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Assessment of Different Removal Techniques for Bioceramic-based Root Filling Material in Long Oval Canals of Mandibular Premolars: A Micro-Computed Tomographic Study

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Abstract

This investigation evaluated the efficiency of various root canal filling removal techniques in removing gutta-percha (GP) and iRoot SP® sealer in mandibular premolars with long-oval shaped canal using micro-computed tomography (micro-CT). A total of forty-eight mandibular premolars with long oval canals were prepared using ProTaper Next® to size X3 (30/.06) and filled with gutta-percha and iRoot SP®. The study samples were randomly divided into four groups based on removal technique (n = 12 for each). The first group was Pro Taper® Universal Retreatment system (PTU Rx), the second group was PTU Rx with Xylol, the third group was PTU Rx with Endo Success™ Retreatment Kit, ET25 tip and the fourth group was PTU Rx with Xylol and ET25 tip of Endo Success™ Retreatment Kit. The study samples were scanned before and after the removal of the root canal filling material using a micro-CT. One-way ANOVA, Student-Newman Keuls post hoc test and Pearson chi-square test were used for data analysis (P = 0.05). The findings revealed no significant differences among the tested groups regarding the amount of residual root filling material or the ability to regain apical patency ($P > 0.05$). The apical third retained the greatest amount of filling remnants compared with the middle and coronal thirds ($P < 0.01$). Overall, none of the retreatment techniques demonstrated superiority in removing bioceramic-based root filling materials from long oval canals. However, bioceramic sealers appear to be negotiable in single, straight root canals.

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, ortho-grade root canal retreatment has the highest success rate (5), is the most conservative (6), and favoured treatment option (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 (11) and retreatment (12) since high percentage of the root canal walls were left unprepared irrespective of the instrumentation method used. These canals are defined as having a ratio of the maximum initial horizontal dimension to the minimum initial horizontal dimensions greater than 2 and lesser than 4 (13). The prevalence of long oval canals in human mandibular premolars was reported to be 27%

(14) and can occur even at the most apical part of the root (15).

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 (17), favourable biological profile (18), and good sealing ability

(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 and 2D and 3D imaging techniques. Micro-computed tomography (micro-CT) provide the advantage of being reproducible, non-destructive while providing accurate 3-dimensional models and acquisition of quantitative data (22). This study aimed to evaluate the efficiency of removing gutta-percha (GP) and iRoot SP® from long-oval shaped canals with and without ultrasonic instrument and solvent using micro-computed tomography (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.

Material and methods

This study was carried out in accordance with the Declaration of Helsinki, and an ethical approval was obtained for this study from the Medical Ethics Committee, Faculty of Dentistry with approval no. RD1721/0070(P). The need for informed consent was waived by the Ethics Committee as this was a retrospective study using extracted teeth, and the reasons for extraction were unrelated to the study. The teeth were collected from governmental and private dental clinics in Kuala Lumpur, Malaysia. The patients' ages and gender were unknown.

Sample preparation:

The 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 Co., New York, USA) using the

exposure parameters of 70 kV, 10 mA, 76 µm voxel size and 100 x 100 mm field of view (Fig. 1a-c). The selection criteria were as the following: teeth with a single long oval canal (the buccolingual length is 2–

4 times the mesiodistal width) (Fig. 1c), completely formed apex with patent foramina, canal curvature of less than 20° (Fig. 1a, b), 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.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® gutta-percha cone Size 30 (0.06) was trimmed apically to fit 2 mm short from the working length, 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 (Fig. 1d). The access cavities were filled with Fuji LC (GC America, Alsip, IL) and the teeth were stored in Memmert incubator IN450 (Memmert, Germany) at 37ºC 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 radiographs.

Micro-CT scanning

A micro-CT machine Xradia 520 Versa (XRM, X-ray micrograph machine, Zeiss, Germany) at the Department of Geology, Universiti Malaya, Kuala Lumpur, Malaysia was used to scan before and after the 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 randomized into 4 groups (n = 12 each group). Group 1: Rotary files only; Group 2: Rotary files and Xylol (5 min); Group 3: Rotary files and ultrasonic instrument; Group 4: Rotary files, Xylol,

and ultrasonic instrument. 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 < 0.05.

Retreatment procedure

The coronal 2 mm of the gutta-percha 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 Group 2 and 4, Xylol was applied to the canal for 5 minutes 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,.06) to remove the remaining obturation material. If the WL was not achieved, it was prepared to the reached length.

