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Original Research Article

CLINICAL OUTCOMES OF MINERAL TRIOXIDE AGGREGATE VERSUS CALCIUM HYDROXIDE FOR PARTIAL PULPOTOMY IN MATURE PERMANENT TEETH WITH IRREVERSIBLE PULPITIS: A RANDOMIZED CONTROLLED TRIAL

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ABSTRACT

Background: Vital pulp therapy has increasingly been considered as a conservative alternative to conventional root canal treatment in selected mature permanent teeth with signs and symptoms of irreversible pulpitis. The choice of pulp-capping material may influence the clinical outcome of partial pulpotomy. The objective is to compare the 6-month clinical outcomes of mineral trioxide aggregate (MTA) and calcium hydroxide (CH) following partial pulpotomy in mature permanent teeth clinically diagnosed with irreversible pulpitis. **Materials and Methods:** This randomized controlled trial was conducted in the Department of Operative Dentistry, Liaquat University of Medical & Health Sciences, Jamshoro/Hyderabad, from January to September 2022. A total of 100 eligible patients were allocated by lottery into two groups of 50 participants each. Following caries removal and pulp exposure, 2–3 mm of inflamed coronal pulp tissue was amputated. Hemostasis was achieved using 2.5% sodium hypochlorite, after which the exposed pulp was treated with either MTA or calcium hydroxide. Patients were clinically evaluated at 3 and 6 months. Clinical success at 6 months was assessed according to the absence of spontaneous pain or discomfort, normal response to cold testing, and absence of swelling or sinus tract. Group outcomes were compared using the chi-square or Fisher's exact test, with $p \leq 0.05$ considered statistically significant. **Results:** The mean age of the participants was 25.77 ± 5.45 years, and 62% were male. The mean baseline pain score was 4.86 ± 0.90 in the MTA group and 4.94 ± 0.99 in the CH group. At 6 months, clinical success was observed in 42/50 (84%) teeth treated with MTA compared with 28/50 (56%) treated with calcium hydroxide. The difference was statistically significant ($\chi^2 = 9.33$, $p = 0.002$). **Conclusion:** MTA demonstrated a significantly higher 6-month clinical success rate than calcium hydroxide when used for partial pulpotomy in mature permanent teeth with clinical signs of irreversible pulpitis. These findings support the potential role of MTA-based vital pulp therapy as a conservative treatment approach in appropriately selected cases.

INTRODUCTION

Irreversible pulpitis has traditionally been managed by complete removal of the dental pulp through root canal treatment.[1] However, increasing understanding of pulpal biology and improvements in bioactive dental materials have challenged the assumption that a clinical diagnosis of irreversible

pulpitis necessarily indicates irreversible inflammation throughout the entire pulp. Vital pulp therapy has consequently emerged as a conservative treatment approach aimed at removing diseased coronal pulp while maintaining the vitality and biological functions of the remaining pulp tissue.[2]

Partial pulpotomy involves removal of approximately 2–3 mm of inflamed coronal pulp tissue beneath the exposure, followed by placement of a biocompatible material over the remaining vital pulp. Preservation of healthy pulp tissue may maintain proprioception, immune defense, vascularity and continued dentine deposition while avoiding the greater removal of tooth structure associated with conventional root canal treatment.[3]

The ability to achieve adequate hemostasis following removal of inflamed tissue may also provide clinically useful information regarding the condition and healing potential of the residual pulp.[4]

The material placed directly over the residual pulp is an important determinant of treatment success. Calcium hydroxide has traditionally been used because of its alkaline pH, antibacterial activity and ability to stimulate hard-tissue formation.[5] Nevertheless, its clinical performance may be compromised by dissolution over time, poor adhesion to dentine and the development of defects within the reparative dentine bridge.[6] Mineral trioxide aggregate has emerged as an alternative bioactive material with favorable biocompatibility, sealing ability, low solubility and dentinogenic properties. Previous clinical studies have demonstrated encouraging outcomes with MTA in vital pulp therapy, including treatment of permanent teeth with clinical signs suggestive of irreversible pulpitis.[7]

However, evidence directly comparing MTA with calcium hydroxide for partial pulpotomy of mature permanent teeth with irreversible pulpitis remains limited, particularly in the local population. Therefore, this randomized controlled trial aimed to compare the postoperative clinical outcomes of MTA and calcium hydroxide following partial pulpotomy in mature permanent teeth clinically diagnosed with irreversible pulpitis.

