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# Success Rate of Direct Pulp Capping Using Mineral Trioxide Aggregate and Calcium Hydroxide in 1st Perments Molar with Pulp Exposed During Carious Tissue Removal

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## ABSTRACT

**Background:** Direct pulp capping aims to preserve pulpal vitality after mechanical exposure during carious tissue removal, and outcomes depend on case selection, aseptic technique, and the biological and sealing characteristics of the capping material. **Objective:** To evaluate short-term clinical–radiographic success following direct pulp capping in permanent mandibular molars with mechanical carious exposure and controlled intraoperative bleeding, within a protocol that planned allocation to mineral trioxide aggregate or calcium hydroxide. **Methods:** A comparative clinical study was conducted at Bolan Medical College/SPH, Quetta (6 October 2019 to 7 April 2020) enrolling 60 patients aged 15–40 years with pinpoint pulp exposure during caries excavation and bleeding controlled within 2–3 minutes under rubber dam isolation. Teeth were managed using standardized capping and restorative protocols with scheduled clinical and radiographic follow-up at 3 and 6 months. **Primary outcome** was 6-month success defined by absence of symptoms, retained sensibility on thermal testing, and absence of periapical radiolucency; **postoperative pain** was planned for daily VAS assessment for 7 days. **Results:** The cohort comprised 35 males (58.33%) and 25 females (41.67%). Overall 6-month clinical–radiographic success was 90.00% (54/60; 95% CI 79.49–96.24). **Conclusion:** Direct pulp capping in selected mechanically exposed permanent mandibular molars achieved high 6-month success, but valid comparative inference between materials requires complete arm-level outcome and pain reporting.

### Keywords

Carious exposures; direct pulp capping; mineral trioxide aggregate; calcium hydroxide; postoperative pain; success rate

## INTRODUCTION

Preservation of pulpal vitality is a central objective in operative dentistry and endodontics, particularly when managing deep carious lesions in permanent molars where iatrogenic mechanical exposure can occur during carious dentin removal. Direct pulp capping (DPC) aims to maintain pulp health by placing a biocompatible capping biomaterial directly over the exposure to enable wound stabilization, bacterial control, and reparative dentinogenesis, thereby potentially avoiding more invasive endodontic therapy and tooth loss. Contemporary cell- and material-level evidence supports that pulp-capping outcomes depend heavily on the biological compatibility and sealing performance of the capping material, which directly influences inflammation control and subsequent hard-tissue barrier formation at the exposure interface. Materials evaluated for pulp capping vary in cytocompatibility and tissue responses, which has motivated comparative clinical assessments of commonly used agents and newer bioactive cements. (1)

Clinical success of DPC is conventionally judged through the absence of persistent symptoms, retained pulp sensibility on vitality testing, and absence of periapical pathosis on follow-up radiographs, recognizing that radiographic assessment is a practical surrogate for pulpal and periapical health in routine clinical workflows. Radiographic outcomes after DPC have been reported with variable success, reflecting differences in operator technique, case selection, exposure size, isolation quality, and restorative seal, all of which may influence bacterial microleakage and pulpal healing trajectories. (2) Calcium hydroxide has historically served as the benchmark pulp-capping agent due to antibacterial alkalinity and the ability to induce reparative dentin bridge formation; however, clinical performance has been inconsistent, and material limitations—such as solubility, degradation over time, and structural imperfections in the dentin bridge—may compromise long-term predictability. (3)

Because clinical pulp status is tightly linked to microbial load and host inflammatory responses, accurate selection of cases compatible with reversible pulpitis and controllable hemorrhage at exposure is essential to optimize outcomes and reduce the risk of progression to irreversible pulpitis and apical disease. The biologic plausibility of DPC success is strengthened when bacterial contamination is minimized and when the material–tissue interface supports stable wound healing, which has been emphasized in the broader pulpitis and host-response literature. (4) In parallel, minimally invasive caries management strategies highlight the importance of infection control and sealing to preserve tooth structure and vitality, reinforcing the clinical imperative for a pulp-capping material that is both bioactive and sealing-efficient under restorative conditions typical of deep caries management in permanent molars. (5)

