

Treatment outcome of coronal pulpotomy and indirect pulp capping in mature permanent molars with symptoms of moderate pulpitis: A randomized clinical trial

E. Melvin Gabriel, S. Swathi Priyadharshini¹, I. Anand Sherwood, Geeth Deepika, Chinnasamy Ragavendran¹, Vaanjay Murugadoss

Department of Conservative Dentistry and Endodontics, C. S. I. College of Dental Sciences and Research, Madurai, ¹Department of Cariology, Saveetha Dental College and Hospitals, Chennai, Tamil Nadu, India

Abstract

Aim: This clinical trial aimed to compare the clinical success of coronal pulpotomy and indirect pulp capping (IPC) in managing symptomatic deep proximal caries in molars with moderate pulpitis over a 12-month period.

Materials and Methods: A total of 108 vital mature permanent molars with moderate pulpitis were randomly allocated to the IPC ($n = 54$) or coronal pulpotomy group ($n = 54$). Dycal and Biodentine were used as pulp-capping materials, followed by composite restoration. The absence of periapical infection and asymptomatic teeth that positively responded to the cold pulp sensitivity test (only in IPC) was considered posttreatment success at 12 months. Data from the study were analyzed using the Chi-square test and Kaplan–Meier survival analysis.

Results: There was a statistically significant difference between preoperative symptoms and the cold pulp sensibility test response ($P = 0.000$), indicating an association between symptoms and pulp sensibility. The average remaining dentine thickness (RDT) value was 0.48 ± 0.5 mm, with no statistically significant difference found between the location of caries and RDT ($P = 0.084$, $P > 0.05$). Compared to the IPC group, the pulpotomy group had a greater number of patients at 12 months after treatment that required no intervention. The Kaplan–Meier survival analysis revealed that the mean survival duration for pulpotomy was 48 weeks, and for IPC, it was 42.3 ± 2.35 weeks.

Conclusion: Coronal pulpotomy with Biodentine proved more effective in reducing symptoms, achieving radiographic success, and ensuring tooth survival compared to IPC with calcium hydroxide.

Keywords: Biodentine; deep caries management; indirect pulp capping; pulpotomy; vital pulp therapy

INTRODUCTION

Dental caries, a chronic condition, typically advances

gradually in the majority of individuals.^[1] It is characterized as a disease that triggers a shift in the biofilm toward acid-producing microorganisms, ultimately resulting in mineral loss from the hard dental tissue. The dental pulp may become mildly to severely inflamed as a result of dental caries. Periradicular lesions have been shown to be detectable before the pulp undergoing necrosis.^[2] Adults with deep carious lesions frequently require invasive

Address for correspondence:

Dr. Anand Sherwood,
Department of Conservative Dentistry and Endodontics, C.S.I.
College of Dental Sciences and Research, Madurai, Tamil Nadu,
India.

E-mail: anand.sherwood@gmail.com

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procedures such as root canal therapy. Nevertheless, there is insufficient data to support the current treatment recommendations for inflammatory pulp and well-defined deep caries (reaching radiographically into the pulpal 1/4).^[3] The traditional way of managing deep caries involves the complete removal of all carious dentin.^[4,5] So far, there has not been a widely accepted method for treating permanent teeth with exposed pulp that is vital.

Because of technological advancements, researchers are concentrating on vital pulp therapies (VPTs) as a viable alternative to root canal therapy. The use of bioactive materials has led to a new knowledge of pulp regeneration and vascularization. VPT is a minimally invasive treatment strategy for teeth with compromised pulp tissue resulting from factors such as dental caries, injury, or previous dental procedures.^[6] Indirect pulp capping (IPC) involves applying a capping material over the affected dentin, covering the unexposed pulp and recent reports suggest that sealing cavitated lesions with bonded composite restorations can halt caries progression for at least a decade, implying that complete caries removal might not always be necessary.

IPC is recommended for deep carious lesions with asymptomatic pulp inflammation, emphasizing proper cavity sealing. Coronal pulpotomy removes all inflamed pulp tissue and forms a sturdy layer at the base of the pulp chamber, ensuring precise positioning and condensation of the pulp capping material.^[7] Coronal pulpotomy in permanent teeth lacks certainty about the pulpal condition during treatment, making its success and long-term outcomes uncertain, despite some studies showing similar success rates to root canal therapy. In cases of pulp exposure during extensive excavation in young permanent teeth, a partial pulpotomy becomes an option for teeth diagnosed with reversible pulpitis.^[8,9] In a study conducted by Taha *et al.*, it was found that mineral trioxide aggregate (MTA) full pulpotomy demonstrated high success rates in treating symptomatic permanent teeth with carious exposures over a 3-year duration, suggesting the potential for healing in teeth showing clinical indications of irreversible pulpitis.^[10]

