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Comparative Evaluation of the Sealing Ability of Three Furcal Perforation Repair Materials in Primary Molars

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ABSTRACT
Purpose: This in vitro study evaluates the sealing ability of three repair materials—Glass Ionomer Cement (GIC), Nano-Hybrid Mineral Trioxide Aggregate (NHMTA), and Biodentine (BD)—used for furcal perforations in primary molars.
Objective: Furcal perforation is a critical challenge in pediatric dentistry, often leading to complications if not managed promptly.
Materials and Methods: Thirty human-extracted mandibular primary molars were divided into three groups based on the repair material used. Furcation perforations were created on the pulp chamber floors of the teeth. The perforations were repaired using biocompatible materials. After 72 hours, the teeth were submerged in a 2% basic fuchsine dye solution for 24 hours. They were subsequently sectioned longitudinally and assessed for dye penetration. Sealing ability was assessed using dye penetration and Scanning Electron Microscopy (SEM). The data were statistically analyzed using the ANOVA test.
Results: There was a statistically significant difference between the microleakage of NHMTA (162.76μm), BD (155.31μm), and GIC (236.18μm) groups ($P>0.008$).
Conclusion: BD exhibited the least micro-leakage and gap distance, followed by NHMTA, while GIC demonstrated the highest leakage. The findings highlight BD as a promising material for furcal perforation repair due to its superior sealing properties.

Keywords: micro-leakage, pediatric, properties, primary

INTRODUCTION

Furcal perforations are a significant complication in endodontic treatments, particularly in pediatric dentistry. These perforations, which create a pathological or iatrogenic communication between the pulp chamber and the surrounding periodontal tissues, pose a considerable challenge to the prognosis of the affected tooth(1). If not repaired promptly and effectively, these perforations may lead to bacterial contamination, inflammation, and ultimately, the loss of the tooth. Preserving primary molars is essential for maintaining proper function, aesthetics, and guiding the eruption of permanent successors(1,2).

The success of furcal perforation management largely depends on the selection of an appropriate repair material.An ideal material should provide a tight seal, resist microleakage, promote biocompatibility, and be easy to handle under clinical conditions(3). Over the years, various materials have been developed, including Glass Ionomer Cement (GIC), Mineral Trioxide Aggregate (MTA) and its modifications, such as Nano-Hybrid MTA (NHMTA), and newer calcium-silicate-based materials like Biodentine. Each material has unique properties that influence its sealing ability and clinical performance(4).

GIC, known for its fluoride release and chemical bonding to dentin, has limitations in terms of mechanical strength and moisture resistance, which may compromise its sealing ability(5). MTA considered the gold standard for many years, has excellent biocompatibility and sealing properties but faces challenges such as extended setting time and handling difficulties(6,7). Biodentine, a more recent material, has garnered attention for its bioactivity, fast setting time, and superior marginal adaptation, making it a strong contender for furcal perforation repair(8,9).

Despite the extensive use of these materials, there is a lack of evidence comparing their effectiveness in sealing furcal perforations specifically in primary molars. Most existing studies focus on permanent teeth or provide limited comparisons among these materials(9, 10). This study aims to address this gap by evaluating and comparing the sealing ability of GIC, NHMTA, and Biodentine in repairing furcal perforations in primary molars. Using dye penetration tests and Scanning Electron Microscopy (SEM), the study seeks to identify the most effective material for this critical clinical application, thereby providing evidence-based recommendations for pediatric dental care.

