THE EFFECTIVENESS OF GUTTAFLOW BIOSEAL OBTURATION MATERIAL IN SINGLE ROOTED MANDIBULAR PREMOLARS: A SCANNING ELECTRON MICROSCOPY STUDY

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Abstract. The effectiveness of obturation with GuttaFlow Bioseal is not clearly understood due to limited scientific evidence. This study aims to evaluate the material adaptation, sealer extrusion and duration taken for obturation. 30 single rooted extracted mandibular premolars were selected. Standard access cavity preparation was done and the root canals were prepared using endodontic rotary files. The samples were divided into 3 groups (n=10); continuous backfill, interrupted backfill and injectable groups. The obturation procedure was timed using a digital timer and the obturation radiograph was taken after procedure. The roots were sectioned horizontally at the apical, middle and coronal regions, then observed under scanning electron microscope (SEM) at 70x magnification. The SEM images were transferred to the SketchAndCalc Area Calculator software for evaluation of the material adaptation. There were no statistically significant differences in regard to the material adaptation at any level of evaluation and presence of sealer extrusion ($P > 0.05$) in all techniques. Duration of obturation using the injectable technique was statistically significant shorter than the other techniques ($P < 0.05$). The material adaptation and presence of sealer extrusion in all obturation techniques were comparable and the duration of obturation procedure using the injectable technique was slightly shorter.

Keywords: obturation, continuous backfill, interrupted backfill, injectable technique, SEM image

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Introduction

The purpose of performing root canal obturation is aimed at reducing the chance of microorganisms to grow, performed after the completion of root canal preparation and disinfection procedures [1]. A silver type obturation material was used in the past but it is no longer practiced due to several drawbacks. Conventional obturation materials are composed of gutta-percha points and root canal sealer, appropriate for various obturation techniques such as cold and warm lateral compaction, continuous and interrupted waves of vertical compaction, thermomechanical compaction, carrier-based and single cone techniques [1-2]. Root canal sealer can fill the space between root canal wall and gutta-percha, root canal irregularities and the spaces between gutta-percha points to provide an effective seal [3]. Warm vertical compaction technique has been the preferred thermoplastic gutta-percha technique because of the ability to seal the root canal effectively. However, this is a technique sensitive procedure, and require operators' skills and experience to be accomplished. A modified version of this technique has been introduced such as continuous and interrupted waves of warm vertical compaction to achieve similar obturation quality [1]. Even though thermoplastic gutta-percha provides good obturation quality, [2] leakage associated with this technique has also been reported in previous study [4] possibly due to contraction of the obturation material during setting. Despite these findings, there have also been reports showing a promising obturation technique when thermoplastic gutta-percha is used with bioceramic root canal sealers.

Bioceramic root canal sealers has been increasingly used for obturation in recent years due to advantages include; biocompatible, able to promote hard tissue formation, improved flow properties and less time-consuming procedure. GuttaFlow Bioseal (Coltène/Whaledent) was introduced in late 2015. It is a non-heated flowable type of obturation material containing gutta-percha, polydimethylsiloxane, zirconium oxide, platinum, and bioactive ceramic glass, developed to improve biocompatibility of GuttaFlow bioactivity and promote periapical healing [5]. GuttaFlow Bioseal is a silicone-based obturation material, containing bioactive substance that enables hard tissue formation upon contact with moisture. With setting time approximately 12-16 minutes, the obturation with GuttaFlow Bioseal is a promising approach, and could serve as an alternative to thermoplastic obturation technique during root canal treatment procedure. The ability of this system to form hydroxyapatite crystals makes it an option to seal a complex root canal system. GuttaFlow Bioseal can also expand during setting, therefore it could improve any marginal gaps inside the root canal. The flowability capacity of GuttaFlow Bioseal may also provide a better sealed root canal with the material conforms to the root canal space and could provide an equal obturation quality as observed with the thermoplastic gutta-percha. However, this aspect is still unclear as there is no evidence on this matter.

