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An *In vitro* Evaluation of Sealing Ability of Resin Modified Glass Ionomer Cement and Different Bioceramic Materials in Furcation Perforation Through Dye Leakage Test

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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

Aim: The present study aimed to assess the sealing ability of various repair materials in furcation perforations using dye penetration.

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Background: Treatment options for furcal region perforations include conservative measures and surgery. The nonsurgical intermediate repair with a suitable restorative material appears to have the best prognosis since it will prevent the pulp chamber from communicating with the gingival sulcus, reducing infection and inflammation in the area.

Methods: A total of 75 human first molars (mandibular and maxillary) with unbroken enamel surfaces, which were extracted completely for periodontal reasons, were chosen. All extracted teeth were kept in a sterile solution up until further use. Endo-access bur was used to prepare endodontic access cavity, and a high-speed long shank round bur was used to create a planned perforation on the floor of pulp. All the specimens were randomly grouped (15 teeth in each group). A stereomicroscope (10×) was used to visualize the highest dye penetration.

Results: The least penetration was seen in teeth repaired by Biodentine group and Bio-C repair, next by Pro-Root MTA group and resin-modified glass ionomer cement group. A statistically significant difference was seen among different perforation repair materials by analysis of variance. A statistically significant difference (p value < 0.05) was found between each group.

Conclusion: This study concluded that, reduced dye penetration in perforation repair along the furcation and improved sealing ability are shown by Biodentine group and Bio-C repair group in comparison to Pro-Root MTA and Resin-modified glass-ionomer cement group. Further in vivo studies are required to prove its effectiveness.

Keywords: Biodentine; dye penetration; perforation; pro-root mineral trioxide aggregate; resin-modified glass-ionomer cement.

1. INTRODUCTION

"The public's preference for root canal therapy (RCT) over tooth extraction has brought to a global revolution in endodontic treatment in the modern period. An important part of improving the bar for oral health is endodontics. Maintaining the integrity of the natural dentition to its ideal form, function, and aesthetics is the aim of endodontic therapy" (Keshrani et al., 2019).

"Procedure errors, also known as endodontic mishaps, are regrettable incidents that might happen while receiving treatment. Some may result from a failure to pay attention to detail, while others are unplanned. These can include mistakes involving obturation and instrument-related incidents, some of which involve perforations. Endodontic errors can occur at any stage of the RCT process, including diagnosis, instrumentation, obturation, and access cavity preparation. Our main concern among all of these issues was the furcal perforations, which are extremely difficult to treat" (Hassan et al., 2015).

"Treatment options for furcal region perforations include conservative measures and surgery. The nonsurgical intermediate repair with a suitable restorative material appears to have the best prognosis since it will prevent the pulp chamber from communicating with the gingival sulcus, reducing infection and inflammation in this area" (Nikoloudaki et al., 2014).

"A variety of materials have been suggested for perforation sealing. These materials include of mineral trioxide aggregates (MTA), glass ionomer cement, resin composites, zinc oxide-eugenol cements (IRM and Super-EBA), and resin modified glass ionomer (RMGI)" (El Tawil et al., 2011).

Fig. 1. Resin modified glass ionomer

Fig. 2. Biodentine

Fig. 3. ProRoot MTA

Fig. 4. Bio-C Repair

"The properties of an ideal furcal perforation repair material should provide good hermetic seal, it should be noncontaminated by hemorrhage, it should be biocompatible, no resorbable, insoluble, should prevent its extrusion into PDL apparatus, should promote osteogenesis and cementogenesis, should be non-toxic, non-carcinogenic, easily available, convenient to the patient or dentist, and non-expensive" (Keshrani et al., 2019).

"RMGIC, substance with strong antibacterial activity, minimal cytotoxicity, a good tissue response, and strong chemo-mechanical bonding has been marketed as ionomer cement. Because they set faster than ordinary GIC, it has been utilized to seal furcal perforations" (Keshrani et al., 2019).

"Tricalcium aluminate, tricalcium silicate, tricalcium oxide, silicate oxide, mineral oxide, and bismuth oxide are the principal ingredients of MTA. It has a pH of 12.5 and sets in the presence of moisture. It is non-resorbable, nontoxic, radiopaque, and incredibly biocompatible" (Keshrani et al., 2019).

