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Spectrophotometric Analysis of MTA Repair HP and Biodentine in Furcation Perforation Repairs of Different Diameters: An In Vitro Study

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Abstract

Aim: The aim of the study was to evaluate the sealing ability of MTA Repair HP (mineral trioxide aggregate, high plasticity; Angelus, Londrina, PR, Brazil) and Biodentine (Septodont, Saint-Maur-des-Fossés, France) in furcal perforations of different diameters using ultraviolet spectrophotometric analysis.

Materials and methods: Seventy extracted human permanent molars with intact furcation areas were selected. Standardized furcal perforations of 1.4 mm and 1.6 mm were created, and the specimens were randomly divided into control and experimental groups (n = 10 each). Positive control groups (P1 and P2) were left unrepaired, while the negative control group had no perforation. Experimental groups included MTA Repair HP (M1: 1.4 mm; M2: 1.6 mm) and Biodentine (B1: 1.4 mm; B2: 1.6 mm), with a collagen matrix placed at the perforation site. After 24 hours of setting, dye penetration was performed using 2% methylene blue, and microleakage was assessed using ultraviolet spectrophotometric analysis. Statistical analysis was carried out using one-way analysis of variance (ANOVA) followed by Tukey's post hoc test ($p < 0.05$).

Results: The positive control group with the larger perforation size (P2) showed the highest dye absorbance, indicating maximum microleakage, whereas the negative control group exhibited the least leakage. Among the experimental groups, B1 demonstrated the lowest microleakage, while M2 showed the highest values. Significant differences were observed among groups ($p < 0.005$). No statistically significant differences were found among B1, M1, and the negative control group, while significant differences were observed between B1 and M2 and between M1 and M2.

Conclusion: Both materials exhibited effective sealing ability; however, Biodentine demonstrated superior performance, particularly in smaller perforations.

Categories: Dentistry
Keywords: biodentine, furcal perforation, microleakage, mta repair hp, ultraviolet spectrophotometric analysis

Introduction

Endodontic perforation is a significant contributor to treatment failure, accounting for approximately 10% of all unsuccessful endodontic cases [1]. It is described as an abnormal communication, either pathological or iatrogenic, between the root canals and adjacent periradicular tissues, leading to inflammation, microbial invasion, and osseous resorption in association with epithelial cell proliferation [2]. Perforations may arise due to extensive caries or root resorption and can also be induced during dental procedures, including post space preparation, or inadvertently during endodontic therapy. Reports indicate that accidental perforations constitute up to 29% of all endodontic mishaps, with nearly 87% affecting the pulp chamber of molar teeth [3]. Furcal perforations generally exhibit a worse prognosis than perforations in different regions, often leading to furcal bone loss and presenting significant therapeutic challenges because of the complex anatomy and topography of the area [4,5].

Numerous materials have been utilized for furcal perforation repair, including calcium hydroxide, reinforced zinc oxide eugenol, glass ionomer cement (GIC), BioAggregate, composite resin, Biodentine, mineral trioxide aggregate (MTA), platelet-rich plasma, platelet-rich fibrin, and various other biomaterials [6]. The success of perforation repair is determined by numerous factors, such as lesion size, location, and the sealing potential of the material used for repair [7,8]. Perforations establish abnormal pathways that allow contamination of the periodontal tissues; thus, it can be inferred that the severity of damage tends to increase with larger perforation sizes. In such cases, the quality of the seal provided by the repair material becomes a crucial determinant of the treatment outcome [9].

MTA is a leading bioceramic material and is considered the gold standard for biologically based pulp therapies and advanced endodontic procedures [10]. To overcome certain drawbacks of mineral trioxide aggregate, including its long setting time, challenging handling properties, and comparatively high cost,

several bioceramic materials have been developed as alternative repair materials [11]. To address these limitations, MTA Repair HP (high plasticity; Angelus, Londrina, Brazil) was introduced as a modified formulation containing calcium tungstate as a radiopacifier and polyvinylpyrrolidone to optimize handling properties [12].

Biodentine (Septodont, Saint-Maur-des-Fossés, France) was developed to mimic the mechanical properties of dentin. Its clinical versatility extends to permanent dentin replacement, vital pulp therapy, and the management of root perforations or resorptive defects. Additionally, it is utilized in endodontic procedures such as apexification and retrograde root-end fillings. Beyond its structural properties, Biodentine's bioactivity stimulates the secretion of reparative dentin, thereby accelerating the biological healing of periradicular and pulpal tissues. Additionally, Biodentine exhibits excellent biocompatibility and favorable effects on living cells. It has gained considerable importance in endodontics, particularly due to its superior sealing ability, which is attributed to its high alkaline pH that promotes mineralization at the material-tissue interface [11].