The effectiveness of obturation has been investigated for many years with various techniques including the scanning electron microscopy (SEM) [6], confocal laser scanning microscopy (CLSM) [7-9], micro computed tomography (micro CT) [10-11] and others, each with its own advantages and disadvantages. SEM is a common utilised method for microscopic analysis of the obturation [6]. The tooth samples were either longitudinally [12] or horizontally sectioned [13] to allow for the microscopic analysis of the samples. To date, there is no conclusive evidence to suggest the superiority of one method over the other even though some researchers opt for double methods [14-17]. Undoubtedly, double methods could provide thorough evaluation and add more value to the analysis, however they are more costly as well as time consuming which explains the utilising of single method in majority of the published studies.

The current state of knowledge regarding the clinical application of GuttaFlow Bioseal is not present. In addition to this, published articles addressing the efficacy of obturation using GuttaFlow Bioseal is limited. Therefore, further evaluation in other aspects related to obturation should be done to provide an insight for future clinical application. Without sufficient evidence, the effectiveness of obturation using this material remains unknown. To our knowledge, there has been no comparative study evaluating different techniques of obturation using GuttaFlow Bioseal being reported. The aim of this study is to evaluate the adaptation of GuttaFlow Bioseal in the root canal, the presence of sealer extrusion and the duration taken for obturation procedure.

Materials and Methods

This study received an ethical approval from IIUM Research Ethics Committee (IREC 2019-203). 30 samples were selected based on the following inclusion criteria; extracted single rooted human mandibular premolars, sound/intact tooth. Exclusion criteria includes; severely curved roots, tooth resorption, severe tooth surface loss, obliterated root canal. Another 6 samples were also allocated for training session and calibration purposes. The samples were mounted on silicone impression materials (Putty soft, President, Coltène/Whaledent). Training session was conducted involving 2 specialists in endodontics at Specialist Clinic of Conservative Dentistry in Kulliyyah of Dentistry. Preoperative radiographs [Planmeca ProSensor Digital Radiography System (Planmeca, Helsinki Finland)] were taken at 2 angles; mesial and buccal. The demonstration on endodontic procedure was carried out followed by discussion to ensure a standardisation between 2 researchers.

Preparation of the samples. Endodontic procedure of all samples was done under dental operating microscope (Zeiss, Germany). A conventional access cavity preparation was performed using a cavity access set (Coltène/Whaledent AG, Altstatten, Switzerland). The root canal terminus was established at 0.5 mm short of the apical foramen using size 15 K files and confirmed with a periapical radiograph (Planmeca, Helsinki Finland) taken at two angles. Root canal preparation was completed using Hyflex CM rotary files (Coltène/Whaledent AG, Altstatten, Switzerland) starting from an orifice opener 25/0.12, then continued until 30/0.06 at 500 rpm rotation speed and 2.5 N cm torque level according to the manufacturer's recommendation. The root canal was irrigated with 5.25% sodium hypochlorite (Coltène/Whaledent AG, Altstatten, Switzerland) and final flush with 17% Ethylenediaminetetraacetic acid (Coltène/Whaledent AG, Altstatten, Switzerland) and 5.25% sodium hypochlorite. Root canals were dried with size 30/0.06 paper points (Coltène/Whaledent AG, Altstatten, Switzerland).

The samples were divided into 3 groups (n=10); continuous backfill, interrupted backfill and injectable technique groups. 30/0.06 gutta-percha cone was fitted into the root canal and periapical radiographs were taken to evaluate gutta-percha fitting.

In the continuous backfill group, a matched-taper gutta-percha cone was thinly coated with GuttaFlow Bioseal and fitted into the root canal. A heated plugger or vertical condensation pen (# F) (Endo-Apex, DXM Co., Ltd) was used to cut the gutta-percha cone and down packing until at 5 mm short of the working length. Backfilling was done by delivering the GuttaFlow Bioseal into the root canal using a delivery tip until at the cemento-enamel junction (CEJ), confirmed visually under dental operating microscope (Zeiss, Germany) at 1.0 magnification.

In the interrupted backfill group, a matched-taper gutta-percha cone was thinly coated with GuttaFlow Bioseal and fitted into the root canal. A heated plugger or vertical condensation pen (# F) (Endo-Apex, DXM Co., Ltd) was used to cut the gutta-percha cone and down packing until at 5mm short of the working length. Backfilling was done by delivering the GuttaFlow Bioseal into the root canal incrementally using a delivery tip, then the material was packed gently and adapted to the root canal wall using endodontic plugger (#1-2, #2-3) (Maillefer, Switzerland) until at the CEJ, confirmed visually under dental operating microscope (Zeiss, Germany) at 1.0 magnification.