MATERIALS AND METHODS

Materials

- Glass Ionomer Cement (GIC) (Riva, SDI, limited, aAustralia)
- Nano-Hybrid Mineral Trioxide Aggregate (NHMTA)(International Biotecthnology Co., USA)
- Biodentine (Septodont, USA)

Methods

Thirty extracted human mandibular primary molars were used in this study. Teeth with Non-fused, well developed roots, Intact pulpal floor with no cracks or extensive decay andnormal furcation area were selected[10]. Each selected tooth was disinfected by immersion in 5% sodium hypochlorite (NaOCl) for 30 minutes to ensure sterilization. The teeth were then stored in saline to prevent dehydration[11]. Standard access cavities were created in all teeth using a #14 diamond round bur (Mani Co., Japan) mounted on a high-speed hand-piece with water spray. In all groups, The molars were decoronated 3mm above cemento-enamel junction, and the roots were amputated 3mm below the furcation area (Figure1.a) using tapered diamond stone mounted on a headpiece (Coxo, china)for ease of manipulation[12]. The root canal orifices and apical ends were then sealed with a light-cured flowable resin composite (Any com flowable composite,Korea) (Figure1.b).

Standardized furcal perforations were created using a #10 diamond round bur (Mani co., Japan) in a high-speed hand-piece under water cooling. The perforations were made at the center of the pulp chamber floor, aiming to create a consistent size and shape across all samples. The bur was replaced after every five perforations.The perforations were kept small (approximately 2mm in diameter) to simulate clinically relevant conditions and to avoid excessive damage to the surrounding tooth structure (Figure1.c).But the length of the perforation depended on the dentine- cementum thickness from pulp chamber to the furcation area[11].

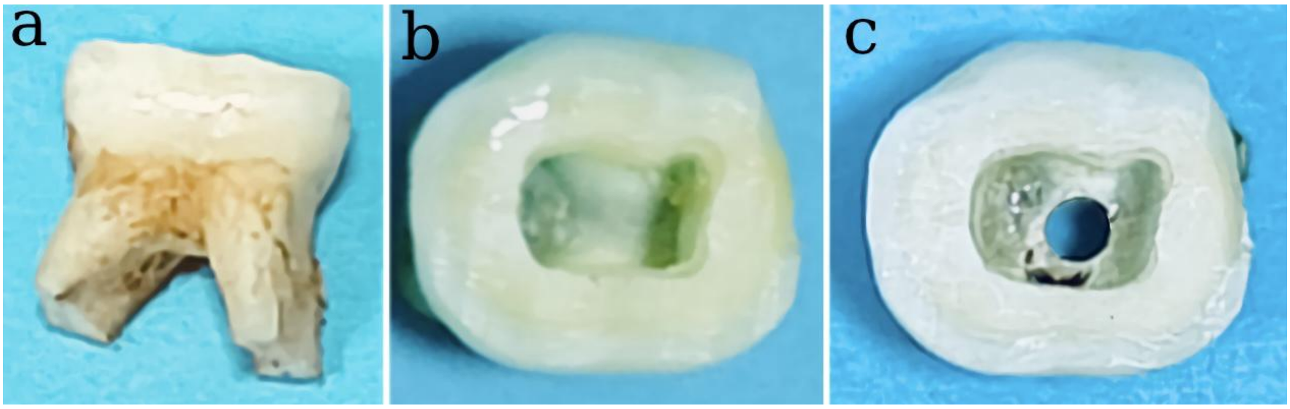


Figure 1:(a)A tooth afterdecoronation3mm above cemento-enamel junctionand amputation 3mm below the furcation area, **(b)**Orifices after sealing with a light-cured flowable composite, and **(d)** A 2mm-in diameter perforation.

The teeth were randomly divided into three groups (n=10 per group), based on the material used for furcal perforation repair:

1. Group I (Glass Ionomer Cement - GIC)
2. Group II (Nano-Hybrid Mineral Trioxide Aggregate - NHMTA)
3. Group III (Biodentine)

