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Success of pulpotomy with MTA in primary teeth: A systematic review and meta-analysis

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Abstract:

The challenge of effectively managing primary teeth with irreversible pulpitis in pediatric dentistry is of interest. The clinical and radiographic success of different pulpotomy materials, including Mineral Trioxide Aggregate (MTA), in comparison to conventional materials like formocresol, ferric sulfate, calcium hydroxide, and Biodentine is reported. Therefore, it is of interest to evaluate the effectiveness of materials like MTA in pulpotomies for primary teeth with irreversible pulpitis. The meta-analysis revealed that MTA pulpotomies had a clinical success rate of 97.02% and a radiographic success rate of 94.21%, outperforming ferric sulfate, Biodentine and calcium hydroxide. CEM and Calcium Silicate Cements showed comparable success rates to MTA. Thus, MTA demonstrated superior clinical and radiographic outcomes for pulpotomy in primary teeth with irreversible pulpitis, showing statistically significant differences compared to other materials.

Keywords: Pulpotomy, mineral trioxide aggregate/ MTA, pulp therapy, formocresol, irreversible pulpitis, primary teeth

Background:

The conservative management of primary teeth with irreversible pulpitis presents a significant clinical challenge in pediatric dentistry **[1]**. Preserving the primary dentition is crucial for maintaining function, aesthetics, and proper alignment of the permanent teeth **[2]**. Pulpotomy, a widely accepted procedure for treating cariously exposed primary molars, is a critical dental procedure frequently employed to manage extensively decayed primary teeth and maintain their functionality until natural exfoliation **[3]**. The technique involves removing the coronal part of the dental pulp, followed by placing a medicament that preserves the vitality of the remaining radicular pulp **[4]**. For decades, numerous materials have been used in pulpotomy, each designed to achieve optimal clinical and radiographic outcomes **[5]**. Mineral trioxide aggregate (MTA) has emerged as a prominent material due to its excellent biocompatibility, practical sealing ability, and regenerative properties **[6]**. However, the quest for the ideal pulpotomy material is ongoing, with numerous studies comparing MTA to other traditional and contemporary materials **[7]**. Therefore, it is of interest to report the clinical and radiographic outcomes of pulpotomy in primary teeth using various materials compared to MTA.

Review:

This systematic review and meta-analysis investigates the success of MTA (calcium silicate-based cements) compared to other materials in pulpotomies of primary teeth with irreversible pulpitis. Using the PICOS framework, the Population (P) included primary teeth with irreversible pulpitis, the Intervention (I) involved calcium silicate-based cements (*e.g.*, MTA, CEM, Biodentine), and the Control (C) group used conventional materials (formocresol, ferric sulfate, calcium hydroxide). The Outcome (O) was clinical and radiographic success rates, and the Study design (S) focused on randomized controlled trials (RCTs). A thorough literature search was performed between March 1 and May 31, 2024, using PubMed, the Cochrane Library, Google Scholar, and Semantic Scholar. Only RCTs published in English or translated into English with full texts were included. Studies with a minimum 12-month follow-up were selected. The review adhered to PRISMA 2020 guidelines, and the detailed study selection process is shown in **Table 1**. The sources and methodology of this systematic review and meta-analysis were designed to ensure accuracy and reliability. A comprehensive literature search was conducted by two researchers between March 1, 2024, and May 31, 2024, targeting English-language studies with full texts available. The primary databases searched were PubMed and the Cochrane Library, extended to Google Scholar and Semantic Scholar for comprehensive coverage. No date restrictions were applied, and only randomized controlled trials (RCTs) were included. The review followed PRISMA 2020 guidelines, ensuring a standardized approach. Eligibility criteria included RCTs involving children under 10 years with irreversible pulpitis in primary teeth and a minimum 12-month follow-up for clinical and radiographic success. The PRISMA 2020 flow diagram of the study selection process is shown in **Figure 1**.

