

COMPARING THE EFFECTIVENESS OF MTA, PRF, AND CALCIUM HYDROXIDE AS PULPOTOMY AGENTS IN MATURE PERMANENT TEETH WITH IRREVERSIBLE PULPITIS: A SYSTEMATIC REVIEW

Running Title: Pulpotomy Biomaterials in Irreversible Pulpitis

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ABSTRACT

Aim and Objective: To compare and to evaluate the effectiveness of MTA, PRF, and Calcium hydroxide as pulpotomy agents based on its clinical and radiographic outcomes in mature permanent teeth with irreversible pulpitis.

Methods: A systematic search was conducted across PubMed, Scopus, the Cochrane Library, ScienceDirect, Google Scholar, and DELNET, covering all eligible studies published till June 2025. Randomised controlled trials that directly compared MTA, PRF, and calcium hydroxide Ch were included. The primary results assessed included postoperative pain, clinical success, and radiographic success, as well as additional results such as pulp sensitivity, cost, and overall treatment duration. The Cochrane RoB 2.0 tool was used to check for bias, and a scoring system was used to rate the level of certainty of the evidence. Because the studies were independent of each other, a qualitative synthesis was done.

Results: Five RCTs involving 637 teeth were included. Mineral trioxide aggregate showed the most consistent

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long-term success, with clinical and radiographic success ranging from 82%–90% up to two years. Platelet-rich fibrin alone or combined with Mineral trioxide aggregate/Bio dentine, demonstrated comparable or improved pain relief and healing, though evidence is limited by smaller sample size and shorter follow-up. Calcium hydroxide showed reduced success over time, falling below 50% at two years in one study.

Conclusion: Pulpotomy with MTA and biologically enhanced materials like PRF is a promising, minimally invasive alternative to Root canal treatments in mature teeth which are diagnosed with irreversible pulpitis. Calcium hydroxide shows inferior long-term outcomes and is not recommended as a primary agent. Further larger-scale, standardized and multicentre trials are needed.

Keywords: Pulpotomy; irreversible pulpitis; vital pulp therapy; mineral trioxide aggregate; platelet-rich fibrin; calcium hydroxide

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Introduction

Irreversible pulpitis among the adult permanent teeth has historically been treated with root canal treatment (RCT), is regarded as the benchmark for pain relief and disease prevention. [1,2] While RCT produces reliable long-term results, it is lengthy, technique-dependent, expensive, and requires removal of significant structure of the tooth, eventually jeopardising the tooth integrity. [3] Vital pulp treatment (VPT) techniques, like pulpotomy, preserve the healthy pulp tissue, allowing it to continue to regenerate. [4]

Pulpotomy success is primarily determined on the substance utilised to cap the pulp tissue. Historically, calcium hydroxide (Ca (OH)₂) being the preferred material because of its antibacterial qualities and capacity to promote dentinal bridge production. [5] However, its limitations, like poor sealing ability, breakdown over time, and creation of tunnel defects within reparative dentin, are well established, resulting with lower longer span success rates. [6] MTA was launched in the 1990s, addressed many of these limitations due to its higher biocompatibility, bioactivity, and sealing capacity. [7,8] MTA induces hard tissue barrier development and has continuously shown good clinical as well as radiological success in pulpotomy treatments. Platelet-rich fibrin, otherwise known as second-generation autologous platelet, concentrate, has gaining increasing attention as a biological scaffold. PRF, which are rich in growth factors and cytokines, promotes tissue repair, angiogenesis, and pulp regeneration, making it a suitable supplement or alternative to synthetic biomaterials. [9]

The research question was formulated with the help of PICOS framework:

Component	Description
Population (P)	Mature permanent teeth with irreversible pulpitis.
Intervention (I)	Pulpotomy using MTA, PRF or Ca (OH) ₂ .
Comparator (C)	Other pulpotomy biomaterials, combinations of biomaterials, or conventional root canal treatment where applicable.
Outcomes (O)	Postoperative pain, clinical and radiographic success, overall treatment success, and when reported, pulp sensibility, treatment cost, and procedure duration.
Study Design (S)	A Randomised controlled trial (RCT)

