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COMPARATIVE ASSESSMENT OF SEALING ABILITY OF BIOACTIVE MATERIALS IN FURCAL PERFORATIONS

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ABSTRACT

Background: One of the causes of endodontic failure is furcal perforation. When perforation occurs, it should be repaired as soon as it is made to prevent bacterial contamination, inflammation, and loss of attachment. Various materials have been described over the years for perforation repair. The present study is to evaluate and compare the sealing ability of four bioactive materials (pro root MTA, light cure MTA, biodentine and biostructure MTA putty) used in furcal perforation repair by dye penetration method using stereomicroscope. **Method:** A total of 50 extracted mandibular molars teeth with divergent roots were selected. All the teeth were mounted in jig saw using alginate. Standard access cavity preparation was done and artificial furcal perforation 2mm diameter was induced. Then the teeth were randomly divided into 5 groups, 4 experimental groups and 1 control group.

GROUP A: Perforation not repaired.
GROUP B: Repair was done using MTA.
GROUP C: Repair was done using light cure MTA.
GROUP D: Repair was done using biodentine.
GROUP E: Repair was done using biostructure MTA putty.

The samples were sealed coronally and later immersed in 2% methylene blue dye and sectioned. The dye penetration scores were recorded using stereomicroscope at 40x magnification.

Results: The overall results showed that the marginal adaptation of light-cure MTA and biostructure MTA putty was better than both MTA as well as Biodentine.

KEYWORDS: Furcation repair, Sealing ability, MTA, Biodentine, Light cure MTA, Biostructure MTA putty.

INTRODUCTION

In endodontic practice, procedural mishaps are encountered that might impact the prognosis of root canal treatment. One of these mishaps is endodontic perforation.[1]

According to the American Association of Endodontics (AAE), perforation is a mechanical or pathological communication between the root canal system and the external tooth surface caused by caries, resorptions, or iatrogenic factors (2003).[1]

As per the studies, root perforations are the second most common cause of failure, accounting for 9.62% of all unsuccessful cases.[3]

Kvinnsland et al. (1989) reported that routine root canal treatment accounts for 47% of iatrogenic perforations, while post insertion accounts for 53% of cases. Complications happened in the maxilla in 74.5% of instances. A furcation perforation refers to a mid curvature opening into the periodontal space and is the worst possible outcome in root canal treatment.[2] As furcal perforations are closest to the epithelial attachment and may communicate with the gingival sulcus, they are the hardest to manage.[5]

Root perforation should be repaired as soon as it is made to prevent bacterial contamination, inflammation, and loss of attachment.[6]

Furcation perforation can be corrected via nonsurgical coronal approach or by intracoronal surgical technique. The best approach, which is nonsurgical, is to fix the perforation right away with a repair material to prevent any potential bacterial infection.[9] Numerous variables, including exposure duration, tooth size, location, and the filling material's capacity to ensure a hermetic seal influence the tooth's prognosis.[8]

This can be accomplished through preventing the formation of voids in the material and spaces between the dentin walls and the material, reducing bacterial microleakage, and raising the success rates for sealing furcal perforations and the perforation walls.[7]

The inherent qualities of the perfect perforation repair material should include the ability to provide a sufficient seal, biocompatibility with oral tissue, resistance to blood contamination, antibacterial activity, and the ability to promote bone formation and healing.[11] It ought to be sufficiently radiopaque to be visible on radiography. Both cementogenesis and mineralization should be induced. It should also be simple to work with and insert into the cavity.[10]

Root perforations have been repaired using a variety of materials. In the past, amalgam, glass ionomer cement, calcium hydroxide, gutta-percha, zinc oxide eugenol cement, Intermediate restorative material (IRM), composite resin, Super EBA, glass ionomer, zinc oxide eugenol, biodentine, mineral trioxide aggregate (MTA), bio aggregate, etc. have been the most widely utilized repair materials.[14]

Because of their hermetic seal and biocompatibility, Biodentine and MTA are recommended as the best materials among the ones mentioned above. But there is still disagreement on the material's gold standard.[22]

