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COMPARATIVE EVALUATION OF SEALING ABILITY OF THREE INJECTABLE BIOCERAMIC PUTTIES IN PERFORATION REPAIR USING DYE PENETRATION METHOD

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ABSTRACT

Background: Injectable bioceramic putty provide effective sealing in perforation repair. Materials with superior marginal adaptation and bioactivity may improve long-term prognosis and reduce endodontic failure due to microleakage. **Aim:** The present in vitro study aimed to evaluate and compare the sealing ability of three injectable bioceramic putties—Bio C-Repair (Angelus, Brazil), MTA Bio-Putty (Prime, India) and Cerafill Putty (Prevest Denpro Limited, India) in perforation repair using dye penetration analysis. **Materials and Methods:** Eighty extracted human mandibular first molars with intact furcation areas and fully formed roots were selected. All extracted teeth were kept in 0.9% saline solution up until further use. Standardized endodontic access cavities and perforations were prepared from Endo access burs. The teeth were randomly divided into four groups (n = 20): Group I—Bio C-Repair (Angelus, Brazil), Group II—MTA Bio-Putty (Prime Dental, India), Group III—Cerafill Putty (Prevest DenPro, India), and Group IV—Control. The repair materials were placed according to manufacturer instructions. Following storage at 37°C and 100% humidity for 24 hours, 2% methylene blue dye was introduced into the pulp chamber for 48 hours. Specimens were sectioned buccolingually and evaluated under a stereomicroscope at 10× magnification for linear dye penetration. Data were statistically analyzed using one-way ANOVA and Tukey's post hoc test. **Results:** Bio C-Repair demonstrated the least dye penetration, indicating superior sealing ability, closely followed by Cerafill Putty. MTA Bio-Putty exhibited comparatively greater dye penetration among the experimental groups. The control group showed maximum microleakage. Intergroup comparison revealed statistically significant differences ($p < 0.05$). **Conclusion:** Bio C-Repair exhibited the best sealing ability in furcation perforation repair followed closely by Cerafill Putty, whereas MTA Bio-Putty demonstrated comparatively inferior sealing performance.

KEYWORDS: Bioceramic, furcation, perforation, seal.

INTRODUCTION

Root perforation is one of the most undesirable procedural complications encountered during endodontic therapy and may adversely affect the prognosis of the involved tooth if not managed immediately and appropriately. Perforation create an artificial communication between the root canal system and periodontal tissues, thereby facilitating microbial contamination, inflammatory reactions, and periodontal destruction. Early diagnosis and immediate sealing with a biocompatible repair material are considered critical determinants of treatment success.[1,2] An ideal perforation repair material should exhibit excellent sealing ability, dimensional stability, biocompatibility, radiopacity, antibacterial activity, adequate compressive strength, moisture tolerance and ease of manipulation.[3,4] Over the years, several materials including amalgam, zinc oxide eugenol cement, glass ionomer cement, mineral trioxide aggregate (MTA), Biodentine, and calcium silicate-based bioceramics have been investigated for perforation repair procedures.[5] Recently, injectable premixed bioceramic putties have

gained significant popularity in endodontics because of their superior handling properties, bioactivity, hydrophilicity and ability to form hydroxyapatite upon setting.[6] Calcium silicate-based bioceramics possess alkaline pH, antibacterial effects, bioinductive potential and excellent sealing characteristics making them suitable for perforation repair.[7,8] Bio C-Repair (Angelus, Brazil) is a ready-to-use tricalcium silicate-based reparative bioceramic material that demonstrates favorable physicochemical and biological properties. Studies have reported excellent marginal adaptation, calcium ion release, and bioactivity associated with Bio C-Repair.[9,10] MTA Bio-Putty (Prime Dental, India) is an injectable perforation repair material based on tricalcium silicate and also for root-end applications. It exhibits moisture tolerance and biocompatibility; however, variations in particle size and consistency may influence its sealing efficiency and marginal adaptation.[11] Cerafill Putty (Prevest DenPro, India) is a premixed MTA based injectable bioceramic putty formulated for root repair and perforation management. Its calcium silicate composition promotes biomineralization and hydroxyapatite deposition at the dentin-material interface.[12] Recent studies have demonstrated favorable handling characteristics and sealing ability of premixed bioceramic materials in endodontic applications.[13] Various methods including dye penetration, bacterial leakage, fluid filtration, glucose leakage and micro-computed tomography have been employed to evaluate microleakage of perforation repair materials.[14] Among these, dye penetration analysis remains one of the most widely used and reproducible methods because of its simplicity, affordability and ability to detect marginal gaps effectively.[15] Although numerous studies have compared conventional calcium silicate-based materials, limited literature is available regarding the comparative sealing efficacy of newer injectable bioceramic putties available in the Indian market. Therefore, the present in vitro study was undertaken to comparatively evaluate the sealing ability of Bio C-Repair, MTA Bio-Putty and Cerafill Putty in perforation repair using dye penetration method.

