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An Evaluation on Sealing Ability of Calcium Silicate-Based Cements and Glass Ionomer Cement as Perforation Repair Materials

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The study evaluated the sealing ability of Biodentine, MTA Repair HP, and Glass ionomer cement as perforation repair materials by using a Stereomicroscopic analysis.

Study Design: Experimental *in vitro* study

Methodology: The access cavity was prepared on 45 samples of maxillary and mandibular teeth with a perforation of the standardized diameter of a No. 2 round bur at the bottom of the pulp chamber. All 45 samples were divided into three different experimental groups of 15 samples each. Group A (n=15), Group B (n=15) and Group C (n=15). The furcation repairs of the samples in groups A, B and C were carried out using Biodentine, MTA Repair HP and glass ionomer cement respectively. All sealed furcation perforation samples were stored at room temperature for 24 hours. Two layers of nail varnish were coated on all the surfaces to avoid dye penetration except for 2 mm around the area of the perforation site. After complete drying, all specimens were separately soaked in 2% methylene blue solution for 48 hours, cleaned with water and dried for 24 hours. They were sectioned buccolingually. The perforation wall of the sectioned sample with the greatest dye penetration was selected for microleakage analysis.

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Results: The collected data from the three experimental groups were subjected to statistical analysis using one-way analysis of variance and Tukey's post hoc test for multiple comparisons of mean differences in dye penetration. The Biodentine group had the significantly lowest dye penetration length compared with the MTA Repair HP and glass ionomer cement groups ($P<0.001$).
Conclusion: Biodentine showed better sealing ability as a repair material for furcation perforations compared to the other two materials.

Keywords: Biodentine; dye penetration; glass ionomer cement; MTA Repair HP; perforation repair; sealing ability.

1. INTRODUCTION

During root canal treatment, an artificial opening in the tooth or root created by the operator through a procedural error is called an endodontic perforation, which is the communication between the root canal system and the outer tooth surface [1-3]. In multirooted teeth, perforation of the pulpal floor in the furcation region leads to periodontal inflammation and irreversible attachment loss. Surgical and non-surgical methods have been recommended as two primary therapies for the correction of such defects [4, 5]. Nonsurgical treatments are especially recommended for inaccessible sites, as surgical approaches to repair such defects may result in the formation of pockets. Perforations should be treated as soon as possible with a biocompatible material to prevent communication between the perforation area and the gingival sulcus. A variety of materials are available for the repair of furcation and root perforations [6,7]. Amalgam, super-EBA, reinforced zinc oxide-eugenol, calcium hydroxide, glass ionomer, composite resins, platelet-rich fibrin, platelet-rich plasma, bioaggregate, and other materials have been used. However, none of them has the characteristics of an acceptable repair material [4,8]. Materials for perforation repair should produce osteogenesis, cementogenesis, and excellent sealing, as well as be nontoxic, biocompatible, extremely durable, and insoluble in body fluids [8,9].

For pulpal capping, apexification, root fillings, and perforations, calcium silicate-based cements have proven popular in recent years. These cements should have biocompatibility, radiopacity, antibacterial properties, ease of handling, and good sealing efficiency [1]. The bioactivity of a biomaterial is important for tissue regeneration and repair [10,11]. Mineral Trioxide Aggregate (MTA) is recognized as a gold standard material for a variety of clinical procedures according to various publications and studies [12,13]. However, MTA has significant drawbacks, such as difficulty in handling, consistency, long setting times, high material cost, and it may also cause discoloration of the tooth. Recently, a new material silicate cement mineral trioxide aggregate Repair "High Plasticity" (MTA Repair HP Angelus®, Brazil) was introduced. Bismuth oxide has been substituted by calcium tungstate as a radiopacifier in MTA Repair HP and this adjustment in cement composition will change the physical, biomechanical and biological properties of the material [14]. Biodentine (Septodont, Saint-Maurdes-Fosses, France) was introduced in 2009 to address the drawbacks of all restorative materials by offering better handling properties, faster setting time, and a variety of other applications, including endodontic repairs [9]. The physical properties of Biodentine have been improved by modified powder ingredients, the addition of setting accelerators and plasticizers, and a new Predose capsule preparation. However, new endodontic repair materials that compensate for the disadvantages of existing materials are still under development [15,16]. In the current study, a stereomicroscope was used to investigate the sealing performance of Biodentine, MTA Repair HP and glass ionomer cement when used as perforation repair materials.

