Original Article

A Spectrophotometric comparative evaluation of the sealing ability of various perforation repair materials with a novel eggshell modified GIC

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Abstract

Objectives: The objective of this study was to evaluate and compare the sealing ability of mineral trioxide aggregate (MTA), Biodentine, glass ionomer cement, and glass ionomer cement modified with Chicken Eggshell Powder when used as furcation perforation repair material.

Materials and Methods: In the present study, 80 human lower first molars were used. Collected teeth had no caries or restoration, and none had fused roots. Every molar had an endodontic access cavity made utilizing a high-speed, long-shank round bur for the initial entry and an Endo-Z for lateral extension and finishing the cavity walls. Each canal's orifice was covered with a temporary filling material. The pulpal floor and cavity walls of every molar were thoroughly coated with two successive coats of clear nail polish. A significant perforation was made between the orifices to the furcation area using a high-speed long shank round bur #4. The perforation centered between the mesial and distal orifice. They were divided into four experimental groups: Group I: 20 molars were repaired using MTA, Group II: 20 molars with Biodentine, Group III: 20 molars were repaired with glass ionomer cement, and Group IV was repaired using glass ionomer cement modified with 7% chicken eggshell powder. Moist cotton pellets were placed over the repair materials, and molars were kept in 100% humidity for 24 h to allow materials to set. Then, according to each group, molars were put in Petri dishes. Methylene blue dye was applied inside the access cavity of all samples for 24 h. Molars were placed under running tap water for 30 min to remove all residues of methylene blue, and then varnish was removed with a Parker blade #15 and polishing discs. Molars were placed in vials containing 1 mL of concentrated (65 wt%) nitric acid for 3 days. Vials were centrifuged at 14,000 rpm for 5 min. The supernatant from each sample was transferred in a quantity of 200 L to a 96-well plate. Sample absorbance was read by an automatic microplate spectrophotometer at 550 nm using concentrated nitric acid as a blank. Statistical analysis was performed using one-way analysis of variance. When the analysis of variance test was significant, the pairwise comparison of the means was done using a Duncan *post hoc* test. The significance level was set at $P < 0.05$. Statistical analysis was performed with SPSS 14.0 (SPSS Inc., Chicago, IL, USA) for Windows (Microsoft, Redmond, WA, USA).

Results: The highest dye absorbance was seen in Group III, followed by Groups IV, II, and I.

Conclusion: Within the limitations of study it was concluded that maximum sealing ability was seen in Biodentine followed by MTA, Glass Ionomer Cement modified with 7% Chicken Eggshell powder and Glass Ionomer Cement.

Keywords: Biodentine; chicken eggshell powder; glass ionomer cement; mineral trioxide aggregate; perforations; sealing ability

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INTRODUCTION

Furcation perforations, or connections between a tooth-supporting structures and root canal system, can be extremely difficult to treat. These perforations can happen for a number of reasons, including dental trauma, iatrogenic errors made during treatment, or severe caries. Furcation perforations can cause additional issues, such as infection, periodontal disease, and even tooth loss if they are not treated.[1] Furcation perforations must be repaired to maintain tooth integrity and promote healing. To stop bacterial entry while promoting the regeneration of the injured tissue, the perforation site must be sealed.[2] The selection of materials with the appropriate qualities, such as biocompatibility, sealing ability, and tissue regeneration capability, is crucial for successful furcation perforation repair.[3]

The location and size of the perforations, clinician preferences, and special needs of the patient all play a role in the selection of materials for furcation perforation repair. Each material has pros and cons, and these aspects should be weighed by the clinician carefully before selecting the best options for each situation. Historically, materials such as calcium hydroxide, amalgam, and mineral trioxide aggregate (MTA) have been used for furcation perforation repair.[4] Although amalgam has exceptional sealing properties, it is not biocompatible. MTA has gained popularity recently due to its biocompatibility, sealing ability, and ability to stimulate tissue regeneration.[5] Many clinicians now choose MTA when repairing furcation perforations. This is a biocompatible cement that, reacts in presence of moisture, converts to hydroxyapatite, forming a tight seal and aids in healing. MTA is a great choice for furcation perforation repair due to its excellent sealing ability, handling properties, and long-term biocompatibility.[6]