MATERIALS AND METHODS

Study design and setting: A randomized controlled trial was conducted at the Department of Operative Dentistry, Liaquat University of Medical & Health Sciences, Jamshoro/Hyderabad, from January 2022 to September 2022.

Sample size: The sample size was calculated using OpenEpi based on previously reported 6-month success rates of approximately 84% for MTA and 62% for calcium hydroxide. The calculated sample consisted of 100 participants, with 50 participants in each treatment group.

Participants

Patients with permanent teeth other than third molars were considered eligible. Participants had a non-contributory medical history, deep caries extending at least two-thirds of the dentine, periodontal probing and mobility within the predefined acceptable range, and no clinical or radiographic evidence of pulp necrosis. Both male and female patients aged ≥10 years were eligible.

Teeth were excluded if they were non-restorable, demonstrated a negative response to cold testing, did not exhibit pulp exposure following caries excavation, showed evidence of complete or partial pulp necrosis, or demonstrated periapical pathology associated with irreversible pulpitis.

Randomization

After informed consent and confirmation of eligibility, participants were allocated to either the MTA or calcium hydroxide group using a lottery method, resulting in 50 participants in each group.

Clinical procedure

Following clinical and radiographic assessment, local anesthesia was administered using 2% lidocaine with epinephrine. The tooth was isolated using a rubber dam and disinfected using gauze soaked in 5.25% sodium hypochlorite.

Caries excavation and cavity preparation were performed under water coolant. Following pulp exposure, approximately 2–3 mm of exposed/inflamed pulp tissue was removed using a sterile round bur. The pulp wound was irrigated with 2.5% sodium hypochlorite, and hemostasis was attempted using a cotton pellet soaked in 2.5% sodium hypochlorite for 2–3 minutes. The procedure could be repeated for another 2–3 minutes when necessary. Teeth in which adequate hemostasis could not be obtained were managed by root canal treatment.

In the MTA group, freshly prepared MTA was applied to the pulp wound. A moist cotton pellet was subsequently placed to facilitate setting, followed by a temporary coronal seal. At the subsequent visit, MTA setting was confirmed, a resin-modified glass-ionomer liner was applied, and the tooth was permanently restored.

In the calcium hydroxide group, calcium hydroxide was placed over the pulp tissue, followed by resin-modified glass ionomer and definitive restoration during the same appointment.

Follow-up and outcome

Participants were clinically evaluated at 3 and 6 months.

The primary outcome was clinical success at 6 months. A case was considered clinically successful when there was:

1. No spontaneous pain or discomfort;
2. A normal response to cold testing; and
3. No clinically detectable swelling or sinus tract.

Statistical analysis

Data were analyzed using SPSS version 24. Continuous variables, including age and pain scores, were summarized using means and standard

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deviations or medians and interquartile ranges where appropriate. Normality was assessed using the Shapiro-Wilk test.

Categorical variables were reported as frequencies and percentages. Clinical success was compared between treatment groups using the chi-square test or Fisher's exact test. Age, sex, tooth number and extension of deep caries were considered potential effect modifiers and were examined through stratified analyses. Statistical significance was established at $p \leq 0.05$.

RESULTS

A total of 100 patients were included, with 50 assigned to the MTA group and 50 to the calcium hydroxide group. The overall mean age was 25.77 ± 5.45 years. Sixty-two percent of participants were male and 38% were female.

