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Research Article

Comparative Analysis of Techniques for Removing Bioceramic Sealer and Gutta-Percha from Long-Oval Canals Using Micro-CT

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ABSTRACT

Background: This study aimed to evaluate the efficiency of different techniques in removing Gutta-Percha (GP) and iRoot SP® sealer in a long-oval shaped canal using micro-Computed Tomography (micro-CT).

Materials and methods: Forty-eight single-rooted mandibular premolars with single long oval straight canals were prepared using ProTaper Next® to size X3 (30/.06) and filled with GP and iRoot SP® using the hydraulic technique 2 mm short of the Working Length (WL). The sample was randomly divided into four groups (n=12) based on removal technique: Group 1: Pro Taper® Universal Retreatment system (PTU Rx); Group 2: PTU Rx with Xylol; Group 3: PTU Rx with Endo Success™ Retreatment Kit, ET25 tip and Group 4: PTU Rx with Xylol and ET25 tip of Endo Success™ Retreatment Kit. All specimens scanned before and after the removal of the root canal filling material using a micro-CT system to assess the remnant of root filling materials. The data analysed using one-way Analysis of Variance (ANOVA), Student-Newman Keuls post hoc test for remaining root filling material and Pearson chi-square test for regaining patency ($p=0.05$)

Results: Results showed no statistically significant difference in the remaining root filling material between groups ($p>0.05$). The apical thirds showed the highest percentage of the remaining root canal filling material compared to the middle and coronal thirds ($p<0.01$). Results showed no statistically significant difference in the ability to achieve patency between groups ($p>0.05$).

Conclusion: No technique proved to be superior to others in removing bioceramic root filling-based material from long oval canals. Bioceramic sealers are negotiable in single, straight root canal anatomy.

Keywords: Long oval canals; Retreatment; Micro-computed tomography; Bioceramics; Patency

INTRODUCTION

Endodontic therapy is a valid treatment approach for teeth with pulpal or periapical disease and has high long-term survival rates [1-3]. Nevertheless, complications and subsequent failures can occur because of inability to completely eradicate infection, missed anatomy or procedural errors [4]. Such cases can be treated successfully by orthograde root canal retreatment, endodontic surgery or extraction. Among those, orthograde root canal retreatment has the highest success rate, is the most conservative, and favoured treatment option [5-7].

The main objective of orthograde retreatment is to remove remaining infected pulp tissues, filling and re-establish the periapical health [8]. The procedure is reliant on adequate shaping and disinfection of the previously unprepared areas of the root canal system [9]. Therefore, safe and efficient removal of the previous root filling material is essential for optimal success. However, the challenge of complete debridement of this material is yet to be achieved [10].

The complex anatomy of long oval canals is perceived as a challenge in achieving the biological and mechanical objectives of root canal treatment and retreatment since high percentage of the root canal walls were left unprepared irrespective of the instrumentation method used [11,12]. These canals are defined as having a ratio of the maximum initial horizontal dimension to the minimum initial horizontal dimensions greater than 2 and less than 4 [13]. The prevalence of long oval canals in human mandibular premolars was reported to be 27% and can occur even at the most apical part of the root [14,15].

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The use of bioceramic-based materials as a root repair cement and root canal sealer is widely accepted. Bioceramic materials may be composed of alumina and zirconia, bioactive glass, glass ceramics, calcium silicate, and hydroxyapatite [16]. iRoot SP® (Innovative Bioceramics, Vancouver, BC, Canada) is premixed calcium silicate-based endodontic sealer. It demonstrated potent anti-microbial activity, favourable biological profile and good sealing ability [17-19]. However, the information available on the methods to remove bioceramic sealers from the root canals, whenever indicated, is limited [20,21]. Various methods have been used to evaluate the remnants of root canal filling materials including tooth sectioning, tooth clearing, 2D and 3D imaging techniques. Micro-CT provide the advantage of being reproducible, non-destructive while providing accurate 3D models and acquisition of quantitative data [22]. This study aimed to evaluate the efficiency of removing GP and iRoot SP® from long-oval shaped canals with and without ultrasonic instrument and solvent using micro-CT. The null hypothesis was that there is no significant difference between the techniques in the efficacy of removing the root filling material from the root canal system.

MATERIALS AND METHODS

Sample preparation

Sample size was calculated using G-power software with the following parameters, α-error probability 0.05, power (1-β) 0.80, Standard Deviation (SD)=(3.6), and the following means (5.70,1.71,2.90,0.70). The total sample size output was 48, which is 12 in each group.

Forty-eight human mandibular premolar teeth with fully developed apices were chosen following examination under a stereomicroscope (Kyowa Optical, Japan) at 10X magnification to rule out cracks, caries, external resorption and fractures. The teeth were then disinfected using a 0.5% chloramine T trihydrate solution for one week. Afterward, the teeth were stored in 4°C distilled water. The selected teeth were then scanned using Cone-Beam Computed Tomography (CBCT) scanner Kodak 9000 (Carestream Kodak Co., New York, USA) using the exposure parameters of 70 kV, 10 mA, 76 µm voxel size and 100 ×100 mm Field of View (FOV). The selection criteria were as the following: Teeth with a single long oval canal (the buccolingual length is 2-4 times the mesiodistal width), completely formed apex with patent foramina, canal curvature of less than 20°, no internal resorption or pulp stones/calcification within the root canal system.