"Biodentine comes as a capsule that includes dicalcium silicate, tricalcium silicate, calcium carbonate, iron oxide, and zirconium oxide filler. The liquid is made up of calcium chloride, an accelerator, and a polymer, a water-reducing agent. The setting period of the material is as short as 9–12 min. The presence of setting accelerator in biodentine results in faster setting, thereby improving its handling properties and strength"s (Mohan et al., 2019).

2. METHODOLOGY

- Seventy-five extracted maxillary and mandibular first molars with intact furcation, caries free, no fracture, extracted purely for periodontal reason were collected. The teeth were cleaned and stored in 0.9 % saline.
- Endodontic access cavity was prepared with the endo round bur which is followed by using Endo - Z bur for extension of the cavity laterally and to finish the cavity walls.
- The canal orifices were negotiated and sealed with the temporary cement. The planned perforation was made between the mesial and distal canal orifices with high-speed long shank round bur # 4.
- Double layer of nail varnish was applied to the cavity walls and the pulpal floor leaving an area of 1mm around the perforation.

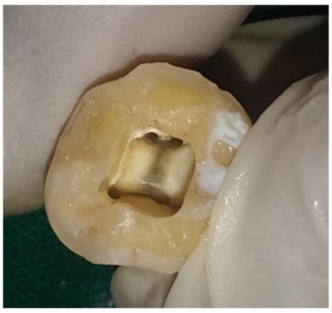


Fig. 5. Completed access opening and canals located

Fig. 6. Furcal perforation done

- The samples were randomly divided into five groups, to compare the sealing ability of different materials. Each group had 15 teeth.

GROUP I - Control (unsealed)
GROUP II - Resin modified glass ionomer cement (RMGIC)
GROUP III - ProRoot MTA
GROUP IV - Biodentine
GROUP V - Bio - C Repair.

- The materials were manipulated according to the manufacturer's instructions and was placed on the perforation site.

Group II -Resin-modified glass-ionomer cement: Before application of the glass ionomer cement, the dentine was treated with primer for 30 sec followed by light-induced polymerisation for 20 sec., powder and liquid were mixed following the manufacturer's instructions. The mixed cement was placed in the perforation and compacted with endodontic plugger. The surface was polymerised for 40 sec using a dental polymerization lamp.

Group III- ProRoot MTA: One scoop of ProRoot MTA powder and one small drop gel, 1 ampoule next to the powder was dispensed on a non-absorbent pad. Mixing was done with a plastic spatula in circular motion until a putty consistency of the mix is obtained. The mix is carried to the perforation site with the help of endodontic plugger and adapted to the perforation site. A moist cotton pellet was placed over ProRoot MTA.

Group IV – Biodentine: Biodentine was mixed according to the manufacturer's instructions until ideal consistency was achieved. The material was collected from the capsule, placed in the perforations with a spatula and slightly condensed with Amalgam pluggers and allowed to set for 12 minutes.

Group V – Bio-C repair: Simple to use and comes as a single product in a syringe rather than powder and liquid form, saving time and eliminating the need to handle the chemical.

- The specimens were placed in the cubical tubes with moist cotton to simulate the clinical condition. Molars were fixed to the tube by cyanoacrylate adhesive (fevikwik, pidilite industries Ltd, India)

- After sealing the perforation site, the specimens were placed in humidity for 24 hours. Then, 2% methylene blue was applied inside the cavity of all samples and the samples were kept for next 48 hours to check the microleakage by dye penetration test.

Fig. 7. Perforation repair done with RMGIC (Group II)

Fig. 8. Perforation repair done with ProRoot MTA (Group III)

Fig. 9. Perforation repair done with Biodentine (Group IV)

Fig. 10. Perforation repair done with Bio -C repair (Group v)

- The specimens were then washed thoroughly under tap water for 30 minutes. The varnish was removed using polishing disk.
- The specimens were then sectioned buccolingually by the diamond disk.
- The samples were then subject to digital stereomicroscope under 10x magnification.