The ideal material for pulp capping should safeguard the health of the pulp while promoting the growth of reparative dentin.^[11] The choice of pulp capping materials is crucial for stimulating the regeneration of the dentin–pulp complex. Calcium silicate cement, such as MTA, Biodentine, and Calcium enriched mixture (CEM), have become more popular for pulp capping due to their biocompatibility and effectiveness.^[12] While calcium hydroxide (Ca(OH)₂) is known for its antibacterial and reparative traits, its gradual dissolution and potential inability to consistently form a complete dentin bridge might impact long-term success. MTA, Biodentine, and CEM show promise in enhancing pulp capping results by supporting the formation of a

thorough dentin bridge without adverse effects and might even surpass Ca(OH)₂. However, MTA has drawbacks such as extended setting time, handling challenges, potential discoloration, and cost concerns. In contrast, Biodentine offers enhanced mechanical strength, resistance to solubility, and better sealing of dentin for VPT when compared to Ca(OH)₂.

This clinical research aims to examine the effectiveness of IPC techniques and coronal pulpotomy in treating symptomatic deep proximal caries with moderate pulpitis in molars over a 12-month period. The null hypothesis of the study is that there should be no difference in the clinical outcomes of the two treatments.

MATERIALS AND METHODS

To guarantee the study's transparency, this randomized clinical trial was planned in accordance with CONSORT guidelines [Chart 1].^[13] The current clinical trial followed the ethical principles set by the Institutional Ethical Committee reference number (CSICDSR/IEC/O198/2021) and was registered with the Clinical Trials Registry-India with the ID CTRI/2022/02/040040. Recruitment for the study population occurred between January 2021 and September 2022 for patients referred to the endodontic specialty for treatment of maxillary and mandibular molars.

Sample size calculation

A sample size of 108 teeth was determined for the two treatment groups using G*Power software version 3.1.9.2 (Universität Kiel, Kiel, Germany). This calculation was based on an effect size of 0.3 and an α error of 0.05, derived from previous clinical studies with a 95% confidence interval.

Study population

Among the patients who were sent to the Department of Conservative Dentistry and Endodontics, those who met the inclusion and exclusion criteria were chosen as eligible patients. Before the procedure, the patients were informed about the process and provided written consent.

Eligibility criteria

- Only maxillary or mandibular first and second molar teeth with deep proximal caries
- Male and female patients of age groups between 14 and 70 years
- Patients who have a history of mild-to-moderate sensitivity or discomfort that would subside on its own after 15–30 s of stimulation
- Cold pulp sensibility test response of exaggerated sensitivity, increased sensitivity, mild-to-moderate pain which subsides immediately
- History of mild sensitivity or pain on percussion

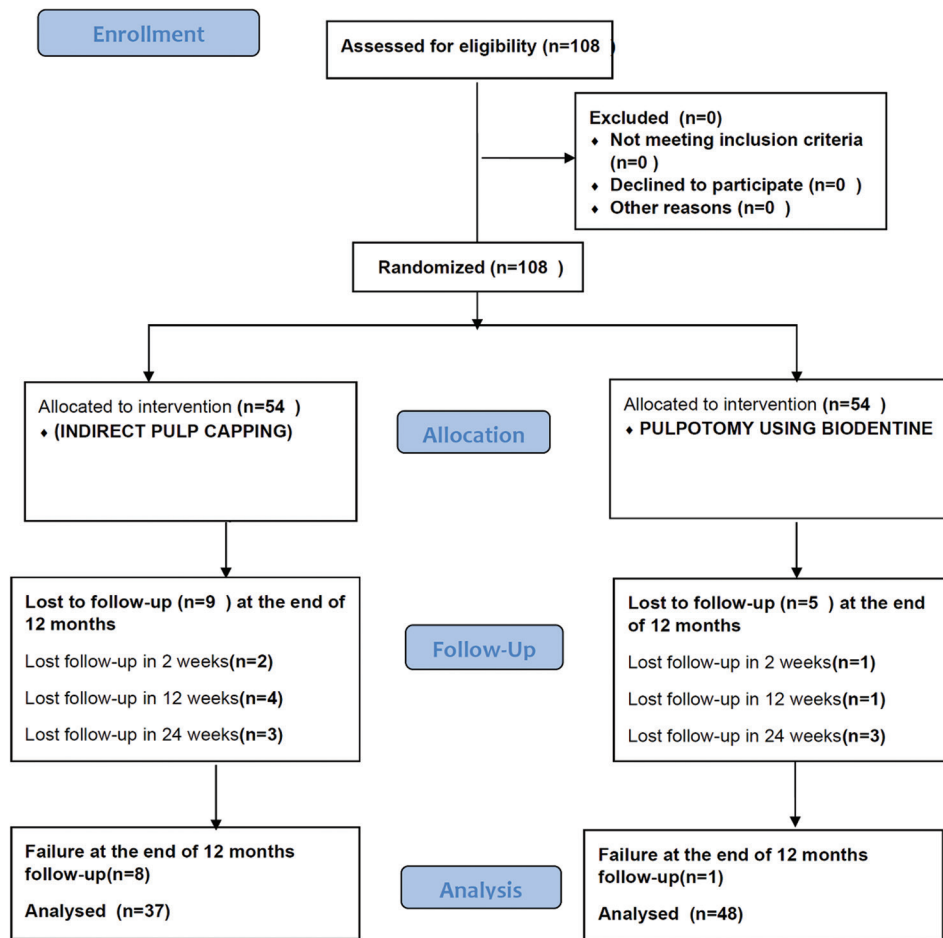


Chart 1: A CONSORT diagram showing the flow of participants through each stage of the study