Other materials have also become available recently as suitable substitutes for furcation perforation repair. Biodentine and EndoSequence BC Sealer are two bioceramic-based sealers that provide improved biocompatibility, bioactivity, and antibacterial properties. They can aid in tissue regeneration and offer a reliable closure at the site of the perforation.[7]

The 1980s saw the first introduction of glass ionomer cement to the market, which is considered a hybrid cement.[8] Water, ion-leachable glass, and polyacrylic acids are some of the components. According to the study by Alhadaini and Himel, after *in vitro* repair of a furcation perforation, light-cured glass ionomer cement exhibits the least dye penetration and provides better sealability when compared to cavit or amalgam.

The possible benefits and dental uses of chicken eggshell powder have drawn interest recently due to its potential therapeutic properties and applications. Dental caries or trauma may damage the hard dentin below the enamel. Collagen, phosphorus, and magnesium are trace elements found in eggshell powder that are essential for the formation and healing of dentin. Eggshell powder may improve and promote tissue regeneration when used in dental materials or as a scaffold in regenerative procedures. Eggshell powder has been demonstrated in studies to have antibacterial effects against common oral infections. The risk of oral infections, such as periodontal disorders and dental caries, can be decreased by these antimicrobial properties.[9]

Therefore, using spectrophotometric analysis, this study evaluates the sealing of MTA, Biodentine, glass ionomer cement, and glass ionomer cement modified with chicken eggshell powder.

MATERIALS AND METHODS

In the present study, 80 freshly extracted human lower permanent first molars were used. These freshly extracted teeth were carefully selected and stored in 0.1% thymol. Collected teeth had no caries or restoration, and none had fused roots. Every molar had an endodontic access cavity made utilizing a high-speed, long-shank round bur for the initial entry and an Endo-Z for lateral extension and finishing the cavity walls [Figure 1]. Each canal's orifice was covered with a temporary filling material. The pulpal floor and cavity walls of every molar were thoroughly coated with two successive coats of clear nail polish. A significant perforation was made between the orifices to the furcation area using a high-speed long shank round bur #4. The perforation thus created is between the mesial and distal orifice opening into the furcal area.

They were divided into four experimental groups: Group I: 20 molars were repaired using MTA, Group II: 20 molars with Biodentine, Group III: 20 molars were repaired with glass ionomer cement, and Group IV was repaired using glass ionomer cement modified with 7% chicken eggshell powder.

The preparations were covered with damp cotton balls, the teeth were subjected to 100% humidity for 24 h to allow the materials to set, and the molars were then placed on the Petri plates according to each group. All samples were stained with methylene blue dye for 24 h in the access cavity. After complete removal of all methylene blue particles, the samples were immersed in running water for 30 min. Then, a Parker blade #15 was used to scrape off the varnish. Samples were placed in vials containing 1 mL of strong (65 wt%) nitric acid for 3 days. Universal 16R centrifuge was used to centrifuge at 14,000 rpm for 5 min. The supernatant from samples was transferred to a 96-well plate in a volume of 200 µl each.