Eligibility Criteria

Inclusion criteria:

Several randomised controlled trials and clinical investigations have explored the comparative efficacy of Ca (OH)₂, MTA, and PRF in the pulpotomy for the adult permanent teeth having irreversible pulpitis. The outcomes in terms of postoperative pain alleviation, clinical healing, and radiographic success have varied. [10,11,12] Individual studies give useful insights, but the variability in research design, patient groups, follow-up durations, and success criteria makes it more difficult to make solid conclusions. Thus, a systematic review is required to further synthesise available information, evaluate clinical as well as the radiographic outcomes across various materials, and develop evidence-based clinical practice recommendations.

This systematic review compared the efficacy of MTA, PRF, and Ca (OH)₂ as pulpotomy agents within the adult permanent teeth diagnosed having irreversible pulpitis and further aims for determining if the pulpotomy using bioactive and biologically derived materials can providing viable alternative for RCT among the adult patients by combining data from several clinical trials.

METHODOLOGY

Protocol and Registration

The systematic review was conducted according to the Preferred Reporting Items of Systematic Reviews and Meta-Analyses (PRISMA 2020). This is a prospectively registered protocol in the International Prospective Register of Systematic Reviews (PROSPERO) [Registration ID: CRD420251164892].

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1. Randomised controlled trials (RCT).
2. Studies done on pulpotomy upon adult permanent teeth having irreversible pulpitis.
3. Randomized controlled trials evaluating one or more pulpotomy biomaterials in mature permanent teeth diagnosed with irreversible pulpitis.
4. Minimum follow-up period 6 months.
5. Outcomes reported include clinical, radiographic, and combination success.

Exclusion criteria:

1. Non-randomised research includes descriptive, case reports, case series, and reviews.
2. Research on immature permanent teeth and primary dentition.
3. Animal studies, in vitro research, and studies with a follow-up time less than six months.
4. Studies published in language other than English.

Information Sources and Search Strategy

A Systematic search was performed across the different databases: PubMed/MEDLINE, Scopus, WoS, Cochrane Central Register of Controlled Trials (CENTRAL), ScienceDirect, Google Scholar, and DELNET, from January 2000 to June 2025. The MeSH terms used in the study were "pulpotomy," "vital pulp therapy," "mineral trioxide aggregate," "calcium hydroxide," "Ca (OH)₂," "platelet-rich fibrin," "PRF," "bio dentine," "bio ceramic," and "irreversible pulpitis" or "mature permanent teeth." To find new

research, we manually scanned the cited lists of all qualifying papers and pertinent reviews.

Study Selection

Two Reviewers independently assessed the titles and abstracts for eligibility. The entire contents of possibly relevant publications were gathered and evaluated to inclusion and exclusion criteria. Any discrepancies were solved by showing the third reviewer.

Data Extraction

To improve accuracy and consistency, data was extracted in proper standardised format by two reviewers. Information collected included study details (authors, country, year, sample size), participant Characteristics, and follow-up duration. We also recorded the pulpotomy material used, any adjuncts/irrigants, and the restorative protocol. Outcomes were noted systematically, including postoperative pain, clinical success, radiographic success, overall success, and—where reported—cost, treatment time, and pulp sensitivity. Dropouts, adverse events, and overall methodological quality of each trial were also documented to support a complete evaluation of the evidence (Figure 1).

