Original Article

# Comparative analysis of Biodentine and Mineral Trioxide Aggregate repair High Plasticity in reinforcing roots with perforation: An *in vitro* study

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## Abstract

**Context:** Root perforation increases the fracture risk, and bioceramic materials can be used for repair. Evaluating the fracture resistance (FR) of these cements in teeth with simulated perforations is crucial for assessing their effectiveness.

**Aim:** The aim of the study was to evaluate the effect of Biodentine (Septodont, France) and Mineral Trioxide Aggregate High Plasticity (MTA Repair HP, Angelus, Brazil), on the FR of teeth with simulated root perforations.

**Design and Settings:** An *in vitro* experimental design was conducted to compare and determine the most reliable repair and obturating material for root perforation.

**Materials and Methods:** Fifty extracted mandibular premolars were randomly assigned to one control group ($n$ = 10) and four test groups ($n$ = 10) based on the repair and backfilling materials used: Biodentine + gutta percha (GP) (Dentsply Maillefer, Germany) and AH Plus sealer (Dentsply, Germany), Biodentine + Biodentine, MTA HP + GP and sealer, and MTA HP + MTA HP. FR was assessed using a universal testing machine.

**Statistical Analysis:** The variance among the five groups was tested using Analysis of Variance and pairwise *post hoc* Tukey's test for intergroup comparisons. The level of statistical significance was set at $P < 0.05$.

**Results:** The highest mean FR value was observed in the MTA HP + MTA HP group. ANOVA test revealed statistically significant differences between the groups ($P < 0.05$).

**Conclusion:** Bioceramic cements with a MOE similar to dentin enhance FR by forming a monoblock for uniform stress distribution. Perforation repair and backfilling with these cement reinforce the tooth.

**Keywords:** Biodentine; fracture resistance; Mineral Trioxide Aggregate repair High Plasticity; perforation repair

## INTRODUCTION

Root perforation is an unintended communication between the root canal space and periodontium, which negatively influences the prognosis of an endodontically treated tooth.[1] In permanent teeth, this can occur due to pathologic conditions such as internal or external inflammatory root resorption or as an iatrogenic complication during endodontic treatment.[2-4] Bacterial infection originating from the root canal or periodontal tissues at the perforation site triggers periodontal inflammation, leading to the destruction of periodontal fibers, loss of attachment,

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Date of submission : 03.10.2024
Review completed : 28.11.2024
Date of acceptance : 22.12.2024
Published : 13.01.2025

Access this article online

Quick Response Code:

Website: https://journals.lww.com/jcde

DOI: 10.4103/JCDE.JCDE_711_24



**How to cite this article:** Anija R, Kalita C, Satheesh SL, Seal M, Kalita T, Saikia A. Comparative analysis of Biodentine and Mineral Trioxide Aggregate repair High Plasticity in reinforcing roots with perforation: An *in vitro* study. J Conserv Dent Endod 2025;28:63-7.

bone resorption, granulomatous tissue formation, and periodontal defects.[5,6] Several factors, including the time elapsed between perforation and detection, as well as the size, shape, and location of the perforation, influence the ability to control infection.[5] Endodontic failure due to perforation varies from 2.9% to 4.2%.[7,8] Early detection and appropriate management of perforations can significantly improve the prognosis and prolong tooth survival.

Perforations, particularly those associated with internal root resorption, weaken the remaining dental structure, making teeth more susceptible to fractures.[9] The strength and fracture resistance (FR) of teeth with perforation repair depends on material properties such as strength and modulus of elasticity (MOE).[10] An ideal filling material must provide a tight seal to prevent bacterial ingress, promote healing through biocompatibility, and offer sufficient mechanical strength to support the weakened tooth structure. Bioceramic materials, known for their high biocompatibility, sealing ability, adequate strength to resist condensation forces, and ability to promote bone formation and healing, are ideal for repair of root resorptions and perforations.[11] Mineral Trioxide Aggregate (MTA) has been widely used for pulp capping and perforation repair due to its bioactivity and biocompatibility.[11,12] However, its limitations include prolonged setting time, difficulty in manipulation, and low compressive strength.[13,14]