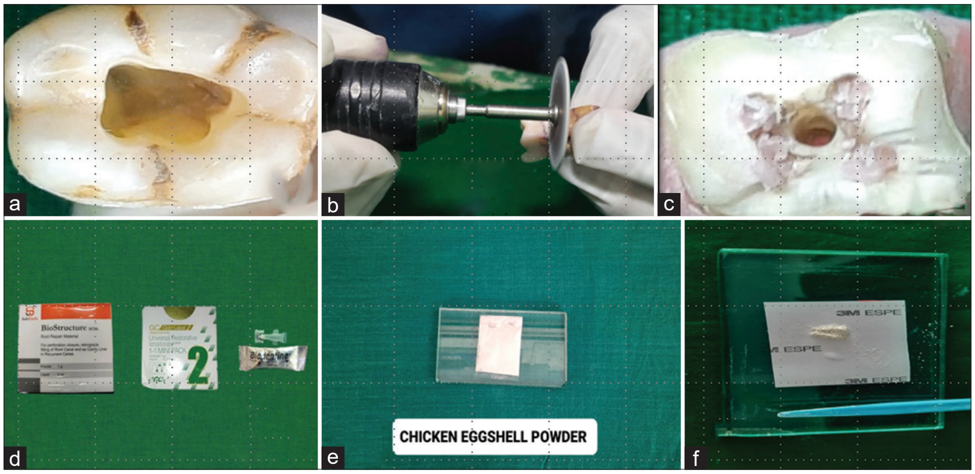


Figure 1: (a) Access opening of first mandibular molar (b and c) Sectioning of The Molar (d) Materials Used (e) Chicken Eggshell Powder (f) Dispensing of Materials

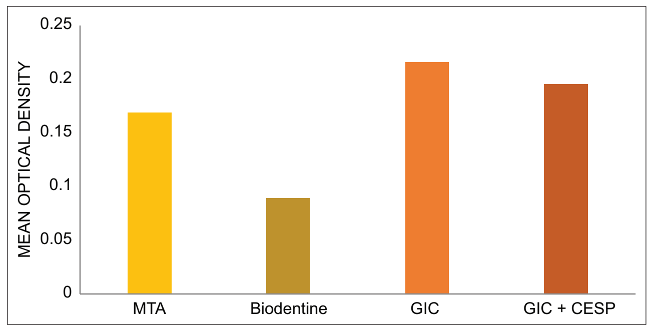
The absorbance of the sample was measured at 550 nm using an automatic microplate spectrophotometer with concentrated nitric acid as blank. Statistical analysis was performed using one-way analysis of variance. Analysis of variance test when found significant, Duncan's *post hoc* test was used for pairwise comparisons between means. The significance level was set at $P < 0.05$. Statistical analysis was performed using SPSS 14.0 (SPSS Inc., Chicago, IL, USA) for Windows (Microsoft, Redmond, WA, USA).

Eggshell Powder Preparation: (Commercially available chicken eggshell powder will be used in my research, although the process to obtain chicken eggshell is described below).

Chicken eggshell powder was attained by calcination following the protocol of the World Property Intellectual Organization (WO/2004/105912: Method of producing eggshell powder).[10] This calcination process was performed to obtain pure powder free of pathogens and to increase its alkalinity. Normally, chicken eggshell powder contains 95% calcium carbonate, which converts basic calcium oxide to calcination.[11] Twelve chicken eggs were cleaned with distilled water and kept in hot boiling water for 10 min at 100°C to facilitate the removal of membranes. The eggshells were crushed and powdered to small particles with a sterile mortar pestle. The tiny, crushed particles obtained were then kept in a muffle furnace at 1200°C to make sure the resulting powder was pathogen-free. Subsequently, the size of the particles was measured using Mastersizer 2000.

RESULTS

The highest dye absorbance was seen in Group III, with a mean value of 0.2137 [Table 1 and Graph 1], and the lowest dye absorbance was seen in Group II, with a mean value of 0.0853 [Table 1 and Graph 1]. MTA and Biodentine continue to be the gold standard for furcation perforation repair, glass ionomer cement modified with 7% chicken eggshell powder did show marginally superior sealability when compared to conventional glass ionomer cement.