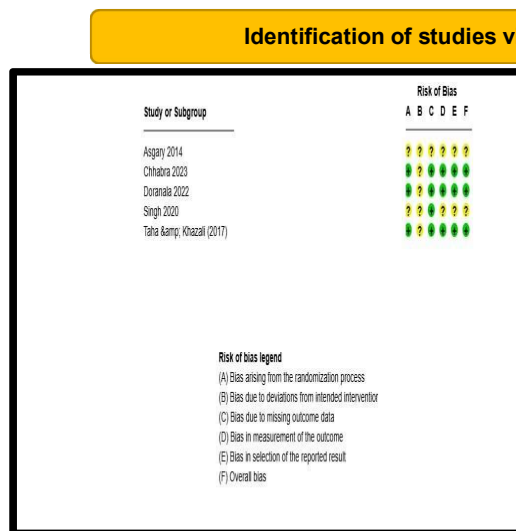


Figure 1. PRISMA 2020 flow diagram for study selection

Risk of Bias Assessment

The Cochrane Risk of Bias 2.0 (RoB 2) technique was utilized to assess the study quality across 5 categories: randomisation, Changes on or after intended treatments, inadequate outcome data, result measurement, and selective reporting. Each domain was classified into low risk, considerable concern, as well as high danger.

Data Synthesis and Statistical Analysis

Because of differences in research design, follow-up durations, and reporting standards across included trials, results were qualitatively synthesised for purposes of this review. Clinical success, radiographic success, and total treatment success were measured by the proportion of teeth that remained asymptomatic as well as free of pathological alterations throughout follow-up periods. These findings were summarized narratively, instead of statistically, by comparing stated percentages of success between various pulpotomy agents across trials.

Certainty of Evidence

All Data was evaluated in level of certainty by using GRADE (Grading of Recommendations, Assessment, Development, and Evaluation).

RESULTS

All included studies were randomised controlled trials conducted across different countries between 2014 and 2025. Sample sizes ranged from 50 treated teeth in small trials to over 400 molars in the largest study, with most enrolling adults with mature permanent molars diagnosed with symptomatic irreversible pulpitis.

Singh et al. (2020) used a three-arm design comparing calcium hydroxide (CH), mineral trioxide aggregate (MTA), and platelet-rich fibrin (PRF), offering a direct comparison between traditional and regenerative pulpotomy agents.

RCT with a two-year follow-up, providing an important benchmark against standard endodontic care. More recent Indian trials by Doranala et al. (2022) and Chhabra et al. (2023) explored bioactive and regenerative strategies, including EndoSequence, T-PRF, Biodentine, and PRF combined with MTA or Biodentine. Taha and Khazali (2017) also compared MTA and CH in cariously exposed molars over two years.

Overall, the evidence suggests a gradual shift from CH-based pulpotomy toward modern bioactive and regenerative materials, with follow-up durations ranging from 6 to 24 months.

Across trials, multiple materials and protocols were tested. Calcium hydroxide (Dycal) was commonly used Traditionally, usually with saline or sodium hypochlorite (NaOCl) irrigation. MTA was the most frequently Checked agent and was restored with amalgam, composite resin, or resin-modified glass ionomer cement, reflecting its broad clinical acceptance. PRF and its variants were assessed as regenerative adjuncts, either alone or in combination with MTA/Biodentine, indicating a shift toward biologically driven approaches. Biodentine and EndoSequence were also evaluated. Sample sizes varied widely, from smaller Indian trials to

>200 teeth in Asgary et al.

Outcome assessment included both the clinical and patient-centred measures. The post-operative pain was evaluated using VAS/NRS at short intervals (6 hours up to 7 days). A clinical success was also measured by a lack of symptoms, including pain, swelling, sinus tract, or with abnormal mobility and determined at a follow-up up to 24 months. Radiographic success was based on the absence of periapical pathology or resorption, providing objective confirmation of healing. Overall success was typically derived from combined clinical and radiographic findings. One study also evaluated treatment duration, cost-effectiveness, and pulp sensitivity testing, offering additional insight into long-term vitality and feasibility

In general, pulpotomy using MTA and newer regenerative approaches produced favourable pain control, high clinical success, and good radiographic healing. MTA repeatedly showed stable long-term success (about 82–90%). PRF, alone or combined with bioactive cements, showed encouraging outcomes for pain reduction and healing, with some studies reporting better overall performance for PRF combinations. In comparison, calcium hydroxide showed decline in success over time. One study reported that its success rate dropped significantly to nearly 43% at the two-year follow-up, suggesting a greater

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tendency for failures in the long term. (Table 2). The risk of bias in RCTs was mainly low to moderate. Most studies had acceptable methodologies; yet, operator blinding was often not possible, and certain trials were lacking in reporting details. Even with these limitations, the overall evidence suggests MTA is the most reliable pulpotomy agent, while PRF showed promising results, but they need bigger and more trials with standardized protocols and longer follow-up. (Table 3).