Calcium silicate cements are indicated as furcal perforation repair materials because they can stimulate an inflammatory response at the injured site including fibroblasts, collagen fibers, and osteoclasts, among other immune agents that can lead to the formation of a newly mineralized tissue and the healing of the perforation.[15]

Since its discovery by Torabinejad at Loma Linda University in California, USA, in 19932, MTA has been the most widely utilized perforation repair material.[16]

Research revealed that it MTA is a good material for many kinds of treatements, including root-end closure, pulp capping, and furcal perforation repair (Sinai et al, 1989; Torabinejad et al, 1995).[12]

MTA is different from other materials in that it can stimulate cementum regeneration, which helps the periodontal apparatus regenerate (Pitt Ford et al, 1995; Arens, Torabinejad, 1996). It also promotes periradicular tissue regeneration (Yildirim et al, 2005; Holland et al, 2001; Zhu, Xia, Xia, 2003; Noetzel et al, 2006).[19] Owing to its elevated alkalinity, it possesses the capacity to trigger the liberation of bioactive dentin matrix proteins and build newly mineralized tissue.[15]

The presence of moisture is necessary for MTA to set. Due to this, set MTA can create great sealability and reach its peak strength when tissue fluids are present (Torabinejad et al., 1994)[23].The formation of cementoblasts with cementum deposition across its surface is made possible by MTA's exceptional osteoconduction property and biocompatibility (Holland et al., 2007; Wang, 2015).[21]

According to a recent study, a favourable prognosis may be obtained by repairing the perforated root non-surgically, with an overall chance of success of about 80.9%, when using mineral trioxide aggregate (MTA) based material[9] MTA-Angelus and Proroot MTA are commercial types of MTA, with MTA-Angelus being a less iron-containing option available in both gray and white forms. MTA Angelus was introduced to shorten the set time of Proroot MTA, which is two hours long. MTA-Angelus, made of 80% Portland cement and 20% bismuth oxide (Hashem et al. 2008), is recommended for furcal perforation repair due to its excellent handling qualities and faster setting time.[15]

Nevertheless, it has certain drawbacks, such as its inability to degrade down to allow for the replacement with natural tissues, low long-term resistance to compression, prolonged setting time, poor handling, and challenging insertion into cavities due to its granular consistency, necessitating additional moisture to activate the cement setting. Lastly, despite its widespread use, it is quite expensive.[18]

Biodentine (Septodont, Saint-Maurdes-Fosses, France), a calcium silicate-based bioactive cement, was introduced in 2011 to replace MTA due to its faster setting time and better handling. Known for its similar properties to MTA, it is now offered in a predosed capsule form, enhancing its physical characteristics and making it a viable alternative to MTA.

Compared to MTA, biodentine displayed a more stable dimension and a 0.58% volume loss (Petta et al., 2020) Compared to Bioaggregate and MTA, Biodentine has emerged as a superior option in endodontics because of its benefits, which include a better microstructure, a higher bond strength, and a decreased risk of discolouration.[13]

In comparison to Bioaggregate and MTA, biodentine with available thickness demonstrated an exceptional ability to resist dislodgement (Zhueta l, 2014b; Ulusoy et al., 2016) and root fracture (Ulusoy and Paltun, 2017).[19]

Many materials, like the resin-modified glass-ionomer cement, have been suggested to benefit from the use of light-curable resins in order to shorten their setting times and improve their mechanical characteristics. By utilizing light-curable MTA can be applied to wet and blood-contaminated surgical sites and have a longer therapeutic life due to its shortened setting time.[2]

Furthermore, the light-curable MTA-like material releases Ca2+ ions and gradually raises the alkalinity of the environment, which may cause the formation of hard tissue.[17]

Biostructure MTA putty initially emerged as a root repair material and has since been recommended for use in cavity liners for recurring caries, perforation repair, and root end filling. As advised by the manufacturer, it sets in the presence of blood and moisture and has a decreased setting time of 16 minutes. It also offers the following benefits: high mechanical resistance, low solubility, high alkalinity, and great biocompatibility.[22,23]

Putty was introduced as a third-generation substance made of calcium silicate. Since these materials don't need to be mixed before being placed in the furcal perforation, application may be quick and simple. Putties have demonstrated positive results in crucial pulp therapies, microsurgeries, and root resorption cases.[16]

The study aims to evaluate and compare the sealing ability of MTA Angelus, Biodentine, light cure MTA, and Biosturcture MTA putty in repairing furcal perforations, as no previous studies have compared their sealing ability.