Graph 1: A histogram showing the mean dye absorbance and standard deviation values of different groups

Table 1: Mean spectrophotometric dye absorbance values of four different experimental groups

Group	*n*	Mean	SD	*P*
Group I	20	0.1673	0.0014	0.05
Group II	20	0.0853	0.0032	
Group III	20	0.2137	0.0024	
Group IV	20	0.1949	0.0006	

SD: Standard error

DISCUSSION

The prognosis for endodontic treatment can be hampered by perforation, regardless of location or cause. Those infectious, mechanical, or iatrogenic contacts between the root canals and external root surface should be rapidly sealed with a biocompatible material.[12] In this study, dye extraction methodology was employed, which, according to Camps and Pashley, gave similar results to the fluid filtration technique as both are based on the quantitative measurements of liquid passage within interfaces.[13] One of the most common methods used to evaluate the sealing ability of the materials is the dye penetration tests. Spectrophotometers are instruments designed to produce the most accurate color measurements. Absorption or reflectance spectroscopy in the ultraviolet (UV)-visible spectral range is called UV-visible spectral photometry. This means that light is used in the near ranges (near UV and near infrared). The perceived color of the particles has a direct effect on its absorption or reflection in the field of view.[14]

When in contact with water, the MTA is hydrated and undergoes two major phases. When tricalcium silicate and dicalcium silicate react with water, calcium silicate hydrate and calcium hydroxide are formed. Tricalcium aluminate reacts with water to form ettringite first in the presence of calcium sulfate. A monosulfate phase is formed as the sulfate content decreases. The same mechanisms found in Portland cement have been demonstrated in MTA after hydration.[15] At the beginning of the reaction, calcium silicate hydrate is formed; further reaction is prevented by coating the cement particles with calcium silicate hydrate. Tricalcium aluminate fuses with calcium sulfate ions in the aqueous phase to form ettringite, which in turn precipitates on the surface of the cement particles. The initial phase is followed by a dormant period, wherein the hydrate coating on the cement grains prevents further hydration.[16] The dormant period lasts for 1–2 h and is a period of relative inactivity when the cement is plastic and workable. On completion of the dormant stage, the cement system moves to an accelerated stage where the hydration rate is further accelerated with an increase in the rate of tricalcium silicate hydration, and more calcium silicate hydration gel is produced. The hydration of the dicalcium silicate also increases during this period. As sulfate ions decompose, the product forms monosulfate. The aqueous phase also yields crystalline calcium hydroxide.[17]

MTA is superior to other common root-end filling materials, according to Bates *et al.* (1996)[18] and their results. MTA has a high sealing ability, which may be due to the expansion of MTA during the setting reaction, according to Schipper *et al.* (2004) and Torabinejad *et al.* (1995),[19] respectively. It is recommended that a moist cotton pellet is placed in MTA before the permanent restoration because the sealing ability of the MTA is improved in the ambient moist environment due to the expansion of the material. As per Valois *et al.* (2004), the MTA only needs to be about 4 mm thick for a solid seal. However, the MTA has some drawbacks, such as handling complications and slowness in setting reactions. New measures have been taken to address these problems.[20]

A water-soluble polymer system based on polycarboxylates is a calcium silicate-based material called Biodentine. Chemomechanical bonds are formed between the tooth, composite, and the Biodentine. High flexural and compressive strength is a characteristic of Biodentine.[21] The Septodont research team developed Biodentine™, a new class of dental materials that can have outstanding mechanical properties, excellent biocompatibility, and bioactive behavior. Based on a new active functional Biosilicate Technology™, Biodentine is the first bioactive and biocompatible, all-in-one substitute to treat damaged dentine for both restorative and endodontic purposes. Compared to others, this material has two advantages over other calcium-based cements: (1) faster setting time of about 12 min and (2) superior mechanical properties. These physicochemical properties associated with the biological behavior suggest that it may be used as a permanent dentine substitute. Biodentine is conditioned in a capsule containing a good ratio of powder and liquid.[22]

