Original Article
DOI: https://doi.org/10.70749/ijbr.v3i7.1643

INDUS JOURNAL OF BIOSCIENCE RESEARCH
https://ijbr.com.pk
ISSN: 2960-2793/ 2960-2807

Clinical Response of Human Pulp Tissue to Direct Pulp Capping with Mineral Trioxide Aggregate and Propolis

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ARTICLE INFO

Keywords: direct pulp capping, mineral trioxide aggregate, propolis, carious pulp exposure, vital pulp therapy, clinical success.

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Declaration

Authors' Contribution: All authors equally contributed to the study and approved the final manuscript.

Conflict of Interest: No conflict of interest.

Funding: No funding received by the authors.

Article History

Received: 07-06-2025 Revised: 05-07-2025
Accepted: 07-07-2025 Published: 15-07-2025

ABSTRACT

Objective: To compare the clinical outcomes of mineral trioxide aggregate (MTA) and propolis when used as a direct pulp capping material in permanent teeth in which carries removal incurred in the exposure of the pulp. **Methods:** This quasi-experimental, single blind study included a total of 110 patients, aged between 18 and 45. Patients with deep carious lesions and signs and symptoms of reversible pulpitis were included. Teeth that developed pulp exposure during caries excavation were selected for the study. Once hemostasis was achieved, the direct pulp capping agent used was either mineral trioxide aggregate (MTA) or propolis, and the definitive restoration was performed with resin composite. After four months, patients were recalled for clinical and radiographic evaluation. The absence of spontaneous pain, no tenderness to percussion, a positive response to pulp vitality testing, and no radiographic evidence of periapical pathology were considered criteria for clinical success. The Chi-square test and Fisher's Exact test were employed for statistical analysis. **Results:** Clinical success was observed in 80.0% of the MTA group (44/55) and 72.7% of the propolis group (40/55) at four months. Despite the fact that MTA exhibited a higher success rate, the difference between the two groups was not statistically significant ($p = 0.501$). The majority of the teeth that were treated were posterior, and no significant correlation was observed between the type of tooth and the outcome of the treatment. **Conclusion:** As direct pulp capping agents in cariously exposed permanent teeth, both MTA and propolis showed good short-term results. Although MTA remains the preferred material, propolis with its natural source, biological action, and less cost may be a good substitute. More long-term, clinical studies are required to prove its clinical consistency and effectiveness.

INTRODUCTION

Vital pulp therapy (VPT) is a clinical intervention, employed when it is intended to preserve the health of the pulp when exposed to the oral environment due to trauma, caries, procedural mishaps, or irregularities in dental structure and formation (1). As one of the vital pulp therapy techniques, direct pulp capping (DPC) involves application of a biocompatible material directly over the exposed pulp tissue to stimulate healing and reparative dentin formation (2). When effectively performed, DPC obviates the need for more aggressive and financially burdensome treatments. It also offers the advantage over less invasive approaches such as selective caries excavation and indirect pulp capping, as it allows direct viewing of the pulp (3). In dental practice, pulp exposure still often occurs because of deep or extensive decay and may be unavoidable, despite adopting selective caries removal approach (4).

Philipp Pfaff first described using gold foil in 1756 to protect the pulp. Later, Herman in 1921 introduced calcium hydroxide (CH) as a biocompatible agent for vital and non-vital pulp therapy (5). However, calcium hydroxide has some limitations, which include tunnel defects, unexpected dentin bridge formation, necessitating the advancement of superior biomaterials (6).

Mineral Trioxide Aggregate (MTA) is a tricalcium silicate–based bioactive cement that is well known dental material, valued for its excellent biocompatibility, superior sealing ability, low solubility, radiopacity, and its ability to stimulate dentin bridge formation. But with it comes the drawbacks of a long setting time, difficult handling and is economically burdensome (7,8,9). This has led researchers to explore alternative materials, especially natural ones, that offer similar effectiveness while being more affordable and easier to use.

