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IP Indian Journal of Conservative and Endodontics

Journal homepage: https://www.ijce.in/

Original Research Article

Comparison of the sealing ability of MTA and titanium nanoparticle modified MTA in access perforation repair: An in vitro study

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Abstract

Aim & Objective: To compare the microleakage caused by MTA and Titanium nanoparticle-modified MTA as a material for treating access perforation repair in extracted human teeth.

Background: Perforation is one of the most frequent side effects of endodontic treatment which can have serious consequences on the further treatment protocol. It happens when practitioners attempt to create access to the pulp chamber to initiate root canal treatment.

Perforation needs to be addressed as soon as it occurs because contamination from the perforation site to the root canal reduces the potential for the wound to heal.

Materials and Methods: The purpose of this study was to assess the microleakage of Mineral Trioxide Aggregate (MTA) and Titanium nanoparticle modified Mineral Trioxide Aggregate (MTA) as materials for treating access perforations. The assessment of microleakage involved the use of a stereo microscope to examine the penetration of methylene blue 1% solution between the perforation site and the restoration material. The Kolmogorov-Smirnov test was used to examine the data.

Results: As a material for treating access perforation, Mineral Trioxide Aggregate (MTA) and Titanium nanoparticle modified Mineral Trioxide Aggregate (MTA) do not significantly differ in microleakage, according to statistical analysis of the data.

Conclusion: Titanium nanoparticles which enhanced the closure density and improved adaptation to the dentin in the perforation area resulted in significant resistance to microleakage of methylene blue dye.

Keywords: Microleakage, Titanium, nanoparticles, Access-perforation, Methylene blue1%, Stereo-microscope, Kolmogorov-Smirnov test

Received: 19-12-2024; **Accepted:** 24-02-2025; **Available Online**:

1. Introduction

The objective of root canal therapy is to preserve tooth function in the absence of clinical signs. Teeth that are adequately healed and undergo root canal therapy can survive and perform better in terms of function. Not every procedure, though, goes as planned. Depending on the conditions that are discovered at the time of treatment, the prognosis may alter.[1] Perforation can have a broad detrimental effect on endodontic therapy. It happens when one tries to access the pulp chamber and it affects the periodontal tissue. [2,3]

The tooth and surrounding bone are affected when this tissue comes in contact with bacteria because it weakens the tissue that supports the tooth. Therefore, to reduce any contamination that may arise during or after the therapy, the perforation needs to be closed as soon as it happens.[2]

A perforation treatment material needs to meet specific requirements. It must be non-toxic, radiopaque, non-soluble, and have good biocompatibility, antimicrobial action, and strong closure capability.[4] Potential materials for use include amalgam, calcium hydroxide, glass ionomer cement (GIC), zinc oxide-eugenol, and mineral trioxide aggregate (MTA). Since its introduction in 1993, MTA has frequently been utilized due to its biocompatibility and effective sealing properties. Numerous studies indicate that this material performs well in terms of microleakage when compared to amalgam, resin-modified GIC, and zinc oxide-Eugenol. However, MTA takes about four hours to set, which is often seen as too long. This prolonged setting time can permit the ingress of liquids or microorganisms into the treatment area, potentially compromising the prognosis and the manual manipulation of the material can result in variations in treatment outcomes.[5] Efforts to enhance the properties of

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http://doi.org/10.18231/j.ijce.2025.008

MTA include the addition of nanoparticles such as silver, zinc, and titanium dioxide (TiO2), which have gained interest in the field of dental materials.[6,7]

Since there are no studies examining the impact of incorporating TiO2 nanoparticles into MTA, the objective of this study was to assess the microleakage when access perforation is repaired with MTA and Titanium nanoparticle-modified MTA.

No research has been conducted to compare the two materials; therefore, it is necessary to do further assessment in terms of their effectiveness for the treatment of root canal system perforation. This study aims to analyze the differences between microleakage of MTA Titanium nanoparticle modified MTA when used for treating access perforation.

2. Materials and Methods

This research was an experimental laboratory study conducted in the Department of Conservative Dentistry & Endodontics. The materials used were: Safe Endo MTA, TiO2 Nanoparticles (Sigma Aldrich), Glass ionomer cements (3M) (GIC), nail polish, and methylene blue 1% solution. The tools employed included plastic instruments, a glass plate, a cutting disc, an amalgamator, a #14 round diamond bur, and a 15x magnification Zeiss Discovery V12 stereo microscope. Twenty single or multi-rooted maxillary and mandibular premolars were cleaned using a scaler and then soaked in NaCl solution until the preparation and perforation closure were completed. Access to the pulp chamber of the tooth samples was achieved with a #14 round diamond bur, followed by shaping and outlining the access with a cylindrical bur. A perforation simulation of the pulp chamber was made 1 mm below the cervical line using the diamond bur (**Figure 1**). The samples were then randomly divided into two treatment groups, each containing 10 teeth.