For Group 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 (Fig. 1e, f). The volume calculation was done using Drishti software Version 2.6.4 (Fig. 1f), and the percentage of the remaining volume of the root canal material from the total volume was then calculated.

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 is 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). Tables 2 and 3 show 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 working length and patency could not be achieved in 5 specimens as shown in Table 4. However, the Pearson chi-square test showed no significant difference between the groups (P=0.48) (marginal).

Discussion

Root canal procedures performed with bioceramic sealer demonstrated promising 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 has a long oval pattern. 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 concerns. The result of such studies should be interpreted with caution as the methodology usually follow

longitudinal tooth sectioning examined under a digital scan or a scanning electron microscopy. The micro-CT scan allows 3D reconstruction of the studied area without destruction and ensures reproducibility (24).

Previous studies have described the limitation of the current techniques in completely removing the root filling material from the root canal system (25-30). Bioceramic sealer and gutta-percha could not be completely removed from the root canal system in any of the specimens. This finding could be due to the complexity of long oval anatomy, where various portions of the canal were left unprepared. This caused the filling materials being trapped in these irregular areas during the removal procedures (31,32). Additionally, the bioceramic sealer's ability to interact (33) and bind (34) with dentine contributes to the challenge of completely removing it from the root canal system. However, it is important to highlight that the sample standardization followed in this study 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 (Group 3) demonstrated 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, one study

(20) reported that the use of gutta-percha solvent left less residual material after retreatment when using the warm vertical compaction technique. The technique uses more gutta-percha than the single cone technique, which may explain the contradictory results. Furthermore, warm vertical compaction can deteriorate the physical properties of BC sealer (37). The remaining root filling materials was compared between apical, middle and coronal thirds. The

current finding was not similar to a previous study (21), which can be explained by the use of the single cone technique instead of cold lateral or warm vertical compaction. However, despite using the single cone technique in this study, the apical third retained a significantly higher percentage of root filling material compared to the other thirds. This contradictory finding may be explained by differences in canal shape, as our study used long oval canals, whereas the previously mentioned study used round canals.

The working length and patency could be reestablished 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 are needed to examine the removal of root canal filling materials in various root canal shapes using different file systems, ultrasonic instruments, sealers and obturation techniques as well as the role of the dental operating microscope in improving the removal of root canal filling.

Conclusion

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

Declarations

The authors deny any conflict of interest

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Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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Tables

Table 1: Comparison (mean and standard deviation) of the percentage of the remaining root filling material between the groups.

	1	2	3	4	
Group	(N=12)	(N=12)	(N=12)	(N=12)	*P**
Percentage of the filling material left	4.94± (5.96)	2.59± (4.16)	1.73± (0.80)	3.60± (3.20)	0.244

One-way ANOVA (significant at <0.05)*

Group 1= rotary files, group 2 = rotary files and Xylol, group 3 = rotary files andultrasonic instrument, group 4 = rotary files, Xylol and ultrasonic instrument

Table 2: Comparison (mean and standard deviation) between the percentage of the remaining root fillingmaterial between the coronal, middle and apical thirds.

Coronal third	**Middle third**	**Apical third**	
			*P**
percentage of the root filling left			
2.27±3.8[a]	1.72±3.28[b]	10.52±11.08[a, b]	<0.01*

Repeated measure ANOVA (significant at p<0.05)*

[a]*Significant different between the coronal and apical third p<0.01*

[b]*Significant different between the middle and apical third p<0.01*

Table 3: Comparison (mean and standard deviation) for the percentage of the remaining root canal filling material in the coronal, middle and apical thirds of the root between groups.

The remaining material in root canal thirds (%)					
				F (df)	*P**
Group	Coronal	middle	Apical		
1	2.31 ± 2.86	1.77 ± 2.11	7.94 ± 7.13		
2	3.49 ± 6.61	2.52 ± 5.63	13.11 ± 15.63	0.944(102.37)	0.491
3	1.05 ± 1.21	1.62 ± 2.27	7.40 ± 4.91		
4	2.23 ± 2.29	0.95 ± 1.78	13.62 ± 13.03		

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

Group 1= rotary files, group 2 = rotary files and Xylol, group 3 = rotary files andultrasonic instrument, group 4 = rotary files, Xylol and ultrasonic instrument

Table 4: Comparison between groups for the re-establishing patency between groups