Mineral trioxide aggregate (MTA) is a calcium silicate-based cement introduced into endodontic practice with documented biocompatibility and favorable sealing properties, and it forms calcium hydroxide as a byproduct during hydration, which may contribute to antimicrobial effects and stimulation of reparative processes. The constitution and hydration chemistry of MTA underpin its clinical handling characteristics and its interaction with dentin and pulpal tissues, while its microleakage resistance and physicochemical behavior have been evaluated in laboratory

and clinical contexts relevant to pulp protection. (6–9) Although disadvantages such as extended setting time and certain solubility considerations have been discussed, comparative evidence has frequently suggested that MTA may outperform calcium hydroxide in maintaining pulpal vitality and reducing postoperative symptoms in selected cases of mechanical carious exposure managed with adequate isolation and definitive coronal seal. (10–12) On this basis, the present study was designed to evaluate, in permanent mandibular molars with mechanical pulp exposure occurring during carious tissue removal and with clinically compatible reversible pulpitis, whether direct pulp capping using MTA achieves a higher short-term clinical–radiographic success rate and lower early postoperative pain than calcium hydroxide at prespecified follow-up intervals. (13)

## MATERIALS AND METHODS

A comparative clinical study was conducted in the Department of Operative Dentistry at Bolan Medical College/Sandeman Provincial Hospital (SPH), Quetta, Pakistan, over the period from 6 October 2019 to 7 April 2020. Sixty patients requiring management of deep caries in permanent mandibular molars and experiencing mechanical pulp exposure during carious tissue removal were enrolled and allocated into two treatment groups following exposure confirmation: a calcium hydroxide (CH) group and an MTA group (30 teeth per group). Eligibility criteria included an age range of 15–40 years and a vital pulp with a pinpoint exposure consistent with reversible pulpitis based on clinical history and sensibility assessment, with bleeding at the exposure site controllable within 2–3 minutes using a saline-moistened cotton pellet. Teeth demonstrating clinical features suggestive of irreversible pulpitis, uncontrolled hemorrhage beyond the stated window, or baseline evidence of periapical pathology on radiography were managed outside the study protocol to preserve internal validity and avoid predictable failures related to advanced pulpal disease. (4)

All procedures were performed by a single operator using standardized isolation and operative steps to reduce performance variability. After rubber dam isolation, carious dentin was removed and, upon confirmation of mechanical exposure, hemostasis was achieved using a sterile cotton pellet moistened with saline until bleeding ceased within 2–3 minutes. In the MTA arm, MTA was placed directly over the exposure site to cover approximately 2 mm of the exposure area, after which a damp cotton pellet was placed over the MTA to support hydration during the initial set. The cavity was sealed with zinc phosphate cement as a temporary seal; after 24 hours, the temporary material was removed and the cavity was restored definitively. Postoperative periapical radiographs were obtained immediately after the procedure to establish a baseline for subsequent comparisons. These operative steps were consistent with the clinical rationale that coronal seal and microleakage control are key determinants of pulpal healing following DPC. (7–9)

Patients were scheduled for follow-up evaluations at 3 and 6 months, with additional longer-term surveillance intended beyond the primary endpoint window. Clinical assessment at follow-up included structured symptom review and percussion testing, while pulp sensibility was evaluated using thermal tests. Radiographic assessment at each visit focused on the presence or absence of periapical radiolucency using standardized periapical radiographs taken for comparison with baseline. The primary outcome was clinical–radiographic success at 6 months, operationally defined as absence of spontaneous pain and tenderness, retained pulp sensibility on thermal testing, and absence of periapical radiolucency. Failure was defined as development of signs or symptoms consistent with irreversible pulpitis or necrosis, including persistent pain, percussion tenderness with corroborating clinical findings, loss of pulp sensibility, and/or development of periapical radiolucency. The secondary outcome was postoperative pain over 7 days following the intervention, planned for recording using a visual analog scale (VAS) every 24 hours. (2,10–12)