The present study aimed to evaluate and compare the sealing efficacy of MTA Repair HP and Biodentine in furcal perforations of varying diameters using ultraviolet spectrophotometric analysis.

Materials And Methods

The study was conducted after approval from the K.D. Dental College Ethics Committee under reference number KDDC/KDDCEC/141/2026. Seventy extracted human permanent molars with intact furcation regions and fully developed roots were included. Teeth exhibiting internal or external resorption were excluded. All specimens were stored in distilled water until further use. The crowns were decoronated 3 mm above the cementoenamel junction (CEJ), and standardized endodontic access cavities were prepared. The canal orifices were covered with sticky wax, and all external tooth surfaces were overlaid with two layers of nail varnish to prevent dye penetration. The specimens were then embedded in polyvinylsiloxane impression material. The perforation site was standardized by marking the furcation area with a black marker. Furcal perforations measuring 1.4 mm and 1.6 mm in diameter were created from the external surface using round burs BR-41 (ISO size 014) and BR-40 (ISO size 016), respectively (MANI, Inc., Japan), using a high-speed handpiece under continuous air-water spray. The 1.4-mm perforations were created using BR-41 (Figure *1*), whereas the 1.6-mm perforations were created using BR-40 (Figure *2*). The perforation sites and pulp chambers were then rinsed with water and dried.

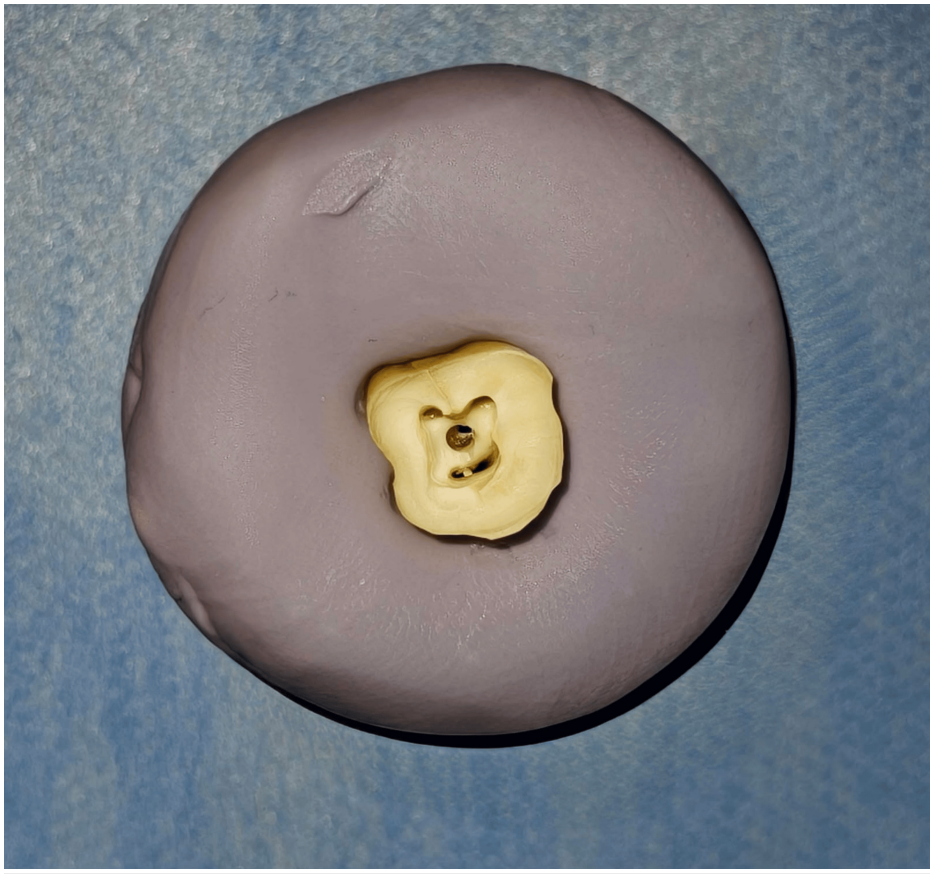


FIGURE 1: Simulated furcal perforation of 1.4 mm diameter created using a BR-41 round bur (ISO size 014).