- A radiograph showing pulp exposure and proximal caries penetrating the inner 3/4 of the dentin
- Periodontal ligament space (PDL) widening that is either modest or intact and limited to the apical quarter of any root.

Exclusion criteria

- Patients who have previously had radiating, sudden, or nighttime pain suggestive of irreversible pulpitis
- Cold pulp sensibility tests showing exaggerated pain that is lingering for more than 20 s or no pulpal response to cold test indicative of necrotic pulp
- Radiograph demonstrating pulp exposure, periodontal bone loss, mobility, and gingival recession
- Widening of the PDL space and loss or discontinuity of the lamina dura beyond the apical 1/4th of the roots
- Patients with systemic complications or psychiatric disturbances
- Patients with a history of analgesics or patients with desensitization treatment.

Three procedures comprised the clinical examination: manual palpation and percussion, the use of the Endo-Frost

(Colténe-Whaledent India Pvt. Ltd., Mumbai, India) for assessing cold sensitivity, and the detection of signs of inflammation such as discomfort, abscesses, sinus tracts, and abnormal mobility.

The pulp condition of the tooth was categorized as moderate based on a modified classification system derived from Wolters *et al.*, in 2017.^[14] Every periapical (PA) radiograph was assessed by a qualified medical professional who was blinded. A single operator (Densmart X-ray film holder; Universal X-rays, New Delhi, India) used a photostimulable phosphor (PSP) scanner (VistaScan Mini Plus; Durr Dental, Bietigheim-Bissingen, Germany) to take the baseline and posttreatment recall PAs using the paralleling cone approach. Standardized exposure settings (70 kVp, 8 mA, and 0.2 s) were used for all radiographs.

Randomization

The study randomly assigned participants to receive either IPC or pulpotomy for all suitable permanent molars. The randomization was done at the patient level, with a minimum of 40 teeth per group to ensure sufficient statistical strength. An online tool (<http://www.randomizer>).

org) was used to generate a set of random numbers, which were exported into an Excel sheet for random assignment. The treating clinician was unaware of the assigned treatment until just before the procedure to maintain treatment concealment. Two experienced independent endodontists reviewed the follow-up radiographs without knowing which material was used. A dental nurse referred to the randomization list and communicated the allocated treatment to the clinician for each patient.

Clinical procedure

A rubber dam was placed in all patients for the entire duration of the procedures, and a single operator performed the treatments using a dental operating microscope at $\times 1.6$. Local anesthesia was provided to alleviate discomfort and ensure patient comfort when necessary.

Indirect pulp capping

First, superficially soft-infected dentin was excavated. Next, a BR-41 round bur was used in a high-speed airtor handpiece with plenty of irrigation. Careful caries excavation was carried out, assuring sound dentine at the cavity's border for better bonding and leaving firm or hard-discolored impacted dentin on the pulpal floor and axial walls. Teeth experiencing pulp exposure were excluded from the study. For teeth without pulp exposure, an IPC procedure using Dycal was executed, applying a $\text{Ca}(\text{OH})_2$ liner (Dycal, Dentsply Sirona, NC, USA) up to 1 mm thick over the pulpal and axial dentin walls. Subsequently, a resin composite restoration (CeramX duo SphereTEC nanoceramic composite, Dentsply Sirona, USA) was incrementally applied and light-cured for 40 s per layer. Occlusal adjustments were made for proper functionality, followed by final finishing and polishing utilizing the Super-snap kit (Shofu Dental, Japan) and Enhance Pogo system (Dentsply Sirona, USA) [Figure 1].