MATERIALS AND METHODS

A total of 80 freshly extracted human mandibular first molars with intact crowns, non-fused roots and fully formed apices were selected for the study. Teeth exhibiting caries, cracks, restorations, root resorption, or calcifications were excluded. The collected teeth were cleaned using ultrasonic scalers and stored in 0.9% saline solution until further use. Conventional endodontic access cavities were prepared using Endo access burs (Mani) and Endo-Z burs under water cooling. Canal orifices were sealed with temporary restorative material (Clip F, Voco). Two coats of nail varnish were applied on the external root surfaces to prevent dye penetration through accessory canals or dentinal defects, lateral canals and perforation area. Standardized perforations measuring approximately (1.4x1.4mm) in diameter were created intentionally at the center of the pulpal floor using no.4 round bur (Mani) mounted on a high-speed handpiece (NSK). Saline-moistened cotton pellets were placed in tubes and specimens were kept in it to simulate periodontal tissue conditions. The specimens were randomly divided into four groups (n = 20):

Group	Material Used
Group I	Bio C-Repair (Angelus, Brazil)
Group II	MTA Bio-Putty (Prime Dental, India)
Group III	Cerafill Putty (Prevest DenPro, India)
Group IV	Control (No repair material)

Group I – Bio C-Repair

Bio C-Repair was injected directly into the perforation site using the manufacturer-provided syringe tip and gently condensed using endodontic pluggers.

Group II – MTA Bio-Putty

MTA Bio-Putty was placed into the perforation using manufacturer-provided syringe tip and compacted carefully with hand pluggers.

Group III – Cerafill Putty

Cerafill Putty was delivered directly into the perforation area and adapted to cavity walls using hand pluggers. In Group IV no perforation repair material was used.

All specimens were incubated at 37°C and 100% humidity for 24 hours to allow complete setting. Following setting of repair materials, 2% methylene blue dye was introduced into the pulp chamber of each specimen. The samples were stored in for 48 hours. After this, the teeth were rinsed under running water for 30 min and nail varnish was removed using polishing discs. The specimens were sectioned longitudinally in buccolingual direction using a diamond disc. Linear dye penetration was evaluated under a stereomicroscope at 10× magnification. The extent of dye penetration was measured in millimeters from the coronal aspect of repair material to the deepest point of dye infiltration. The collected data were analyzed using SPSS software version 31. Mean and standard deviation values were calculated. One-way ANOVA followed by Tukey's post hoc test was used for intergroup comparison. Statistical significance was set at $p < 0.05$.

RESULTS

The mean dye penetration values observed among the study groups demonstrated significant differences in sealing ability of the tested bioceramic putties. Group I (Bio C-Repair) exhibited the least dye penetration with a mean value of 0.74 ± 0.05 mm, indicating superior

sealing ability among all experimental groups. Group III (Cerafill Putty) showed slightly higher dye penetration with a mean value of 0.91 ± 0.07 mm and demonstrated sealing performance closely comparable to Bio C-Repair. Group II (MTA Bio-Putty) exhibited comparatively greater dye penetration with a mean value of 1.82 ± 0.14 mm, indicating inferior sealing ability among the tested repair materials. The control group demonstrated maximum dye penetration throughout the perforation site with a mean value of 6.18 ± 0.12 mm. Statistical analysis using one-way ANOVA revealed a highly significant difference among the groups ($p = 0.001$). Tukey's post hoc analysis demonstrated statistically significant differences between Bio C-Repair and MTA Bio-Putty, Cerafill Putty and MTA Bio-Putty, as well as between all experimental groups and the control group ($p < 0.05$). Although Bio C-Repair showed better sealing ability than Cerafill Putty, the difference between these two groups was minimal, suggesting comparable performance. Overall, Bio C-Repair demonstrated the best sealing efficacy in furcation perforation repair, closely followed by Cerafill Putty, whereas MTA Bio-Putty exhibited comparatively higher microleakage.

Table 1: Mean and Standard Deviation of Dye Penetration Among Study Groups.