Newer modifications such as MTA Repair High Plasticity (MTA HP, Angelus, Brazil) contain calcium tungstate as a radiopacifier.[15] Calcium tungstate increases calcium release, leading to enhanced biomineralization.[16] The high-plasticity of MTA HP improves the marginal adaptation of the cement to the root walls and demonstrates a higher bond strength than MTA. It also shows an increase in compressive strength over time and a rapid initial setting time of 15 min reducing the susceptibility to cement failure.[15,17] According to previous research, MTA HP has been shown to be less sensitive to NaOCl solution compared to other bioceramic cements, enhancing its effectiveness as a perforation repair material.[15] Biodentine (Septodont, France), another bioactive calcium silicate-based cement, offers advantages over traditional MTA such as faster setting time and higher push-out bond strength at 24 h; improvements in physical qualities and handling characteristics, making it suitable for a wide range of applications such as endodontic repair and pulp capping in restorative dentistry.[18]

Restorative materials with a MOE comparable to dentin reduce stress concentration.[19] A hybrid technique may be employed to repair perforation defects. After obturating the canal apical to the resorption defect, the defect and coronal portion can be obturated with calcium silicate cements.[20] Root perforations, particularly iatrogenic root perforations, affect the prognosis of root canal treatments. Therefore, materials with reinforcing capabilities should be used to repair resorption areas and prevent fractures.[21] Stress distribution in an endodontically treated tooth is influenced by the remaining tooth structure.[22] Achieving an ideal monoblock for root canal reinforcement requires matching the elastic moduli of all components with root dentin.[23] MTA Repair HP, known for its high bioactivity and good cytocompatibility, promotes healing; however, there is a scarcity of studies comparing the FR of teeth after perforation repair.[24]

No studies have exclusively compared Biodentine and MTA Repair HP, highlighting the need to evaluate these materials to improve treatment outcomes. Moreover, there is limited research specifically assessing the FR of teeth with perforations. Therefore, the aim of this study was to evaluate and compare the FR of teeth with simulated root perforations repaired using Biodentine and MTA Repair HP.

## MATERIALS AND METHODS

### Selection of samples

Teeth with open apices, caries, immature apices, anatomical aberrations, calcifications, root fractures, root resorption, multiple canal anatomy, and presence of root canal filling materials or restorations were excluded from the study. The sample size was estimated to be 50, using the formula:

$$n = \left( \frac{z_{\alpha/2} . \sigma}{E} \right)^2$$

Where $z_{\alpha/2}$ is 1.96 for a 95% confidence level, σ is the standard deviation (90), and *E* is the margin of error (±25).[20] A total of fifty extracted noncarious permanent mandibular premolar teeth, with similar dimensions and single root canal verified by radiograph were selected. The steps involved in the preparation and testing of the specimens are depicted in Figure 1.

### Preparation of samples

The extracted teeth, preserved in 10% formalin, were disinfected using 2.5% sodium hypochlorite (Asian acrylates, India) for 30 min and stored in saline. The teeth were decoronated using a diamond disk to a standardized root length of 15 mm, verified with a digital caliper (Mitutoyo, Kanagawa, Japan). The working length was established 1 mm short of the apical foramen and root canals were instrumented with a rotary file system (Neoendo, Orikam) up to size 35/06 using EDTA gel (Avue Prep, Palghar, India). The root canals were copiously irrigated using 3 mL, 2.5% sodium hypochlorite (Asian acrylates, Mumbai, India) during instrumentation. After preparation, the impression of the root samples was taken using the addition polyvinyl silicone material (Speedex, Coltene, Switzerland) filled in Eppendorf tubes to simulate an alveolar socket. The simulated perforation cavities were prepared 8 mm from the apical foramen using a No. 8 round bur (Mani, Inc. Japan). The