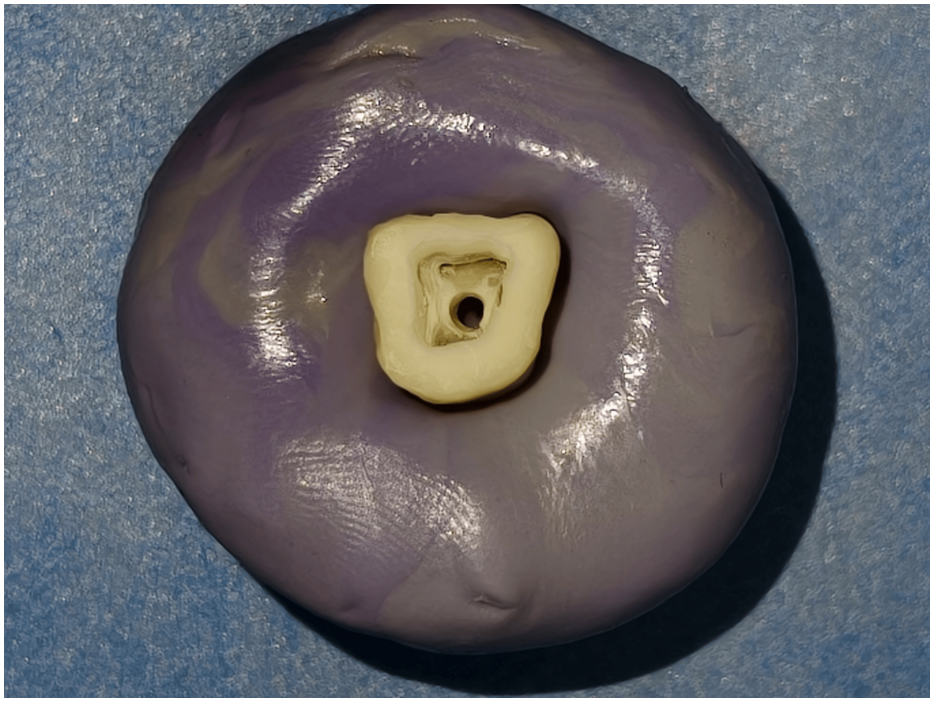


FIGURE 2: Simulated furcal perforation of 1.6 mm diameter created using a BR-40 round bur (ISO size 016).

The specimens were randomly allocated into seven groups (n = 10 per group), comprising three control groups and four experimental groups. The positive control specimens were divided into P1, consisting of specimens with a 1.4-mm perforation without repair, and P2, consisting of specimens with a 1.6-mm perforation without repair. The negative control group (N) consisted of specimens without perforation. In all experimental groups, an internal matrix of collagen plug (ColoGenesis Healthcare Pvt. Ltd., Salem, Tamil Nadu, India) was placed at the perforation site to provide a barrier for condensation of the repair material.

The experimental specimens were allocated into four groups according to the perforation diameter and repair material. Group 1 (M1) comprised specimens with a 1.4-mm furcal perforation repaired with MTA Repair HP, whereas Group 2 (M2) comprised specimens with a 1.6-mm furcal perforation repaired with the same material. Group 3 (B1) consisted of specimens with a 1.4-mm furcal perforation repaired with Biodentine (Septodont, Saint-Maur-des-Fossés, France), while Group 4 (B2) consisted of specimens with a 1.6-mm furcal perforation repaired with Biodentine. In all experimental groups, a ColoPlug sterile collagen sponge (ColoGenesis Healthcare Pvt. Ltd., Salem, India) was placed at the perforation site as an internal matrix before placement of the respective repair material. Following repair, all specimens were allowed to set for 24 hours before further evaluation.

Dye leakage and spectrophotometric analysis

All samples were immersed in 2% methylene blue dye up to the CEJ for retrograde dye penetration, while the access cavities were filled with dye to allow orthograde penetration. The samples were stored under these conditions for 48 hours.

Following dye exposure, the specimens were cleaned under running water for 30 minutes to remove the nail varnish. To extract the penetrated methylene blue dye, each specimen was then immersed in 5 mL of 65% nitric acid for three days. The resulting solutions were centrifuged at 3500 rpm for five minutes, after which 4 mL of the supernatant from each specimen was collected and subjected to spectrophotometric analysis using a UV-VIS spectrophotometer (UV-160; Shimadzu Corporation, Kyoto, Japan) at 550 nm. The 65% nitric acid was used as the blank, and the absorbance values were recorded as a quantitative measure of methylene blue dye penetration and microleakage.