The baseline mean age and VAS pain scores were comparable between the MTA and calcium hydroxide groups. However, some differences were observed in the distribution of sex, age categories, and extension of deep caries between the treatment groups. [Table 1]

Table 1: Baseline Demographic and Clinical Characteristics of Participants by Treatment Group

Characteristic	MTA (n=50)	Calcium Hydroxide (n=50)
Age (years), mean ± SD	25.36 ± 5.24	26.18 ± 5.68
Baseline VAS pain score, mean ± SD	4.86 ± 0.90	4.94 ± 0.99
Male, n (%)	34 (68.0)	28 (56.0)
Female, n (%)	16 (32.0)	22 (44.0)
Age ≤30 years, n (%)	43 (86.0)	38 (76.0)
Age 31–45 years, n (%)	7 (14.0)	12 (24.0)
Deep caries extension: Yes, n (%)	50 (100)	40 (80.0)
Deep caries extension: No, n (%)	0 (0)	10 (20.0)

Postoperative pain scores decreased in both groups during follow-up, with lower mean VAS scores observed in the MTA group at both 3 and 6 months. At 6 months, a positive sensibility response was observed in 42 of 50 patients (84%) of the MTA group compared with 28 of 50 (56%) of the calcium hydroxide group. [Table 2]

Table 2: Postoperative Clinical Assessment at 3 and 6 Months According to Treatment Group

Follow-up	Clinical parameter	MTA (n=50)	Calcium Hydroxide (n=50)
3 months	VAS pain score, mean ± SD	1.32 ± 0.25	2.68 ± 0.36
	Sinus tract: Yes, n (%)	0 (0)	3 (6.0)
	Sinus tract: No, n (%)	50 (100)	47 (94.0)
	Sensibility test: Positive, n (%)	40 (80.0)	21 (42.0)
	Sensibility test: Negative, n (%)	10 (20.0)	29 (58.0)
6 months	VAS pain score, mean ± SD	0.80 ± 0.26	2.60 ± 0.37
	Sinus tract: Yes, n (%)	0 (0)	0 (0)
	Sinus tract: No, n (%)	50 (100)	50 (100)
	Sensibility test: Positive, n (%)	42 (84.0)	28 (56.0)
	Sensibility test: Negative, n (%)	8 (16.0)	22 (44.0)

The difference was statistically significant (χ^2 = 9.33, p = 0.002).

At 6 months, clinical success was significantly higher in the MTA group (84%) than in the calcium hydroxide group (56%). The difference between the two treatment groups was statistically significant (χ^2 = 9.33, p = 0.002). [Table 3]

Table 3: Comparison of 6-Month Clinical Success Between MTA and Calcium Hydroxide Groups

Clinical outcome	MTA (n=50)	Calcium Hydroxide (n=50)	Total (n=100)	p-value
Successful	42 (84.0%)	28 (56.0%)	70 (70.0%)	0.002
Unsuccessful	8 (16.0%)	22 (44.0%)	30 (30.0%)	
Total	50 (100%)	50 (100%)	100 (100%)	

DISCUSSION

The present randomized controlled trial compared mineral trioxide aggregate (MTA) and calcium hydroxide (CH) as pulp-capping materials following partial pulpotomy in mature permanent teeth with clinical signs of irreversible pulpitis. The principal finding was that MTA produced a significantly better clinical outcome than calcium hydroxide at six months. Clinical success was achieved in 84% of teeth treated with MTA compared with 56% treated with calcium hydroxide (p = 0.002). These findings support the potential use of vital pulp therapy as a conservative treatment approach in carefully selected mature permanent teeth.

The superior outcome observed with MTA is consistent with previous comparative research. Chailertvanitkul et al. (2014),[8] conducted a randomized controlled trial comparing MTA and calcium hydroxide for partial pulpotomy of cariously exposed permanent molars. Similarly, Qudeimat et al. (2007),[9] compared calcium

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hydroxide and MTA for partial pulpotomy of permanent molars with deep caries. Furthermore, the meta-analysis by Taneja and Singh (2019),[10] favored MTA over calcium hydroxide as a pulpotomy agent in permanent teeth.

The 84% success rate with MTA observed in the present study is also broadly comparable with previous clinical investigations. Previous evidence reported a 92.7% success rate at three years following MTA pulpotomy in permanent teeth with reversible or irreversible pulpitis. Another study involving young permanent teeth with irreversible pulpitis reported a 91% success rate (20/22) at one-year follow-up.[11,12] Although these rates are somewhat higher than the 84% observed in the present study, differences in patient selection, age, pulpal diagnosis, treatment protocol, follow-up duration and definitions of treatment success may explain the variation.

