Journal of Chemical Health Risks

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JCHR (2025) 15(4), 643-650 | ISSN:2251-6727

# Comparative Evaluation of Sealing Ability of Mineral Trioxide Aggregate and Biodentine Used for Root Furcation Perforation Repair – A Systematic Review"

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***(Received: 16 May 2025 Revised: 20 June 2025 Accepted: 02 July 2025)***

Biodentine, Mineral Trioxide Aggregate, Furcation Perforation, Calcium silicate cement, endodontic repair, and sealing capabilities.

**ABSTRACT:**

**Introduction**: During endodontic operations, furcation perforations are a serious complication that might jeopardize periodontal health and the affected tooth's long-term prognosis. To stop microbial leaking and encourage periodontal repair, these perforations must be properly sealed. Because of its sealing capabilities and biocompatibility, Mineral Trioxide Aggregate (MTA) has long been regarded as the gold standard for furcation healing. A more recent calcium silicate-based substance called biodentine has gained attention as a possible substitute because of its advantageous physical characteristics and bioactivity.

**Objectives**: The aim of the present systematic review is to evaluate and compare the sealing ability of Mineral Trioxide Aggregate and Biodentine when used for the repair of root furcation perforations.

**Methods**: A comprehensive electronic search was carried out across databases such as PubMed, Scopus, and Google Scholar. The included studies compared the sealing capabilities of MTA and Biodentine in the repair of furcation perforations by in vitro or ex vivo experimental investigations. Two reviewers independently carried out the data extraction and quality assessment in accordance with PRISMA criteria.

**Results**:The majority of the included research evaluated the effectiveness of sealing using spectrophotometric, fluid filtration, dye penetration, or bacterial leakage techniques. Although MTA and Biodentine both showed adequate sealing capabilities, a number of studies found that

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JCHR (2025) 15(4), 643-650 | ISSN:2251-6727

Biodentine performed better or on par with MTA in terms of marginal adaption and decreased leakage.

**Conclusions**: Root furcation holes can be successfully repaired using both mineral trioxide aggregate and biodentine. Although MTA is still often used, Biodentine seems to provide a similar sealing capacity combined with benefits like quicker setting time and better handling. To confirm these results and encourage evidence-based material selection in clinical practice, more standardized clinical and in vivo research is advised.

## Introduction

An unintentional communication between the root canal system and the exterior tooth surface at the level of the root furcation can result in a furcation perforation, a serious procedural complications in endodontic therapy.(1) If this issue is not properly treated, it may weaken the periodontal attachment system and result in tooth loss. Furcal holes must be properly sealed to stop microbial infection and encourage tissue repair. The long-term outcome of the damaged tooth is greatly influenced by the choice of restoration material. Furcal holes have been repaired using a range of materials over the years, such as amalgam, glass ionomer cement, materials based on zinc oxide eugenol, and more recently, biomaterials based on calcium silicate.Because of its exceptional biological qualities and sealing capabilities, Mineral Trioxide Aggregate (MTA) has become the industry standard.(2) However, because of its better handling qualities and quicker setting time, Biodentine, a more contemporary calcium silicate-based substance, has grown in prominence as a possible substitute for MTA.

## Clinical Implications of Furcation Perforation and Management Objectives

Endodontic blunders including over-instrumentation or improper post-space preparation frequently result in furcation perforations. They serve as a direct line of contact between the periodontium to the pulp area, opening the door for possible bacterial invasion.(3)These perforations are linked to bone resorption, inflammation, and attachment loss. If treatment is not received, the damaged tooth may need to be extracted.Creating a tight seal that stops microbiological leaking and promotes the healing of the underlying periodontal tissues is the main goal of furcation hole repair.(4)