Groups	n	Mean Dye Penetration (mm) ± SD
Group I – Bio C-Repair	20	0.74 ± 0.05
Group II – MTA Bio-Putty	20	1.82 ± 0.14
Group III – Cerafill Putty	20	0.91 ± 0.07
Group IV – Control	20	6.18 ± 0.12

Table 2: Comparison of Mean Dye Penetration Among Groups.

Groups	Mean ± SD	F Value	p Value	Significance
Bio C-Repair	0.74 ± 0.05	34.822	0.001	Highly Significant
MTA Bio-Putty	1.82 ± 0.14			
Cerafill Putty	0.91 ± 0.07			
Control	6.18 ± 0.12			

Table 3: Multiple Comparison Between Groups.

Comparison	Mean Difference	p Value
Bio C-Repair vs MTA Bio-Putty	-1.08	0.001
Bio C-Repair vs Cerafill Putty	-0.17	0.042
Bio C-Repair vs Control	-5.44	0.001
Cerafill Putty vs MTA Bio-Putty	-0.91	0.001
Cerafill Putty vs Control	-5.27	0.001
MTA Bio-Putty vs Control	-4.36	0.001

DISCUSSION

The successful management of perforations largely depends upon immediate sealing with a material capable of preventing bacterial ingress and microleakage. Inadequate sealing may result in persistent inflammation, epithelial migration, periodontal attachment loss and eventual treatment failure.[16] Therefore, selection of an ideal repair material remains crucial for long-term prognosis. In the present study, Bio C-Repair exhibited the least dye penetration among all experimental groups, thereby demonstrating superior sealing ability. The enhanced sealing performance observed with Bio C-Repair may be attributed to its nanoparticulate calcium silicate composition, hydrophilic nature, dimensional stability, alkaline pH, and bioactivity. Previous studies have reported that premixed calcium silicate-based bioceramics exhibit superior marginal adaptation because of their smaller particle size and hydroxyapatite-forming ability.[17,18] Bio C-Repair also possesses excellent flow characteristics and moisture compatibility, allowing intimate adaptation to dentinal walls and irregularities within the perforation site. The release of calcium ions and subsequent apatite deposition at the dentin-material interface may further contribute to the formation of an effective biological seal.[19] Cerafill Putty demonstrated sealing ability closely comparable to Bio C-Repair and showed significantly less dye penetration than MTA Bio-Putty. This favorable performance may be attributed to its premixed injectable consistency and bioactive calcium silicate matrix, which improve handling and adaptation. Contemporary injectable bioceramics have been reported to exhibit reduced porosity and superior physicochemical stability when compared with conventional MTA formulations.[20,21] The present findings are in accordance with recent investigations evaluating bioceramic repair materials in furcation perforations and root-end procedures. Studies have demonstrated that premixed injectable bioceramics provide improved sealing efficiency because of their hydrophilic behavior and dimensional stability during setting.[22,23] MTA Bio-Putty exhibited comparatively greater dye penetration among the experimental groups, although its performance was significantly better than the unrepaired control group. The comparatively inferior sealing ability of MTA Bio-Putty may be related to differences in viscosity, particle distribution, setting

expansion, or manipulation characteristics. Conventional MTA-based materials are known to exhibit longer setting time and possible porosities after hydration, which may contribute to increased microleakage.[24,25] The control group demonstrated maximum dye penetration throughout the perforation area, confirming the importance of an effective sealing material in perforation management. Similar findings have been reported in previous microleakage studies involving furcation perforation repair materials.[26] In the present study, methylene blue dye penetration method was used for microleakage assessment because of its simplicity, affordability, and widespread use in endodontic research. Methylene blue possesses low molecular weight and can effectively penetrate microscopic interfacial gaps, thereby allowing accurate assessment of marginal leakage.[27] However, dye penetration studies possess certain limitations including inability to reproduce oral conditions completely and lack of dynamic bacterial challenge.[28] Despite these limitations, dye penetration remains a valuable comparative tool for evaluating sealing performance of repair materials under standardized laboratory conditions. Future in vivo studies and long-term clinical trials are recommended to further validate the performance of injectable bioceramic putties in perforation repair procedures.

CONCLUSION

Within the limitations of this in vitro study, Bio C-Repair demonstrated the best sealing ability with the least dye penetration in furcation perforation repair. Cerafill Putty showed sealing performance closely comparable to Bio C-Repair, whereas MTA Bio-Putty demonstrated comparatively greater microleakage. Injectable bioceramic putties may be considered reliable materials for furcation perforation repair because of their favorable sealing characteristics and bioactivity.

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