Furcation perforation sites in group I were sealed with GIC(Riva, SDI, limited, aAustralia), which was mixed according to the manufacturer’s instructions. GIC was lightly condensed using a 1.5- mm-diameter amalgam condenser and adapted with a moistened cotton pellet to ensure good contact with the dentinal walls, minimizing air gaps and enhancing sealing efficiency. For groupII,NHMTA (International Biotecthnology Co., USA) was mixed with sterile water in a 3:1 powder-to-liquid ratio for 30-60 s, creating a putty-like consistency. This was done on a glass slab, ensuring a smooth, homogenous paste.The material was transferred into the perforation site using an amalgam carrier and slightly condensed with a condenser to ensure complete adaptation to the dentinal walls. This process minimized voids and enhanced material-to-dentin contact. In groupIII Biodentine (Septodont, USA) was mixed using a triturator for 30 seconds, following the manufacturer’s instructions. The

material was mixed into a gel-like consistency that could be easily manipulated. Biodentine was applied into the perforation using a plastic applicator, and lightly condensed to ensure intimate contact with the dentinal walls.
After application, the access cavity was sealed with Orafil-G (Prevest Direct, India). The materials were allowed to set an incubator at 37°C and 95% humidity for 72 h to simulate clinical conditions. The specimens were then stored in saline to maintain hydration and prevent desiccation(11).
Aftersetting, each tooth was coated with two layers of nail polish except ~1 mm around the perforated area so that, the dye would only penetrate through the furcation area (Figure2.a). The teeth were then immersed in 2% basic fuchsine dye (Sigma-Aldrich Co., LLC, USA) for 24 hours. Afterward, the specimens were thoroughly washed to remove excess dye(Figure2.b), and then mounted in transparent acrylic.The teeth were sectioned bucco-lingually parallel to their long axis(Figure2.c).

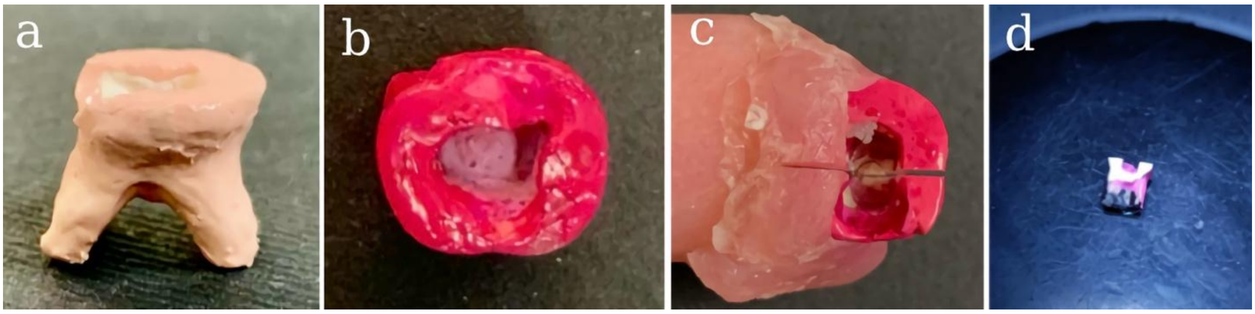
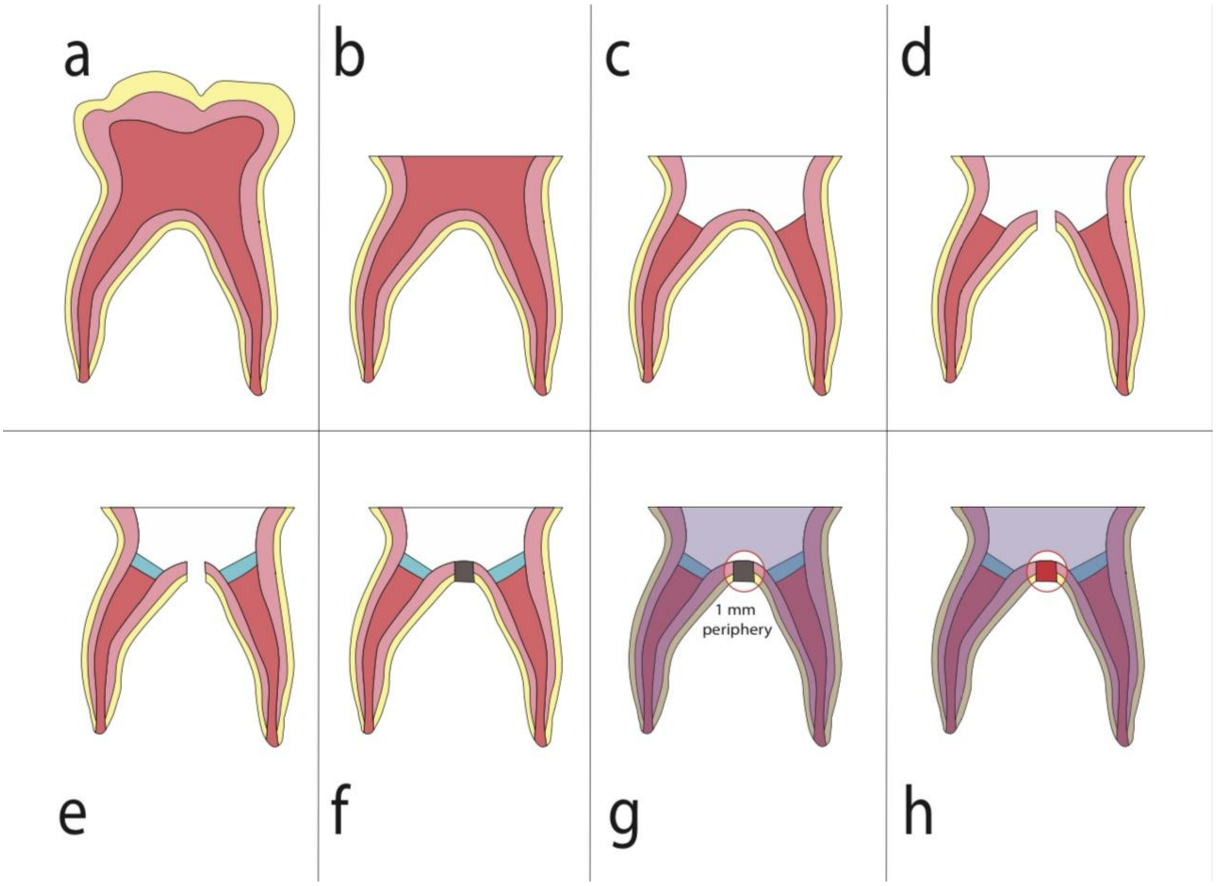