A biocompatible material with superior sealing ability, dimensional stability, non-resorbability, and resistance to microleakage in wet environments—which are typical of the furcation area—is necessary for a successful repair. Additionally, the optimum material should encourage the cementum and periodontal ligament to regenerate. Due to their high cytotoxicity and poor sealing ability, materials like amalgam and intermediate restorative material (IRM) have been employed with little success in the past.(5)

## Mineral Trioxide Aggregate (MTA): The Benchmark Material

Since its introduction in the 1990s, MTA has been the preferred material for perforation repair because of its superior sealing capabilities and capacity to promote the creation of hard tissue.(6) MTA is bioactive, hydrophilic, and sets in the presence of moisture, making it appropriate for perforation repair. It is mostly composed of tricalcium silicate, dicalcium silicate, and bismuth oxide (as a radiopacifier).(7)

MTA's exceptional sealing capacity has been shown in numerous in vitro investigations. When it comes into contact with fluids, it creates a layer that resembles calcium hydroxide, which combines with phosphate ions to create hydroxyapatite crystals, which helps to seal the perforation site (8). Furthermore, MTA has demonstrated good biocompatibility and marginal adaptability with surrounding tissues. MTA is not without its restrictions, though.(9) Researchers are looking at alternative materials because of their lengthy setting time (about two to four hours), challenging handling properties, and possibility for discoloration (10).

## Biodentine: A Promising Alternative

A more recent calcium silicate-based substance called biodentine was created to address MTA's drawbacks. Because it shares mechanical and physical characteristics with genuine dentine, it is advertised as a "dentine substitute." Tricalcium silicate is the primary ingredient in the material, which sets in 12 minutes.(11) It also comprises calcium carbonate, zirconium oxide, and a water-based liquid that contains calcium chloride as a

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setting accelerator.

Biodentine has a quicker setting time, better handling, and a lower chance for discoloration than MTA. Additionally, it creates a tight seal at the repaired site, promotes mineralization, and exhibits great biocompatibility.(12)
When used for curing furcation perforations, laboratory tests have shown that Biodentine has sealing performance that is either equal to or better than MTA (1, 2). It is a good choice in clinical settings where time efficiency and aesthetic results are crucial because of its advantageous physical and chemical properties, such as low solubility and strong compressive strength.(13)

**Evaluating Sealing Ability of both material**

A variety of techniques, such as bacterial leakage tests, dye penetration, fluid filtration, dye extraction, and scanning electron microscopy (SEM), are commonly used to assess the sealing capacity of perforation repair materials in vitro.(14) These techniques evaluate how well a material can stop fluids or microorganisms from passing through the repaired perforation. To stop microbiological contamination, a proper seal is necessary,which is the primary cause of endodontic treatment failure.(15)

A significant amount of research examines the sealing capabilities of MTA and Biodentine for the healing of furcation perforations. Using a bacterial leakage model, it is evaluated MTA, Biodentine, and calcium-enriched mixed cement and discovered that Biodentine had the least amount of leakage.(16) Using UV spectrophotometry, compared several materials and found that Biodentine performed well.(17) Using bacterial models and fluid filtering techniques, (18)further validated these findings. Comparing Biodentine to MTA, similarly showed that Biodentine offers superior marginal sealing.A few studies have also looked into the impact of other factors such setup conditions, perforation size, and internal matrix use.(19)

The use of an interior matrix greatly enhanced sealing for both MTA and Biodentine, according to Patel et al. (20). Results have also been demonstrated to be influenced by the thickness of the repair material and the type of irrigant used. A thorough and methodical assessment of the data is required despite the increasing amount of research due to variations in study designs and contradictory findings.(21) Comparing results is made more difficult by the fact that many current research use disparate models, uneven evaluation procedures, and small sample numbers. Furthermore, there are no precise clinical guidelines to assist practitioners in selecting between Biodentine and MTA in different perforation settings.(22)

The purpose of this systematic review is to compile the available data about MTA and Biodentine's capacity to seal root furcation holes. This review aims to give dental professionals an evidence-based understanding of the relative effectiveness of these two commonly used materials by critically analyzing and synthesizing data from in vitro research.