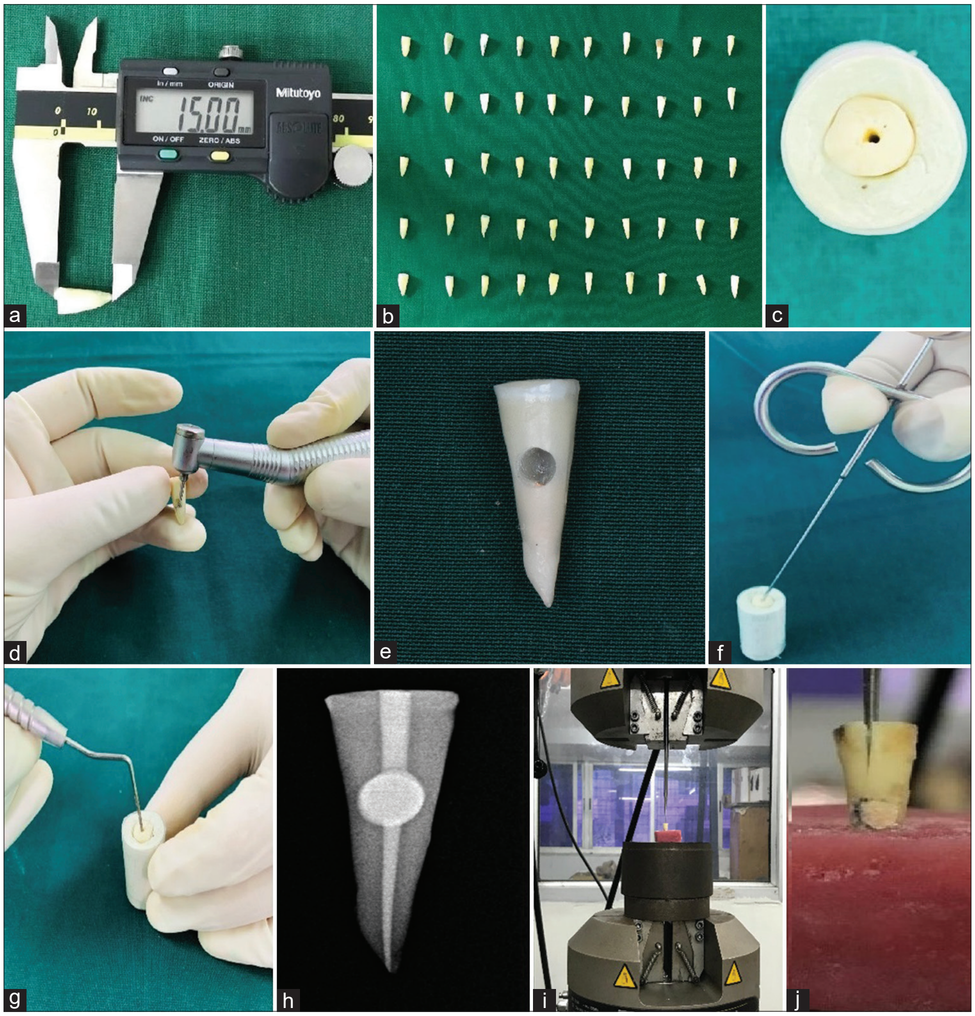


**Figure 1:** (a) Standardization of the root sample; (b) decoronated root samples; (c) specimen in Eppendorf tube filled with addition polyvinyl silicone impression material; (d) preparation of the perforation defect; (e) simulated perforation defect; (f and g) repair of the perforation defect and backfilling with Biodentine; (h) representative radiographic image of Biodentine + Biodentine group (i) sample positioned in a Universal Testing Machine; (j) fractured sample after loading

cavities were standardized to a diameter of 2.5 mm with a digital caliper (Mitutoyo, Kanagawa, Japan). Final irrigation was done with 2 mL of 17% EDTA solution (Ultradent, South Jordan, UT) for 1 min, rinsed with distilled water, and dried with paper points (Diadent, Korea).