Pulpotomy

The pulpotomy process involved administering local anesthesia with a mixture of 2% lignocaine and 1:80,000 adrenaline, adhering to the standardized pulpotomy protocol. A high-speed air rotor handpiece and an endo access bur (Dentsply Maillefer) were used to prepare the access, and active bleeding from the pulp chamber was used to verify the pulp's viability. A complete pulpotomy was conducted by removing the coronal pulp tissue with a 2 mm sharp spoon excavator (Hu-friedy, USA) up to the canal orifices. Hemostasis was attained by direct pressure using a cotton pellet soaked in saline for 2 min after the pulp chamber was fully irrigated with sterile saline (NS 500 mL, sodium chloride 0.9%, Fresenius Kabi, Mumbai, India Pvt. Ltd.). Periodic checks and maintenance of pressure were carried out for up to 5 min. If bleeding persisted beyond 5 min, the tooth was excluded and scheduled for nonsurgical root canal treatment. After satisfactory hemostasis, 2–3 mm of Biodentine™ (Septodont Healthcare India Pvt. Ltd., Raigad, India) was applied to the root canal orifices in accordance with the manufacturer's recommendations. As the baseline radiograph, a PA confirmatory radiograph was obtained using a PSP scanner to verify the Biodentine™ implantation. The Biodentine™ was then covered with a layer of glass-ionomer cement (GC Fuji II), and each layer of the resin composite repair (CeramX dual SphereTEC Nano-Ceramic Composite) was cured for 40 s. After making any required occlusal corrections, the restorations were polished and finished in the same manner as the previous set [Figure 2].

In both the groups, a baseline posttreatment intraoral PA radiograph (IOPA) was taken using the paralleling technique. Patients were advised to take prescribed analgesics only if necessary and to promptly report any persistent posttreatment pain. Figures 1 and 2 show the preoperative photograph, the placement of the dycal and biodentine, and the placement of the composite restoration.

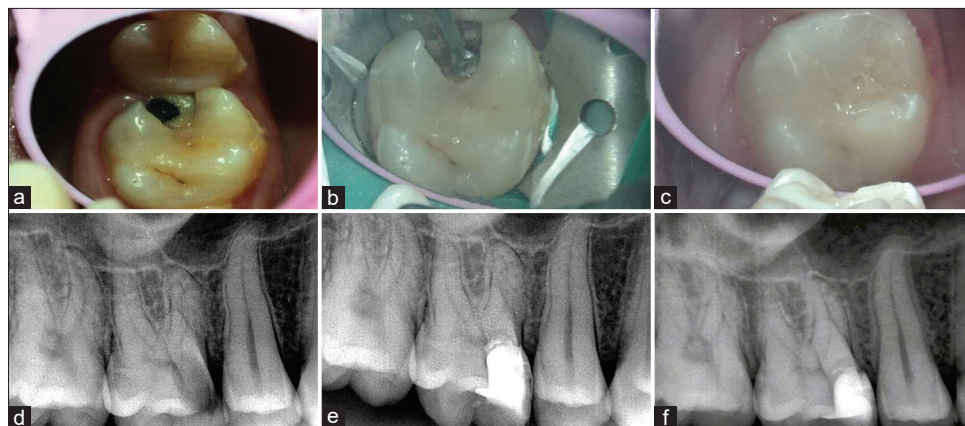


Figure 1: (a) preoperative clinical image of upper molar 16 with deep proximal caries (mesio occlusal) under $\times 1.6$ using dental operating microscope, (b) 1 mm of calcium hydroxide (dycal, dentsply sirona) as a base material over the cavity floor, (c) final finished and polished composite restoration, (d) preoperative radiograph of 16 with mesio occlusal caries, (e) immediate postoperative radiograph, and (f) 12-month postoperative radiograph

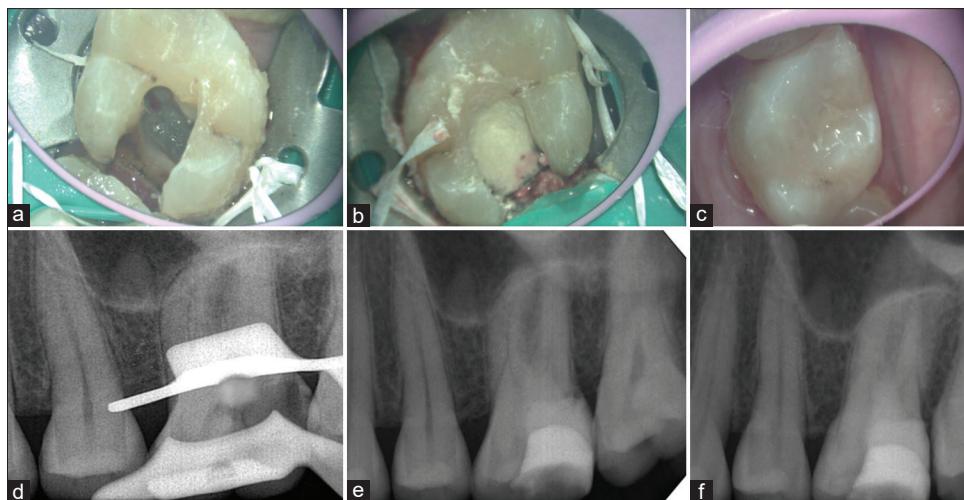


Figure 2: (a) Complete removal of pulp chamber tissues and hemostasis achieved with 0.9% saline, (b) Biodentine placed over canal orifices up to a thickness of 2–3 mm, (c) final finished and polished composite restoration, (d) radiograph confirming the placement of Biodentine over canal orifices Biodentine placed over canal orifices up to a thickness of 2–3 mm, (e) immediate postoperative radiograph, and (f) 12-month postoperative radiograph