Table 1. General Study Characteristics

Author (Year)	Country	Study Design	Sample Size (N)	Population Type	Diagnosis	Follow-up Duration
Singh et al. (2020) ³	India	RC T (3-arm)	60 mandibular molars (20 CH, 20 MTA, 20 PRF)	Adults ; mature permanent mandibular molars	Irreversible pulpitis	6 and 12 months
Asgary et (2014) ⁴	Iran	RC T (2-arm)	407 molars (212 pulpotomy,	Adults , mature permanent mandibular molars	Symptomatic irreversible pulpitis	2 years
Doranal et al. (2022) ⁵	India	RC T (3-arm, double-blind)	60 molars (CH, EndoSeq, T-PRF+EndoSeq)	Adults , 15–55 molars	Symptomatic irreversible pulpitis	12 months

Chhabra et (2023) ⁶	India	RC T (4-arm, double-blind)	60 molars (MTA, Biodentine, PRF+MTA, PRF+Biodentine)	Adults , 20–55 molars	Symptomatic irreversible pulpitis	9 months
Taha and Khazali (2017) ⁸	Jordan	RC T (2-arm, parallel)	50 molars (27 MTA, 23 CH)	Adults , 20–52	Symptomatic irreversible pulpitis (caries exposures)	6m,

Table 2. Intervention Details

Group	Pulpotomy Agent	Adjunct Irrigant	Restoration	N
Singh G1 ³	Calcium hydroxide (Dycal)	Saline	Standard restoration	20
Singh G2 ³	MTA	Saline	Standard restoration	20
Singh G3 ³	PRF	Saline	Standard restoration	20
Asgary G1 ⁴	MTA pulpotomy	NaOCl irrigation	Amalgam/composite	212
Doranal G1 ⁵	CH (Dycal)	Saline	Cavit → GIC + composite	18
Doranal G2 ⁵	EndoSeque	Saline	Cavit → GIC + composite	19
Doranal G3 ⁵	T-PRF + EndoSeq	Saline	Cavit → GIC + composite	17

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Chhabra a G1 ⁶	MTA	NaOCl, saline	RMGIC + composite	1 5
Chhabra a G2 ⁶	Biodentine	NaOCl, saline	RMGIC + composite	1 5
Chhabra a G3 ⁶	PRF + MTA	NaOCl, saline	RMGIC + composite	1 5
Chhabra a G4 ⁶	PRF + Biodentine	NaOCl, saline	RMGIC + composite	1 5
Taha Khazali i G1 ⁸	White	2.5% hemostasi s min	IRM temp → Vitrebond liner + amalgam/com posite	2 7
Taha Khazali i G2 ⁸	Dycal (Ca(OH) ₂)	2.5% hemostasi s min	Vitrebond	2 3

Table 3. Results (Summary)

Study	Group	Post-op Pain	Clinical Success	Radiographic Success	Overall Success	Notes
Singh 2020 2023 ³	CH	Similar pain relief	81.5% (6m), , , (1y)	81.5% (6m), , , (1y)	~81%	—
			81.2% (1y)			
Singh 2020 2023	MTA	Similar pain reli	82.4% (6m), 92.3% (1y)	83.4% (6m), 92.3% (1y)	~87%	Best radiographic