The samples were randomly divided into a control group ($n$ = 10) with no intervention and four test groups ($n$ = 10 each) based on the materials used for perforation repair and canal filling. The apical 8 mm of the root canals in the test groups were obturated with master gutta percha (GP) (Dentsply Maillefer, Konstanz Germany) and AH Plus sealer (Dentsply, Konstanz, Germany) using the single-cone technique. The perforation defects were restored with bioceramic cement and backfilled with bioceramic cement incrementally using hand pluggers or with a thermoplasticized GP and AH Plus sealer using warm vertical compaction (E and Q MASTER™, Meta Biomed). The groups compared are detailed below:

- Group 1: Control group
- Group 2: Biodentine + GP and sealer: Resorption defects were repaired with Biodentine and backfilled with thermoplasticised GP and sealer
- Group 3: Biodentine + Biodentine: Resorption defects were repaired and backfilled with Biodentine
- Group 4: MTA HP + GP and sealer: Resorption defects were repaired with MTA HP and backfilled with thermoplasticised GP and sealer
- Group 5: MTA HP + MTA HP: Resorption defects were repaired and backfilled with MTA HP.

All samples were then stored in an incubator (Coslab, Model: CLE-102) at 37°C with 100% humidity for 1 week until tested for FR. The apical 8 mm of all samples (control and test groups) were covered with a thin layer of polyether impression material (Impregum Soft, 3M ESPE, Germany) to simulate the periodontal membrane and mounted vertically in acrylic resin blocks (DPI R.R Cold cure, Mumbai, India), exposing the repaired defect as shown in Figure 1.

### Testing for fracture resistance

The samples were subjected to FR analysis in a universal testing machine (Instron 8801, MA, USA). A crosshead speed of 1 mm/min was maintained with a spherical tip of 1 $mm^2$ toward the center of the filling material at a loading angle of 90°. The force at which the fracture occurred was recorded in Newtons (*N*). Statistical analyses were performed using the Statistical Package for the Social Sciences (IBM SPSS Statistics, version 20, Armonk, NY, USA: IBM Corp). The data were statistically analyzed with analysis of variance and Tukey's *post hoc* tests at $P = 0.05$.

## RESULTS

The mean (standard deviation) values of the FR test are shown in Table 1. Among the test groups, the highest mean FR value was observed in the MTA HP + MTA HP group, 347.61 (±105.45) Newtons, followed by the Biodentine + Biodentine group, 262.75 (±72.95) Newtons, the MTA HP + GP and sealer group, 195.98 (±61.09) Newtons, and the lowest in the Biodentine + GP and sealer group, 150.24 (±56.97) Newtons. There was a statistically significant difference between the groups according to the analysis of variance ($P < 0.05$). The FR of the control group was statistically lower than that of the groups filled with bioceramic cement ($P < 0.05$).

Pairwise *post hoc* Tukey's test revealed a statistically significant difference ($P < 0.001$) in mean FR value between both the MTA HP + MTA HP group and the Biodentine + Biodentine group compared to the control group. Furthermore, a statistically significant difference in mean FR value was found between the MTA HP + MTA HP group and the Biodentine + GP and sealer group ($P < 0.001$); between the MTA HP + MTA HP group and the MTA HP + GP and sealer group ($P < 0.001$); and between the Biodentine + GP and sealer group and Biodentine + Biodentine group ($P < 0.006$) [Table 2].

## DISCUSSION

Root perforations either pathologic or iatrogenic, negatively impact the prognosis of root canal procedures.[2,9] Studies evaluating iatrogenic root perforation models have demonstrated that the type of repair material influences the stress distribution.[10] The current study aimed to evaluate and compare the FR after repairing root perforation defects with Biodentine and MTA HP, followed by backfilling using either Biodentine, MTA Repair HP, or GP with AH Plus sealer. An increased resistance to fracture after perforation repair is clinically important because cracks and fractures initiate from the high-stress areas. In this study, pathologic or iatrogenic resorption defects were simulated in the middle third of the root. Previous studies have indicated that strip and post-drill perforations are associated with maximum stress compared to furcal perforations.[10]

The type and technique of perforation repair employed in this study significantly affected the FR of the tooth. Among the test groups, the highest mean FR value was in the MTA HP + MTA HP group, followed by Biodentine + Biodentine group, then MTA HP + GP and sealer group, and least by Biodentine + GP and sealer group. The roots backfilled with bioceramic cement showed significantly higher FR compared to those that were backfilled with GP and sealer. Both MTA HP and Biodentine promote biomineralization.[15] The improved handling properties and marginal adaptation of MTA HP could be attributed to the low particle size and lower film thickness.[17] Furthermore, MTA HP has high plasticity and improved physical properties, as compared with White MTA.[17]