Figure2:(a)A coated tooth wit a nail polish, **(b)**A tooth after washing-up from the dye, **(c)** The tooth in the acrylic resin block after sectioning bucco-lingually, and **(d)**A tooth section under SEM.



Illustrative Diagram showing steps of methods.

Linear dye penetration(Figure3) was measured on each wall from the apical end of the perforation to the pulp chamber floor using a Scanning Electron Microscope to assess the surface adaptation and marginal sealing of the materials (Figure2.d)(Figure4).The micro-leakage and gap distance was recorded and statistically analyzed by ANOVA test(11,13).

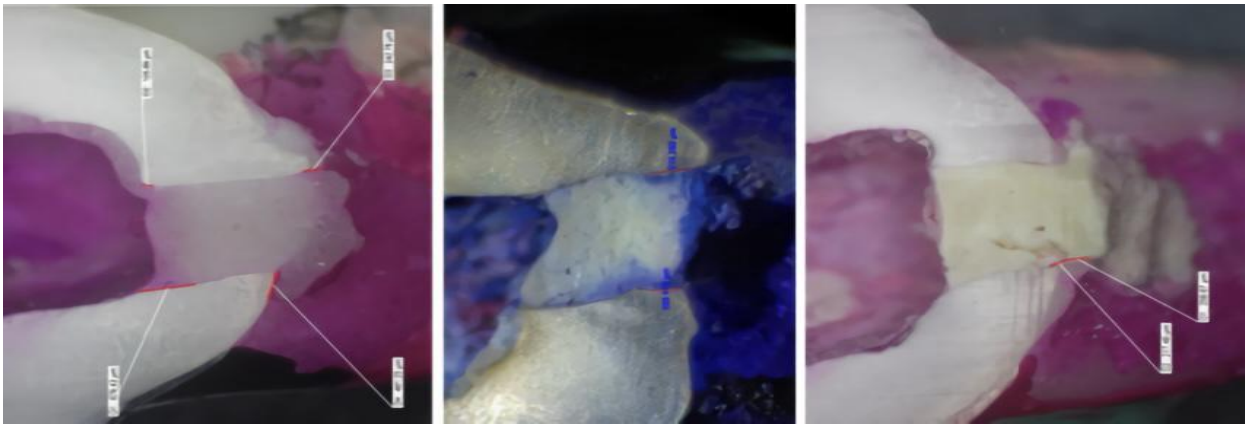


Figure 3: Linear dye penetration in GIC, Nano Hybrid MTA and Biodentinerespectively.

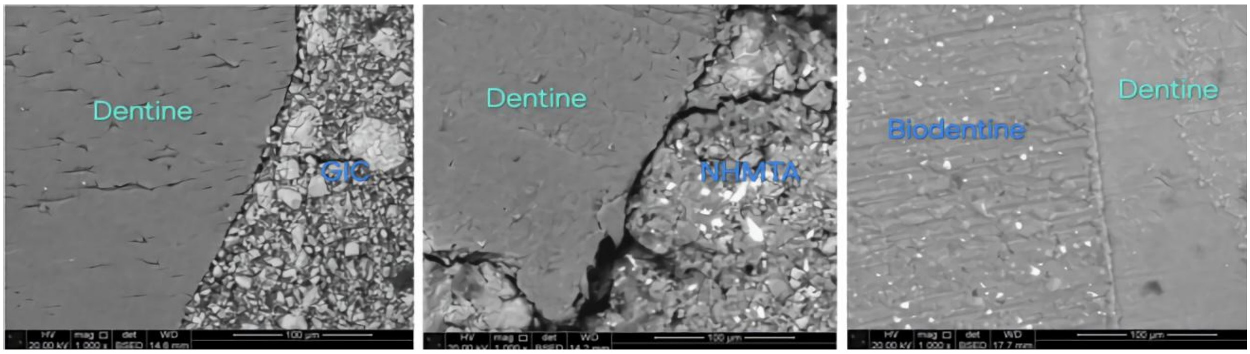


Figure 4: SEM of primary molar tooth repaired by GIC, NHMTA, and BD in its furcal perforation at magnification 1000 xrespectively.

Statistical Analysis

Data was analyzed using Medcalc software, version 22 for windows (MedCalc Software Ltd, Ostend, Belgium). Data was explored for normality using Kolmogrov Smirnov test and Shapiro Wilk test. Continuous data showed nonparametric distribution and was described as median and range and mean and standard deviation, comparison between non-parametric data was performed using the Kruskal-wallis test followed by Dunn post-hoc test. Spearman's correlation was used to correlate between micro-leakage and gap distance. A P value less than or equal to 0.05 was considered statistically significant and all tests were two tailed.

RESULTS

Quantitative and qualitative assessments of microleakage and gap distances revealed significant differences among the three materials tested for furcal perforation repair(Table1,2).Biodentine (BD) exhibited the lowestmicro-leakage, with a mean value of 53.3 µm (statistically more significant), indicating its superior sealing capability.NHMTA showed slightly higher microleakage, with a mean value of 57.15 µm.GIC, however, exhibited the highest microleakage, with a mean value of 71.05 µm (statistically less significant). The relatively higher porosity of GIC compared to the other materials could explain its inferior performance in preventing micro-leakage.