## 1. Objectives

**Need of the review:** Establishing evidence-based guidelines to enhance clinical outcomes in endodontics requires evaluate and compare the sealing ability of Mineral Trioxide Aggregate and Biodentine when used for the repair of root furcation perforations. When linked publications yield conflicting results, a systematic review can be used for a number of reasons to address issues that the individual research are unable to address. Prior research has demonstrated the, but none of them have compared all of the methods for CH medication elimination.

The research question was the following: "'which amterial have better sealing ability mta/biodentine?"'

The PICO framework was used for the prisma flowchart.

## 2. Methods

**Protocol and Registration**
Following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) standards, this systematic review was carried out. The Open Science Framework (OSF) prospectively registered the study protocol to guarantee the methodology's reproducibility and transparency. The registration ID is: https://orcid.org/0009-0008-2007-3449

**Study Selection**

Every article that was retrieved had its titles and abstracts checked for relevancy by two separate reviewers. After that, full-text publications of possibly qualifying research were evaluated using the inclusion and exclusion criteria. Discussions or consultations with a third reviewer were used to settle any disagreements between the reviewers.

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**Information Sources and Search Strategy**

The electronic databases PubMed, Scopus, Google Scholar, and Web of Science were used to do a thorough literature search. The search yielded articles published as recently as to [15 April 2025].

The following keywords and Boolean operators were used:
**("furcation perforation" OR "root perforation") AND ("sealing ability") AND ("MTA" OR "Mineral Trioxide Aggregate") AND ("Biodentine")**

" Boolean operators (AND, OR) were used to combine relevant search terms to ensure comprehensive coverage of the literature.

Additionally, the reference lists of all included articles were manually searched to identify any other relevant studies not captured through the database search.

**Data Extraction**

A standardized data extraction form was used to record the following information from each included study:

- Author(s), year of publication
- Study design and sample size
- Type of teeth and perforation model used
- Type of repair material (MTA, Biodentine)
- Method used to assess sealing ability (e.g., dye penetration, bacterial leakage)
- Outcome measures and results

**Quality Assessment**

The quality of included in vitro and ex vivo studies was assessed using a modified checklist adapted from previously validated tools for laboratory studies. Each study was evaluated based on the following criteria:

- Standardization of perforation size and location
- Randomization and blinding
- Sample size justification
- Appropriateness of sealing ability assessment method
- Clear outcome reporting

Each criterion was rated as "Yes," "No," or "Unclear," and a risk of bias assessment was completed for all included studies.

**Inclusion Criteria:**

Published in peer-reviewed journals.
All In vitro study included (Studies that conducted on extracted permanent tooth Studies that conducted on extracted permanent tooth.)
Studies comparing MTA and BIODENTINE.
Studies for managing posterior furcation perforation repair in permanent teeth.
Studies reporting relevant clinic outcomes such as tooth survival, better sealing capacity, and root canal treatment success.

**Exclusion Criteria:**

Animal studies.
Studies with inadequate sample size or insufficient data.
Studies focusing on surgical interventions for perforation repair in permanent teeth.
Study include primary tooth.
Study that include tooth with immature apex.

**Risk of Bias Assessment and Statistical Analysis:**
The risk of bias resulting from the following five domains was evaluated using the Cochrane's risk-of-bias methodology (RoB 2.0): the randomization process, variations from intended interventions, missing outcome data, outcome assessment, and selection of the reported result. After a series of signaling questions, two authors independently rated the risk of bias in each domain. They then used the algorithm outlined in the RoB 2.0 guidelines to estimate the overall bias of each included trial. The study was deemedto have a low risk of overall bias if it was low risk in every domain. The study was deemed to have a high risk of overall bias if it had high risk in any one of the domains.

