Sealing ability of Biodentine versus ProRoot mineral trioxide aggregate as root-end filling materials

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Abstract  \textit{Aim:} This study evaluated the sealing ability of ProRoot MTA and Biodentine as root-end filling materials.

\textit{Method:} In total, twenty (N = 20) extracted human maxillary central incisor teeth were decontaminated, cleaned and decoronated. Instrumentation was performed according to the step back technique using #50 Flex-o-file. Then the canals were flared to #70 Flex-o-file. Obturation was performed with conventional gutta percha and a resinous sealer (AH26) using the lateral condensation technique. Resection of 3 mm of apical end of each root was achieved perpendicular to the long axis of the root. Root-end cavity was prepared in each sample ultrasonically then filled with tested materials (N = 10). Fluid filtration method was used to assess the sealing ability of each tested material at three different experimental periods; one day, one week and one month after setting. All data were tabulated and statistically analyzed with a level of significance set at $P < .05$.

\textit{Results:} At each specific time interval, the leakage mean values were not consistent among the tested materials. At one day interval, ProRoot MTA samples had a higher leakage mean value than Biodentine samples. However, this difference in leakage was not statistically significant ($P > .05$). At one week interval, both materials showed an increased degree of leakage mean value with no significant difference ($P > .05$). At one month interval, ProRoot MTA samples showed a decrease in leakage mean value, while the Biodentine samples showed a further increase in leakage mean value. This difference was statistically significant ($P < .05$).
1. Introduction

Complete sealing of the root canal system to obtain a fluid tight seal is essential for the success of endodontic therapy (Estrela et al., 2014). Sometimes treatment of the periapical lesions through conventional endodontic therapy is not enough and a surgical endodontic interference is a mandatory therapeutic choice. The main surgical intervention is the root tip resection and periapical curettage (von Arx, 2011).

During the peri-radicular surgery, an exposure of apical dentin surface bounded by cementum usually results from the root-end resection. For good bone regeneration and apical seal, the orthograde gutta-percha filling only is not sufficient. Application of a root-end-filling material after the root-end resection and ultrasonic root-end preparation is recommended for enhancing a good apical seal (von Arx, 2011).

Sealing ability means the ability of a material to resist the microleakage through its entire thickness. The leakage of irritant materials from the infected root canals into the peri-radicular tissues is the main cause for most endodontic failures; therefore, an efficient apical seal is essential for enhancing endodontic success (Mulyar et al., 2014).

Different materials have been used as root-end filling materials such as amalgam, intermediate restorative material (IRM), glass-ionomer cement, Super ethoxy benzoic acid (Super- EBA), and composite resin (Jou and Perl, 1997; Soundappan et al., 2014; Asawaworarit et al., 2016). However, an ideal root-end filling material has yet to be found.

Nowadays, Mineral Trioxide Aggregate (MTA) has a more clinical success compared with other root-end filling materials due to its lower cytotoxicity, better biocompatibility and microleakage protection (von Arx, 2011; Hassamien et al., 2015). On the other hand, MTA has several disadvantages such as; long setting time, difficult handling, expensiveness, potential discoloration, and lower compressive and flexural strengths (Unal et al., 2010; Negm et al., 2017).

Biodentine is considered as an alternative to MTA because it has several similar properties when compared with MTA with better consistency and faster setting time. Biodentine powder mainly has tricalcium silicate, dicalcium silicate and calcium carbonate which are the main components of MTA. The liquid has an aqueous solution of calcium chloride and an admixture of polycarboxylate. Calcium hydroxide is produced during the setting of the cement (Butt et al., 2014).

According to several previous studies, MTA has a high clinical success as a root-end filling material (Shahabang et al., 1999; Apaydin et al., 2003; Bernabé et al., 2005; Camilleri and Pattford, 2006; Felipe et al., 2006; Holland et al., 2007; Chhaparwal et al., 2017).

The manufacturer of Biodentine claims that Biodentine, as an endodontic repair material, has superior features to MTA. Therefore this study evaluated the sealing ability of Gray ProRoot Mineral Trioxide Aggregate versus Biodentine as root-end filling materials.

2. Materials and methods

2.1. Materials

Gray ProRoot MTA (Dentsply/Tulsa Dental, Tulsa, OK-USA)

Biodentine (Septodont, Saint Maur des Fausses, France).