MATERIALS AND METHODS

50 extracted, permanent mandibular molars were collected. Immediately after extraction, the roots of each tooth were cleaned of soft tissues or bone remnants, disinfected with 3% NaOCl for 10 min, and stored in normal saline at room temperature.

Inclusion Criteria

1. Teeth with intact crowns without caries, restoration, or cracks, and with non-fused and two completely formed roots.
2. Teeth with intact furcation.

Exclusion Criteria

1. Teeth with root caries.
2. Teeth with cracks
3. Teeth with fused root
4. Teeth with dilacerations

METHODOLGY

Tooth Preparation

- Access cavity preparation was done with number 2 round bur in a high speed airotar hand piece.
- Each molar, the crown is decoronated such that the distance from the roof of pulp chamber to crown is 4mm. artificial perforation of 2 mm in diameter was made directly in the centre of the pulp floor using a number 2 round bur in a low speed handpiece with water coolant.
- The preparation were thoroughly irrigated with saline and dried with paper points. The depth of perforation depended on the dentin cementum thickness from the pulpal floor to furcation area.
- A piece of cotton pellet dampened with water was placed in the furcation area of each tooth to stimulate clinical environment at perforation site.
- A plastic mould was used to serve as a jig to mount the teeth and to stabilize the teeth during perforation repair. The teeth were mounted in the jig using alginate impression material.

Application of sealing material

The teeth were randomly divided into five groups:

GROUP A	CONTROL GROUP: PERFORATION WAS NOT REPAIRED
GROUP B	PERFORATION REPAIRED WITH MTA
GROUP C	PERFORATION REPAIRED WITH LIGHT CURE MTA
GROUP D	PERFORATION REPAIRED WITH BIODENTINE
GROUP E	PERFORATION REPAIRED WITH BOISTRUCTURE MTA PUTTY

GROUP B: Perforations were sealed with MTA. Manipulation is done according to manufacturer’s instructions.

GROUP C: Light cure MTA (Dentigrate, Dentact Solutions Private Limited, India) the paste was filled into the perforation with the help of a bent needle provided by the manufacturer and cured for 1 minute as per the manufacturer’s instructions.

GROUP D: perforations were sealed with biodentine. The powder and liquid was mixed according to the manufacturer’s instructions.

GROUP E: perforation were sealed with boistructure mta putty, the paste is condensed into the perforation with a help of a plugger.

- All experimental perforation defects were filled with repair material to the level of pulpal floor. After 24 hours, the teeth surfaces were coated with two layers of clear nail varnish leaving 1mm around the perforation site exposed.
- After completion of the repair, pulp chamber and access preparation of all teeth were filled with temporary filling material Cavit (3M ESPE) and kept in an incubator at 100% humidity, at 37 degree Celsius for 72 hours.
- All experimental and control group samples were immersed in 2% Methylene blue solution for 48 hours at room temperature.

MICROLEAKAGE ASSESSMENT

After removal from the dye, the teeth were washed thoroughly in tap water and sectioned parallel to the long axis through the repaired perforation in bucco-lingual direction. Using a diamond disc and examined for dye leakage under stereomicroscope at 40X magnification.

To evaluate the sealing ability of RRMs in this *in vitro* study, we used mean values of apical dye leakage at perforation site and Escobar's criteria which used to evaluate the infiltration proportions[8]:

- 0-Infiltration loss (dye penetration 0– 1.5 mm).
- 1-Simple infiltration (dye penetration 1.5– 3 mm).
- 2-Medium infiltration (dye penetration more than 3 mm).