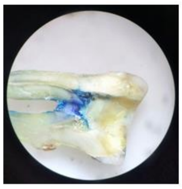
The scores were given according to dye penetration as follows: (Lodiene et al., 2011)

1. no leakage detected
2. Leakage extending to ¼ of repair material
3. Leakage extending to ½ of repair material
4. Leakage extending to — of repair material
5. Leakage extending beyond — of repair material.

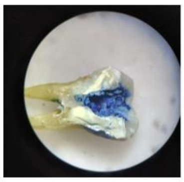
2.1 Statistical Analysis

One-way ANOVA test followed by Tukey's post hoc analysis was used to compare the mean length of dye penetration between 5 groups.

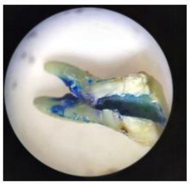
The level of significance [P-Value] will be set at $P<0.05$



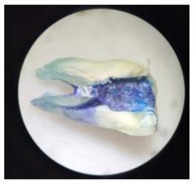
GROUP I



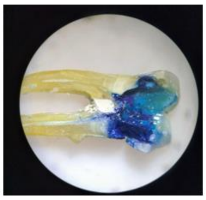
GROUP II



GROUP III



GROUP IV



GROUP V

Plate 1. Stereomicroscopic images

Table 1. Dye Penetration Scores

Sl	Control	RMGIC	ProRoot MTA	Biodentine	Bio-C Repair
1.	4	3	3	2	1
2.	4	2	1	1	0
3.	4	4	3	2	1
4.	4	3	3	0	0
5.	4	3	2	1	0
6.	3	2	1	0	2
7.	4	3	3	2	0
8.	4	2	3	1	1
9.	4	3	2	2	2
10.	4	3	2	1	1
11.	4	4	3	2	0
12.	3	3	3	0	1
13.	4	3	2	1	2
14.	4	4	1	2	1
15.	4	3	2	2	0

Table 2. Comparison of mean Dye Penetration scores b/w 5 groups using Kruskal Wallis

Test						
Groups	N	Mean	SD	Min	Max	p-value
Control	15	3.87	0.35	3.0	4.0	
RMGIC	15	3.00	0.66	2.0	4.0	
ProRoot MTA	15	2.27	0.80	1.0	3.0	<0.001*
Biodentine	15	1.27	0.80	0.0	2.0	
Bio-C Repair	15	0.80	0.78	0.0	2.0	

3. RESULTS

Multiple comparison of mean differences between groups revealed that mean Dye Penetration scores was significantly least in Bio-C Repair group, & Biodentine group, which was followed by ProRoot MTA group, RMGIC groups and highest in Control group.

4. DISCUSSION

During a root canal treatment, the tooth's infected or injured pulp is extracted, cleansed, and the root canal gaps are sealed and filled with materials that are biologically inert. As a result, errors in procedure occur during treatment, which could have an impact on the root canal treatment's outcome (Shah et al., 2019).

Endodontic errors can occur at any stage of the RCT procedure, including diagnosis, instrumentation, obturation, and access cavity preparation. Our main concern among all of these issues was the furcal perforations, which are extremely difficult to treat (Hassan et al., 2015).

Furcation perforation, which is a mid-curvature opening into the periodontal ligament (PDL) space, is one such complication that might lead to the worst possible outcome during therapy (Sinkar et al., 2015).

Treatment options for furcal region perforations includes conservative measures and surgery. The nonsurgical intermediate repair with a suitable restorative material appears to have the best prognosis since it will stop the pulp chamber from communicating with the gingival sulcus, reducing infection and inflammation in this area (Nikoloudaki et al., 2014).

The present study employed mandibular and maxillary first molars to produce perforation. First molars were perforated the most frequently, discovered by Kvinnsland et al. It could be as a result of the fact that these teeth in the oral cavity also have the highest restoration levels. In their analysis, molars accounted for about 73% of the cases, with a greater proportion of maxillary molars than mandibular molars (Shah et al., 2019).

A #4 long shank carbide round (SS White) bur was used to create furcation perforations from the pulpal floor to the furcation area. As a result, perforations with a diameter of nearly 1.4 mm were produced. Teeth with a furcation diameter of 1-1.5 mm have a better prognosis than teeth with substantially larger perforation diameters. As a result, the study's chosen perforation diameter makes sense (Shah et al., 2019).