2.2. Sample selection

The research proposal was approved by the Ethical Committee at Faculty of Dentistry Ain Shams University, Egypt. The present study was carried out on twenty extracted human maxillary central anterior teeth collected from the outpatient clinic of Oral Surgery Department at Ain Shams University. All examined teeth had the following criteria; mature apices, absence of multiple canals, severe apical curvatures, obvious fractures/cracks and root resorption and/or root canal calcifications.

2.3. Sample preparation

All teeth were immersed for 30 min in 5.25% Sodium hypochlorite solution for decontamination. The teeth were then cleaned and scaled for removing any dental deposits and/or calculus. At the level of cement-enamel junction and under water coolant, all teeth were decoronated using isomet saw (Isomet, Buehler; Ltd., Lake, Bluff, IL). The length of all roots was standardized in 16 mm by coronal surface grinding. Then all samples were stored at the room temperature in a sterile normal saline solution.

2.4. Root canal instrumentation

An endodontic explorer was used for locating the orifice of the root canal. Patency and working length of each canal was determined by passing the #15 Flex-o-File (Maillefer, Johnson City, TN, USA) to the anatomical foramen. This length was reported, and the final working length was established 1 mm short of this reported length. All teeth were irrigated with 5.25% Sodium hypochlorite solution by a 27-gauge needle, 2 mL between each file size. The canals were then cleaned and shaped by using the step-back method and #50 Flex-o-File was used as the master apical file. The canals were then flared to #70.

The instrumented root canals were then dried with the paper points and obturated by gutta-percha (Henry Schein, Melville, NY) and AH26 sealer (Dentsply, Konstanz, Germany) by using the lateral condensation technique. To verify proper obturation, all obturated teeth were radiographed (Fig. 1a). The samples showing insufficient obturation were re-obturated until proper form, fill and density were seen. IRM (Dentsply, York, PA-USA) was used to seal the coronal surfaces of the canals. The roots were wrapped in moist gauze and stored for 1 week at 100% humidity and 37 °C.
2.5. Root-end resection

Under water coolant, resection of 3 mm of the apical end of each root was performed perpendicular to the long axis of the root using a carbide bur (KOMET, Santo André, São Paulo, Brazil) mounted on a high speed hand piece (Fig. 1b).

Root-end cavity preparation, 3 mm in depth and 0.8 mm diameter was prepared in each sample using an ultrasonic tip (Ultrasonic tip, E32D NSK, Tochigi, Japan) powered by an ultrasonic device (Piezon Master, EMS, Nyon, Switzerland) at a frequency of 32 KHz. A periodontal probe was used to measure the preparation depth.

2.6. Sample grouping

The prepared teeth were randomly divided into 2 equal experimental groups according to the tested root-end filling materials; Group 1: Mineral Trioxide Aggregate (N = 10 teeth) and Group 2: Biodentine (N = 10 teeth).

To avoid any possible bias, all samples were coded throughout the study

2.7. Root-end filling

Gray ProRoot MTA was mixed according to the manufacturer’s instructions and used to fill the prepared root-end cavity in group 1. After drying of the root-end cavity with paper points, ProRoot MTA was dispensed into the root end cavity using MTA carrier and compacted using a small plugger (Dentsply, York, PA-USA). Any excessed material was removed and the surface of the root was cleaned with a moist piece of gauze (Fig. 1c).

According to the manufacturer’s instructions, Biodentine was mixed and used to fill the root-end cavity preparations in group 2.

2.8. Evaluation of sealability

The sealability of the tested materials was evaluated using the fluid filtration method described by Derkson et al. (1986) and as shown in Fig. 2.

2.9. Statistical analysis

The obtained data were represented as mean and standard deviation (SD) values of apical leakage for the tested materials at different tested periods.

Leakage data showed non-parametric distribution, so non-parametric tests were used for the comparisons. Mann-Whitney U test was applied to compare between the groups. Kruskal-Wallis test was used to compare between more than two groups. Friedman’s test was used to evaluate the effect of time in comparison with more than two follow up times. Wilcoxon signed-rank test was used for assessment of the effect of time in comparison with two follow up times. Dunn’s test was applied for pair-wise comparison when Kruskal-Wallis test or Friedman’s test had significant results. The significance level was set at $P < .05$. IBM® SPSS® Statistics Version 20 for Windows (IBM® Corporation, NY, USA) was applied for the statistical analysis.