The total etch adhesive methodology was followed in both groups as per the guidelines provided by the manufacturers (Prime and Bond NT, Dentsply Sirona, USA). The etchant gel (37% phosphoric acid, EAZ ETCH, Anabond Stedman Pharma, Chennai, India) was applied selectively to the cavity walls alone to preserve the integrity of the pulp capping materials (Biodentine™ and glass ionomer cement/Dycal). This was followed by a thorough rinse with water. The cavities were then dried while preserving the moisture content of the dentin using sterile cotton pellets. After carefully applying the Prime and Bond NT bonding agent to the etched surface, the light-cured (LED D, Woodpecker Medical Instruments Co., Ltd., Guilin, China) process was run for 30 s.

Posttreatment evaluation

An unbiased examiner evaluated patient-reported symptoms using a four-point scale at 24 and 48 h after treatment: (i) no symptoms, (ii) sensitivity, (iii) pain, and (iv) tenderness or sensitivity on mastication or stimulation. Patients exhibiting symptoms of irreversible pulpitis or necrosis, including spontaneous or nocturnal pain, were considered treatment failures.

Independent endodontic evaluations were conducted at 15 days, 3, 6, and 12 months posttreatment. While specific recall visits were scheduled for certain time points, data were collected within a $\pm 10\%$ window of these periods. The examinations included: (1) Symptom Inquiry: using the same criteria as the immediate posttreatment assessment. (2) Percussion Evaluation: assessment of tenderness on percussion. (3) Cold Pulp Sensibility Test (IPC Only): testing for pulp vitality using a cold stimulus. (4) Radiographic Evaluations: a. Baseline IOPA: Radiograph taken immediately after treatment. b. Repeat IOPA's: For

individuals who experienced discomfort, persistent cold sensitivity (IPC), severe tenderness to percussion, or a negative response to cold sensitivity testing in addition to or without radiographic findings of widening of the PDL space/lamina dura loss along the entire length of all or any of the roots. For these patients, root canal treatment or extraction was scheduled, and the treatment procedure was recorded as a failure.

Re-restoration was carried out in the event of a fractured restoration if the tooth was asymptomatic and the pulp sensitivity test was normal; if not, endodontic therapy was started.

Statistical analysis

All the above statistical analysis was done using IBM SPSS software version 23 (IBM Corp., Chicago, IL, USA), with statistical significance set at 5%. In the current study, the descriptive statistics for age, gender, tooth type, preoperative symptoms, and remaining dentin thickness were presented as mean \pm standard deviation, number, and percentage. The relationship between the preoperative symptoms, the response to the cold test, and the treatment result in the two treatment groups was examined using the Pearson Chi-square test. For a 48-week (12-month) timeframe, the Kaplan–Meier survival analysis was used to determine the survival of the treatment procedures.

RESULTS

The study involved 108 symptomatic deep proximal carious molar teeth from 108 subjects, with a mean age of 30.7 ± 10.1 years. Table 1 shows the frequency distribution of teeth, gender, preoperative symptoms, and Cold test response. There was a statistically significant

difference between preoperative symptoms and the cold pulp sensibility test response ($P = 0.000$). The study also found that there was no statistically significant difference between the location of caries and treatment outcome ($P > 0.05$). The remaining dentin thickness (RDT) assessment revealed that the minimum value of RDT in preoperative radiograph was 0.1 mm, whereas the average RDT value was 0.48 ± 0.5 mm. A Chi-square test indicated that there was no statistically significant difference between the location of caries and the remaining dentin thickness ($P = 0.084, P > 0.05$).

12-month posttreatment results are depicted in Table 2. Overall, compared to IPC, the pulpotomy therapy had a greater percentage of no intervention at 12 months after treatment in both treatment groups. At the end of 12 months, nine failures were reported, with 14 subjects lost to follow-up. Failure of restorations and treatment failure is given in Table 2.

The Kaplan–Meier survival analysis graph showed a mean survival period for IPC 42.3 ± 2.35 weeks and for pulpotomy 48 weeks. The overall success rate of restorations was 90.4%, with IPC having a success rate of 82.2% and pulpotomy having a success rate of 98%. The log-rank test determined that there was a statistically significant difference in the survival distributions for the different treatment procedures ($P = 0.009$).