Several methods like dye penetration, fluid filtration, bacterial and protein leakage models, dye extraction method have been used to assess microleakage (Shrestha et al., 2022).

In this investigation, we employed the dye penetration method, the fact that the dye molecules are smaller in molecular size than those of bacteria, which only assess the dye's deepest point rather than the volume absorbed by the sample. It is extremely difficult to determine the precise depth of dye penetration because it depends on the tooth being sliced into two. Despite these disadvantages, Torabinejad et al. claimed that a chemical capable of stopping the infiltration of small molecules (dye) ought to be able to stop larger things like germs and their by-products (Shah et al., 2019).

“The ability of a substance to seal has been assessed in the literature using a variety of dyes, such as methylene blue, fuchsin, rhodamine B, silver nitrate, India ink, and Pelikan ink. MTA was found to discolour methylene blue dye in a prior investigation. However, using 1% Basic Fuchsin Solution did not produce a similar staining result, thus methylene blue dye was utilized in the present investigation nstead” (Nikoloudaki et al., 2014).

"The first repair material used in the study was Resin Modified Glass Ionomer Cement: Resin -modified glass ionomer cement, A substance with strong antibacterial activity, minimal cytotoxicity, a good tissue response, and strong chemo-mechanical bonding has been marketed as ionomer cement. Because they set faster than ordinary GIC, it has been utilized to seal furcal perforations. It cures slowly and sets right away. Its reduced susceptibility to moisture, less curing shrinkage, deeper penetration of the polymer into the tooth surface, and other factors all contribute to its lower microleakage volume" (Keshrani et al., 2019).

In the present study, highest dye penetration was recorded in resin-modified glass ionomer cement group in comparison to Pro-Root MTA group and Biodentine group. This may have been noted in the RMGIC group as a result of the material's contraction during polymerization. A dentine that is contaminated by excessive moisture, solvent, or voids can experience difficulty in bonding, which could affect the treatment outcome (Mohan et al., 2021).

The second repair material used was ProRoot MTA for Group-III: Tricalcium aluminate, tricalcium silicate, tricalcium oxide, silicate oxide, mineral oxide, and bismuth oxide are the principal ingredients of MTA. It has a pH of 12.5 and sets in the presence of moisture. It is non-resorbable, nontoxic, radiopaque, and incredibly biocompatible. It has been showed that MTA seals better than amalgam, zinc-oxide eugenol, resin-modified GIC, and resin materials. Moreover, MTA has been shown to have less cytotoxicity than Super EBA or IRM (Keshrani et al., 2019).

"ProRoot MTA is composed of refined Portland cement, bismuth oxide, and gypsum, with trace amounts of SiO_2, CaO, MgO, K_2SO_4, and Na_2SO_4. ProRoot MTA has been widely employed as a perforation repair material due to its reported good sealing properties, biocompatibility, and dentinogenic activity. However, it has a long setting time and is sensitive to excessive or deficient moisture, which adversely impacts its qualities" (Mohan et al., 2019).

"Biodentine is released by Septodent in 2010, as calcium silicate-based dentin substitute. It is specifically designed as a "dentine replacement" material. Biodentine comes as a capsule that includes dicalcium silicate, tricalcium silicate, calcium carbonate, iron oxide, and zirconium oxide filler. The liquid is made up of calcium chloride, an accelerator, and a polymer, a water-reducing agent. The setting period of the material is as short as 9–12 min. The presence of setting accelerator in biodentine results in faster setting, thereby improving its handling properties and strength. It is appropriate for pulp capping, pulpotomy, apexification, root perforation, internal and external resorption, and as a root end filling material in periapical surgery. Biodentin has advantages over MTA in terms of setting time, handling, and mechanical qualities" (Mohan et al., 2019; Pradhan et al., 2015).

Torabinejad et al. found that a delayed setting time increases the possibility of partial material loss and interface change during the procedure's final phase. As a result, in terms of setting time, biodentine surpasses ProRoot MTA (Mohan et al., 2019).