2. MATERIALS AND METHODS

A total of 45 permanent extracted human teeth were obtained. The study included both maxillary and mandibular molars without or with minimal restoration, caries and non-fused roots. In the study, samples with cracks, open tips, root caries, or evidence of pathological resorption were removed. The samples were kept in 10% formalin for one week. After ultrasonic removal, the teeth were cleaned with tap water and placed in saline.

2.1 Preparation of Samples

Access cavity preparation was performed on all samples by using a high-speed handpiece with a round diamond bur and a #557 straight fissure carbide bur along with water irrigation. Perforations were made in the centre of the pulp chamber using a no.2 round carbide bur. For all samples, the width of the perforation was kept standardized at the diameter of a no.2 round bur at the bottom of the pulp chamber. However, the depth of the perforation sites varied depending on the thickness of the dentin-cement material in the furcation area. The samples were rinsed with water and dried with air.

2.2 Furcal Perforation Repair with Materials

All 45 samples were divided into three different experimental groups of 15 samples each. Group A (n=15), Group B (n=15) and Group C (n=15). A total of four additional teeth served as control groups. The positive controls included two teeth that were perforated but not restored whereas, the negative controls included two teeth that were not perforated.

For the samples in Group A, furcation repair of the samples was performed with Biodentine (Biodentine™, Septodont®, France) according to the manufacturer's guidelines. Both powder and liquid were placed in a capsule, and the amalgam was triturated for 30 seconds to manipulate the material. It was scooped into the tray provided and applied to the perforation site using endodontic plugs.

Group B samples were treated with MTA Repair HP (Angelus ®, Brazil) according to the manufacturer's guidelines. Both powder and liquid were mixed to the desired putty-like consistency on the non-absorbent pad. An endodontic condenser was used to condense the material at the furcation site and then moist cotton pellets were used to condense the material onto the pulp chamber without air bubbles.

For Group C samples, Riva self-curing glass ionomer cement (GIC) (SDI, Limited, Australia) was used to repair the furcation perforation according to the manufacturer's guidelines. Powder and liquid were spread and mixed on the mixing block using a plastic spatula. The mixed paste was carried to the perforation site and compacted. All the samples with sealed furcal perforation were stored at room temperature for 24 hours to allow the materials to cure.

2.3 Stereomicroscopic Analysis after Dye Penetration

After the materials in all three different groups had cured after 24 hours, all surfaces were evenly coated with two coats of nail polish to prevent dye penetration, except for 2 mm around the perforation site. After complete drying,