Table 1: Frequency distribution of teeth, gender, preoperative symptoms, and cold test response

	Frequency, <i>n</i> (%)
Distribution of teeth	
Upper first molar	50 (45)
Upper second molar	9 (9)
Lower first molar	38 (35)
Lower second molar teeth	11 (11)
Gender	
Male	50 (46)
Female	58 (54)
Preoperative symptoms	
Pain or sensitivity on mastication	35 (32.4)
Occasional sensitivity	45 (41.6)
Occasional pain	4 (3.7)
Occasional sensitivity and pain	24 (22.2)
Cold test response	
Exaggerated sensitivity	50 (46.3)
Increased sensitivity	26 (24.7)
Mild pain	22 (20.3)
Sensitivity with pain	4 (3.7)
Moderate pain	5 (4.6)
Sensitivity with lingering	1 (0.9)

Table 2: Treatment follow-up distribution at a 12-month period in both the treatment groups

Treatment group	No intervention, <i>n</i> (%)	Repeat restoration, <i>n</i> (%)	Inflamed or necrotic pulp requiring root canal treatment, <i>n</i> (%)	Lost in follow-up, <i>n</i> (%)
IPC (<i>n</i> =54)	33 (61.1)	4 (7.4)	8 (14.8)	9 (16.7)
Pulpotomy (<i>n</i> =54)	44 (81.5)	4 (7.4)	1 (1.9)	5 (9.3)

IPC: Indirect pulp capping

DISCUSSION

Maintaining the health of the pulp is crucial when treating deep cavities. The current study evaluated the efficacy of two different treatment modalities for molar teeth with symptomatic proximal deep caries lesions. The outcome of therapy depends on careful case selection, evaluation, caries removal, and restoration.

Research shows that proximal restorations in posterior teeth may have lower success rates than occlusal restorations and achieving optimal proximal contact in direct Class II composite resin restorations presents a considerable challenge, due to various factors.^[15,16] Thus, the scope of this study was limited to managing deep caries specifically in the proximal areas of molar teeth. A modified categorization system based on Wolters *et al.*, 2017^[14] was used to assess the pulp status of the study’s teeth; only teeth exhibiting moderate pulpitis were included. Teeth with moderate pulpitis were chosen because it was believed that this was the final stage of reversible pulpitis before it became irreversible inflammation and to determine if moderate pulpitis influences treatment outcomes.

Previous studies have shown that IPC can be effective in managing deep caries, with a success rate of 94% at 24-month posttreatment.^[17] Other research on pulpotomy procedures using calcium silicate cement has also shown promising results in managing deep caries in teeth with or without pulp exposure and in teeth with reversible or irreversible pulpitis.^[18-22] However, there is insufficient evidence to determine the most appropriate treatment option for managing deep caries, regardless of whether there is pulp exposure evident in PA radiographs or signs and symptoms of reversible or irreversible pulpitis.^[23] To better understand the most appropriate conservative treatment strategy for these teeth, a randomized allocation was made for pulpotomy and IPC operations in the management of proximal deep caries lesions in molar teeth with symptomatic moderate pulpitis.

In this study, all firm or hard-discolored damaged dentin in the pulpal floor and axial walls was left during caries excavation in a single visit to prevent pulp exposure. To improve bonding techniques, peripheral cavities were excavated until sound dentin was preserved.^[24] Only three teeth out of the 108 subjects had pulp exposure during the caries excavation procedure and were treated with direct pulp capping. A recent study indicates that age

does not appear to be a significant role in the results of VPT, despite the fact that the majority of VPT studies have concentrated on younger age groups.^[25,26] The age group in this study also did not seem to have a significant impact on the treatment outcomes, which is consistent with earlier research. Patients ranging in age from 15 to 68 years had the treatment; the age group of 21–30 years had a greater success rate (37.5%).

According to various clinical studies, irreversible pulpitis does not preclude a patient from undergoing VPT. In this study, patients presented with different preoperative symptoms such as occasional sensitivity, pain, and tenderness on mastication, as well as sensitivity on percussion. When seen radiographically, a few of these teeth showed PDL space widening, and discontinuity in lamina dura was limited to the apical quarter of each root. Testing for cold pulp sensitivity is thought to be the most accurate way to detect teeth that have necrotic pulps.^[27] In this study, the results of the cold pulp sensitivity test showed a statistically significant change between the preoperative symptoms and the cold pulp sensitivity test response.

In this study, the thickness of the remaining dentin was measured before treatment using an IOPA, and no significant relationship was found between the location of the caries (occlusal or proximal) and the thickness of the remaining dentin, or between the thickness of the remaining dentin and the treatment outcome. In addition, the thickness of the remaining dentin was similar in both treatment groups, with minimal standard deviations. This result is in line with previous research by Murray *et al.*, which found no statistically significant relationship between pulp inflammatory symptoms and the thickness of the remaining dentin.^[28] The findings of this study suggest that eliminating all infected dentin in deep carious lesions may not be necessary for effective caries treatment, as long as the restoration effectively seals the lesion and isolates it from the oral environment.