Propolis, a natural alternative material, has gained attention in recent dental research for its possible clinical uses. Propolis is a natural resinous compound produced by honeybees, known for its anti-inflammatory, antimicrobial and regenerative properties (10,11,12). Although MTA

and propolis have each been studied for dental use, there is little direct comparison between them as pulp capping materials.

Researchers conducted a clinical and microscopic study, to evaluate how MTA and propolis perform as a direct pulp capping agent. This study involved mechanically prepared cavities in premolars scheduled for orthodontic extraction. The results demonstrated a 100% clinical success rate for MTA and 91.7% for propolis (13)

This study seeks to compare the clinical efficacy of MTA and propolis as a direct pulp capping agent. Through evaluation of clinical success rates, pulp healing response, treatment outcomes, this study adds to the current knowledge, if propolis can serve as a natural and less expensive alternative to MTA and other pulp cap materials. Most of the prior studies were conducted on teeth that were not carious, mechanically induced pulp exposures, where bacterial contamination was minimal or not present.

Propolis may have useful therapeutic effects, but its long-term success compared to MTA is still not clear, so more research is required on healing, pain outcomes, and success rates. Additionally, unlike MTA, which has a consistent formulation, propolis is a naturally derived compound, and its composition can vary depending on geographical origin and extraction methods, leading to potential inconsistencies in clinical performance. (14)

MATERIALS AND METHODS

The study was undertaken at the Department of Operative Dentistry, Fatima Jinnah Dental Hospital, between August 2023 and May 2025. The study was planned in compliance with the Declaration of Helsinki and authorized by the Institutional Review Board of Fatima Jinnah Dental College (Approval No. FJDC_IRB_2023-01). All participants gave a written informed consent after receiving a detailed description of the study's goal, procedures, benefits, and potential dangers.

Study Population and Sample Size

A total of 110 patients were enrolled. The individual selected for the study exhibited a deep carious lesion nearly approaching the pulp in a mature permanent tooth with fully formed apices. Teeth exhibiting signs of pulpal vitality, symptoms of reversible pulpitis and pulp exposure during the removal of caries were selected. All participants were between the ages of 18 and 45 and were systemically healthy (ASA 1).

This quasi-experimental study was conducted using a single-blind design, in which the participants were uninformed of which pulp capping material, mineral trioxide aggregate (MTA) or propolis was utilized. Due to variances in material handling, blinding of the operator and outcome assessor was not practicable.

The sample size was calculated using a two-sided test for comparing proportions, with $\alpha = 0.05$ and 80% power. Based on the clinical outcomes reported by Nasri et al. (2022), who observed success rates of 100% for MTA and 91.7% for propolis in non-carious mechanically exposed teeth, the present study applied more conservative estimates of 95% for MTA and 75% for propolis to reflect increased biological variability associated with carious pulp exposures and clinical-only evaluation (13)

The minimum required sample size was determined to be 47 teeth per group. To account for potential dropouts, the final sample size was increased to 55 teeth per group, totaling 110 teeth.

Inclusion and Exclusion Criteria

Inclusion Criteria

- Patients aged 18–45 years
- Permanent teeth with deep carious lesions approaching the pulp (as seen in the periapical radiograph)
- Symptoms of reversible pulpitis
- Positive response to cold test and electric pulp test (EPT)
- Closed apices of the tooth
- Normal response to percussion and palpation

Exclusion Criteria

- Symptoms of Irreversible pulpitis
- Negative response to pulp sensibility tests
- No bleeding from the exposure site
- Radiographic signs of periapical pathology
- Systemic disorders that impede in the healing process
- Periodontal disease
- Inability to control bleeding from the exposure site within 5 minutes
- Teeth that did not result in pulp exposure during caries excavation were also excluded.