Group	N	Percentage of the sample achieved patency(N)	*P**
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)	

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

Group 1= rotary files, group 2 = rotary files and Xylol, group 3 = rotary files andultrasonic instrument, group 4 = rotary files, Xylol and ultrasonic instrument

Figures

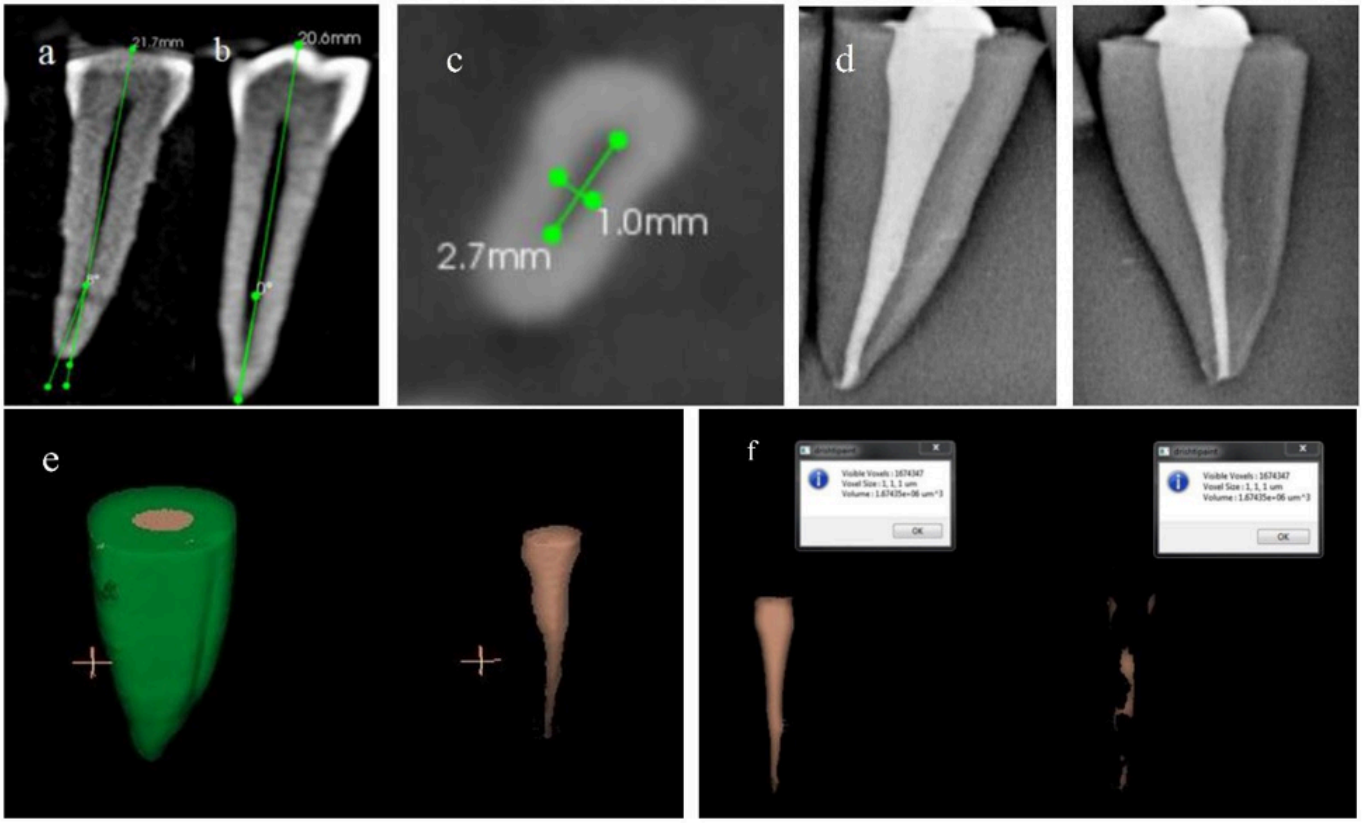


Figure 1

Calculation of the root canal angle at the long axis of the tooth (a – mesiodistal and b – bucco-lingual). c) Measurement of the canal diameters at 6 mm from the apex. d) Mesiodistal and buccal lingual periapical views of root canal filled roots. e) Segmentation of the roots and root canal filling material after micro-CT scanning. f) Calculation of the volume of the remaining root canal filling material before (left) and after (right) retreatment.