**Literature Screening and Data Extraction:**

A standardized data extraction form was used to extract data, and quality evaluation checklists were used to carry out the appraisal process (PRISMA Guidelines, 2009). These checklists included topics including study design and analysis and pointed out any potential bias-related errors. Two different reviewers completed this stage to increase the results' dependability. Disagreements among the reviewers were settled by discussion. Information from each included study was extracted as follows.

characteristics of the study (authors, year of publication,

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study design), characteristics of the participants, Details of the intervention (biodentine and MTA for perforation repair), Key discoveries and outcome measures (improved sealing ability).

### Data Synthesis

Due to heterogeneity in study designs, sealing ability evaluation techniques, and outcome reporting, a qualitative synthesis was performed rather than a meta-analysis. Comparative findings were summarized narratively, and trends were identified across studies.

### Ethics and Conflicts of Interest:

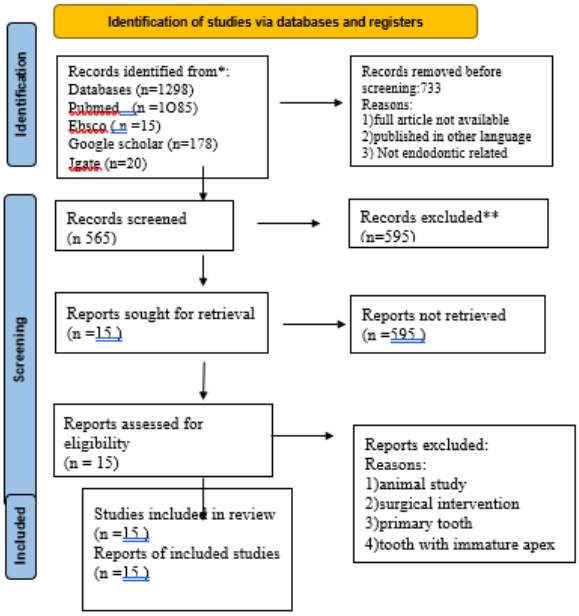
As this systematic review involved the analysis of existing literature, ethical approval was not required. All potential conflicts of interest were declared and managed in accordance with ethical guidelines.

## 3. Results

### STUDY SELECTION:

Figure 1 presents a PRISMA flowchart of the systematic review process. A total of 8 studies met the criteria for the inclusion.

### PRISMA flowchart:




### DATA EXTRACTION

| Author Name | Year | Sample Size | Methods of Assessment | Result |
|---|---|---|---|---|
| Eppala Jeevani | 2014 | 40 mandibular molars | Dye extraction leakage method | Biodentine has highest dye absorption. |
| H. Melike Bayram | 2015 | 130 human maxillary molars | Computerized fluid filtration method | No significant difference seen. |
| Maha M. Yahya | 2015 | 55 lower molars | Stereo microscope to evaluate dye penetration | Biodentine shows least leakage. |
| Roshan Chandrakant Sinkar | 2015 | 35 mandibular molars | UV spectrophotometric dye extraction method | Biodentine has least dye absorption. |
| E. Övsay | 2018 | 140 mandibular molars | *E. faecalis* leakage model | MTA has better microleakage control than Biodentine. |
| Azeez Ajas | 2018 | 35 mandibular molars | Dye leakage method | Biodentine has less microleakage. |
| Tony Francis | 2019 | 65 molars | Bacterial leakage | No significant difference. |
| Mulla, Saquib | 2019 | 36 mandibular molars | Field emission gun-SEM | Significant difference seen in Biodentine. |
| Grover, Rashu | 2020 | 20 mandibular molars | Dye penetration method | Higher microleakage in MTA. |
| Yanti Johari | 2020 | 68 mandibular molars | Dye penetration and microleakage measurement | No significant difference. |
| Abhijeet K. Kakani | 2020 | 70 extracted maxillary and mandibular molars | Protein leakage assessment | Biodentine has least leakage. |
| Dennis Mohan | 2021 | 80 human first molars | Dye penetration method | Biodentine has least dye absorption. |
| Kriti Shrestha | 2022 | 60 maxillary and mandibular molars | Dye penetration method | Least microleakage in Biodentine. |
| Maneesha Das | 2022 | 60 mandibular molars | SEM at 2000× magnification | Biodentine exhibited the finest sealing capacity. |
| Patel, Mahendra | 2023 | 60 mandibular molars | Dye penetration method | Biodentine has excellent sealing capabilities. |