3. Results

3.1. Longitudinal data for leakage values of the tested root-end filling materials

In group 1, the sealing ability of ProRoot MTA as a root-end filling material was affected by time. The leakage mean values of ProRoot MTA samples were $0.80 \pm 0.63$, $1.40 \pm 0.52$ and $0.60 \pm 0.52$ after one day, one week and one month, respectively (Fig. 3).
Statistically, there was a significant change in sealing ability scores by time ($P = .003$). Pair-wise comparisons between the follow-up times revealed a statistically significant increase in sealing ability scores after 1 week followed by a significant decrease in sealing ability scores from 1 week to 1 month. However, there was no difference ($P < .05$) between sealing ability scores reported from 1 day to 1 month.

In group 2, the sealing ability of Biodentine as a root-end filling material was affected by time. The leakage mean values of Biodentine samples were 0.20 ± 0.42, 1.40 ± 0.52 and 2.10 ± 0.57 after one day, one week and one month, respectively (Fig. 4).

Statistically, there was a significant change in sealing ability scores by time ($P < .001$). Pair-wise comparisons between the follow-up times revealed a statistically significant increase in sealing ability scores after 1 week as well as from 1 week to 1 month.

3.2. Comparison of the leakage values of the two tested root-end filling materials at the three time intervals

The leakage values at each specific time interval were not consistent among the two tested materials.

At one day interval, ProRoot MTA samples showed a higher mean leakage value reaching 0.80 ± 0.63 when compared to Biodentine samples which was 0.20 ± 0.42. This difference in leakage values was not significant ($P = .052$).

At one week interval, both materials showed an increased degree of leakage mean value to be 1.40 ± 0.52 with no significant difference ($P = 1.000$).

At one month interval, ProRoot MTA samples showed a decreased leakage mean value reaching 0.60 ± 0.52, while Biodentine samples showed further increase in the leakage mean value to be 2.10 ± 0.57. This difference in leakage values between the two tested materials was significant ($P < .001$, Fig. 5).

4. Discussion

The successful root canal therapy aims to eliminate the microorganisms from the root canal and to fill the intra-canal space for prevention of the possible apical pathology caused by the bacterial colonization. Conventional endodontic treatment is unsuccessful curing in some clinical cases; hence the surgical endodontic intervention is a mandatory procedure. Root-end resection and root-end filling are the common surgical procedures when the conventional endodontic treatment fails.

The ideal root-end filling material has a good adherence to dentinal walls, a bioactive promotion of healing and a peri-radicular tissue tolerance (Jou and Perl, 1997).

However Biodentine has similar properties to those of ProRoot MTA, calcium hydroxide is produced during the setting of Biodentine cement (Butt et al., 2014). Therefore, this study evaluated the sealing ability of both Gray ProRoot MTA and Biodentine as root-end filling materials because the manufacturer of each material claims its superior features in clinical performance.

It is well known that Biodentine is recommended as an endodontic repair material due to its good sealing ability, short setting time, high compressive strengths, biocompatibility and biomineralization properties.
In dentistry, the microleakage evaluation could be performed by various methods and devices such as fluid filtration, dye extraction, dye penetration, bacterial and protein leakage models. New alternative methods are introduced recently such as artificial caries, radioactive isotopes, scanning electron microscopy, neutron activation analysis, and electrical conductivity (Gogna et al., 2011).

The fluid filtration system is widely used in the literature for microleakage evaluation. This technique evaluates the sealing ability of different restorative and endodontic sealers (Bates et al., 1996; Tang et al., 2002; Fridland et al., 2003). Therefore this method has gained popularity in endodontic for the evaluation of apical or coronal microleakage (Yoshimura et al., 1990).

In the present study, fluid filtration method described by Derksen et al. (1986) was employed. This method, as the dye extraction technique, depends upon the quantitative measurements of liquid passage within interfaces therefore both techniques gave similar results in a previous study (Camps and Pashley, 2003).

The fluid filtration method has several advantages when compared to the other techniques used for microleakage evaluation. These advantages include; the samples are not destroyed as that with dye penetration, no tracer is needed, no intermediate materials as in bacterial penetration or radioactive studies are required. Moreover, the fluid filtration method gives very accurate results due to the automatic recording of very small volumes, so avoiding any possible operator bias.

Ten minutes monitoring of the air bubble at 2 min interval was selected to assure regular movement of the air bubble. A small measurement time may lead to misinterpretation.