To reduce microbial contamination, the treatment operations in this investigation were carried out in rubber dam isolation, and magnification was achieved using a dental operating microscope. Normal saline was used to control hemostasis for 2 min, with the rationale of not altering radicular pulp biology with the use of NaOCl. There was no significant correlation found between bleeding time and the outcome of VPT in high-success clinical investigations, which reported bleeding periods ranging from 1 to 10 min.^[20]

Complete radiographic healing was seen at 3, 6, and 12 months after a full pulpotomy with Biodentine. Clinical signs and symptoms were improved within 48 h after the procedure. Research indicates that calcium silicate has

a greater ability to promote tissue repair than Ca(OH)₂, likely due to the recruitment of pulp stem cells by calcium silicate.^[29] In this study, more early failures were the outcome of IPC using Ca(OH)₂.

In a research by Baranwal *et al.*,^[7] they examined the use of Biodentine in partial and complete pulpotomies for permanent molars with symptomatic irreversible pulpitis. They observed a success rate of 80.7% for partial pulpotomy and 92.8% for full pulpotomy after a 12-month follow-up period. In addition, the overall success rate of pulpotomies in this study was 98%, aligning with findings from a previous study by the same author. In this study, the researchers selected biodentine as the preferred material for pulpotomy due to its superior antimicrobial properties compared to MTA and its ability to form a hermetic seal at both the coronal and radicular levels.^[30]

It has been demonstrated that Ca(OH)₂, which was formerly thought to be the gold standard for pulp capping, produces erratic and unexpected outcomes, with success rates decreasing with time and failing to offer a sufficient barrier against outside contamination. Over time, Ca(OH)₂ may also dissolve and soften, creating gaps and openings for bacterial growth. This study found that pulpotomy performed better than IPC, which is consistent with the findings of Schwendicke *et al.* (2013) that pulp capping is more suitable for nonsymptomatic pulp in occlusal exposure sites than proximal caries.^[31] More failures were observed in the IPC group due to the thinner composite material compared to pulpotomy. The recall rates at 15 days, 3 months, 6 months, and 12 months postoperatively were 99.1%, 92.6%, 88%, and 81.5%, respectively. A total of 14 patients (13%) were lost to follow-up, likely due to the COVID-19 pandemic lockdown.

Considering the effectiveness of the treatment groups, coronal pulpotomy with Biodentine was found to be more effective in reducing clinical signs and symptoms, achieving radiographic success (absence of PA pathosis), and tooth survival in deep proximal caries molar teeth with symptomatic moderate pulpitis compared to IPC using Ca(OH)₂ (Dycal). However, the study's limitations included the unknown long-term outcomes of pulp status and restoration failures. A comprehensive evaluation of the long-term outcomes for both the pulp and the restored tooth, along with the potential risk factors for early and late failures, is necessary.

CONCLUSION

The study aimed to compare the clinical success of pulpotomy and IPC procedures in treating deep proximal cavities in molar teeth with moderate pulpitis. While previous research has shown promising results for both

methods, there is currently insufficient evidence to determine the best treatment option. The study found that age did not significantly impact treatment outcomes, but IPC with Ca(OH)₂ resulted in more early failures compared to pulpotomy using Biodentine. In addition, the remaining dentin thickness was not a significant factor in the outcome of treatment.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