In the injectable group, a gutta-percha cone was thinly coated with GuttaFlow Bioseal initially. The root canal was then filled with GuttaFlow Bioseal using a delivery tip until at the CEJ followed by placement of a GuttaFlow Bioseal coated gutta-percha cone into the root canal. The gutta-percha cone was cut with a heated plugger or vertical condensation pen (# F) (Endo-Apex, DXM Co., Ltd) at the CEJ level, confirmed visually under dental operating microscope (Zeiss, Germany) at 1.0 magnification.

The duration of time required to obturate the root canal was recorded using a digital timer starting from coating of the gutta-percha cone with GuttaFlow Bioseal until the excess materials in the access cavity were completely removed. Periapical radiographs [Planmeca ProSensor Digital Radiography System (Planmeca, Helsinki Finland)] were taken after the obturation to assess the obturation quality and the presence of material extrusion. Restoration of the access cavity was done with composite resin (NTPremium, Coltene). Then, all samples were stored in separate vials at room temperature with 100% humidity for 7 days to ensure complete setting of the root filling materials.

Preparation for scanning electron microscopy. The root of each sample was sectioned horizontally at the apical, middle and coronal regions with EXAKT cutter machine (EXAKT Apparatebau systems, Norderstedt, Germany) under distilled water. The resected roots were immersed in 25%, 50% and 75% ethanol for 20 minutes each concentration, 95% ethanol for 30 minutes and 100% ethanol for 60 minutes. All of the samples were then placed in the automated tissue processor (Leica TP 1020, Leica, Germany) for dehydration process.

The resected roots were mounted on brass stubs and sputter-coated with thin platinum coating using Sputter Coater Machine (BAL-TEC SCD005, Scotia, New York) at 70 mA for 70 seconds. Then, the resected roots were placed in the SEM chamber (FEI ESEM Quanta 450 FEG, Hillsboro, Oregon, USA) and observed under SEM at 70x magnification.

Evaluation of volumetric percentage of the obturated root canals. The SEM images were transferred to the SketchAndCalc Area Calculator software (iCalc) for evaluation of the material adaptation in the root canals. The outline of root canal wall, obturation material and voids/gaps were carefully sketched using SketchAndCalc Area Calculator software (iCalc). The value of each surface area was generated automatically in the software for further calculation. The volumetric percentage of obturated root canal at the apical, middle and coronal regions were evaluated using the following equation.

$$\text{Volumetric percentage of obturated canals (\%)} = \frac{\text{Adaptation of root filling material (mm}^2\text{) - Void (mm}^2\text{)}}{\text{Surface area of root canal space (mm}^2\text{)}} \times 100$$

Statistical analysis. Data analysis was conducted using SPSS 25.0. Kolmogorov-Smirnov normality test was conducted to evaluate the distribution of data whether normally or not normally distributed. Kruskal Wallis test was carried out for the volumetric percentage of obturated root canals and Chi-Square test for the extrusion of material beyond the apical foramen. Then, one-way analysis of variance (ANOVA) and Tukey HSD post hoc test for the duration taken for obturation procedure.

Results and Discussion

The limitations associated with continuous and interrupted backfill techniques are shown in Figure 1. Inadequate obturation can be seen at mid root regions due to ineffective delivery of GuttaFlow Bioseal into the root canals. The SEM images of obturated root canals are shown in Figure 2 in which the focused regions are material adaptation in the root canals, marginal gaps and voids. The material is well adapted, conformed to the root canal space, and absence of marginal gaps and voids in a well obturated root canal. Conversely, the marginal gaps and/or voids are present when the material is not adapted effectively (Figure 3).

SEM images were transferred to the SketchAndCalc Area Calculator software (iCalc) for evaluation of the material adaptation in the root canals. Then, the outline of root canal wall (green), obturation material (pink) and voids (blue) were carefully sketched using SketchAndCalc Area Calculator software (iCalc). Sketched images revealed marginal gap and void (Figure 4).