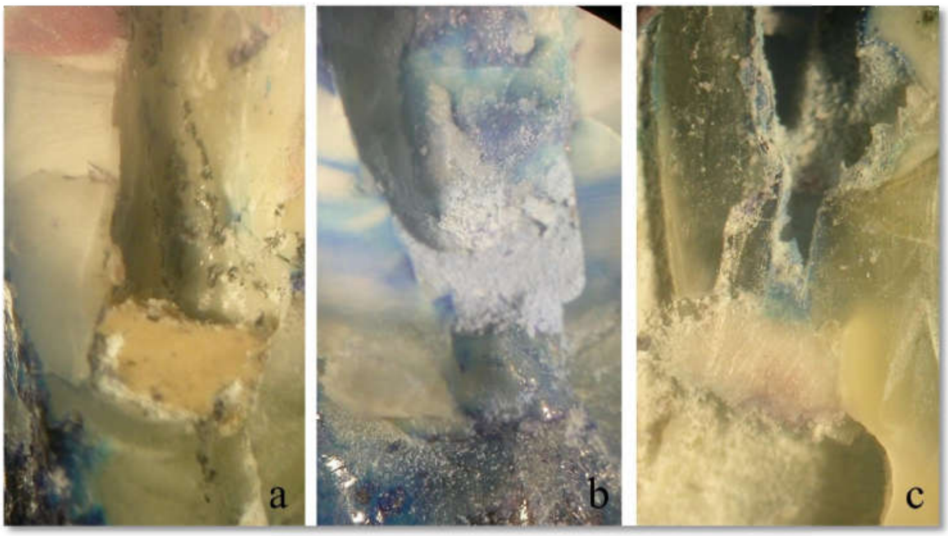


Fig. 1. Sectioned sample of a) Biodentine, b) MTA Repair HP, and c) Glass ionomer cement viewed under a Stereomicroscope respectively

all group samples were separately soaked in a 2% methylene blue solution for 48 hours and washed with water. They were allowed to dry at room temperature for 24 hours. All experimental samples were sectioned buccolingually using a diamond disc and a water cooler without additional laboratory work. The material between the two perforation walls, with one end facing the pulp chamber and the other facing the furcation, was visible in the sectioned samples. The perforation wall of the sectioned sample with the greatest dye penetration was selected for microleakage analysis (Fig. 1. a, b, c). The collected data from all the groups was analyzed statistically using one-way analysis of variance (ANOVA) and Tukey's post hoc test to compare the mean dye penetration and multiple comparison of mean differences in dye penetration.

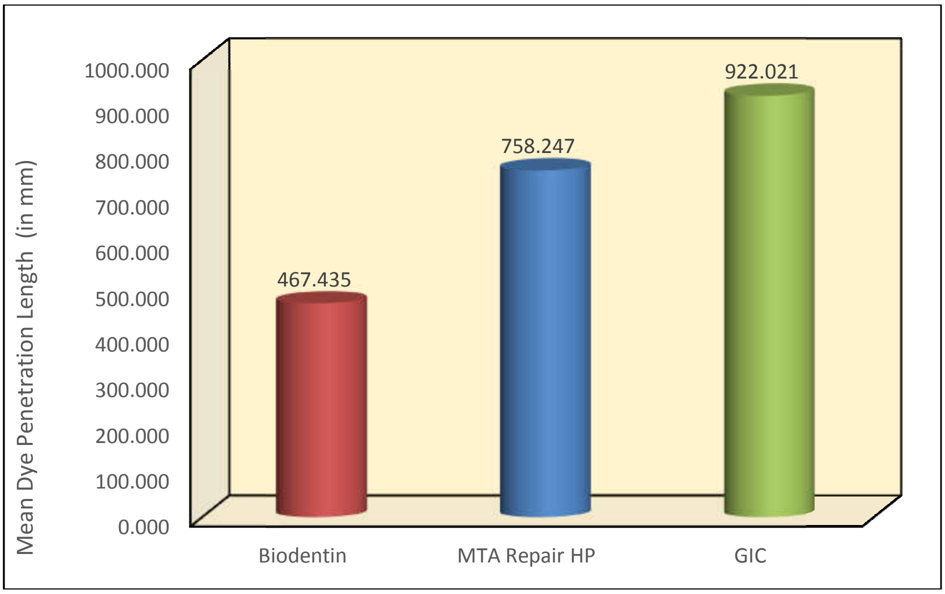
3. RESULTS

Table.1 illustrates the comparison of mean dye penetration length between 3 different groups. The test results show that the mean dye penetration length for the biodentine group was 467.435 ± 140.152, for the MTA repair HP group was 758.247 ± 120.143, and for the GIC group was 922.021 ± 209.045. This mean difference in dye penetration length between the 3 groups was statistically significant at $P<$ 0.001 (Graph 1).

The multiple comparison of the mean differences in dye penetration length between the 3 groups was presented in Table 2. The test results showed that the Biodentine group had the significantly lowest dye penetration length compared to the MTA-Repair- HP and GIC groups ($P<0.001$). Subsequently, the MTA repair HP group showed significantly lower dye penetration length compared to the GIC group ($P=0.02$). Hence, Biodentine showed significantly lowest dye penetration length followed by MTA Repair HP and highest penetration in GIC group (Graph 2-5).