Each of the teeth were decoronated with a diamond disk (Bego, Germany) where the tooth length was standardized to 13 mm. Working Length (WL) was established to be 12 mm. K-files size 15 (Dentsply Maillefer, Switzerland) was used to achieve WL. The canals were prepared using ProTaper Next® system (Dentsply Maillefer, Switzerland) to size X3 (30/0.06). All rotary files were operated using an engine-driven motor VDW.Silver® Reciproc® (VDW, München, Germany) at 300 rpm according to the manufacturer's instruction. K-file size 10 was used to reconfirm patency throughout the procedure. After each instrument, irrigation with 5.25% Sodium hypochlorite (NaOCl) was performed and patency reconfirmed. The final irrigation regime for each canal was 3 ml of 5.25% NaOCl followed by 17% Ethylenediaminetetraacetic Acid (EDTA) (SmearClear™, SybronEndo, Orange, USA) with the subsequent of 5.25% NaOCl. Canals were dried with paper points (Dentsply Maillefer). Canal patency was reconfirmed prior sealer placement.

All canals were obturated using the hydraulic technique. The iRoot® SP sealer was introduced into the canals using a lentulo spiral until the sealer was extruded through the apical foramen. ProTaper Next® GP cone Size 30 (0.06) was trimmed apically to fit 2 mm short from the WL, coated with the sealer and then introduced into the canal to mimic a short root canal filling which will allow re-establishing patency to be achieved through the sealer. The access cavities were filled with Fuji II LC (GC America, Alsip, Illinois) and the teeth were stored in Memmert incubator IN450 (Memmert, Germany) at 37°C and 100% relative humidity for two weeks. 48 specimens were elected out of the 60 based on the quality of the obturation. The obturation was assessed using buccolingual and mesiodistal periapical radiograph views.

Micro-CT scanning

A micro-CT machine Xradia 520 Versa (Zeiss, Germany) at the Department of Geology, University of Malaya, Kuala Lumpur, Malaysia) was used to scan before and after retreatment. The selected micro-CT scanning parameters were 18 µm voxel size, 70 kVp, 357 mA, 0.5 mm aluminum filter, 0.49° angular step and 360° scanning rotation. The specimens were fixed in a cylindrical shape of beading wax, fitted and mounted into the holder before scanning to reduce any possible movements during the scanning process. Data were analysed using Drishti software version 2.6.4.

Sample randomization

The sample was randomly divided into four groups (n=12) based on removal technique: Group 1: Pro Taper® Universal Retreatment system (PTU Rx); Group 2: PTU Rx with Xylol; Group 3: PTU Rx with Endo Success™ Retreatment Kit, ET25 tip and Group 4: PTU Rx with Xylol and ET25 tip of Endo Success™ Retreatment Kit. After randomization, the homogeneity within each group was tested ($p=0.115$). The volume difference between the groups was also tested ($p=0.755$). For both tests, p was significant at $p<0.05$.

Retreatment procedure

The coronal 2 mm of the GP was removed from all the roots using BeeFill (VDW, München, Germany) system to facilitate the introduction of the instruments and to act as a reservoir for Xylol. ProTaper® Universal (PTU) retreatment files (Dentsply Maillefer, Switzerland) were used for all groups according to manufacturer instructions until WL is reached or resistance is met. Additionally, for groups 2 and 4, Xylol was applied to the canal for 5 min before using the PTU retreatment files. For all groups, the removal procedure was ended when there were no remnants of the filling material on the file's flutes. The canals were negotiated using K-file size 10 and considered patent if the file extends 1 mm beyond the WL. Once the WL was reached, the canals were prepared using ProTaper Next® (40,0.06) to remove the remaining obturation material. If the WL was not achieved, it was prepared to the reached length.

For groups 3 and 4, following the use of PTU retreatment files, the ultrasonic instrument, Endo Success™ Retreatment Kit, ET25 tip (Acteon, England) was used according to manufacturer instruction with Newtron® P5 XS (Satelec Acteon, France) together with K-files size (10) to achieve patency. ET 25 tip was also used on the walls with copious irrigation to pulverize and remove any excess of the root filling material. After the retreatment procedures were performed, all roots were scanned with the same micro-CT machine and parameters used in the initial scanning.

Statistical analysis

The data was analyzed using SPSS version 25 (IBM, USA). The normality of data was tested using the Shapiro-Wilk test. As most of

the groups were normally distributed (p>0.05), One-way ANOVA and a Student-Newman Keuls post hoc test were performed for statistical analysis. Repeated measure ANOVA was performed to compare the remaining filling material between the coronal, middle and apical thirds. Pearson chi-square test was performed to analyse the ability to reach the WL and regain patency.