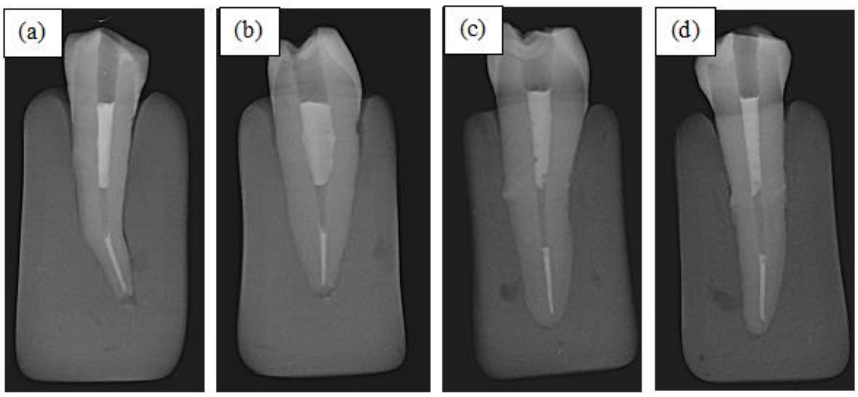

Figure 1. Obturation radiographs in continuous backfill (a) mesio-distal angle, (b) bucco-lingual angle, and interrupted backfill (c) mesio-distal angle and (d) bucco-lingual angle