Table 1. Comparison of mean dye penetration length between 3 study groups using One-way ANOVA Test

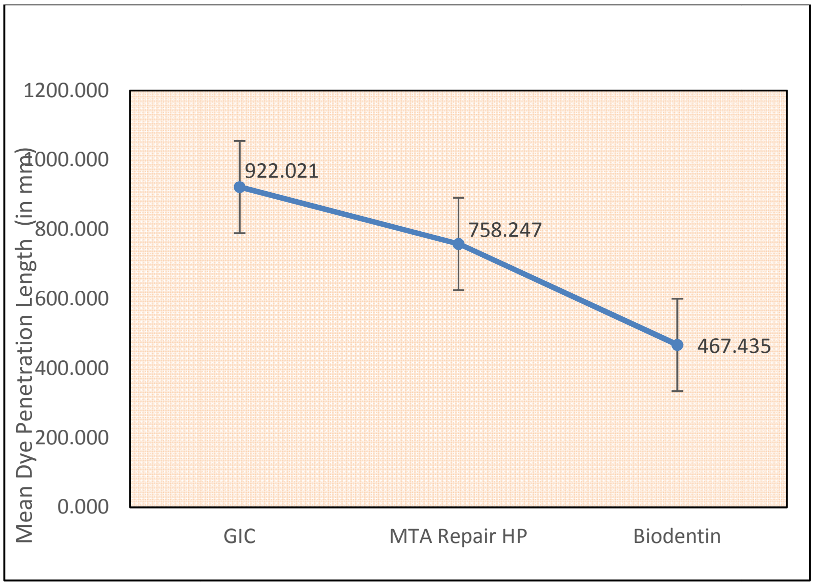
Dye penetration length between 3 study groups						
Groups	**N**	**Mean**	**SD**	**Min**	**Max**	***P*-Value**
Biodentine	15	467.435	140.152	183.40	644.03	<0.001
MTA Repair HP	15	758.247	120.143	580.70	930.20	
GIC	15	922.021	209.045	629.50	1462.01	



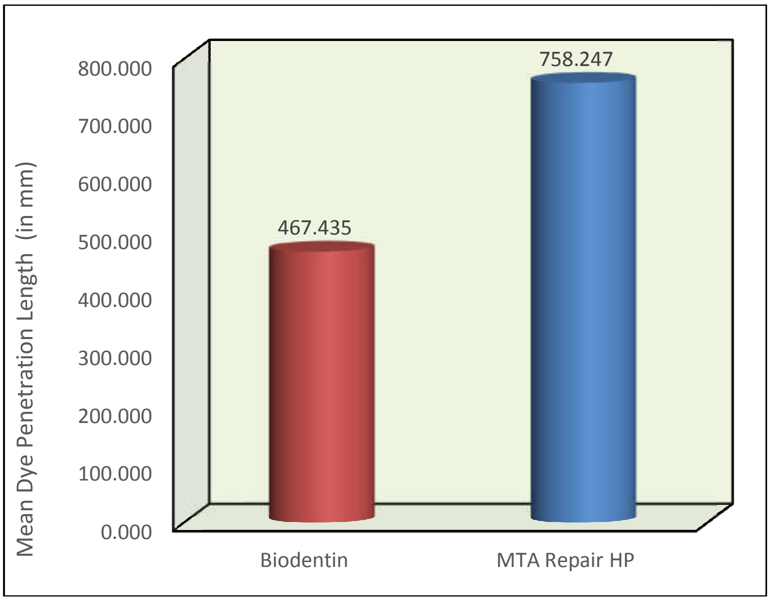
Graph 1. Mean dye penetration length between 3 study groups

Table 2. Multiple comparison of mean difference in dye penetration length between the groups using Tukey's Post hoc Test