STATSTICAL ANALYSIS

Statistical Package for Social Sciences [SPSS] for Windows Version 22.0 Released 2013. Armonk, NY: IBM Corp., was used to perform statistical analysis. One-way ANOVA test followed by Tukey's post hoc analysis / Kruskal Wallis Test followed by Dunn's post hoc test will be used to compare the mean dye penetration scores between 5 groups.

RESULTS

The Test scores demonstrated that the mean dye penetration scores for MTA was 1.60 ± 0.84, for Light Cure MTA was 0.90 ± 0.74, for Biodentine was 1.20 ± 1.03, MTA Putty was 1.00 ± 0.94 and Control group was 3.00 ± 0.00. This difference was statistically significant at $p<0.001$.

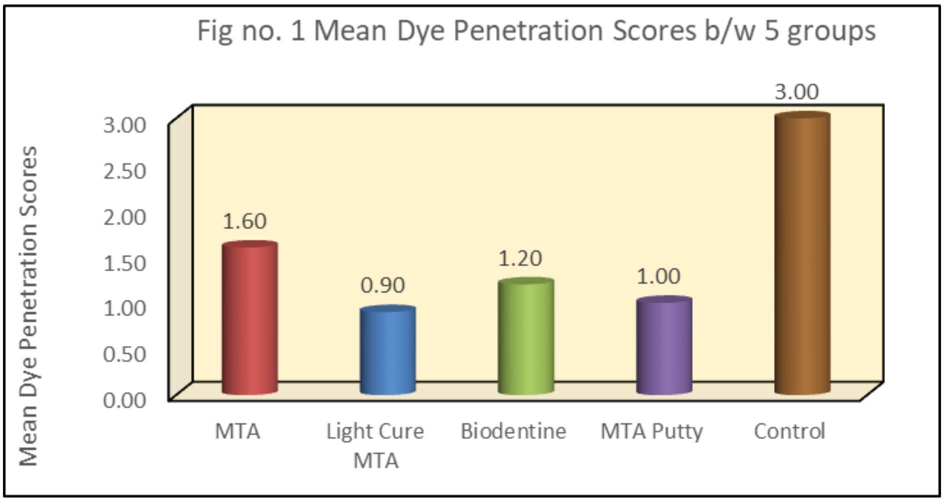
The study found that the Control group had significantly higher mean dye penetration scores compared to MTA, Light Cure MTA, Biodentine, and MTA Putty. These differences were statistically significant at $p=0.005$ and $p<0.001$, respectively. The MTA group also showed higher mean dye penetration scores compared to Light Cure MTA, Biodentine, and MTA Putty. However, no significant differences were found between different study groups, indicating that the Control group had the highest mean dye penetration scores.

Comparison of mean Dye Penetration scores b/w 5 groups using Kruskal Wallis Test

Groups	N	Mean	SD	Min	Max	p-value
MTA	10	1.60	0.84	0	3	<0.001*
Light Cure MTA	10	0.90	0.74	0	2	
Biodentine	10	1.20	1.03	0	3	
MTA Putty	10	1.00	0.94	0	3	
Control	10	3.00	0.00	3	3	

Multiple comparison of mean difference in the Dye Penetration scores b/w groups using Dunn's Post hoc Test

(I) Groups	(J) Groups	Mean Diff. (I-J)	95% CI for the Diff.		p-value
			Lower	Upper	
MTA	Light Cure MTA	0.70	-0.32	1.72	0.14
	Biodentine	0.40	-0.62	1.42	0.40
	MTA Putty	0.60	-0.42	1.62	0.20
	Control	-1.40	-2.42	-0.38	0.005*
Light Cure MTA	Biodentine	-0.30	-1.32	0.72	0.54
	MTA Putty	-0.10	-1.12	0.92	0.85
	Control	-2.10	-3.12	-1.08	<0.001*
Biodentine	MTA Putty	0.20	-0.82	1.22	0.67
	Control	-1.80	-2.82	-0.78	<0.001*
MTA Putty	Control	-2.00	-3.02	-0.98	<0.001*



DISCUSSION

Endodontic therapy aims to remove microbes and seal the root canal system, but accidental perforations can cause damage. Successful management involves non-surgical coronal approaches, immediate repair of furcal perforations, and an effective seal between the root canal system and periodontal ligament, influenced by the repair material's properties.[1,3]

This study compared the sealing ability of light-cured MTA and biostructure MTA putty with commonly used MTA-Angelus and Biodentine.