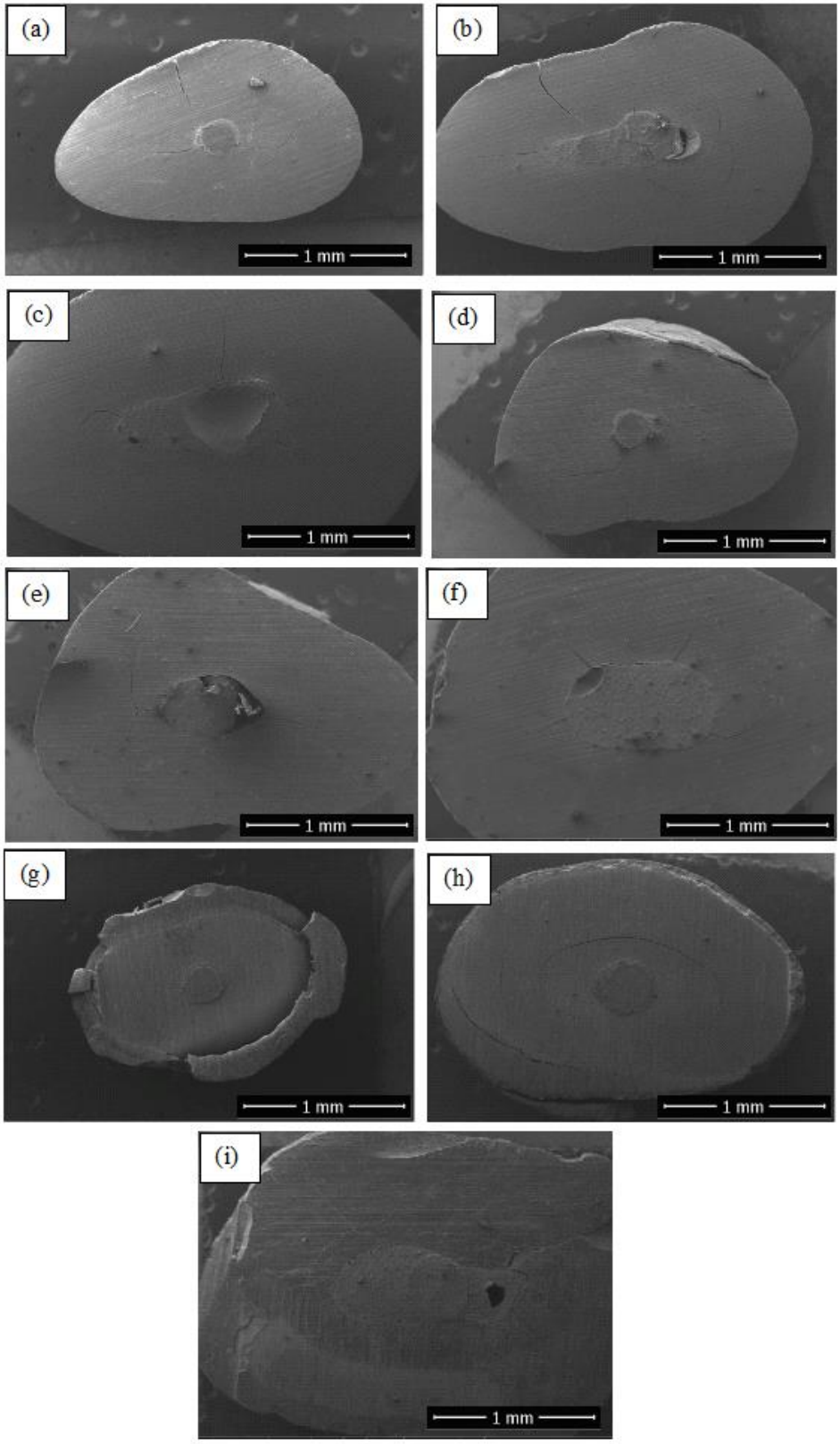

Figure 2. SEM images of three obturation techniques at the apical, middle and coronal root regions (a) continuous backfill – apical, (b) continuous backfill – middle, (c) continuous backfill – coronal, (d) interrupted backfill – apical, (e) interrupted backfill – middle, (f) interrupted backfill – coronal, (g) injectable – apical and (h) injectable – middle, (i) injectable – coronal