"The Bio-C Repair material was developed to address MTA issues. It is a new substance for root-end filling that promotes tissue regeneration and biomineralization by becoming bioactive when in touch with essential tissues. Bio-C Repair is an excellent material for endodontic therapy due to its outstanding properties such as reduced moisture sensitivity, insolubility, and tissue-inductive properties. It is simple to use and comes as a single product in a syringe rather than powder and liquid form, saving time and eliminating the need to handle the chemical. CAMPI et al. first investigated the physicochemical characteristics, bioactivity, and cytotoxicity of the Bio-C Repair material, in contrast to MTA Angelus" (Hammadi & Abdul-Ameer, 2023).

Bio-C Repair is not only biocompatible, but it also has the ability to biomineralize when it comes in contact with live tissues (Hammadi & Abdul-Ameer, 2023).

"Biodentine had the highest cell viability, followed by Bio-C repair and MTA Repair HP, which was consistent with the findings of Klein Junior et al., who discovered that bioceramic material had superior cell viability to MTA when exposed to NIH 3T3 fibroblasts. This could be because Biodentine and Bio-C Repair released significantly more calcium (Ca) than MTA, as suggested by the manufacturer. Calcium hydroxide generation is crucial not only for dentin bridge development and cementoblast differentiation, but also for its antibacterial properties. Other Bio-C Repair components, such as iron oxide, may have affected SHED cell viability, depending on the chemical composition and solubility of each cement constituent, when contrasted with calcium silicate. In comparison to calcium silicate materials with bismuth oxide (MTA), those with zirconium oxide (Bio C Repair) cause less inflammation” (Maru et al., 2023).

“MTA has good marginal adaptability because its composition includes tricalcium silicate, tricalcium aluminate, tricalcium oxide, silicate oxide, and other mineral oxides, which combine to form a hydrophilic powder that solidifies in the presence of water. It shows the precipitation of calcium phosphate at the contact between the two substances. This interface layer reduces the chance of marginal percolation, paving the way for long-term clinical success. During the Bio-C Repair the presence of mineral precipitate at the interface of calcium silicate-based cement and dentin improves the sealing capacity of these materials” (Maru et al., 2023).

In this study result showed that group I (control group) showed highest microleakage followed by Group II (RMGIC), Group III (ProRoot MTA). Group IV (Biodentine) and Group V (Bio-C Repair) showed no significant difference in microleakage.

There was a significant difference between Group I, II and III, but there was no significant difference between Group IV and Group V.

According to Hassan et al., (2019) stated that the mean of dye absorbance of Biodentine is less than ProRoot MTA in both Orthograde and retrograde directions when used for furcal perforation repair, which was in accordance with our study. Regardless the material used no difference was detected between orthograde and retrograde leakage.

According to Vanishree H et al., (Shivakumar et al., 2021) Biodentine showed better sealing ability as a repair material for furcation perforations compared to MTA Repair HP and glass ionomer cement groups, which is in accordance with our study.

The results of our study are in accordance with the studies of Dennis Mohan et al., (Keshrani et al., 2019) which demonstrated that reduced dye penetration in perforation repair along the furcation and improved sealing ability are shown by Biodentine group in comparison with Pro-Root MTA and resin modified glass ionomer cement group.

5. CONCLUSION

The highest and lowest dye penetration was observed with the control group (untreated tooth), and Biodentine respectively, but there was no statistical difference between dye penetration with Biodentine and Bio-C repair. RMGIC showed significantly higher microleakage as compared with ProRoot MTA, Biodentine and Bio-C repair groups respectively. ProRoot MTA showed significantly higher microleakage compared with Biodentine and Bio-C repair.

The results infers that the mean Dye Penetration scores was significantly least in Bio-C Repair group & Biodentine group, which was followed by ProRoot MTA group, RMGIC groups and highest in Control group.

The evaluation of clinical performance of the materials *In- vivo* is needed to give reliable recommendations for dentists.

CLINICAL SIGNIFICANCE

Root perforations along the furcation that develop due to the endodontic procedures have a remarkable damaging effect on prognosis and frequently result in loss of secondary periodontal attachment, thus resulting in early loss of the involved tooth. Therefore, the selection of biocompatible repair material aids to enhance the treatment prognosis.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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