### DISCUSSION

The size of the hole, the degree of microleakage, and the amount of time the material was exposed to contamination before sealing are some of the variables that can affect the repair material's capacity to seal, which is crucial to the effectiveness of furcation perforation repair. The comparative effectiveness of MTA, Biodentine, and other repair materials in various situations is assessed in this paper. (23,24)

### Size of the Defect

The effectiveness of the repair material's sealing is largely dependent on the size of the perforation. Larger flaws make adaption more difficult, and materials with superior handling qualities and less shrinkage typically work better.(25) An E. faecalis leakage model was used to assess the sealing capabilities of Biodentine, MTA, and IRM in furcal holes of varying sizes [5].

According to the results, MTA fared better in larger perforations, indicating better adaptation to larger defect sizes and superior dimensional stability.(26)

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MTA's expansion upon setting and long-term dimensional stability allow it to maintain a superior seal in wide perforations. However, because of its superior handling and quicker setting time, Biodentine was more adaptable and provided good flexibility in both tiny and moderately sized flaws (27).

**Microleakage After Repair**

Microleakage remains a significant concern in perforation repair as it may lead to bacterial ingress and eventual failure of treatment. According to most of the investigations in our review, Biodentine showed less microleakage than MTA (28). In models of dye extraction and bacterial leakage, MTA offered better sealing, particularly when evaluated over an extended period of time.This could be explained by MTA's slow crystallization and ongoing hydration over time, which improves its sealability after setting. (29) A few investigations also found no statistically significant variation in the materials. Both claimed that MTA and Biodentine functioned similarly under controlled circumstances when using computerized fluid filtration and bacterial leakage techniques. These variations demonstrate how the experimental design and evaluation procedure affect the outcomes.(30)

Furthermore, high-resolution evidence from SEM-based investigations showed that Biodentine reduces microgaps that allow leakage by producing a more consistent marginal adaptation to dentin.(31)

**Time Period of Exposure to Contamination**

Another important factor is the amount of time that passes between the perforation and sealing. A delayed repair increases the chance of leaking and compromises material bonding by allowing oral and sulcular fluids to pollute the site.(32) In clinical situations when quick repair is necessary, polymers like Biodentine, which have quicker setting times (about 12 minutes), have a benefit because early sealing greatly lowers microleakage (33).

On the other hand, MTA is more at risk for contamination during the first phase if it is not sufficiently protected due to its prolonged setup time (about 3–4 hours). further underlined that because of washout and crystalline structural disruption, delayed insertion or exposure of unset MTA results in a reduced sealing ability.(34) The review further emphasizes the therapeutic significance of prompt healing by noting that bacterial penetration starts as early as 24 hours post-perforation, necessitating prompt intervention regardless of the material used.(35)

**LIMITATIONS:**

This systematic review has several limitations that may impact the accuracy and generalizability of the results. Most of the included studies were in vitro, which is not representative of the clinical environment, particularly when it comes to elements like masticatory pressures, blood contamination, and healing responses. The wide range of techniques used to quantify microleakage, such as dye penetration, bacterial leakage, UV spectrophotometry, and SEM analysis, made direct comparison challenging. Variations in the size, position, and duration of the perforation's exposure to contamination before repair further add to the variability. Furthermore, it is challenging to draw clear conclusions about the materials' effectiveness in real-world scenarios due to the paucity of clinical trials and lack of long-term follow-up.