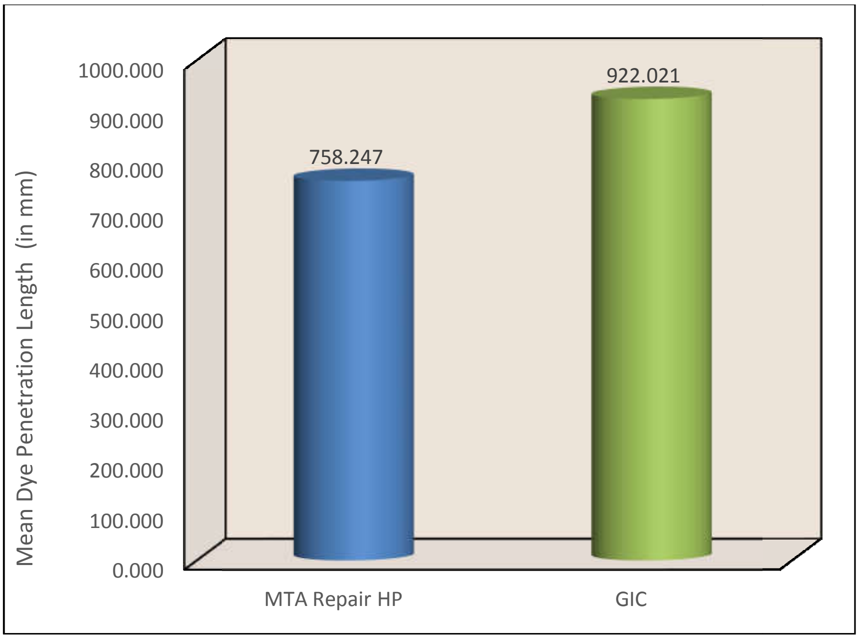
Multiple comparison of mean difference between groups					
Groups	**(Groups**	**Mean Diff.**	**95% CI for the Diff.**		***P*-Value**
			Lower	**Upper**	
Biodentine	MTA Repair HP	-290.811	-433.651	-147.972	<0.001
	GIC	-454.585	-597.425	-311.746	<0.001
MTA Repair HP	GIC	-163.774	-306.614	-20.934	0.02



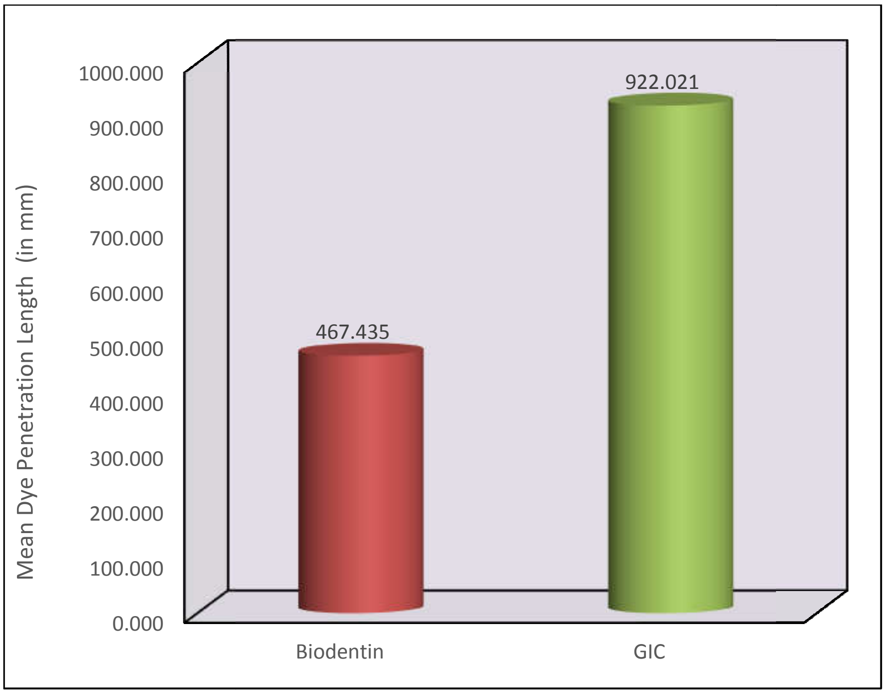
Graph 2. Mean dye penetration length between 3 study groups [arranged in descending order]