One group received treatment with MTA, while the other group was treated with Titanium nanoparticle-modified MTA. For the MTA group, the MTA was prepared according to the manufacturer's instructions and carefully placed into the perforation from the pulp chamber until it was filled and compacted. The excess material that overflowed in the buccal area was smoothed down with a plastic instrument until it was level with the surface of the tooth. For group 2, the TiO2 nanoparticles were added 1 wt% of MTA. In both groups the powder-to-liquid ratio was 3:1. The modified MTA was prepared following the manufacturer's instructions and placed into the perforation from the pulp chamber until it was fully packed and dense.

The excess material that overflowed in the buccal area was smoothed with a plastic instrument to merge with the surface of the tooth. Finally, in both groups, the access to the pulp chamber in the occlusal area was sealed using GIC. After the perforation closure was completed, each sample was assessed for closure density using a digital radiographic image (Digora)(**Figure 2**).

The samples were then stored for 24 hours in a humid environment, using a sponge placed inside a plastic container. (**Figure 3**) The samples were then dried with air spray, and all tooth surfaces were coated with nail polish, leaving a 1 mm area around the restoration on the buccal side uncovered. Next, the samples were soaked in a 1% methylene blue solution for 24 hours, then rinsed under running water for 10 minutes and allowed to drain. The samples were sectioned in a buccolingual direction using a disc while cooling with water. Afterwards, a stereo microscope was utilized to examine the teeth.

Data were collected on dye permeation along the perforation closure, and the depth of permeation was measured using ZEN 2011 software. Two statistical tests were employed to analyze dye penetration. Chi-square analysis was conducted to assess the statistical significance of differences between the two groups, using a significance limit of $p<0.05$. However, since the requirements for the Chi-square analysis were not met, a Kolmogorov-Smirnov test was used as an alternative method for analysis.

3. Results

Leakage data were obtained by evaluating the penetration of a 1% methylene blue solution using a 15x magnification stereo microscope. The leakage score was assigned as follows:

1. Value of 0 for no penetration,
2. Value of 1 for penetration of less than 0.5 mm,
3. Value of 2 for penetration between 0.5 mm and 1 mm,
4. Value of 3 for penetration greater than 1 mm.

Table 1 shows in group 1 microleakage Score 0 was found in 10% of subjects, Score 1 was found in 30% of subjects, Score 2 in 20% and Score 3 in 40% of subjects. In group 2 micro leakage Score 0 was found in 40% of subjects, Score 1 in 20%, Score 2 was found in 20% of subjects and Score 3 was found in 20% of subjects.

At the start of the study, the plan was to analyze and compare the two groups using Chi-square analysis. However, this approach was not feasible because the sample size requirements for the Chi-square test were not met.

Figure 1: A perforation simulation of the pulp chamber was made 1 mm below the cervical line

Figure 2: After perforation closure was completed, each sample was assessed for closure density using a digital radiographic image.

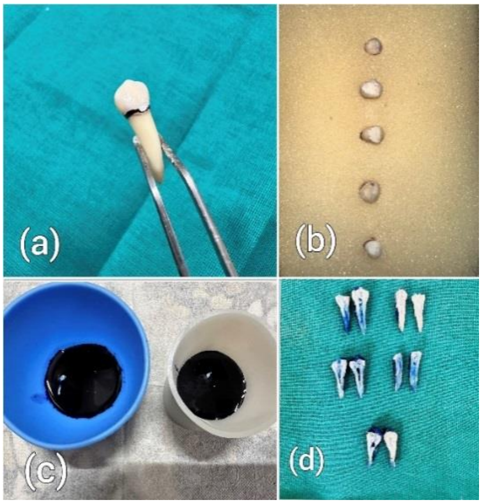

Figure 3: **a**: Perforation repair done; **b:** The samples were then stored for 24 hours in a humid environment, using a sponge; **c:** The samples were soaked in a 1% methylene blue solution for 24 hours, then rinsed under running water for 10 minutes; **d:** The samples were sectioned in a buccolingual direction using a disc.

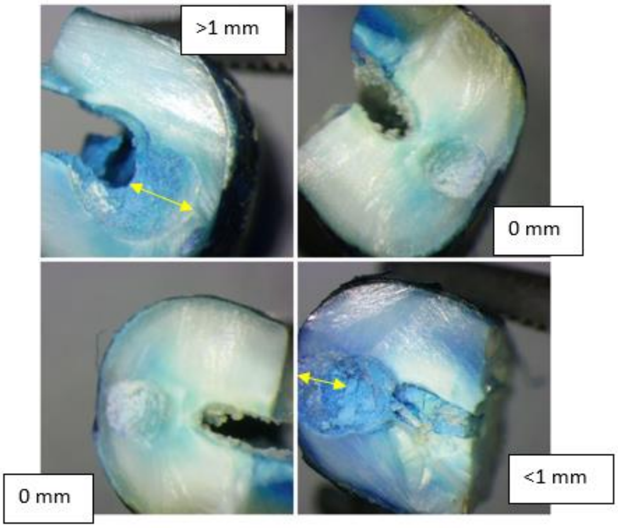

Figure 4: Represents the stereomicroscopic the pictures depicting permeation of Methylene Blue dye in the groups.