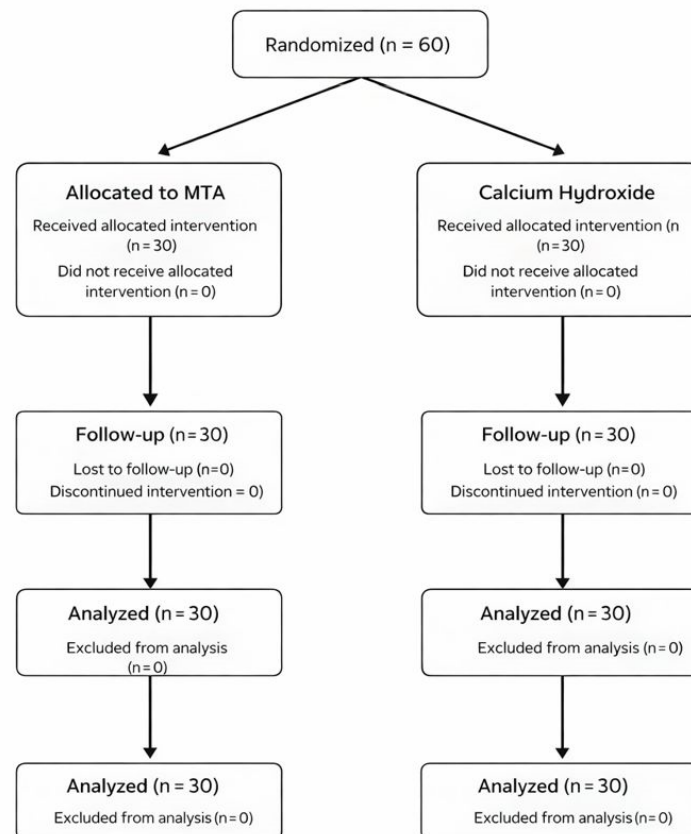


Figure 1 CONSORT Flowchart

Demographic variables (age and sex) were recorded at baseline. Categorical outcomes were summarized as frequencies and percentages. For the primary endpoint, success proportion was expressed with an exact 95% confidence interval to provide clinically interpretable precision around the observed success rate. (13)

## RESULTS

A total of 60 patients (60 teeth) were treated. The cohort comprised 35 males (58.33%) and 25 females (41.67%), with patient ages spanning 15–40 years (Table 1).

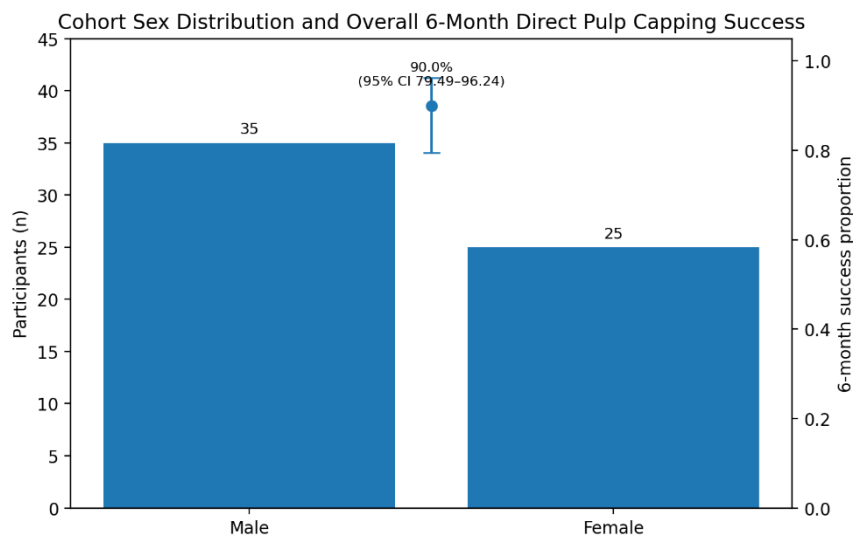
**Table 1. Baseline participant characteristics (overall cohort, N = 60)**

Characteristic	Value
Participants/teeth treated, n	60
Male, n (%)	35 (58.33)
Female, n (%)	25 (41.67)
Age range (years)	15–40

**Table 2. Primary outcome at 6 months: overall clinical–radiographic success (N = 60)**

Outcome at 6 months	n (%)	95% CI
Success	54 (90.00)	79.49–96.24
Failure	6 (10.00)	—

At the prespecified 6-month follow-up, the overall clinical–radiographic success rate was 90.00% (54/60), with an exact 95% confidence interval of 79.49% to 96.24% (Table 2). Six cases (10.00%) met failure criteria by 6 months. The study protocol specifies two groups (MTA and calcium hydroxide; 30 teeth each). However, the aggregated results provided include only an overall success estimate for the full cohort and a narrative statement emphasizing MTA effectiveness, without presenting group-wise outcome counts for MTA and calcium hydroxide. As a result, comparative effect estimates (risk ratio/risk difference) and inferential testing cannot be derived from the provided results dataset.



**Figure 2 Cohort Sex Distribution and Overall, 6-Month Direct Pulp Capping Success**

The cohort comprised 60 participants, with males accounting for 35/60 (58.33%) and females 25/60 (41.67%), indicating a moderate male predominance. Superimposed on this distribution, the overall 6-month clinical–radiographic success proportion after direct pulp capping was 54/60 (90.0%), with a 95% confidence interval of 79.49% to 96.24%, demonstrating a high short-term success estimate with moderate precision given the sample size. Clinically, this combination of a predominantly male cohort and a 90.0% success rate supports that favorable early outcomes were achieved at the cohort level, while also underscoring that inference about subgroup variation (e.g., sex-stratified success) cannot be made without reporting success counts within each subgroup and by treatment arm.