The cement sets and hardens due to the reaction of the powder with the liquid. When hydration happens during the mixing of tricalcium silicate, a hydrated calcium silicate gel (CSH gel) and calcium hydroxide are formed. Cement found in the intergrain zones contains large amounts of calcite ($CaCO_3$).[23] Hydrolysis of tricalcium silicate occurs through the dissolution of tricalcium silicate and precipitation of calcium silicate hydrate. Chemists often refer to this as C-S-H (C = CaO, S = SiO_2, and H = H_2O). The aqueous phase is where calcium hydroxide first appears. C-S-H gel layers are formed after nucleation and growth on the tricalcium silicate surface. Layers of comparatively insoluble calcium silicate hydrated gels surround tricalcium silicate grains, limiting the influence of subsequent reactions. Tricalcium silicate, which remains hydrated, and gradually fills the space between its grains and forms C-S-H gel.[24]

The glass ionomers are formed by an acid-base reaction in about 2–3 min after mixing. Glass particles and hydrated protons from the polyacid react first at key surface sites. Consequently, ions such as Na+ and Ca2+ (or Sr2+) leave the crystals and enter the polyacid solution, followed shortly thereafter by Al3+ ions. Subsequently, these ions influence polyacid molecules to form ionic crosslinks, which act as a stable structure for the cement set. When this setting process occurs, there is no phase separation because all the water is included in the cement. After this rough start, other processes take place in sequence and are collectively known as growth. They are associated with many changes in the physical properties of the final glass-ionomer cement (GIC). Transparency and strength are great for mutual enhancement. In addition, the percentage of water tightly bound to the structure increases.[25] Since their introduction, conventional GICs have undergone numerous improvements with positive impact on properties such as improved handling characteristics, increased strength, and enhanced wear resistance.[26]

On the other hand, growing global interest in sustainable technologies has led to the invention of products with lower environmental impact.[27] Eggshells are one of the by-products produced in large quantities daily in households, restaurants, and the food industry. Its chemical composition and availability rank as one of the world's worst environmental problems. At the same time, eggshells are considered the best source of natural calcium.[28] Calcium ions improve the mechanical properties of traditional glass ionomers.

According to our study results, conventional glass ionomer cement had the highest dye absorption, followed by glass ionomer cement modified with chicken eggshell powder, MTA, and Biodentine, which had the lowest dye absorption.

CONCLUSION

Within the limitations of the study, it was concluded that maximum sealing ability was seen in Biodentine followed by MTA, glass ionomer cement modified with 7% chicken eggshell powder, and glass ionomer cement.

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Nil.

Conflicts of interest
There are no conflicts of interest.