In this study, perforation defects repaired and backfilled with MTA HP demonstrated the highest FR compared to those repaired and backfilled with Biodentine; however, there was no statistically significant difference between these two groups. This observation might be because the elastic modulus of MTA HP is closer to that of dentine. Eram *et al*. reported that MTA exhibited higher FR compared to Biodentine and Bioaggregate when used as an apical plug in immature teeth.[19] In our study, perforation defects repaired and backfilled with Biodentine also showed higher FR, although it was less than that of the MTA Repair HP group. This indicates that materials with a higher MOE than dentin will lead to increased stress accumulation, thereby reducing FR. Both MTA and Biodentine have a MOE close to dentin and function as a dentin structure, allowing them to share stress effectively.[19]

The ability of Biodentine to form a chemical bond through the development of a hydroxyapatite-like layer enhances FR by

**Table 1: Fracture resistance mean±standard deviation of control and test groups**

| Groups | *n* | FR (Newton), mean±SD | Minimum | Maximum | ANOVA | |
|---|---|---|---|---|---|---|
| | | | | | *F*-statistic | *P* |
| Control group | 10 | 111.33±23.44 | 70.32 | 141.32 | 18.335 | <0.001* |
| Biodentine + GP and sealer | 10 | 150.24±56.97 | 90.13 | 274.60 | | |
| Biodentine + Biodentine | 10 | 262.75±72.95 | 153.87 | 357.27 | | |
| MTA HP + GP and sealer | 10 | 195.98±61.09 | 108.56 | 285.58 | | |
| MTA HP + MTA HP | 10 | 347.61±105.45 | 145.73 | 541.15 | | |

*Statistically significant *P* value. SD: Standard deviation, FR: Fracture resistance, ANOVA: Analysis of variance, MTA HP: Mineral trioxide aggregate high plasticity, GP: Gutta-percha

**Table 2: *Post hoc* pairwise comparison of the mean difference in fracture resistance among the test groups**

| Pairs | | Mean difference | *P* |
|---|---|---|---|
| Biodentine + GP and sealer | Biodentine + Biodentine | 112.50 | 0.006* |
| Biodentine + GP and sealer | MTA HP + GP/sealer | 45.74 | 0.582 (NS) |
| Biodentine + GP and sealer | MTA HP + MTA HP | 197.36 | <0.001* |
| Biodentine + Biodentine | MTA HP + GP/sealer | 66.77 | 0.215 |
| Biodentine + Biodentine | MTA HP + MTA HP | 84.86 | 0.063 |
| MTA HP + GP and sealer | MTA HP + MTA HP | 151.63 | *P*<0.001* |

*Statistically significant *P* value. MTA HP: Mineral trioxide aggregate high plasticity, GP: Gutta-percha, NS: Nonsignificant

creating a mineral infiltration zone with the dentin.[20,25] The lower overall FR of Biodentine compared to MTA HP could be due to the difference in MOE between Biodentine and dentin.[26] Bioceramic cement with a MOE similar to that of dentin create a monoblock structure, facilitating uniform stress distribution.[10] The low FR of teeth backfilled with GP and sealer can be attributed to the low cohesive strength of GP and a very low MOE, making them too plastic, which fails to effectively reinforce the roots of endodontically treated teeth.[20]

These findings highlight the importance of selecting appropriate materials, and techniques for the management of root perforations in clinical practice. The MOE of the material must match that of dentin to reinforce the tooth structure. However, it's important to acknowledge that other factors such as contamination with oral fluids, remaining dentin thickness, pre-existing cracks, angular load, irrigants, intracanal medicaments, chelating agents, type of coronal restoration, and placement techniques can also affect the final FR of calcium silicate cement and various backfilling materials.

## CONCLUSION

The results of this study demonstrate the substantial impact of root perforation repair materials and techniques on the FR of teeth with perforation defects. The findings indicate that both MTA HP and Biodentine effectively enhance the structural integrity of endodontically treated teeth, with MTA HP exhibiting superior performance in terms of FR.


### Financial support and sponsorship

Nil.

### Conflicts of interest

There are no conflicts of interest.


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