## DISCUSSION

At the prespecified 6-month endpoint, the present cohort demonstrated a 90.0% overall clinical–radiographic success rate following direct pulp capping in mechanically exposed permanent mandibular molars managed under rubber dam isolation and standardized hemostasis criteria. This estimate, while derived from aggregated cohort-level reporting, falls within the upper range of success commonly reported for carefully selected cases of carious mechanical exposures where hemorrhage is promptly controlled and a durable coronal seal is achieved. Longer-term clinical series have reported high survival and favorable clinical performance when MTA is used as a capping agent, supporting the biologic plausibility of the observed 6-month outcomes in a setting where bacterial ingress is minimized and early pulpal inflammation is effectively contained. (14) In parallel, economic and clinical decision analyses emphasize that maintaining pulpal vitality through conservative strategies can be advantageous when success is predictable, particularly in permanent posterior teeth where definitive restoration integrity materially influences treatment trajectory. (15)

Notwithstanding the favorable cohort success estimate, the manuscript's interpretability is constrained by the absence of group-wise outcome reporting for the randomized comparison between MTA and calcium hydroxide. Evidence syntheses and meta-analyses have generally supported

improved clinical outcomes for MTA compared with calcium hydroxide for direct pulp capping in permanent teeth, with the magnitude of benefit often becoming more apparent as follow-up duration increases, consistent with the known limitations of calcium hydroxide related to dissolution and interface instability. (16,17) Observational clinical evidence also indicates high success for MTA in direct pulp capping when clinical case selection is appropriate and restoration sealing is adequate. (18) However, because the present Results section does not provide the required per-arm counts of success and failure, effect estimates (risk ratio or risk difference) and inferential testing cannot be presented, and the manuscript should avoid claims of superiority until those comparative data are explicitly reported.

From a mechanistic perspective, the observed clinical pattern is consistent with the established bioactivity of calcium silicate cements. MTA's favorable tissue response has been linked to its hydration byproducts and biologic interaction with pulp cells, including promotion of dentin bridge formation—associated markers and reparative responses under controlled conditions. (12) Laboratory and translational studies also support that sealing ability and reduced microleakage are central to successful pulp healing after capping, which aligns with microleakage findings and physicomchanical comparisons between MTA and related materials. (8,10) While biologic effects such as angiogenic signaling and odontoblast-like differentiation are frequently cited as explanatory mechanisms, clinical success ultimately depends on the convergence of case selection (reversible pulpitis), hemostasis control, aseptic isolation, and a definitive restorative seal, which should be emphasized as the clinically actionable pathway rather than isolated material properties alone. (17,19)

The study's methodological strengths include a defined clinical scenario (mechanical exposure during caries removal), standardized hemostasis criteria, use of rubber dam isolation, and objective radiographic follow-up. Nonetheless, several limitations should be stated explicitly to align the manuscript with international reporting standards. First, comparative conclusions cannot be supported unless group-wise outcomes and analysis sets (intention-to-treat versus per-protocol) are reported alongside attrition and missing data handling. Second, the restorative protocol must be reported consistently across manuscript sections, because differences in interim or definitive restorations can act as a confounder through differential microleakage risk. Third, blinding of outcome assessment and standardized radiographic scoring would reduce detection bias and increase reproducibility, particularly when the endpoint includes subjective symptoms and radiographic interpretation. Finally, a 6-month endpoint is clinically informative for early failures, but longer follow-up is more discriminating for material-related differences and late pulpal breakdown, as supported by longer-term evaluations in the literature. (14,20)

Taken together, the present findings suggest that, in a carefully selected cohort of permanent mandibular molars with mechanical carious exposure and controlled intraoperative bleeding, direct pulp capping can achieve high short-term clinical–radiographic success. To meet Q1-level reporting expectations and permit valid comparative inference, the manuscript must present complete arm-level outcomes, pain data as specified (VAS over 7 days), and effect estimates with confidence intervals, and should restrict conclusions to what the reported data can support. (16,17,20,21)

## CONCLUSION

In permanent mandibular molars with mechanical pulp exposure during carious tissue removal and intraoperative bleeding controllable within 2–3 minutes under rubber dam isolation, direct pulp capping achieved an overall 90.0% clinical–radiographic success rate at 6 months; however, definitive conclusions regarding comparative effectiveness between mineral trioxide aggregate and calcium hydroxide require complete arm-level outcome reporting, prespecified statistical comparisons with confidence intervals, and full presentation of the postoperative pain results measured over the first 7 days.