Clinical Procedure

Pulp vitality was validated by sensibility tests, cold test [Friljet refrigerant spray (Frilab SA, Buenos Aires, Argentina)] and EPT (Woodpecker Medical Instrument Co., Ltd., Guilin, China). Teeth were tested for vitality using Endo-Ice spray (Coltene) on the middle third of the buccal surface with a cotton pellet. If there was no initial response, the procedure was repeated after a 30-second interval. EPT was performed with a digital pulp tester on the middle third of the facial surface using toothpaste as a conducting medium. The test was done twice per tooth, and the lowest recorded value was considered. A rubber dam was used to isolate the tooth after the administration of 2% lidocaine with 1:80,000 epinephrine as the anesthetic agent. The first step was to eliminate peripheral caries by employing a high-speed handpiece with water spray. A sterile round carbide bur was then used to remove the remaining lesions at the base of the cavity. A caries-disclosing dye was employed for the complete removal of infected dentin.

Only teeth that experienced pulp exposure during this procedure were incorporated into our study. All exposures were less than 1 mm.

To control bleeding, a saline-moistened cotton pellet was applied for five minutes. Teeth that continued to bleed were excluded from the study.

Pulp capping materials were then placed as follows:

• MTA Group: ProRoot MTA (Dentsply, USA) was produced in accordance with the manufacturer's instructions and applied in a 2 mm layer directly over the exposed pulp

• Propolis Group: The protocol outlined by Mamik et al. (2013) was followed to combine 100% pure propolis powder (France) with 70% ethyl alcohol to form a paste. The exposure site was coated with a 2 mm coating.

The pulp capping material was covered with a resin-modified glass ionomer cement [Harvard Ionoglas Fill LC (Harvard Dental International GmbH, Hoppegarten, Germany)]. Composite resin (RubyFill by rubydent made in Turkiye) was subsequently employed to permanently restore the cavity. Analgesics were not prescribed.

Follow-Up and Evaluation

Any occurrence of pain, swelling, sensitivity, biting discomfort, or related issues after the procedure was to be promptly reported to the OPD. A clinical failure was recorded for any tooth that necessitated endodontic treatment during the follow-up period.

A recall appointment was scheduled after 4 months. EPT and cold tests were conducted to check pulp vitality, clinical examination was perfomed to check for signs and symptoms that would indicate symptoms of irreversible pulpitis. The paralleling technique was employed to obtain standardized periapical radiographs, to check for periapical changes.

Success Criteria

- Absence of pain or spontaneous symptoms
- Negative percussion and palpation tests
- Positive response to cold testing and/or EPT
- No signs of swelling or sinus tract
- No periapical changes seen on radiograph

Failure Criteria

- Spontaneous, persistent or severe pain
- Tenderness to percussion or palpation
- Negative response to pulp sensibility tests
- Presence of apical changes

Statistical Analysis

SPSS version 27.0 (IBM Corp., Armonk, NY) was used to analyze the data. Categorical variables, such as gender, pulp capping material, tooth type, and clinical outcome, were analyzed to determine frequencies and percentages. The associations between categorical variables were evaluated using the Chi-square test. Small subgroup counts necessitated the implementation of Fisher's Exact Test. The mean age of the groups was compared using an independent samples t-test. Statistical significance was defined as a p-value of less than 0.05

RESULTS

A total of 110 patients were included, with 55 assigned to each treatment group. The mean age of participants in the MTA group was 29.5 years, while in the Propolis group it was 31.5 years. This age difference was statistically significant ($p = 0.045$, independent samples t-test). The distribution of age among groups is depicted in Figure 2. Gender distribution was comparable between groups. The bulk of treated teeth were posterior teeth (about 85%), with no significant variation in tooth type across the groups. The tooth type distribution is displayed in Figure 3.

Clinical Outcomes

At the 4-month follow-up, clinical success was observed in 44 out of 55 teeth (80%) in the MTA group, and 40 out of 55 teeth (72.7%) in the Propolis group. Clinical failure was noted in 11 MTA cases and 15 Propolis cases. These results are reported in Table 1 and shown in Figure 1. Although the MTA group displayed a better success rate than the Propolis group, the difference was not statistically significant, as indicated by the Chi-square test ($p = 0.501$) and Fisher's Exact Test ($p = 0.501$). The findings reveal a trend toward greater performance with MTA, although without a statistically substantial difference.