Based on the Kolmogorov-Smirnov test, D(10,10) = 0.30 & p=0.663 (Non-Significant). K-S-test did not indicate a significant difference between the two groups. Thus, there are no statistically significant differences between MTA and Titanium nanoparticle-modified MTA regarding microleakage-wise in the treatment of access perforation.

Table 1: Micro leakage – scores

Micro leakage – scores								
0		1		2		3		Total
n	%	n	%	n	%	n	%	n (%)
1	10	3	30	2	20	4	40	10(100)
4	40	2	20	2	20	2	20	10(100)
5		5		4		6		20

4. Discussion

The dye penetration method is the most widely used approach to assess microleakage. This technique involves immersing the specimen in dye for a specified duration, followed by examining the interface between the tooth and the restorative material.[8]

The presence of staining at the interface indicates that microleakage has occurred. Dye penetration testing is straightforward and does not require any chemical reactions.[8] In this study, microleakage was assessed using the methylene blue 1% solution penetration method, with an immersion duration of 24 hours. Methylene blue was chosen because its molecular size is very small, even smaller than that of bacteria.[9] Consequently, the methylene blue 1% solution can penetrate more deeply than other dyes due to its small molecular size (0.5–0.7 nm). As a result, it may yield false positive results and indicate a higher leakage rate than what is typically observed in clinical situations.[9]

This was carried out because, according to research by Tsesis (2010), lateral perforation is the second most commonly perforated area after the bifurcation.[10] The perforation closure materials were applied through the access to the pulp chamber using a plastic instrument, gradually inserting the material until the perforation area was filled. Radiography was employed to determine whether the perforation closure was complete or if there was a gap between the restorative material and the tooth's perforated wall.

MTA material exhibits excellent sealing ability and edge adaptation. Its inherent properties cause MTA to expand during the setting process, enhancing its fit to dentin. Additionally, MTA chemically bonds to the dentin wall, as the calcium hydroxide it releases reacts with phosphate ions to form a hydroxyapatite-like precipitate that adheres to the dentin structure. A study by Reyes-Carmona indicated the formation of interfacial layers through biomineralization between MTA and dentin.[11]

All samples had a powder-to-liquid ratio of 3:1. One operator performed the placement and packing of the materials, and all samples were kept under the same environmental conditions and moisture until they were used for the study.

In a study, adding TiO2 nanoparticles to white Portland cement enhanced its flexural and compressive strengths while reducing its setting time. Due to the similarities between MTA and Portland cement, it is anticipated that incorporating these nanoparticles into MTA will also improve its properties.[12] As there are no studies on the impact of incorporating TiO2 nanoparticles into MTA regarding the evaluation of microleakage in access perforation management, this study aimed to assess the effects of titanium dioxide nanoparticles on microleakage of access perforation repair.

The humid conditions were simulated by placing the sample on a moistened sponge inside a sealed plastic container for 24 hours. At least some of the samples received a leakage score of 0, indicating that they met the conditions necessary for the bioactive properties of both cements to be activated by the fluid in the dentin tubules. This process initiated hardening and led to the formation of hydroxyapatite-like precipitate.[13] The extracted teeth may have lacked natural fluid in their dentin tubules, preventing the calcium hydroxide generated from the reaction of calcium silicate in the hydrated restorative material from reacting to form the hydroxyapatite-like precipitate that binds to the dentin structures. From a statistical analysis standpoint, there was no significant difference in microleakage between MTA and Titanium nanoparticle-modified MTA. However, descriptively, the distribution of leakage scores for the Titanium nanoparticle-modified MTA sample group was more favourable than that of the MTA group, particularly in the scores of 0 and 3. This was likely attributed to the titanium nanoparticles, which enhanced the tightness of the closure and improved adaptation to the dentin in the perforation area.

Within the limitations of this study, adding TiO2 to MTA positively influenced the management of perforation in the samples, but it negatively affected the setting and working times according to the various literature present on this subject. Thus, further research is suggested before considering clinical use.[14]

5. Conclusion

In this study, no statistically significant difference in microleakage was found when comparing the use of MTA Titanium nanoparticle Mineral Trioxide Aggregate (MTA) as materials for treating access perforations although the Titanium nanoparticle-modified MTA sample group was more favourable than that of the MTA group, particularly in the scores of 0 and 3.

This was likely attributed to the titanium nanoparticles, which enhanced the tightness of the closure and improved adaptation to the dentin in the perforation area. In the current study, the addition of titanium dioxide nanoparticles enhanced resistance to microleakage.[15]

6. Ethical No.

576/Ethics/2024, XXII-PGTSC-IIA/PI.

7. Source of Funding

None.

8. Conflict of Interest

None.

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Cite this article: Mall A, Yadav RK, Verma P, Pal P.Comparison of the sealing ability of MTA and titanium nanoparticle modified MTA in access perforation repair: An in vitro study. *IP Indian J Conserv Endod*. 2025;10(1):48-52.