**CONCLUSION:**

Within the limitations of this systematic review, it can be said that both Biodentine and Mineral Trioxide Aggregate (MTA) have good sealing properties for repairing root furcation perforations. Several studies have demonstrated that Biodentine performs on par with or better than MTA in terms of marginal adaptation and decreased microleakage. The sealing results are strongly influenced by the defect size, the length of time exposed to contamination, and the microleakage measurement technique. Biodentine is a possible substitute for MTA since it provides additional clinical benefits such better handling qualities and a faster setup time. To confirm these in vitro results and create conclusive clinical protocols, more extensive long-term clinical research is required.

**ABBREVIATIONS :**

- **MTA** – Mineral Trioxide Aggregate
- **PRISMA** – Preferred Reporting Items for Systematic Reviews and Meta-Analyses
- **RoB 2.0** – Cochrane Risk of Bias 2.0 Tool
- **SEM** – Scanning Electron Microscope
- **FEG-SEM** – Field Emission Gun-Scanning Electron Microscope
- **UV** – Ultraviolet
- **GIC** – Glass Ionomer Cement
- **OSF** – Open Science Framework
- **CFU** – Colony Forming Units (used in bacterial leakage studies)

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JCHR (2025) 15(4), 643-650 | ISSN:2251-6727

**REFERENCES:**


1. Azim AA, Lloyd A, Huang GT. Management of longstanding furcation perforation using a novel approach. J Endod. 2014 Aug;40(8):1255-9. doi: 10.1016/j.joen.2013.12.013. Epub 2014 Jan 17. PMID: 25069944.
2. Das M, Al Malwi AA, Mohapatra A, et al. In Vitro Assessment of Sealing Ability of Various Materials Used for Repair of Furcal Perforation: A SEM Study. J Contemp Dent Pract 2022;23(11): 1136–1139.
3. Fuss Z, Trope M. Root perforations:Classification and treatment choices based on prognostic factors. Endod Dent Traumatol 1996;12:255–64.
4. Koulaouzidou EA, Papazisis KT, Economides NA, Beltes P, Kortsaris AH. Antiproliferative effect of mineral trioxide aggregate, zinc oxide-eugenol cement and glass-ionomer cement against three fibroblastic cell lines. J Endod 2005;31:44–6.
5. Arens DE, Torabinejad M. Repair of furcal perforations with mineral trioxide aggregate:two case reports. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1996;82:84–8 doi:10.1016/s1079-2104(96)80382-9. PMID:8843459.
6. Ford TR, Torabinejad M, McKendry DJ, Hong CU, Kariyawasam SP. Use of mineral trioxide aggregate for repair of furcal perforations. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 1995;79:756–63.
7. Sarkar NK, Caicedo R, Ritwik P, Moiseyeva R, Kawashima I. Physicochemical basis of the biological properties of mineral trioxide aggregate. J Endod 2005;31:97–100