Graph 3. Mean dye penetration length between biodentine and MTA repair HP



Graph 4. Mean dye penetration length between MTA repair HP and GIC



Graph 5. Mean dye penetration length between Biodentine and GIC

4. DISCUSSION

Perforation may occur in any portion of the root, including the furcation area, due to caries, iatrogenesis, or resorption. It presents a significant clinical difficulty in traditional endodontic treatment [17]. Iatrogenic perforations can occur for a variety of reasons, including abnormal canal morphology, misjudgment in attempting to gain access to the pulp chamber, placement of an intracanal post, inadequate wear of the canal walls, or lack of operator experience. Eventually, loss of integrity of the pulp chamber floor and adjacent periodontium may occur [1,2,18]. For successful healing of the furcation perforation, an adequate seal between the internal and external tooth environments is required. The size of the perforation, its location, the time required to repair the perforation, and the material used to seal the perforation are all aspects that influence the prognosis of the perforation repair procedure [19]. In the present study, the sealing capacity of Biodentine, MTA Repair HP and glass ionomer cement in perforation repair was investigated using the dye penetration method. Methylene blue was chosen because it has a lower molecular weight than bacterial toxins, is easier to handle, and is inexpensive [20]. Compared to the other two calcium silicate-based cements, glass ionomer cement had the longest dye penetration length. It was invented by Wilson and Kent in the early 1970s and is commonly known as glass polyalkenoate cement [21]. It is generally a powder-liquid system. The powder consists of alumina, silica, sodium fluoride, aluminium phosphate, calcium fluoride, and aluminium fluoride. The liquid consists of tartaric acid, polyacrylic acid and water. Previous studies have shown that light-cured glass ionomer cement has better impermeability compared to chemically cured glass ionomer cement [22]. It has also shown better sealing when compared to cavit and amalgam [23]. Moreover, microleakage was low when resin-modified glass ionomer cement was used over hydroxyapatite as matrix and highest when no matrix was used [24]. This could be due to a lack of flow of the glass ionomer cement, which did not completely fill the defect. The materials placed in the furcation should have sufficient flow to fill and seal the perforations [25]. In other studies, glass ionomer cement was found to have the highest dye penetration, followed by Calcium Phosphate Cement and MTA [26].

In the present study, Biodentine had the lowest dye penetration length compared to MTA Repair HP and glass ionomer cement. These results are in agreement with previous studies that Biodentine has the lowest microleakage and better sealing performance than MTA Repair HP [27-30]. The improved sealing ability is due to the addition of setting accelerators and plasticizers to the powder mixture. In addition, more calcium and silicon ions are absorbed into the dentin than with MTA, resulting in the formation of tag-like structures [31]. Biodentine particles are smaller, and the porosity of the sealing surface and the pore volume in the set material are lower than those of MTA, which may explain the reason for its better sealing ability [32]. In addition, Biodentine has better handling and mechanical properties than MTA Repair HP and faster setting time, which seals the interface and reduces the risk of bacterial contamination [33]. In another study, Biodentine was found to have lower dye penetration and better sealing performance than Pro-Root MTA and resin-modified glass ionomer cement in perforation repair [34]. However, these materials have been similarly evaluated as promising alternative when used to seal furcation perforations [35]. In contrast to our findings, previous studies have shown that MTA has less microleakage than Biodentine when analyzed by a liquid filtration method [36]. Compared with Biodentine and resin-modified glass ionomer cement, it has given a satisfactory seal [37]. It is difficult to say exactly which materials are best for the treatments. Biodentine, on the other hand, has a cost and flexibility advantage.

5. CONCLUSION

The current in vitro evaluation showed that Biodentine has the lowest dye penetration length and better sealing ability compared to MTA Repair HP and glass ionomer cement when used as a repair material for furcation perforations.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

CONSENT

It is not applicable.

ETHICAL APPROVAL

An in vitro study was conducted with the approval of Institutional Ethical Clearance Committee at SEGi Oral Health Centre, Kota Damansara, Malaysia.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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