Statistical analysis

Statistical analysis was carried out to evaluate intergroup differences and their statistical significance. The obtained data were statistically analyzed using one-way analysis of variance (ANOVA). Subsequently, Tukey's post hoc multiple comparison test was performed. A p-value of less than 0.05 was considered statistically significant. Statistical analysis was carried out using IBM SPSS Statistics for Windows, Version 17 (Released 2008; IBM Corp., Armonk, New York).

Results

The mean absorbance values of both control and experimental groups are presented in Table *1*. Among all groups, the positive control group with the larger perforation size (P2) exhibited the highest dye absorbance, indicating maximum microleakage, whereas the negative control group (N) showed the lowest absorbance values. Within the experimental groups, B1 demonstrated the lowest dye absorbance, while M2 exhibited the highest absorbance values. One-way ANOVA revealed a statistically significant overall difference in mean spectrophotometric dye absorbance among the seven groups ($F = 195.023$, $P < 0.001$), as shown in Table *2*. Tukey's post hoc analysis demonstrated no statistically significant difference among the B1, M1, and negative control groups, as shown in Table *3*. Similarly, no significant difference was observed between the B1 and M1 groups. However, statistically significant differences were noted between B1 and M2, as well as between M1 and M2.

Groups	N	Mean	SD	Minimum	Maximum
P1	10	0.685	0.120	0.461	0.83
P2	10	0.791	0.070	0.631	0.86
N	10	0.105	0.019	0.058	0.121
B1	10	0.142	0.046	0.101	0.228
B2	10	0.226	0.034	0.203	0.32
M1	10	0.144	0.046	0.11	0.242
M2	10	0.261	0.057	0.202	0.353

TABLE 1: The mean spectrophotometric dye absorbance values of both control and experimental groups

Group	n (mean ± SD)	F	P-value	Inferences
P1	10 (0.685 ± 0.120)	195.023	<0.000	S
P2	10 (0.791 ± 0.070)			
N	10 (0.105 ± 0.019)			
B1	10 (0.142 ± 0.046)			
B2	10 (0.226 ± 0.034)			
M1	10 (0.144 ± 0.046)			
M2	10 (0.261 ± 0.057)			

TABLE 2: One-way ANOVA revealed a statistically significant overall difference in mean dye absorbance among the seven groups (F = 195.023, P < 0.001)

The F and P values represent the overall seven-group ANOVA. A P-value < 0.05 was considered statistically significant. S indicates a statistically significant difference.

Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	P-value	Inferences
Value	P1	P2	-0.106	0.008	S
		N	0.580	0.000	S
		B1	0.543	0.000	S
		B2	0.459	0.000	S
		M1	0.541	0.000	S
		M2	0.424	0.000	S
	P2	N	0.685	0.000	S
		B1	0.648	0.000	S
		B2	0.565	0.000	S
		M1	0.646	0.000	S
		M2	0.529	0.000	S
	N	B1	-0.037	0.848	NS
		B2	-0.121	0.001	S
		M1	-0.039	0.811	NS
		M2	-0.156	0.000	S
	B1	B2	-0.083	0.067	NS
		M1	-0.002	1.000	NS
		M2	-0.119	0.002	S
	B2	M1	0.081	0.080	NS
		M2	-0.035	0.874	NS
	M1	M2	-0.117	0.002	S

TABLE 3: Tukey's HSD post hoc multiple comparison analysis of mean dye absorbance among the seven study groups

The mean difference represents the difference in mean dye absorbance between the respective groups (I–J). A P-value < 0.05 was considered statistically significant. S indicates a statistically significant difference, whereas NS indicates a non-statistically significant difference

Discussion

The success and long-term prognosis of such treatment depend on multiple factors, including the location and size of the perforation, the timeliness of the intervention, and the material used. Therefore, it is essential to evaluate the properties of restorative materials, particularly their sealing ability and resistance to microleakage [13].

Perforation repair may be accomplished either through an intracoronal, nonsurgical approach or via an external surgical method, with the intracoronal technique generally being the first line of management. The fundamental objective is to obtain a reliable seal between the tooth structure and the adjacent periodontium [14]. A desirable endodontic biomaterial should provide a complete seal, thereby avoiding any connection between the root canal system and the periradicular environment [15].

Microleakage has been assessed using a variety of techniques, such as fluid filtration, dye penetration, dye extraction, bacterial leakage, and protein leakage models. Advanced techniques such as radioactive isotope tracing, artificial caries models, scanning electron microscopy, neutron activation analysis, and electrical conductivity have also been employed [16]. In this study, the dye extraction method was selected, as it has been shown to produce results comparable to the fluid filtration technique, given that both rely on quantitative assessment of fluid movement across interfaces [17].