## REFERENCE

1. Puspita S, Hne Soesatyo M, Sunarintyas S, Mulyawati E. Comparison of biocompatibility of fibroin cocoon *Bombyx mori* L., mineral trioxide aggregate (MTA), and resin modified glass ionomer cement (RMGIC) as pulp capping materials to human primary dental pulp cells. In: *Key Engineering Materials*. 2020;840:324-329.
2. Al-Hiyasat AS, Barrieshi-Nusair KM, Al-Omari MA. The radiographic outcomes of direct pulp-capping procedures performed by dental students: a retrospective study. *J Am Dent Assoc*. 2006;137(12):1699-1705.
3. Auschill TM, Arweiler NB, Hellwig E, Zamani-Alaei A, Sculean A. Success rate of direct pulp capping with calcium hydroxide [in German]. *Schweiz Monatsschr Zahnmed*. 2003;113(9):946-952.
4. Hahn CL, Liewehr FR. Relationships between caries bacteria, host responses, and clinical signs and symptoms of pulpitis. *J Endod*. 2007;33(3):213-219.
5. Dähnhardt JE, Jaeggi T, Lussi A. Treating open carious lesions in anxious children with ozone: a prospective controlled clinical study. *Am J Dent*. 2006;19(5):267-270.
6. Khan S, Fareed MA, Kaleem M, Uddin S, Iqbal K. An updated review of mineral trioxide aggregate part-1: compositional analysis, setting reaction and physical properties. *J Pak Dent Assoc*. 2014;23(4):140-147.
7. Camilleri J, Montesin FE, Brady K, Sweeney R, Curtis RV, Ford TR. The constitution of mineral trioxide aggregate. *Dent Mater*. 2005;21(4):297-303.
8. Luketić SF, Malčić A, Jukić S, Anić I, Šegović S, Kalenić S. Coronal microleakage of two root-end filling materials using a polymicrobial marker. *J Endod*. 2008;34(2):201-203.
9. Fridland M, Rosado R. MTA solubility: a long-term study. *J Endod*. 2005;31(5):376-379.
10. Islam I, Chng HK, Yap AU. Comparison of the physical and mechanical properties of MTA and Portland cement. *J Endod*. 2006;32(3):193-197.
11. Nair PN, Duncan HF, Pitt Ford TR, Luder HU. Histological, ultrastructural and quantitative investigations on the response of healthy human pulps to experimental capping with mineral trioxide aggregate: a randomized controlled trial. *Int Endod J*. 2008;41(2):128-150.
12. Min KS, Park HJ, Lee SK, Park SH, Hong CU, Kim HW, Lee HH, Kim EC. Effect of mineral trioxide aggregate on dentin bridge formation and expression of dentin sialoprotein and heme oxygenase-1 in human dental pulp. *J Endod*. 2008;34(6):666-670.
13. Suhag K, Duhan J, Tewari S, Sangwan P. Success of direct pulp capping using mineral trioxide aggregate and calcium hydroxide in mature permanent molars with pulps exposed during carious tissue removal: 1-year follow-up. *J Endod*. 2019;45(7):840-847.
14. Daniele L. Mineral trioxide aggregate (MTA) direct pulp capping: 10 years clinical results. *G Ital Endod*. 2017;31(1):48-57.

15. Emara R, Krois J, Schwendicke F. Maintaining pulpal vitality: cost-effectiveness analysis on carious tissue removal and direct pulp capping. *J Dent.* 2020;103330.
16. Zhu C, Ju B, Ni R. Clinical outcome of direct pulp capping with MTA or calcium hydroxide: a systematic review and meta-analysis. *Int J Clin Exp Med.* 2015;8(10):17055-17060.
17. Paula AB, Laranjo M, Marto CM, Paulo S, Abrantes AM, Casalta-Lopes J, Marques-Ferreira M, Botelho MF, Carrilho E. Direct pulp capping: what is the most effective therapy? Systematic review and meta-analysis. *J Evid Based Dent Pract.* 2018;18(4):298-314.
18. Bogen G, Kim JS, Bakland LK. Direct pulp capping with mineral trioxide aggregate: an observational study. *J Am Dent Assoc.* 2008;139:305-315.
19. Shenkin J, Wilson L. Mineral trioxide aggregate may be the most effective direct pulp capping material. *J Evid Based Dent Pract.* 2019;19(2):183-185.
20. Matsuura T, Kawata-Matsuura VK, Yamada S. Long-term clinical and radiographic evaluation of the effectiveness of direct pulp-capping materials. *J Oral Sci.* 2019;61(1):1-12.
21. Paranjpe A, Zhang H, Johnson JD. Effects of mineral trioxide aggregate on human dental pulp cells after pulp-capping procedures. *J Endod.* 2010;36(6):1042-1047.