The pressure used in this study (20 Psi) was relatively higher than the average pressure (15 Psi) used by Bashisha et al. (1998). The 20 Psi pressure seems to be far too high because it corresponds to a 1406 cm H₂O pressure. Under clinical conditions, a root-end filling material is subjected to pressure due to local bleeding, tooth function and post-operative swelling (Taschieri et al., 2004).

The results of the present study showed that both ProRoot MTA and Biodentine exhibited microleakage, but there was a difference in the leakage value at different time intervals.

After one day, Biodentine was superior with regard to sealing ability; however, the difference was not statistically significant. This was in agreement with the results of other studies which concluded that Biodentine exhibited best sealing ability followed by MTA when evaluated at 24 h (Khandelwal et al., 2015; Malhotra and Hegde, 2015) and at 48 h after setting (Pathak, 2015; Sinkar et al., 2015).

The difference in microleakage seen in Biodentine in comparison to ProRoot MTA when evaluated at 1 day after setting could be attributed to the formation of calcium or phosphate rich crystalline deposits that increases over time and minimizes the gap between the tooth and the root-end filling material (Lee, 2000; Byakod et al., 2012). The relatively high leakage of ProRoot MTA observed during the initial 24 h can be due to the longer setting time of MTA (Sarkar et al., 2005).

Therefore the setting time is one of the most clinically determinant factors (Han and Okiji, 2011). Biodentine has a rapid setting time that decreases the risk of dislodgement and contamination of the root-end filling materials (Ishikawa et al., 1997). Moreover, the handling property is another important feature of the root-end filling materials. In contrast to the difficult manipulation of MTA, due to its grainy nature and its poor consistency, Biodentine is relatively easily handled and easily condensed.

At one week interval, both ProRoot MTA and Biodentine had an increased degree of leakage mean value with no significant difference. For Biodentine, the increased leakage value after one week may be attributed to the formation of a high pH solution containing Ca²⁺, OH⁻, and silicate ions with formation of calcium silicate hydrated gel (CSH) that precipitates on the cement particles, whereas calcium hydroxide nucleates (Lenander-Lumikari and Loimaranta, 2000).

At one month interval, ProRoot MTA samples showed a decrease in leakage mean value, while the Biodentine samples showed further increase and this difference was statistically significant. These results are in accordance with other studies which concluded that MTA has a better long-term sealing ability than Biodentine (Gandolfi et al., 2010; Camilleri et al., 2013). This improvement in the sealing ability of ProRoot MTA by time is due to its hydrophilic properties and formation of an interfacial layer between the dentin and MTA. This interfacial layer decreases the risk of marginal percolation and enhances long-term clinical success (Guvv et al., 2014). In addition, further hydration of MTA powder by moisture increases the compressive strength and decreases leakage (Kubo et al., 2005). Sarkar et al. (2005) added that MTA has the ability to precipitate hydroxyapatite crystals in the presence of moisture and minimizing leakage. Also, the small particle size of MTA increases the surface available for hydration and induces greater early strength (Sarkar et al., 2005; Camilleri, 2007; Camilleri et al., 2013).

Regarding Biodentine, an increase in the alkalinity of the surrounding medium is observed due to release of calcium hydroxide and formation of a solid network. An interaction between the calcium silicate based cements and the phosphate ions of saliva results in formation ofapatite deposits with increasing the scalability of the material as reported before (Lenander-Lumikari and Loimaranta, 2000; Camilleri, 2008). Moreover, Han and Okiji (2011) recorded that biomineralization ability of Biodentine is more than MTA, with a wider calcium and silicon rich layer at material dentine interface.

The relatively higher leakage values in this study compared to other studies (Butt et al., 2014; Chhaparwal et al., 2017) could be attributed to the high pressure used. In the fluid filtration method, several factors can affect the results such as; the diameter of the tube, the length of the bubble, and the measurement time.

5. Conclusion

Although the sealing ability of ProRoot MTA is superior to Biodentine, Biodentine could be considered as an acceptable alternative to ProRoot MTA in the peri-radicular surgeries. Further comparative studies on the biocompatibility of ProRoot MTA and Biodentine as root-end filling materials are recommended.

Conflict of interest

The authors declare no conflict of interests.
Ethical statement

All author approved the writing and submission of this article and none of them has any conflict of interests. This article did not published elsewhere before in any form.

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