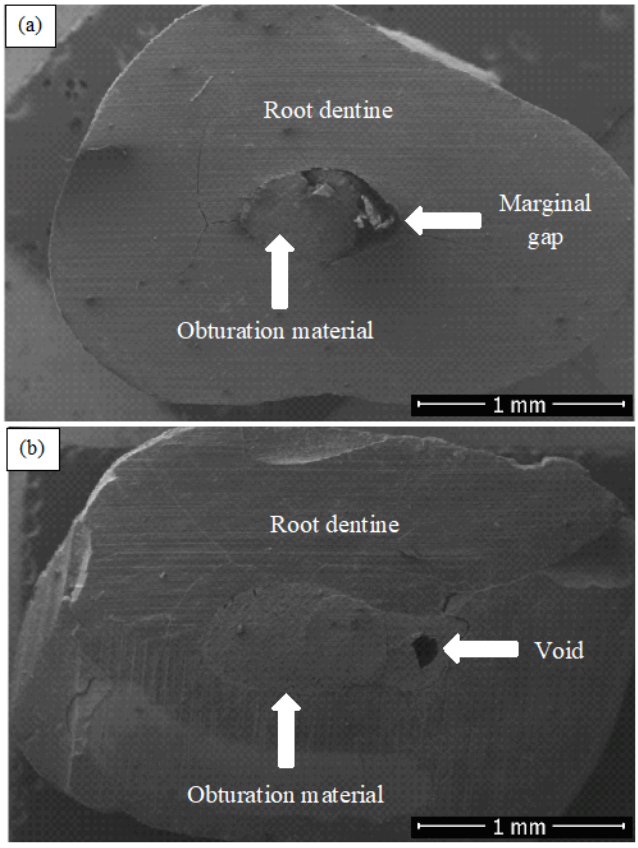

Figure 3. SEM images revealed (a) marginal gap and (b) void

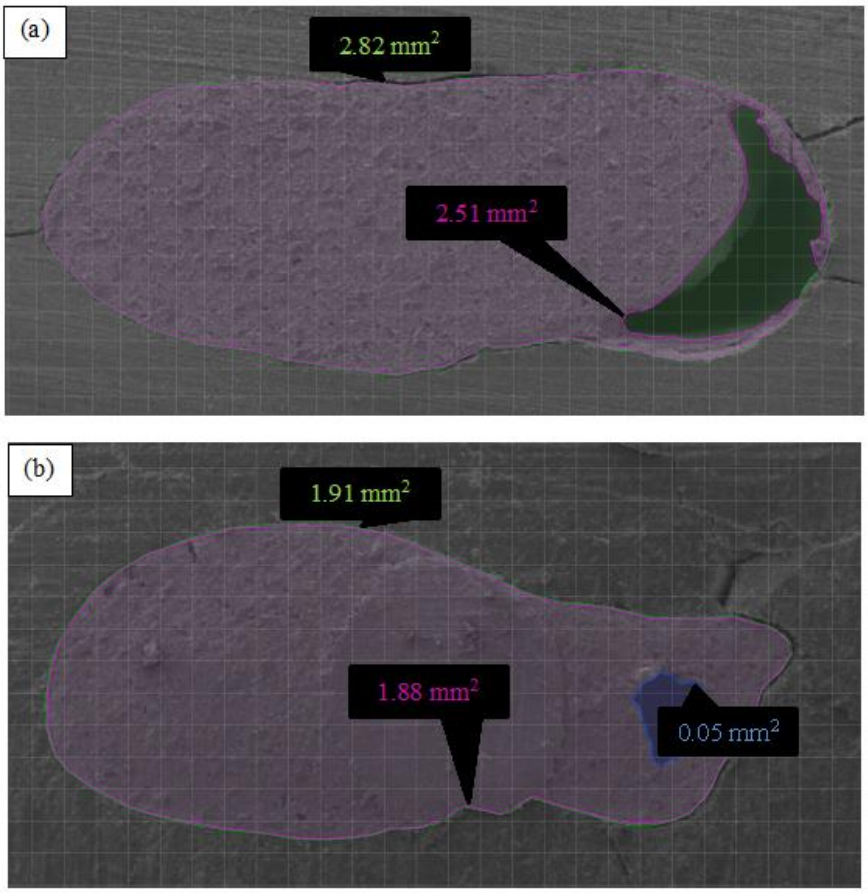

Figure 4. Sketched images revealed (a) marginal gap and (b) void

Kruskal Wallis test showed no statistically significant differences in the volumetric percentage of material adaptation in the root canals in all the obturation techniques at any level of evaluation ($P > 0.05$) (Table 1).

Table 1. Volumetric percentage of material adaptation in the root canals

Obturation technique		Volumetric Percentage Median (IQR), Min-Max	Chi square statistic (df)	*P* value
Continuous Backfill	Apical	99.05(3.05), 90.2-100	3.771(2)	0.152
	Middle	96.55(10.67), 72.6-98.80		
	Coronal	98.6(2.13), 85.10-99.30		
Interrupted backfill	Apical	97.55(38.13), 0-100		
	Middle	95.65(38.13), 0-100		
	Coronal	98.00(3.92), 89.00-99.00		
Injectable technique	Apical	98.95(2.95), 75.60-100.00		
	Middle	98.65(1.12), 98.00-100.00		
	Coronal	96.85(3.93), 86.50-99.50		

Chi-Square test at 0.05 level of significance showed no statistically significant differences in the presence of material extrusion in all the obturation techniques ($P > 0.05$) (Table 2).

Table 2. Presence of material extrusion

Obturation technique	Extrusion of GuttaFlow Bioseal *n* (%)		X^2(df)	*P* value
	No	Yes		
Continuous backfill	5(50%)	5(50%)	1.875 (2)	0.392
Interrupted backfill	7(70%)	3(30%)		
Injectable technique	4(40%)	6(60%)		

One-way ANOVA showed statistically significance differences in the duration of time required for obturation in all the obturation techniques ($P < 0.05$) (Table 3). Further analysis using Tukey HSD post hoc test showed no statistically significant differences between continuous backfill and interrupted backfill ($P > 0.05$). Other pair comparisons showed statistically significant differences ($P < 0.05$) (Table 4).

Table 3. Duration of obturation

Obturation technique	Duration Mean (SD)	F statistic (df)	*P* value
Continuous Backfill	7.41(2.47)	10.978 (2)	0.00
Interrupted backfill	6.74(1.89)		
Injectable technique	3.54(1.41)		

Table 4. Pair comparison of duration of obturation procedure

Obturation technique	Mean Difference (95% CI)	*P* value
Continuous backfill vs Interrupted backfill	0.665 (-1.522, 2.852)	0.734
Continuous backfill vs Injectable	3.865 (1.678, 6.052)	0.000
Interrupted backfill vs Injectable	3.200 (1.013, 5.387)	0.003

The obturation with GuttaFlow Bioseal has been investigated in the past studies [14, 17-18]. Based on the reported data, the obturation with GuttaFlow Bioseal by means of a single gutta-percha cone, or cold lateral compaction [18] showed excellent quality and low mean value of leakage [17]. The utilisation of extracted human mandibular premolars in the present study was in accordance with the previous studies [17] and basically the most commonly investigated teeth. Evaluation of material adaptation in the root canals at the apical, middle and coronal root regions were corroborated with the previous studies [14] however, the microscopic analysis was performed using micro CT, which was different from the present study. Evaluation using SEM was conducted previously [17] not focusing on the apical, middle and coronal root regions but on 1.5 mm thickness of the resected root. Due to methodological differences, it is rather difficult to make a definite conclusion pertaining to this aspect and would require further investigation.