Mandibular molars were chosen for the current study because they are frequently lingually tilted, making it possible that access cavities positioning in relation to the pulp chamber of the idealized occlusal anatomy may not always be important. This could result in furcal perforations.[5]

The study used the dye penetration approach due to its convenience and its ability to measure the deepest point the dye reaches. However, it has limitations as the dye molecules are smaller than those of bacteria. Despite these, dye penetration is a reliable method for sealing furcation perforations. Camps and Pashley found similar results with dye extraction and fluid infiltration, with the former requiring fewer teeth in the lab. Kaya et al. concluded that the volumetric determination of dye penetration was identical to dye extraction, but due to its simplified process, it might be chosen for additional research.[13,19]

Various materials have been used to repair furcation perforations, including amalgam, hydroxyapatite, gutta percha, calcium hydroxide, zinc oxide, Eugenol-based cement, glass ionomer cement, composite resins, resin-glass ionomer hybrids, demineralised freeze-dried bone, and MTA, but none meet the criteria for an ideal biomaterial.[8]

Balla et al (1991) found that epithelium and acute inflammatory cells occupied the defect site at the furcation perforation defect site, not hard tissue, when treated with tri-calcium phosphate, hydroxyapatite, amalgam, or calcium hydroxide.[1]

The ability of MTA and related bioactive endodontic cements to stimulate cementum regeneration, so promoting the regeneration of the periodontal apparatus, sets them apart from other materials (Arens & Torabinejad, 1996; Pitt Ford et al., 1995).[1] Repair materials were unable to initiate this regenerative process prior to the introduction of MTA (Main et al., 2004). Biocompatibility is made clear by the absence of negative consequences following the extrusion of MTA into the furcation in both situations (Arens & Torabinejad, 1996; Pitt Ford et al., 1995).[12] Based on existing information, MTA improves the prognosis of perforation repair (Main et al., 2004; Pitt Ford et al., 1995; Torabinejad et al., 2018) and creates an effective seal (Hamad et al., 2006; Hashem & Hassanien, 2008).[21]

The impact of time and moisture on the setting, retention, and adaptability of MTA in furcal perforation repair was evaluated by Sluyk, Moon, and Hartwell (1998), their results demonstrated that moisture enhanced MTA's adaptability to perforation walls, and they proposed the use of a moistened matrix beneath MTA to prevent the material from being over- or underfilled.[4] When in contact with tissues, MTA activates bone markers necessary for biomineralization and the healing of periapical bone defects while also stimulating immune system cells to generate lymphokines that promote cementum repair and regeneration.[2]

According to a study by Reyes-Carmona and colleagues, the formation of an apatite layer on the surface of the material as a result of the chemical bonding of MTA to dentin improved the material's sealing ability.[6]

Comparing MTA to other materials, Siew et al. found that nonsurgical repair yielded a higher success rate. Using MTA material to patch perforations has an overall success rate of about 81%, therefore it makes sense to save the tooth without surgery (Siew et al., 2015).[17]

When compared to MTA, Guneser et al. hypothesized that Biodentine's superior interlocking with dentin might be because of its homogeneous components and generally lower particle size. Possible explanations for biodentine's adherence to dentinal tubules include tag-like structures that serve as a micromechanical anchor within the tubules.[13] Comparing Biodentine to MTA-Angelus, the former demonstrated comparatively reduced bacterial leakage. The Additionally, it has the ability to create mineral tags of hydration products through intertubular diffusion, resulting in the creation of hybrid zones with dentine.[3]