REFERENCES

1. Torabinejad M, Watson TF, Pitt Ford TR. Sealing ability of a mineral trioxide aggregate when used as a root end filling material. J Endod 1993;19:591-5.
2. Torabinejad M, Parirokh M. Mineral trioxide aggregate: A comprehensive literature review – Part II: Leakage and biocompatibility investigations. J Endod 2010;36:190-202.
3. Yaltırık M, Ozbas H, Bilgic B, Issever H, Reznikov N. Evaluation of microleakage and cytotoxicity of a new root-end filling material in different dilutions. J Endod 2006;32:833-6.
4. Kamal SA, Garlapati R, Bolla N, Vemuri S, Pydiahnaidu B, Suvarna YL. Comparison of sealing ability of mineral trioxide aggregate, biodentine with and without bioactive glass as furcation repair materials: An ultraviolet spectrophotometric analysis. Endodontology 2022;34:45-9.
5. Macwan C, Deshpande A. Mineral trioxide aggregate (MTA) in dentistry: A review of literature. J Oral Res Rev, 2014;6:71-4.
6. Kaushik M, Wadhwani KK, Saraswathi MV. Root perforations: A review of literature and case reports. Indian J Dent Res 2013;24:258-73.
7. Hegde MN, Hegde P, Mahesh M. Materials used for repair of furcal perforation: A literature review. J Conserv Dent 2012;15:199-207.
8. Hamad HA, Tordik PA, McClanahan SB. Evaluation of furcation perforation repair using mineral trioxide aggregate or resin-modified glass ionomer cement: A micro-computed tomography study. J Endod 2009;35:57-9.
9. Kim HM, Kim HE, Knowles JC. Production and potential uses of chicken eggshell powders as natural calcium supplements. Adv Appl Ceram 2011;110:280-7.
10. Fred S, Wang PY, Weatherspoon J, Mead L. Method of producing eggshell powder. Patent: US 20060062857 A. 2006;1.
11. Shen P, Manton DJ, Cochrane NJ, Walker GD, Yuan Y, Reynolds C, *et al*. Effect of added calcium phosphate on enamel remineralization by fluoride in a randomized controlled *in situ* trial. J Dent 2011;39:518-25.
12. American Association of Endodontists. Glossary of Endodontic Terms. 7th ed. Chicago, IL: American Association of Endodontics; 2003.
13. Camps J, Pashley D. Reliability of the dye penetration studies. J Endod 2003;29:592-4.
14. Sinkar RC, Patil SS, Jogad NP, Gade VJ. Comparison of sealing ability of ProRoot MTA, RetroMTA, and biodentine as furcation repair materials: An ultraviolet spectrophotometric analysis. J Conserv Dent 2015;18:445-8.
15. Camilleri J, Pitt Ford TR. Mineral trioxide aggregate: A review of the constituents and biological properties of the material. Int Endod J 2006;39:747-54.
16. Roberts HW, Toth JM, Berzins DW, Charlton DG. Mineral trioxide aggregate material use in endodontic treatment: A review of the literature. Dent Mater 2008;24:149-64.
17. Macwan C, Deshpande A. Mineral trioxide aggregate (MTA) in dentistry: A review of literature. J Oral Res Rev 2014;6:71.
18. Bates CF, Carnes DL, del Rio CE. Longitudinal sealing ability of mineral trioxide aggregate as a root-end filling material. Journal of Endodontics. 1996;22:575-8.
19. Torabinejad M, Hong CU, Lee SJ, Monsef M, Ford TR. Investigation of mineral trioxide aggregate for root-end filling in dogs. Journal of endodontics. 1995;21:603-8.
20. Valois CR, Costa Jr ED. Influence of the thickness of mineral trioxide aggregate on sealing ability of root-end fillings in vitro. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology. 2004;97:108-11.
21. Malik G, Bogra P, Singh S, Samra RK. Comparative evaluation of intracanal sealing ability of mineral trioxide aggregate and glass ionomer cement: An *in vitro* study. J Conserv Dent 2013;16:540-5.
22. Rajasekharan S, Martens LC, Cauwels RG, Verbeeck RM. Biodentine™ material characteristics and clinical applications: A review of the literature. Eur Arch Paediatr Dent 2014;15:147-58.
23. Malkondu Ö, Karapinar Kazandağ M, Kazazoğlu E. A review on biodentine, a contemporary dentine replacement and repair material. Biomed Res Int 2014;2014:160951.
24. Garrault S, Behr T, Nonat A. Formation of the C-S-H layer during early hydration of tricalcium silicate grains with different sizes. J Phys Chem B 2006;110:270-5.
25. Solanki NP, Venkappa KK, Shah NC. Biocompatibility and sealing ability of mineral trioxide aggregate and biodentine as root-end filling material: A systematic review. J Conserv Dent 2018;21:10-5.
26. Lagisetti AK, Hegde P, Hegde MN. Evaluation of bioceramics and zirconia-reinforced glass ionomer cement in repair of furcation perforations: An *in vitro* study. J Conserv Dent 2018;21:184-9.
27. Raji SA, Samuel AT. Egg shell as a fine aggregate in concrete for sustainable construction. Int J Sci Technol Res 2015;4:8-13.
28. Shiozawa M, Takahashi H, Iwasaki N, Uo M. Effect of calcium chloride solution immersion on surface hardness of restorative glass ionomer cements. Dent Mater J 2013;32:828-33.