Table 1: Mean, SD, Median and range of micro-leakage for different sealing materials:

	Rank	Mean	SD	Median	Range
Biodentine	53.3	155.31	248.29	0.00^{A}	0 to 834.5
NHMTA	57.15	162.76	199.76	0.00^{A}	0 to 578.5
GIC	71.05	236.18	225.41	161.00^{B}	0 to 678.4
P value	P = 0.0379*				

Table 2: Mean, SD, Median and range of gap distance for different sealing materials:

	Rank	Mean	SD	Median	Range
Biodentine	8.11	3.13	1.55	2.04^{A}	1.35 to 6.35
NHMTA	12.10	6.38	6.54	3.89^{A}	1.79 to 23.84
GIC	22.43	17.67	7.75	15.68^{B}	9.26 to 26.68
P value	P = 0.0007*				

Biodentine demonstrated the smallest mean gap distance (8.11 µm), (statistically more significant) suggesting excellent marginal adaptation to the dentinal walls. NHMTA showed a slightly larger mean gap distance (12.10 µm) compared to Biodentine. GIC recorded the largest gap distance, with a mean value of 22.43 µm (statistically less significant), indicating its limited ability to adapt closely to the dentin. This finding aligns with its higher micro-leakage results and highlights the impact of mechanical properties on material adaptation.

A strong positive correlation (p = 0.625, p = 0.0127) was observed between micro-leakage and gap distance, indicating that smaller gaps are associated with lower micro-leakage. This highlights the importance of material adaptation in minimizing bacterial penetration (Figure3).

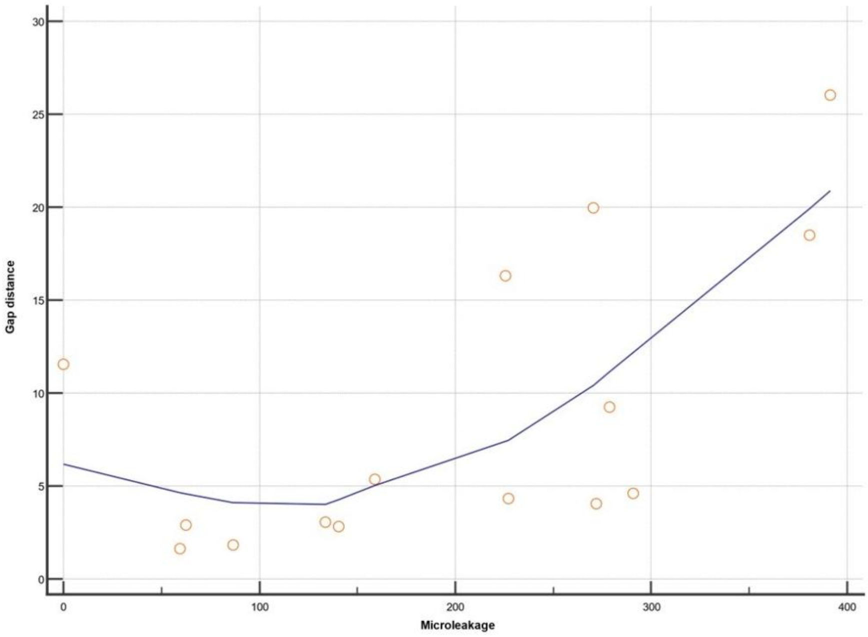


Figure 3: Scatter diagram showing correlation between gap distance and micro-leakage.

DISCUSSION

Effective sealing of furcal perforations is crucial for preventing bacterial contamination and ensuring the success of endodontic treatments(14). This study highlights Biodentine's (BD) superior sealing properties, which are likely due to its calcium-silicate-based composition and rapid setting time. Nano-Hybrid Mineral Trioxide Aggregate (NHMTA) also performed well, demonstrating comparable sealing ability to Biodentine. Conversely, Glass Ionomer Cement (GIC) showed inferior results, likely due to its higher porosity and limited biocompatibility .

Biodentine has been extensively studied for its bioactivity and sealing properties, particularly in cases requiring a strong bond between the material and dentin. Camilleri et al. (2023) and Grech et al. (2024) highlighted Biodentine's ability to promote pulp healing and tissue regeneration due to its bioactive nature, which encourages mineralization(15,16). NHMTA, another calcium-silicate-based material, is effective in sealing and promoting healing but tends to perform slightly less well in sealing ability compared to Biodentine. This finding is consistent with Badreldin et al. (2022), who compared MTA and Biodentine for furcal perforation repair and found that Biodentine demonstrated superior sealing properties (17).

