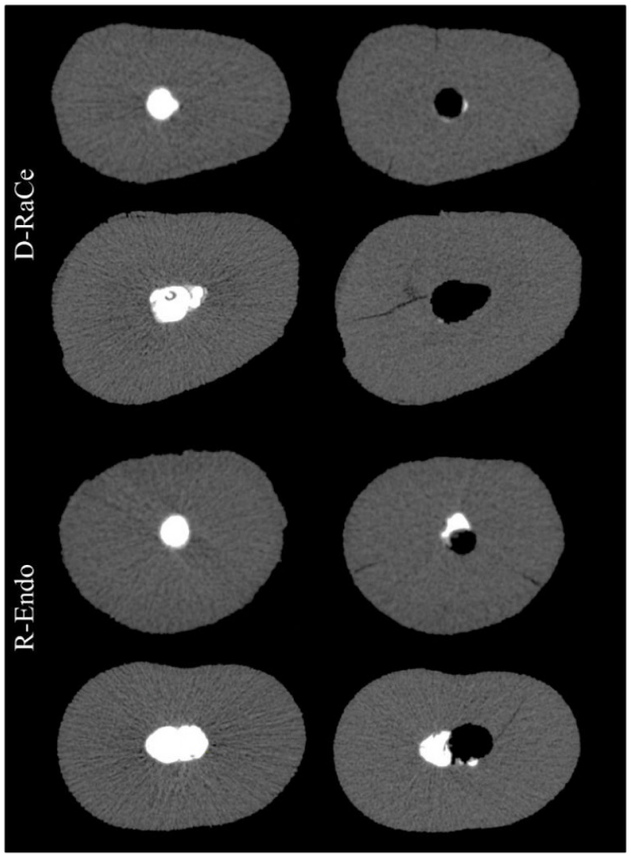

Figure 2. *Microcracks in pre – and post-retreatment cross-sectional micro-CT images of a representative sample of each group.*

3.3. Dentinal Microcrack

The cross-sectional images of all specimens were examined (n = 28.864) to determine the existence of dentin microcracks. Before retreatment procedure, 6.99% (n = 2019) of sections displayed microcracks. Dentin cracks were identified in 3.47% (n = 1002) and 3.52% (n = 1017) of sections in the root filling samples of R-Endo and D-Race groups, respectively. After retreatment procedure, dentinal microcracks were visualized in 26.73% (n = 7717) of sections. These cracks were observed in 14.06% (n = 4059) and 12.67% (n = 3658) of sections in retreatment samples of the R-Endo and D-Race groups, respectively. There were significant differences between the pre-retreatment and post-retreatment images for both systems ($p < .05$) (Figure 2). But no significant difference was noticed in new microcrack formation between the retreatment systems ($p > .05$).

4. DISCUSSION

In this current study, D-Race and R-Endo systems were selected for the retreatment procedure. As far as we are aware, no investigation has been conducted utilizing micro-CT to compare the effectiveness of D-Race and R-Endo systems on the remnant filling material and crack formation after retreatment. According to our results, our null hypothesis was rejected in terms of remaining filling material. D-Race system was more effective in the removal of filling material in comparison to R-Endo system, but both groups showed similar effects on new crack formation during retreatment. In this study, retreatment times of both systems were also measured and D-Race was found to be faster than R-Endo.

Various techniques such as longitudinal splitting of the roots (4,14,15) or radiographic evaluation (9,16) are used to examine the residual filling material after retreatment. But, these techniques have major drawbacks. For example, loss of remnant filling material may occur during the longitudinal splitting of roots and radiographic assessment cannot show all residual filling material and only offers two-dimensional details (17-19). Moreover, micro-CT imaging enables three-dimensional quantitative assessment without damaging dentin and provides high accuracy information (13). In this non-destructive technique, the samples can be evaluated both preoperatively and postoperatively. Since micro-CT was used in the present investigation, the filling material volumes of the groups were statistically compared before retreatment procedure and equal distribution of the samples between the experimental groups, which provided more reliable results, was confirmed.

In the current research, the Endosequence BC filling materials could not be entirely eliminated from the canal walls with the retreatment systems used similar to previous studies (2,3,12). In the literature, only Bedier and Roshdy (15) compared the effects of D-Race and R-Endo systems on the remaining obturation materials after retreatment using the longitudinal splitting method and revealed that D-Race system was more efficient and faster, in compliance with our findings. These results might be due to the alternating cutting edges of D-Race rotary files. Rödig et al (3) indicated that this design may facilitate penetration into the filling material and improve cutting ability. Since both file systems have a triangular cross-section, there may not be any correlation between the cross-section of the files and these findings. Besides, the improved effectiveness of D-Race system might be attributed to the thermoplasticization of the gutta-percha at the higher speed, which makes gutta-percha removal easier. One of the factors that shorten the retreatment time of D-Race system may be active tip of DR1 instrument, unlike R1 file.

Considering root canal thirds, no significant difference was noticed among the retreatment systems used only in the coronal thirds according to our findings. The reason for this may be that the operator can see the obturation materials in the coronal third more clearly in comparison to other thirds. Moreover, in the present study, tooth crowns were removed to acquire a uniform working length similar to most previous studies. Even though decoronation does not represent the clinical practice, it eliminates variables, such as crown anatomy and access cavity. Thus, more accurate data are obtained about the effectiveness of the instruments (20).

The use of mandibular teeth with straight canals in our study resulted in no procedural errors except instrument fractures. Whereas no rotary file separation occurred in D-Race group, two R-Endo files were broken in this study. In contrast, Rödig et al (3) reported the high incidence of rotary file separation in D-Race group, which might be related to their use of teeth with sudden canal curvatures.

In the literature, there is only 1 research comparing the effects of D-Race and R-Endo systems on dentinal microcrack formation. In that study, the number of dentinal defects in the samples before retreatment could not be evaluated because the destructive sectioning technique was used (11). However, extraction and sawing of the samples, as well as initial root canal instrumentation and canal filling procedures, might result in dentin cracks (21,22). Therefore, they chose instrumentation and obturation techniques that minimize these limitations in their study and reported that these two retreatment systems had same efficiencies on dentin defect formation in agreement with our findings (11). This result indicates that the instrument's design and size variations may not be a direct factor for microcrack formation.

In the current study, retreatment procedures with D-Race and R-Endo systems caused new microcrack formations. Previous studies reported that various nickel-titanium retreatment systems trigger new crack formations during retreatment (12,23). In comparison to the initial root canal treatment, more dentin tissue is removed from the root canals and more mechanical manipulation is required during retreatment procedure (7,8,22). Therefore, regardless of the retreatment file systems used, the retreatment procedure may induce the formation of microcracks.

EndoSequence BC Sealer, a premixed bioceramic-based root canal sealer, was used in our study. This highly biocompatible sealer can form a strong chemical bond with dentin hydroxyapatite (24). For this reason, the removal of bioceramic sealers from the canals might be more difficult and may result in more dentin cracks on the canal walls compared to other sealers. However, our results are consistent with similar studies using AH Plus (11,15). Furthermore, previous studies revealed no significant difference between EndoSequence BC Sealer and AH Plus in the remaning filling material and microcrack formation after retreatment (14,25).

5. CONCLUSION

In this study, the Endosequence BC filling materials could not be entirely eliminated from root canals with the retreatment systems used. D-Race system was more effective and quicker at removing of obturation materials than R-Endo system. D-Race and R-Endo files caused new microcrack formations. But both systems showed similar effects on new crack formation during retreatment. Clinicians may prefer the D-Race system to the R-Endo system for a shorter and more successful retreatment.

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