³		ef	1% (1y)			
Singh 2020 2023	PRF	Similar pain reli ef	83.8% (6m), 84.1% (1y)	84.2% (6m), 84.1% (1y)	~84%	Comparable
Asgary 2014 ⁴	MTA pulpotomy	Faster relief	~90% at 2y	~88% at 2y	~88–90%	Comparable/better than RCT
Asgary 2014 ⁴	RCT	Slower	~87% at 2y	~85% at 2y	~86%	More invasive
Dorana 2022 ⁵	CH	Gradual reduction	~70% at 1y	~70% at 1y	~70%	Lower than T-PRF
Dorana 2022 ⁵	EndoSeque	Good relief	~75% at 1y	~75% at 1y	~75%	Comparable
Dorana 2022 ⁵	T-PRF EndoSeq	Best relief	~80% at 1y	~80% at 1y	~80%	Highest group
Chhabra 2023 ⁶	MTA	Reduced pain	90% at 9m	70% at 9m	58.3%	Lowest overall
Chhabra 2023 ⁶	Biodentine	Reduced pain	92% at 9m	72.7% at 9m	61.5%	Moderate
Chhabra 2023	PRF + MTA	Reduced pain	95% at 9m	76.9% at 9m	71.4%	Good

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Chhabra 2023 ⁶	PRF Biodentine	Least postoperative pain	97% at 9m	71.4% at 9m	78.5%	Best performer
Taha and Khazali 2017 ⁸	MTA	Immediate failures: 1 case	84% (6m); 83% (1y); 85% (2y)	Comparable to clinical	85% at 2y	Stable long-term success
Taha and Khazali 2017 ⁸	CH	Immediate failures: 3 cases	62% (6m); 55% (1y); (	Declining trend	43% at 2y	>50% failure by 2y

			1y); 43% (2y)			
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Table 3. Risk of Bias (RoB 2.0)

Study	Randomization	Deviations	Missing Data	Outcome Measurement	Reporting	Overall Risk
Singh 2020 ³	Some concerns (limited details)	Some concerns	Low	Some concerns (no blinding stated)	Some concerns	Some concerns
Asgary 2014 ⁴	Low (computer randomization)	Some concerns (operator unblinded)	Low	Low	Low	Low
Dorrala 2022 ⁵	Low	Some concerns (operator unblinded)	Low	Low (blinded evaluator)	Low	Low

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		nded)				
Chhabra 2023 ⁶	Low	Some concerns (operator unblinded)	Low	Low (independent assessor)	Low	Low
Taha and Khatzali (2023)	Low (coin toss allocation, not blinded)	Some concerns (operator unblinded)	Low (few dropouts, >90%)	Low (independent blinded radiographic evaluation)	Low	Low
				(GRADE)		
Postoperative pain	MTA, Biodentine, PRF+ Bio	All short-term relief; PRF + Biodentine showed pain relief	High (>80% reported significant reduction in pain)	Moderate	Operator non-blinding may bias subjective pain reporting.	

017) ⁸		ratio not blinded)	recall)			
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Table 5: Summary of Findings Table (GRADE Approach) Pulpotomy in mature permanent molars with irreversible pulpitis

Outcome	Comparison (Studies)	Relative Effect (Summary)	Absolute Success Rates (approx.)	Certainty of Evidence	Notes

Clinical success	MTA vs CH (3 RCTs)	MTA consistently higher	MTA ~82–90%; CH 81%	Moderate	CH showed marked decline at 2 years (Taha 2017).
	PRF MTA/CH	Comparable to MTA; higher than CH	PRF ~83–84%	Low–Moderate	Limited by small

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					samp les (Singh 2020). ³
	PRF + MTA / PRF Biode ntine (1 RCT)	Higher than MTA/Bio dentine alone	PRF + Bio dentine 97% at 9m	Low	Short follo w- up, singl e trial.
Radio graph ic succe s	MTA vs CH (3 RCTs)	MTA superior	MTA ~83– 92% ; CH 81%	Mo der ate	Long- term superi ority of MTA confir med.