- Selwitz RH, Ismail AI, Pitts NB. Dental caries. *Lancet* 2007;369:51-9.
- Siqueira J Jr. Microbiology of apical periodontitis. In: Ørstavik D, Pitt Ford T, editors. *Essential endodontology*. 2nd ed. Oxford UK: Blackwell Munksgaard Ltd.; 2008. p. 135-96.
- Schwendicke F, Meyer-Lueckel H, Dörfer C, Paris S. Failure of incompletely excavated teeth – A systematic review. *J Dent* 2013;41:569-80.
- Ricketts D, Lamont T, Innes NP, Kidd E, Clarkson JE. Operative caries management in adults and children. *Cochrane database of systematic reviews*. 2013.
- Bjørndal L, Simon S, Tomson PL, Duncan HF. Management of deep caries and the exposed pulp. *Int Endod J* 2019;52:949-73.
- Selvendran KE, Ahamed AS, Krishnamurthy M, Kumar VN, Raju VG. Comparison of three different materials used for indirect pulp capping in permanent molars: An *in vivo* study. *J Conserv Dent* 2022;25:68-71.
- Baranwal HC, Mittal N, Yadav J, Rani P, Naveen Kumar PG. Outcome of partial pulpotomy versus full pulpotomy using biodentine in vital mature permanent molar with clinical symptoms indicative of irreversible pulpitis: A randomized clinical trial. *J Conserv Dent* 2022;25:317-23.
- Asgary S, Eghbal MJ, Fazlyab M, Baghban AA, Ghoddusi J. Five-year results of vital pulp therapy in permanent molars with irreversible pulpitis: A non-inferiority multicenter randomized clinical trial. *Clin Oral Investig* 2015;19:335-41.
- Asgary S, Eghbal MJ, Ghoddusi J. Two-year results of vital pulp therapy in permanent molars with irreversible pulpitis: An ongoing multicenter randomized clinical trial. *Clin Oral Investig* 2014;18:635-41.
- Taha NA, Ahmad MB, Ghanim A. Assessment of mineral trioxide aggregate pulpotomy in mature permanent teeth with carious exposures. *Int Endod J* 2017;50:117-25.
- Motwani N, Ikhar A, Nikhade P, Chandak M, Rathi S, Dugar M, *et al.* Premixed bioceramics: A novel pulp capping agent. *J Conserv Dent* 2021;24:124-9.
- Witherspoon DE. Vital pulp therapy with new materials: New directions and treatment perspectives – Permanent teeth. *J Endod* 2008;34:S25-8.
- Moher D, Hopewell S, Schulz KF, Montori V, Gøtzsche PC, Devereaux PJ, *et al.* CONSORT 2010 explanation and elaboration: Updated guidelines for reporting parallel group randomised trials. *Int J Surg* 2012;10:28-55.
- Wolters WJ, Duncan HF, Tomson PL, Karim IE, McKenna G, Dorri M, *et al.* Minimally invasive endodontics: A new diagnostic system for assessing pulpitis and subsequent treatment needs. *Int Endod J* 2017;50:825-9.
- Opdam NJ, Loomans BA, Roeters FJ, Bronkhorst EM. Five-year clinical performance of posterior resin composite restorations placed by dental students. *J Dent* 2004;32:379-83.
- Anantula K, Vankayala B, Yadav SS. Proximal contact tightness of direct Class II composite resin restorations with various matrix systems: A systematic review. *J Conserv Dent Endod* 2024;27:11-6.
- Koc Vural U, Kiremitci A, Gokalp S. Randomized clinical trial to evaluate MTA indirect pulp capping in deep caries lesions after 24-months. *Oper Dent* 2017;42:470-7.
- Witherspoon DE, Small JC, Harris GZ. Mineral trioxide aggregate pulpotomies: A case series outcomes assessment. *J Am Dent Assoc* 2006;137:610-8.
- Taha NA, Abdelkhalder SZ. Outcome of full pulpotomy using biodentine in adult patients with symptoms indicative of irreversible pulpitis. *Int Endod J* 2018;51:819-28.
- Taha NA, Khazali MA. Partial pulpotomy in mature permanent teeth with clinical signs indicative of irreversible pulpitis: A randomized clinical trial. *J Endod* 2017;43:1417-21.
- Elmsmari F, Ruiz XF, Miró Q, Feijoo-Pato N, Durán-Sindreu F, Olivieri JG. Outcome of partial pulpotomy in cariously exposed posterior permanent teeth: A systematic review and meta-analysis. *J Endod* 2019;45:1296-306.e3.
- Linsuwanont P, Wimsutthikul K, Pothimoke U, Santiwong B. Treatment outcomes of mineral trioxide aggregate pulpotomy in vital permanent teeth with carious pulp exposure: The retrospective study. *J Endod* 2017;43:225-30.
- Zanini M, Hennequin M, Cousson PY. A review of criteria for the evaluation of pulpotomy outcomes in mature permanent teeth. *J Endod* 2016;42:1167-74.
- Singh S, Mittal S, Tewari S. Effect of different liners on pulpal outcome after partial caries removal: A preliminary 12 months randomised controlled trial. *Caries Res* 2019;53:547-54.
- Matsuo T, Nakanishi T, Shimizu H, Ebisu S. A clinical study of direct pulp capping applied to carious-exposed pulps. *J Endod* 1996;22:551-6.
- Simon S, Perard M, Zanini M, Smith AJ, Charpentier E, Djole SX, *et al.* Should pulp chamber pulpotomy be seen as a permanent treatment? Some preliminary thoughts. *Int Endod J* 2013;46:79-87.
- Pigg M, Nixdorf DR, Nguyen RH, Law AS, National Dental Practice-Based Research Network Collaborative Group. Validity of preoperative clinical findings to identify dental pulp status: A national dental practice-based research network study. *J Endod* 2016;42:935-42.
- Murray PE, Smith AJ, Windsor LJ, Mjör IA. Remaining dentine thickness and human pulp responses. *Int Endod J* 2003;36:33-43.
- Tran XV, Gorin C, Willig C, Barouk B, Pellat B, Decup F, *et al.* Effect of a calcium-silicate-based restorative cement on pulp repair. *J Dent Res* 2012;91:1166-71.
- Bhavana V, Chaitanya KP, Gandhi P, Patil J, Dola B, Reddy RB. Evaluation of antibacterial and antifungal activity of new calcium-based cement (Biodentine) compared to MTA and glass ionomer cement. *J Conserv Dent* 2015;18:44-6.
- Schwendicke F, Stolpe M, Meyer-Lueckel H, Paris S, Dörfer CE. Cost-effectiveness of one- and two-step incomplete and complete excavations. *J Dent Res* 2013;92:880-7.