Tooth Type and Clinical Outcome

No statistically significant correlation was identified between tooth type (anterior vs. posterior) and treatment outcome.

Table 1

Clinical Outcomes by Group

Group	Success	Failure
MTA	44	11
Propolis	40	15

Figure 1

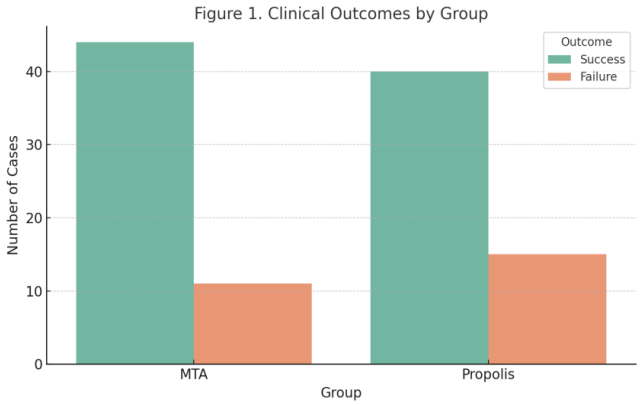


Figure 2

Age Distribution by Group

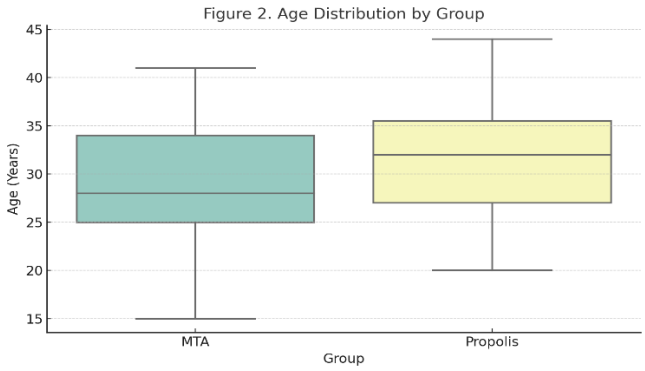
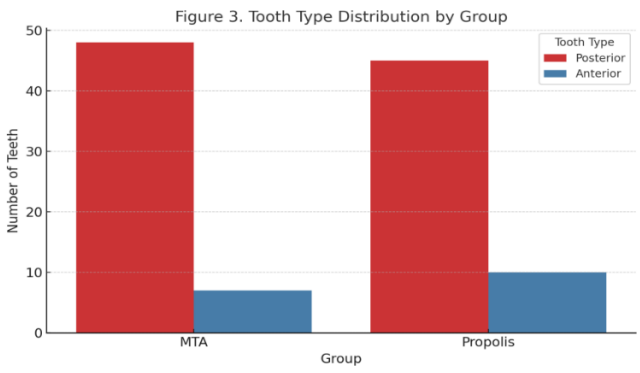


Figure 3

Tooth Type Distribution by Group



DISCUSSION

This study assessed the clinical efficacy of mineral trioxide aggregate (MTA) and propolis as direct pulp capping (DPC) materials in adult permanent teeth exhibiting carious pulp exposures and clinical indications of reversible pulpitis. Success was characterized by the lack of spontaneous or persistent pain, a normal response to pulp vitality assessments (cold or electric pulp testing), no sensitivity to percussion, and the absence of radiographic evidence of periapical disease at the 4-month follow-up.

MTA achieved a clinical success rate of 80.0%, while the propolis group achieved a rate of 72.7%. While MTA exhibited a numerically higher success rate, the difference was not statistically significant ($p > 0.05$), indicating that the two materials exhibited comparable short-term efficacy under clinical conditions involving carious exposures. These findings support the potential use of propolis as a direct pulp capping agent, due to its natural composition, biologically effectiveness and cost-effectiveness relative to MTA in vital pulp therapy.