RESULTS

Remnants of the root canal filling were detected in all specimens. The mean percentage of the remaining root filling volume was presented in Table 1. The mean percentage volume of the remaining root filling material was the lowest in the group that used ultrasonic instrument in addition to the rotary files (1.73%), whereas the group that used rotary files alone had the highest percentage (4.94%). However, no significant difference was found between the different groups (p=0.24). Table 2 shows the mean percentage of the remaining filling material volume in each third of the canal. Statistical analysis showed a significantly higher percentage in the apical third compared to the middle and coronal thirds (p>0.01). The difference between the middle and the coronal thirds was not statistically significant. The ability to re-establish WL and patency could not be achieved in 5 specimens as shown in Table 3. However, the Pearson chi-square test showed no significant difference between the groups (p=0.48) (marginal).

Table 1: Mean percentage of the remaining root filling material between the groups.

Group	1 (n=12)	2(n=12)	3(n=12)	4(n=12)	p-value*
	Mean ± (SD)	Mean ± (SD)	Mean ± (SD)	Mean ± (SD)	
Percentage of the filling material left	4.94 ± (5.96)	2.59 ± (4.16)	1.73 ± (0.80)	3.60 ± (3.20)	0.244

Note: One-way ANOVA (*significant at p<0.05).

Table 2: Mean percentage of the remaining root filling material between the coronal, middle and apical thirds.

	Coronal third	Middle third	Apical third	p-value*
	Mean ± SD	Mean ± SD	Mean ± SD	
Percentage of the root filling left	2.27 ± 3.8a	1.72 ± 3.28b	10.52 ± 11.08a,b	<0.01

Table 3: The ability to re-establishing patency and WL between groups.

Group	n	Percentage of the specimens achieved patency(n)	p-value*
1	12	83.3%(10)	
2	12	91.7%(11)	0.483
3	12	100% (12)	
4	12	83.3%(10)	
Overall	48	89.6%(43)	

Note: Chi-square test (*significant at p<0.05).

DISCUSSION

Root canal procedures performed with bioceramic sealer demonstrated potential performance in clinical settings [23]. Along with the favourable characteristics, the use of bioceramic sealers is expected to be more appealing. The limited data available on the removal of bioceramic sealers necessitate the need for studies on the retrievability of these sealers. Hence, this study aimed to evaluate the ability to remove iRoot SP® from long oval canals.

Mandibular premolar was selected as majority of the canal is long oval. Single cone GP with bioceramic sealer can give a short chair time for obturation. Nevertheless, it can result in a poor quality obturation thus requiring retreatment due to technical or biological issues. The result of each study should be interpreted with care as methodology used was longitudinal tooth sectioning followed with digital scan surfacing or electron microscopy. Use of micro-CT allow reconstruction of the study area into 3D without destruction and reproducible [24]. Studies previously performed on the retreatment of bioceramic sealers showed the lack of current techniques to completely remove the root filling material from the root canal system [25-30]. Hence, the results of this study confirmed this finding the null hypothesis was rejected. The root filling composed of bioceramic sealer and GP could not be completely removed from the root canal system in any of the specimens. This finding can be explained by the complexity of long oval anatomy as variable portions of such canal anatomy were left unprepared causing the root canal filling to be compacted into these irregular areas during the removal procedure [31,32]. Furthermore, the ability of bioceramic sealer to interact and bond with dentine might also play a role in the difficulty of completely removing it from the root canal system [33,34]. However, it is important to interpret the results of this study with care as the sample standardization in which the crowns were removed could have potentially facilitated the retreatment procedure as it improves the visibility and facilitates the instruments' introduction.

The group that utilized rotary files and ultrasonic instruments resulted in the lowest percentage of remaining root canal filling material. However, there was no statistically significant difference between the groups. This could be explained by the ability of ultrasonic instruments to pulverize the cement and agitate the irrigants [35,36]. In contrast to the present study, the use of GP solvent was reported to leave less residual material after retreatment procedure [20]. The use of warm vertical compaction can explain the contradictory results as it utilizes more GP than single cone technique. Furthermore, warm vertical compaction can deteriorate the physical properties of bioceramic sealer [37]. Upon comparing the remaining root filling in the apical, middle and coronal thirds one study found no significant difference between the different thirds. This is in contrast to all previous studies [21]. This difference was explained by the use of single cone technique instead of cold lateral or warm vertical compaction. However, despite the use of single cone technique in this study, the apical third retained a significantly higher percentage of the root filling material in comparison to other thirds. This contradictory finding may be explained by the difference in the canal shape as our study used long oval canals while round canals were used in the previously mentioned study.

The WL and patency could be re-established in 89.5% of the specimens. The use of xylol was not beneficial in contrast to what has been reported by Carpenter et al. [38]. This may be due to the difference in the bioceramic sealer used since the previous study used MTA Fillapex which contains a resin matrix. Future studies should be designed to cover the variations in root canal morphologies, different file systems, ultrasonic instruments, sealers and obturations techniques as well as the role of microscope.

CONCLUSION

No technique proved to be superior to the others in removing bioceramic root filling-based material. The apical third retained a significantly higher percentage of its filling material compared to the middle and coronal third. Bioceramic sealers are negotiable in single, straight root canal anatomy.

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CONFLICT OF INTEREST

None to report. Data included in this study can be accessed by request from the corresponding author.

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