In the present study, the material adaptation in the root canals did not show statistically significant differences at any level of evaluation for all the obturation techniques. This could be attributed to the careful handling of the material and performed under dental operating microscope by the specialists in endodontics. However, there were some problems encountered during the experiment such as, the use of standard size and length of the delivery tips from the manufacturer resulted in ineffective placement of GuttaFlow Bioseal into the root canals particularly at mid root regions and in narrow root canal space despite careful placement of the material. This could explain the inadequate obturation at mid root regions in some of the samples in continuous and backfill techniques (Figure 1(a-d)). Having delivery tips available in different sizes and length would potentially overcome this problem. In addition to that, it is difficult to standardise the root canal morphology in all of the samples albeit being from the same tooth category. Even though a matched-taper gutta-percha cone was used, the injectable technique could not obturate large root canal space adequately, owing to inadequate pressure to allow the material to flow inside the root canals. Due to anatomical variations, the use of a matched-taper gutta-percha cone could inevitably produce voids and/or marginal gaps compared to a compacted obturation technique, and may not be suitable for complex root canal morphology [19]. Cold lateral compaction can be considered in large root canals or unusual root canal morphology instead [18].

Data pertaining to the extrusion of bioceramic root canal sealers beyond the apical foramen has been reported by limited number of researchers. The extrusion has been assessed from clinical perspective [20] and ex vivo analysis [21-22], however the researchers found that the use of bioceramic root canal sealers did not significantly affect endodontic treatment outcomes [20], pain levels [23] and the frequency of extrusion was comparable as of the conventional root canal sealers [21-22]. In the present study, when three types of obturation techniques with GuttaFlow Bioseal were evaluated, the frequency of material extrusion was equivalent. This could be due to the use of a matched-taper gutta-percha cone and effective length control resulting in no statistically significant differences in the extrusion of material beyond the apical foramen. Insufficient studies do not allow direct comparison of the findings from the present study with those published previously.

Duration of obturation procedure is not commonly investigated by the researchers possibly because of no direct influence in the endodontic treatment outcomes. However, this aspect has been evaluated from *ex vivo* perspective [21-22] and the researchers found that the duration of obturation procedure with GuttaFlow Bioseal was slightly longer than the conventional root canal sealer. When GuttaFlow Bioseal was further investigated in the present study, the duration of obturation in the injectable technique was statistically significant shorter

than the other techniques, could be related to a much simpler procedure, resulting in a less time-consuming procedure.

Studies have shown, factors that could improve the dentinal tubule penetration of bioceramic root canal sealers include; 1) adjunctive irrigation by means of laser activation prior to obturation [24], 2) a matched-taper gutta-percha cone [7], 3) warm vertical compaction obturation technique [25], 4) pre-mixed sealer rather than powder/liquid form [8], and 5) sonic or ultrasonic activation of root canal sealer during obturation procedure [9]. The fact that fluid-tight seal could be influenced by some factors, limited published articles are related to GuttaFlow Bioseal while others are related to different bioceramic root canal sealers [7-9, 25].

Conclusion

Within the limitations of the present study, the conclusions that can be suggested are;

1. The volumetric percentage of material adaptation in the root canals and the presence of material extrusion in three obturation techniques with GuttaFlow Bioseal were comparable.
2. The duration of obturation procedure using the injectable technique was statistically significant shorter than the other techniques.

Obturation with GuttaFlow Bioseal is a predictable approach and effective. Clinician can opt different techniques depending on clinical cases, personal preference and availability of the material. These findings should be further evaluated from clinical aspect so that treatment outcomes on patients can be assessed.

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Author Contributions

All authors contributed toward concept and design of the study, data collection, data analysis and interpretation of the results, preparation of the draft manuscript, critically revising the manuscript, and agreed to be accountable for all aspects of the work.

Disclosure of Conflict of Interest

The authors have no disclosures to declare.

Compliance with Ethical Standards

The work is compliant with ethical standards and received an ethical approval from IIUM Research Ethics Committee (IREC 2019-203).

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