MTA has been shown to induce TNF-, IFN-, and RANKL expression in mice with furcation perforations repaired, and enhance IL-10 expression later in the process. In dogs, MTA can limit epithelial infiltration and encourage the formation of calcified bridges. At one month, MTA caused a slight increase in inflammation, which subsided at three months and vanished entirely at six months. New cementum formed, beginning at one month and ending at six months.[13]

Comparing Biodentine to MTA, Han and Okiji found that Biodentine had higher calcium and silicon ion uptake into dentin, which led to the formation of tag-like structures.[15]

Biodentine is composed of a hydrosoluble polymer that acts as a water-reducing agent and calcium chloride, which acts as an accelerator. The content is set for a maximum of nine to twelve minutes. Biodentine's handling qualities and strength are enhanced by the faster setting it achieves when setting accelerator is present. Compared to MTA, this is advantageous.[4]

According to a recent study (Kakani AK, Veeramachaneni C, 2020), Biodentine and Endosequence have a significantly better sealing ability compared to MTA-Angelus when used to treat severe furcal perforations. They also have better handling properties.[9]

Numerous in vitro investigations have shown that biodentin has high push-out mechanical properties even after being exposed to various endodontic irrigation solutions, and that blood contamination had no effect on the dentin's push-out bond strength (Priyalakshmi S, Ranjan M, 2014; Guneser MB, Akbulut MB, Eldeniz AU, 2013).[11]

According to Tomas-Catala C J et al. (2018), biodentine exhibits high levels of cytocompatibility and cell migration with human dental pulp stem cells.[9] In comparison to the control group, Biodentine treated to NaOCl increased the size and quantity of calcium hydroxide crystals. The release of calcium, the creation of calcium hydroxide, and raising the PH all contribute to the material's improved sealing.[10]

Although biodentine has several positive attributes, studies have shown that it has poor radiopacity and a significant washout propensity (Grechetal., 2013b; Caronetal., 2014).[17] The lack of fluoride ions in biodentine prevented the formation of plaque bacteria and driveremineralization, which is why its antibacterial and anticariogenic properties were less potent than those of glassionomercement. Thus, to encourage the development of apatite, bioactive glass could be added to biodentine (Forss et al., 1991; Simila and associates (2018).[13]

The results of this study revealed significant differences between the tested materials, with LC-MTA outperforming Biodentine and MTA-Angelus in terms of marginal adaption. Dentigrate light cure is calcium silicate-based, single-paste calcium silicate-based substance that the manufacturer advises using as a cavity liner beneath all filling materials, a pulp capping material, and a material for perforation repair. Light activates the setting reaction of the polymerizable component. The material's flow, which enables faster application and quick setting, may be responsible for the enhanced sealing ability.[2] Light cure MTA's good marginal adaptation in spite of the anticipated polymerization shrinkage may be explained by the material's calcium silicate basis, which promotes the production of hydroxyapatite on the surface and creates a biological seal. It could have the appearance of or serve as a scaffold to aid in the production of dentin. When dentinal fluids are absorbed, calcium and hydroxide ions are released.[15]

The last material used in this study is Biostructure MTA putty. It consists of Mineral Trioxides: Tricalcium silicate, Dicalcium Silicate, Tricalcium Aluminate Zirconium Oxide Paste forming agents ready-to-use bioceramic material presented in a threaded syringe that facilitates better handling and insertion while working in parallel with the practice and saving time. Comparable to MTA in terms of cytotoxicity, biocompatibility, and biomineralization.[19]

MTA putty had greater sealing ability which could be attributed to hardening of the cement in presence of moisture and blood, Controlled setting time, High mechanical resistance, Low solubility (Övsay et al).[23]

CONCLUSION

Light-cure MTA and Biostructure MTA putty has superior sealing ability compared to Biodentine and Mineral Trioxide Aggregate. However, further research on biocompatibility, solubility, calcium release properties, and remineralizing potential is needed to determine its biological and clinical efficacy. Further in-vitro and in-vivo studies are also required.

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