8. Evaluation of Sealing Ability of MTA Flow, Biodentine and Pro-Root MTA to Seal the Furcal Perforation with and without Internal Matrix- An *In vitro* Study Patel, Mahendra1 ; Patel, Hardik2 ; Kesharani, Pooja3 ; Jani, Karna4 ; Shah, Khyati5 ; Kapadia, Utsavi6 Journal of Pharmacy and Bioallied Sciences 15(Suppl 2):p S1192-S1194, July 2023. | DOI: 10.4103/jpbs.jpbs_165_23 Comparison of the Sealing Ability of MTA-Angelus, Biodentine and CEM
9. Cement in the Repair of Large Furcal Perforations-A Bacterial Leakage Study Journal of Clinical and Diagnostic Research January 2019 DOI: 10.7860/JCDR/2019/38476.12503
10. Ajas A, Anulekh B, Nasil S, Thaha KA, Mary VJ. Comparative Evaluation of Sealing Ability of Biodentine and White MTA-Angelus as Furcation Repair Materials: A Dye Extraction Study. Int J Oral Care Res 2018;6(1):54-57.
11. Camilleri J, Sorrentino F, Damidot D. Investigation of the hydration and bioactivity of radiopacified tricalcium silicate cement, Biodentine and MTA Angelus. Dent Mater 2013 May;29(5):580-593.
12. Ramazani N, Sadeghi P. Bacterial Leakage of Mineral Trioxide Aggregate, Calcium-Enriched Mixture and Biodentine as Furcation Perforation Repair Materials in Primary Molars. Iran Endod J. 2016 Summer;11(3):214-8. doi: 10.7508/iej.2016.03.013. Epub 2016 May 1. PMID: 27471534; PMCID: PMC4947847.
13. 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 Nov-Dec;18(6):445-8. doi: 10.4103/0972-0707.168803. PMID: 26752836; PMCID: PMC4693315.
14. Jeevani E, Jayaprakash T, Bolla N, Vemuri S, Sunil CR, Kalluru RS. "Evaluation of sealing ability of MM-MTA, Endosequence, and biodentine as furcation repair materials: UV spectrophotometric analysis". J Conserv Dent. 2014 Jul;17(4):340-3. doi: 10.4103/0972-0707.136449. PMID: 25125846; PMCID: PMC4127692.
15. Kakani AK, Veeramachaneni C. Sealing ability of three different root repair materials for furcation perforation repair: An *in vitro* study. J Conserv Dent. 2020 Jan-Feb;23(1):62-65. doi: 10.4103/JCD.JCD_371_19. Epub 2020 Oct 10. PMID: 33223644; PMCID: PMC7657416.
16. Övsay E, Kaptan RF, Şahin F. The Repair of Furcal Perforations in Different Diameters with Biodentine, MTA, and IRM Repair Materials: A Laboratory Study Using an *E. Faecalis* Leakage Model. Biomed Res Int. 2018 Jan 15;2018:5478796. doi: 10.1155/2018/5478796. PMID: 29568756; PMCID: PMC5820666.
17. Koç C, Aslan B, Ulusoy Z, Oruçoğlu H. Sealing ability of three different materials to repair furcation perforations using computerized fluid filtration method. J Dent Res Dent Clin Dent Prospects. 2021 Summer;15(3):183-187. doi: 10.34172/joddd.2021.031. Epub 2021 Aug 25. PMID: 34712409; PMCID: PMC8538151.
18. Sealing Ability of Injectable Dental Composites, Biodentine and MTA in Repairing Furcal Perforation of Permanent Molar Teeth Johari, Yanti ; Pungut, Nur Aini ; Yin, Valerie Wong Xiu ; Khamis, Mohd Fadhli ; Md Yusoff, Mohd

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JCHR (2025) 15(4), 643-650 | ISSN:2251-6727