The present findings are particularly relevant because the participants had mature permanent teeth with clinical features of irreversible pulpitis. Traditionally, such teeth have frequently been managed by conventional root canal treatment; however, contemporary evidence suggests that a clinical diagnosis of irreversible pulpitis does not necessarily indicate irreversible inflammation throughout the entire pulp. Removal of superficially inflamed pulp tissue may therefore leave underlying tissue capable of healing and maintaining vitality.[13] The ability to control bleeding following removal of inflamed pulp tissue has also been proposed as an indicator of the degree of inflammation and healing potential of the remaining pulp.[14]

At three months, 80% of teeth in the MTA group showed a positive sensibility response compared with 42% in the calcium hydroxide group, while at six months the corresponding proportions were 84% and 56%, respectively. Postoperative VAS pain scores were also lower in the MTA group at both follow-up assessments.

Several biological and material properties may explain the superior performance of MTA. Calcium hydroxide has traditionally been used in vital pulp therapy because of its highly alkaline pH, antibacterial activity and ability to stimulate hard-tissue formation. However, its disadvantages include potential caustic effects on pulp tissue, dissolution over time, poor adhesion to dentine and the occurrence of tunnel defects within the reparative dentine bridge, which may provide pathways for microleakage.[15-17]

In contrast, MTA demonstrates favorable biocompatibility, sealing ability, low solubility and dentinogenic activity. Experimental evidence also indicates that MTA may produce a relatively mild inflammatory response and promote more predictable calcified/dentine bridge formation. Its sealing properties may further reduce microleakage and subsequent bacterial contamination.[18,19] These properties provide a plausible biological explanation for the higher clinical success observed with MTA in the present study.

Age appeared to influence treatment outcomes. Among participants aged ≤30 years, success was observed in 95.3% of the MTA group compared with 65.8% of the calcium hydroxide group ($p = 0.001$). Younger permanent teeth may possess greater pulpal healing and self-repair capacity than older or fully mature teeth.20 Nevertheless, the older subgroup in the present study was small; therefore, the lack of statistical significance among participants aged 31–45 years should be interpreted cautiously.

Sex-stratified analysis showed significantly greater success with MTA among females (87.5% vs. 45.5%, $p = 0.008$), whereas the difference among males (82.4% vs. 64.3%, $p = 0.106$) did not reach statistical significance. There is insufficient evidence from this study to conclude that sex modifies the biological effectiveness of MTA, particularly given the relatively small subgroup sample sizes.

Similarly, among participants with deep caries extension, clinical success was 84% with MTA and 70% with calcium hydroxide, although the difference was not statistically significant ($p = 0.112$). This subgroup finding should be interpreted cautiously because of the imbalance in the distribution of deep caries extension between the two treatment groups.

Previous clinical evidence has demonstrated encouraging outcomes for MTA pulpotomy in cariously exposed permanent teeth, and longer-term evidence has suggested that MTA may provide more favorable outcomes than calcium hydroxide.21,22 These findings, together with the present results, support the growing role of bioactive materials such as MTA in vital pulp therapy.

Overall, the present study demonstrated an 84% six-month clinical success rate with MTA compared with 56% with calcium hydroxide. This finding is consistent with previous comparative studies and meta-analytic evidence indicating more favorable outcomes with MTA than calcium hydroxide in vital pulp therapy.21-23 MTA-based partial pulpotomy may therefore represent a conservative treatment option for appropriately selected mature permanent teeth with clinical signs of irreversible pulpitis. Larger multicenter trials with longer clinical and radiographic follow-up are needed to establish its long-term effectiveness.

CONCLUSION

Partial pulpotomy using mineral trioxide aggregate demonstrated a significantly higher 6-month clinical success rate than calcium hydroxide in mature permanent teeth with clinical signs of irreversible pulpitis (84% versus 56%, $p = 0.002$).

MTA-based partial pulpotomy may therefore represent a conservative vital pulp treatment option

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for appropriately selected mature permanent teeth. However, longer-term clinical and radiographic evidence is required before the findings can be generalized broadly.

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