The dye penetration test, employed in this study, is a widely accepted method for assessing the sealing ability of restorative materials. Our findings, with Biodentine showing the least dye penetration, support the idea that materials with higher mineral content and bioactivity may offer better performance in preventing microleakage.

NHMTA also performed well, but GIC exhibited the highest degree of microleakage. This result aligns with Youssef and Balachandran (2022), who found that MTA and ERRM materials outperformed GIC in sealing capacity ortant factor contributing to the superior performance of Biodentine over NHMTA and GIC is its fast setting time and ability to resist moisture during application[18].

Studies such as those by Mohan et al. (2018) have emphasized the impact of Biodentine's working properties, which allow it to effectively seal perforations even in moist environments. NHMTA, while a reliable material, can suffer from handling difficulties, such as the requirement for proper moisture control during placement, which could explain its slightly lower performance compared to Biodentine in this study[18].Nano-Hybrid Mineral Trioxide Aggregate (NHMTA) exhibited good sealing properties in this study, but its handling characteristics present certain challenges. NHMTA is sensitive to variations in the powder-to-liquid ratio and requires precise mixing for optimal performance. Additionally, it is moisture-sensitive, which can lead to marginal gaps if isolation is inadequate. These issues align with findings from and Badreldin et al. (2022),Mohan et al. (2018) who highlighted the importance of correct handling to minimize errors and ensure sealing efficiency.[17,18]

To address these challenges:

- Strict Mixing Protocols: Adhering to manufacturer instructions for proper mixing and consistency is crucial (Camilleri & Pitt Ford, 2013).[19]
- Enhanced Isolation: Using rubber dams effectively can prevent moisture contamination during application (Grech et al., 2013).[20]
- Incremental Placement: Applying NHMTA in small increments with proper condensation improves adaptation to dentinal walls (Nagesh et al., 2023).[13]

When handled appropriately, NHMTA remains a reliable material for furcal perforation repair in pediatric dentistry, offering sealing properties close to Biodentine

The application of GIC, which, despite its ease of use and good biocompatibility, showed inferior results in sealing capacity compared to the other materials. This can be attributed to its relatively lower mechanical strength and tendency to degrade over time when exposed to moisture. Abdallah and Ezzat (2022) found that GIC was more susceptible to bacterial infiltration, which further emphasizes the need for stronger, more bioactive materials for furcal perforation repairs.[21]

The this study underline the importance of material selection in furcal perforation repair, particularly in pediatric cases where the tooth structure is delicate and requires materials that offer both good sealing ability and biocompatibility. Further studies with longer follow-up periods and clinical trials will be essential to determine the long-term effectiveness of Biodentine and NHMTA in preventing failure of furcal perforation repairs in primary teeth.

CONCLUSION

SEM images revealed clear differences in material adaptation. Biodentine displayed a smooth, continuous interface with minimal gaps, while NHMTA showed slight irregularities. GIC exhibited the largest voids and inconsistent adaptation to the dentinal surface.The results emphasize the significance of material selection for furcal perforation repair, particularly in pediatric cases where bacterial contamination can lead to poor prognosis. Materials like Biodentine, with excellent sealing properties and biocompatibility, are particularly suitable for such applications.

The superior performance of Biodentine can be attributed to its rapid setting time, ability to maintain dimensional stability in moist environments, and bioactivity, which promotes the formation of a tight seal.NHMTA, while a close contender, requires precise handling to optimize its sealing ability.GIC, despite being widely used, may not be ideal for furcal perforation repair due to its mechanical limitations and susceptibility to microleakage, as confirmed in this study.

Recommendation

Further in vivo studies to evaluate the clinical and histological outcomes of these materials in primary teeth are recommended.

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Conflict of interest

The authors had no conflict of interest to declare.

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