Nazrulhuzaimi . Journal of International Dental and Medical Research

19. Salehimehr G, Nobahar S, Hosseini-Zijoud SM, Yari S. Comparison of physical & chemical properties of Angelus MTA and new endodontic restorative material. J App Pharm Sci 2014 Jul;4(7):105-109.
20. comparative evaluation of sealing ability of three perforation repair materials using a field emission gun scanning electron microscope Mulla, Saquib; Kamat, Sharad; Hugar,Santosh; Nanjannawar, Girish; Kulkarni, NishitaJuly 13, 2019 Saudi Endodontic Journal 10(2):p 95-99, May–Aug 2020. | DOI: 10.4103/sej.sej_55_19
21. Fuss Z, Trope M. Root perforations:Classification and treatment choices based on prognostic factors. Endod Dent Traumatol 1996;12:255–64.
22. Valois CRA, Costa ED Jr. Influence of the thickness of mineral trioxide aggregate on sealing ability of root-end fillings *in vitro*. Oral Surg Oral Med Oral Pathol Oral Radiol Endod2004;97:108–11.
23. Han L, Okiji T. Uptake of calcium and silicon released from calcium silicate based endodontic materials into root canal dentine. Int Endod J 2011 Dec;44(12):1081-1087.
24. Butt N, Talwar S, Chaudhry S, Nawal RR, Yadav S, Bali A. Comparison of physical andmechanical properties of mineral trioxide aggregate and Biodentine. Indian J Dent Res 2014 Nov-Dec;25(6):692-697.
25. Sealing ability of Biodentine as a root Perforation Treatment Material (An in Vitro Study) Maha M. Yahya. BDS, M.Sc (Lecturer) (1) Tikrit Journal for Dental Sciences 1(2015) https://doi.org/10.25130/tjds.2015.1.8
26. Seda Aydemir, Hale Cimilli, Parla Meva Gerni, Alperen Bozkurt, Hasan Orucoglu, Nicholas Chandler, Nevin Kartal. Comparison of the Sealing Ability of Biodentine, iRoot BP Plus and Mineral Trioxide Aggregates. Cumhuriyet Dent J 2016;19(2): 166 171.
27. Castellucci A. The use of mineral trioxide aggregate in clinical and surgical endodontics. Dent Today. 2003 Mar;22(3):74-81. PMID: 12705015.
28. Alhadainy HA, Abdalla AI. Artificial floor technique used for the repair of furcation perforations:A microleakage study. J Endod 1998;24:33–5.
29. Sealing ability of mineral trioxide aggregate, Biodentine, and EndoSequence RRM putty used as retrograde restorative material An *in vitro* bacterial leakage model study Antony, Jesmy K.; George, Liza1 ; Mathew, Josey1 ; Joy, Aleesha January 17, 2022 Endodontology 34(1):p 16-21, Jan–Mar 2022. | DOI: 10.4103/endo.endo_176_21
30. da Silva EJ, Andrade CV, Tay LY, Herrera DR. Furcal-perforation repair with mineral trioxide aggregate: Two years follow-up. Indian J Dent Res. 2012 Jul-Aug;23(4):542-5. doi: 10.4103/0970-9290.104967. PMID: 23257493.
31. Nazari Moghadam K, Aghili H, Rashed Mohassel A, Zahedpasha S, Moghadamnia AA. A comparative study on sealing ability of mineral trioxide aggregate, calcium enriched cement and bone cement in furcal perforations. Minerva Stomatol. 2014 Jun;63(6):203-10. PMID: 25267149.
32. 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 Jan;28(1):63-67. doi: 10.4103/JCDE.JCDE_711_24. Epub 2025 Jan 13. PMID: 39974673; PMCID: PMC11835356.
33. De-Deus G, Reis C, Brandão C, Fidel S, Fidel RA. The ability of Portland cement, MTA, and MTA Bio to prevent through-and-through fluid movement in repaired furcal perforations. J Endod. 2007 Nov;33(11):1374-7. doi: 10.1016/j.joen.2007.07.024. Epub 2007 Sep 10. PMID: 17963967.
34. Silva LAB, Pieroni KAMG, Nelson-Filho P, Silva RAB, Hernandéz-Gatón P, Lucisano MP, Paula-Silva FWG, de Queiroz AM. Furcation Perforation: Periradicular Tissue Response to Biodentine as a Repair Material by Histopathologic and Indirect Immunofluorescence Analyses. J Endod. 2017 Jul;43(7):1137-1142. doi: 10.1016/j.joen.2017.02.001. Epub 2017 May 2. PMID: 28476469.
35. Adl A, Sadat Shojaee N, Pourhatami N. Evaluation of the Dislodgement Resistance of a New Pozzolan-Based Cement (EndoSeal MTA) Compared to ProRoot MTA and Biodentine in the Presence and Absence of Blood. Scanning. 2019 May 9;2019:3863069. doi: 10.1155/2019/3863069. PMID: 31210836; PMCID: PMC6532292.