The type of pulp exposure plays a significant role in the outcome of direct pulp capping. Research has shown that mechanically induced pulp exposures with limited bacterial contamination generally yield better outcomes, than cariously exposed pulps, which are inflamed and subjected to microbial challenges. (16,17). This study involved pulp exposures occurring during caries excavation, resulting in a clinically pertinent but more demanding treatment context.

A study assessing MTA in cariously exposed teeth indicate d a success rate of 77.3%, which is comparable to our MT A outcome of 80.0% (14).

In vitro and in vivo research has shown that propolis, a resinous compound derived from honeybees exhibits multiple therapeutic properties including antibacterial, anti-inflammatory, antioxidant, and regenerative activity. (18). These therapeutic effects are largely attributed to bioactive constituents like caffeic acid phenethyl ester (CAPE), quercetin, and naringenin, which modulate inflammatory cytokines and promote pulp tissue repair. (19). The 72.7% success rate attained in this investigation corroborates prior studies on the application of propolis in vital pulp therapy, but marginally lower than rates documented in non-carious or mechanically induced exposure models.

In contrast to MTA, propolis has natural variability based on its botanical source, geographical origin, and extraction technique, potentially impacting its clinical consistency (20). MTA, in contrast, is a synthetically produced substance characterized by a uniform composition, established biocompatibility, and enhanced sealing ability, factors that enhance its clinical reliability (9).

Ahmad et al. also reported favorable results with MTA, Biodentine, and propolis, although they noted slightly improved long-term performance with MTA (4). This trend may be attributed to the superior sealing and mechanical properties of MTA, whereas propolis, despite its biological benefits, may not possess the same level of physical strength and dimensional stability.

Clinical Relevance

MTA has a well-established composition, biocompatibility, and long-term stability. However, its high cost, prolonged setting time, and synthetic nature may limit accessibility, particularly in low-resource settings. Propolis, in contrast, is natural and economical, making it an attractive alternative (16). A critical limitation of propolis is its lack of standardization, which affects its clinical reliability. Consequently, future development of standardized, pharmaceutical-grade formulations of propolis is essential to support its integration into evidence-based clinical practice. Clinical outcomes in pulp therapy are influenced by more than just the capping agent, meticulous rubber dam isolation, precise caries removal, and accurate placement of the material, is essential (2,9).

Long-Term Considerations

Although the short-term outcomes were favorable during the four-month follow-up period, long-term monitoring is still necessary. Delayed failures have been observed in other studies, most commonly in cases involving teeth with existing pulpal inflammation. (4). MTA has demonstrated long-term effectiveness in these types of situations; however, there is still a scarcity of comprehensive clinical data on propolis. In order to verify the reliability of propolis in vital pulp therapy, it is necessary to conduct future randomized controlled trials with larger patient cohorts and extended follow-up periods.

Limitations

This study has several limitations. The quasi-experimental design without randomization may introduce selection bias. The relatively short follow-up period of four months may not detect late failures, particularly in inflamed pulps. Additionally, as propolis is a naturally derived material, its chemical composition may vary, affecting reproducibility. The generalizability of these results may be constrained by the study's single-center setting and narrow age range of participants. This study did not include histological evaluation, which may limit the understanding of tissue-level healing responses.

CONCLUSION

Within the scope of this study, MTA and propolis both demonstrated positive results when used for direct pulp capping in permanent teeth affected by carious pulp exposures and reversible pulpitis. Although MTA demonstrated a higher clinical success rate (80%) than propolis (72.7%), the disparity was not statistically significant. Propolis may be regarded as a viable alternative to MTA, due to its biological activity, antimicrobial properties, affordability, and natural origin. For propolis to be integrated into routine clinical practice for pulp therapy, future studies should focus on long-term outcomes, consistent propolis formulations, and validation across multiple centers.

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