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	Biodegradable MTA (1 RCT)	Similar trends; slightly lower overall	MTA 70%; Biodentine 72.7% at 9m	Low	Short duration, modest sample size.
	PRF / PRF + Bio (2 RCTs)	Comparable	PRF ~84%; PRF Bio dentine ~71%	Low	Heterogeneous results, small samples.
Overall success	MTA vs CH (3 RCTs)	MTA superior & stable; CH declines	MTA 82–90%; CH 43–81%	Moderate	Supported by multiple trials, though some small.
	PRF Biodegradable (1 RCT)	Best performer at 9m	~79%	Low	Single small study, needs replica

					tion.
	Endosseous T-PRF (1 RCT)	T-PRF Endosseous best at 1y (~80%) vs Endosseous Seq (~75%) & CH (~70%)	70–80%	Low	Novel material, limited data.

Discussion

In this systematic review, data analysis was done from randomised controlled trials that compared MTA, PRF (individually or in combinations), & CH as pulpotomy medications in adult permanent teeth with irreversible pulpitis. Our qualitative synthesis indicates that MTA and PRF-based treatments provide superior and more consistent clinical and radiographic results than CH, especially PRF-augmented formulations (e.g., PRF + MTA, PRF + Bio dentine) demonstrating intriguing synergistic benefits in several trials. Across multiple trials, MTA consistently outperformed calcium hydroxide in both clinical & radiographic success. For instance, in Singh et al. (2020)³, MTA achieved ~82–92% radiographic success at 6 to 12 months, versus ~81% for CH; in Taha & Khazali (2017)⁸, CH’s performance declined sharply to ~43% at 2 years while MTA maintained ~85%. These results mirror findings of broader reviews, Silva et al. (2023) found that pulpotomy with ProRoot MTA produced considerably more successful rates compared CH with permanent teeth. [13,14,15,17] Similarly, Li et al.’s (2024) comprehensive evaluation found that MTA had a higher pooled success rate than Calcium hydroxide. [18]

In studies incorporating PRF (Singh, Chhabra, Doranala)[3,5,6] PRF alone showed comparable clinical success to MTA (~83–84%), & PRF + MTA or PRF + Biodentine sometimes surpassed MTA alone (e.g., Chhabra G4’s ~78.5% overall success & lowest post-operative pain).[6] This suggests a potential regenerative advantage due to PRF’s growth factors & scaffold properties. Although PRF is less represented in large-scale

studies, its integration with bioactive cements is consistent with the trend toward biologically enhanced VPT.[16-19]

The transition from CH to bio ceramics, calcium silicate cements, and regenerative adjuncts is consistent with current assessments of vital pulp treatment (VPT). For example, one study found that success rates for VPT utilising hydraulic calcium-silicate cements (HCSCs) in adult posterior teeth which were diagnosed with symptomatic irreversible pulpitis varied from 78% to 90%, which was equivalent to root canal therapy in several trials. Similarly, comprehensive pulpotomy with contemporary bioactive materials might be a feasible option to RCT in situations of irreversible pulpitis.[20-22] Despite the consistent direction favoring MTA & regenerative approaches, absolute success rates varied markedly across studies, especially in the Chhabra trial, where MTA & Biodentine alone had modest overall success (~58–62%) while PRF-based combinations fared better.[6] Differences in hemostasis protocol, irrigants, operator skill, restoration type, & follow-up durations likely contributed to this heterogeneity.[23-24]

Conclusions

Within the limitations of the available evidence, pulpotomy using a newer bioactive and regenerative materials is slowly emerging as an alternative to conventional root canal treatment in adult permanent teeth with irreversible pulpitis. Within the limitations of this study, MTA showed the most reliable approach with clinical and radiographic effectiveness even at longer follow-up periods. PRF alone or in combination with MTA or Bio dentine looks promising, especially in terms of postoperative pain reduction and healing. Calcium hydroxide, on the other hand, tends to lose its success with time and is therefore less reliable in today's practice. However, bigger, well-designed randomised controlled trials with longer follow-up are still needed to corroborate these findings and further improve the existing data.

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