Although dye penetration is commonly employed to evaluate the sealing potential of dental materials, it has certain limitations. It depends on sectioning the tooth, which may not always correspond to the area of maximum dye penetration. This limitation is overcome by the dye extraction technique, which enables recovery of the entire penetrated dye, providing a more accurate and reproducible assessment. Additionally, the method is relatively simple to perform and does not require sophisticated equipment. Spectrophotometry was used to quantify dye leakage in this study. Spectrophotometers are designed to provide precise color measurements by assessing the absorbance of light. UV-visible spectrophotometry measures absorbance or reflectance in the ultraviolet and visible spectral ranges, allowing accurate quantification of dye concentration based on light absorption characteristics [18,19]. The size and site of a perforation are pivotal factors in determining treatment success, with a favorable prognosis generally linked to small perforations located coronal or apical to the level of the crestal bone [2]. Perforation size was found to significantly influence microleakage in the present study, with larger perforations exhibiting greater dye leakage compared to smaller perforations. Furthermore, the negative control group showed the lowest mean absorbance, whereas the positive control groups exhibited the highest, thereby validating the reliability of the experimental model. Among the experimental groups, the highest microleakage was observed in the M2 group, followed by B2, M1, and B1. Tukey's post hoc analysis revealed no significant difference between the B1 and M1 groups.

In the present study, Biodentine demonstrated comparatively better sealing ability than MTA Repair HP; however, the difference was not statistically significant, indicating that both calcium silicate-based materials exhibited comparable sealing performance.

These findings are concordant with those reported by Aguilar et al. [20], who demonstrated that Biodentine exhibited the highest sealing ability; however, no significant difference was found between Biodentine and MTA Repair HP, indicating comparable sealing efficacy between these two materials.

The present study findings align with those of Sinkar et al., who reported that Biodentine exhibited the least microleakage among the tested materials [18]. Likewise, another study demonstrated that Biodentine showed the highest sealing ability when used as a furcation perforation repair material, as assessed using ultraviolet spectrophotometric analysis [19].

Biodentine has been shown to induce dentin-like matrix formation by human odontoblast-like cells through mineralization nodules resembling the molecular composition of natural dentin [21]. Additionally, it promotes cellular proliferation and facilitates the formation of hydroxyapatite on its surface when in contact with simulated body fluid, indicating strong bioactive potential [22,23]. Han and Okiji [24] examined the interaction of Biodentine and ProRoot MTA with root canal dentin by assessing calcium and silicon uptake in a phosphate-buffered saline environment. Their results demonstrated the formation of tag-like interfacial structures, which were composed either of the material itself or of calcium- and phosphate-rich crystalline precipitates. Both materials exhibited a time-dependent increase in the thickness of calcium- and silicon-rich interfacial layers, with Biodentine demonstrating significantly higher values than MTA at 30 and 90 days. This suggests enhanced dentinal ion uptake and superior biointeractive properties of Biodentine [18].

Das et al. [25] reported that Biodentine exhibits significantly improved sealing efficacy over other restorative materials. The authors proposed that the enhanced sealing performance may be attributed to its accelerated setting time, primarily due to calcium chloride as a setting accelerator. This rapid setting reduces the risk of contamination and material washout at the cement-tooth interface. Consequently, it facilitates improved stability and adaptation of cement crystals along the dentinal walls, thereby enhancing the overall sealing efficacy.

Conclusions

Within the limitations of this in vitro study, it can be concluded that both Biodentine and MTA Repair HP demonstrated effective sealing ability when used as furcation perforation repair materials. Although Biodentine exhibited comparatively lower microleakage values than MTA Repair HP, the difference between the two materials was not statistically significant, indicating comparable performance.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Deepika ., Ajay Nagpal, Mandeep Kaur

Acquisition, analysis, or interpretation of data: Deepika ., Ajay Nagpal, Mandeep Kaur

Drafting of the manuscript: Deepika ., Mandeep Kaur

Critical review of the manuscript for important intellectual content: Deepika ., Ajay Nagpal

Supervision: Deepika ., Ajay Nagpal

Disclosures

Human subjects: Informed consent for treatment and open access publication was obtained or waived by all participants in this study. K.D. Dental College Ethics Committee issued approval KDDC/KDDCEC/141/2026. This study involved extracted human permanent teeth obtained from routine clinical extractions for therapeutic indications. The use of extracted human teeth for this in vitro study was approved by the K.D. Dental College Ethics Committee. No animal subjects were involved in this study. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

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