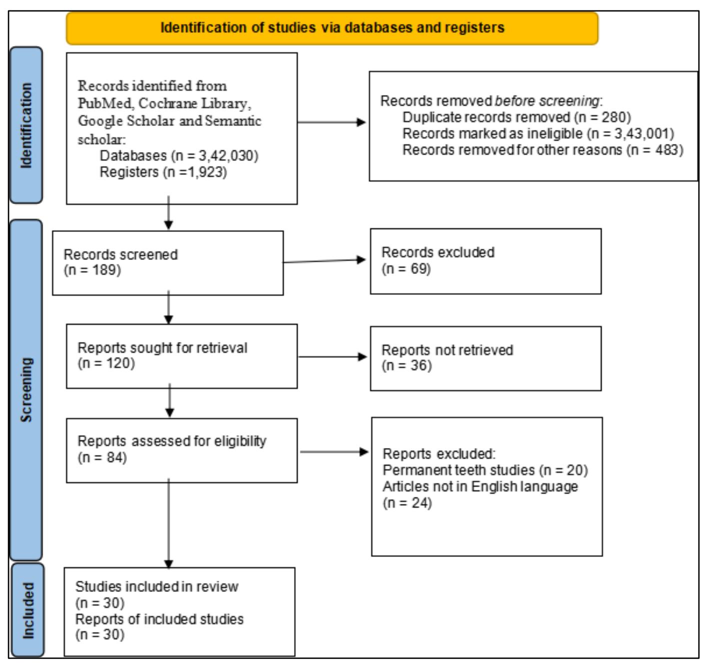

Figure 1: PRISMA 2020 flow diagram

The risk of bias (ROB) in the studies was assessed using the Cochrane Risk of Bias II tool, with independent assessments by both researchers and resolution of discrepancies through

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discussion or a third reviewer. The study is registered on PROSPERO (CRD42023468690, October 2023). Meta-analysis was conducted using forest plots to evaluate pooled clinical and radiographic success rates of pulpotomy materials. Heterogeneity was assessed with the I^2 statistic, and publication bias was examined through funnel plot analysis. Statistical analysis was performed with MedCalc software, ensuring a rigorous, unbiased comparison of MTA and other materials in primary teeth with irreversible pulpitis. This study follows PRISMA guidelines to provide reliable insights for pediatric dental practitioners. The clinical and radiographic successes of pulpotomy using MTA and other materials in primary teeth with irreversible pulpitis for 30 studies (over 2500 participants) are reported in **Table 2**. Comparison of clinical and radiographic success of pulpotomy of calcium hydroxide, Biodentine, formocresol, ferric sulfate with MTA in primary teeth with irreversible pulpitis is reported in **Table 3**. The Risk of Bias summary was assessed using the Cochrane Risk of Bias II tool (**Figure 2)**. The corresponding funnel plots for detecting publication bias are available in the additional information. Clinical and radiographic success of pulpotomy using MTA in primary teeth with irreversible pulpitis for 30 studies (over 2500 participants), the forest plot and funnel plot analyses are reported in **Figure 3 to Figure 6**.

Table 1: Data extraction

AUTHOR	SAMPLE SIZE	Comparison between	After 12 months follow-up			
(total articles - 30)			CLINICAL SUCCESS (%)		RADIOGRAPHIC SUCCESS (%)	
			Intervention	Control	Intervention	Control
Alnassar *et al*. [9]	40 s primary mandibular molars in 40 healthy children aged 6−8 years	MTA vs Bioceramic putty	Bioceramic putty	MTA	Bioceramic putty	MTA
			100%		100%	
				95%		95
Khorakian *et al*. [10]	102 primary second molars in 51 children aged between 4 and 6 years	CEM vs zinc oxide eugenol after electrosurgery (ES/ZOE)	CEM	ES/ZOE	CEM	ES/ZOE
			100%	100%	97.90%	98.00%
Haghgoo *et al*. [11]	34 children aged 3-8 years	MTA, CH, or CEM	CH 96.7%	MTA 100%	CH 86.7%	MTA 100%
			CEM 100%		CEM 100%	
Malekafzali *et al*. [12]	80 teeth from Forty children aged 4-8 years	MTA and CEM	CEM	MTA	CEM	MTA
			100%	100%	100%	100%
Çelik *et al*. [40]	44 mandibular primary molars in 44 children (24 boys, 20 girls) aged 5–9 years	MTA vs Biodentine	MTA	Biodentine	MTA	Biodentine
		(24 Month follow up)				
			100%	89.40%	100%	89.40%
Pastor *et al*. [13]	90 primary Molars from patients aged 4–9 years	Biodentine and MTA	Biodentine	MTA	Biodentine	MTA
			100%	97.40%	94.40%	97.40%
Silva *et al*. [14]	Forty-five primary mandibular molars	calcium hydroxide mixtures and mineral trioxide aggregate	calcium hydroxide mixtures	MTA	calcium hydroxide mixtures	MTA
			i)CH+saline33%	100%	i)CH+saline33%	100%
			ii) CH+PEG		ii) CH+PEG	
			73%		73%	
Kang *et al*. [15]	151 molars from 102 children of 3–10 years old	ProRoot MTA, OrthoMTA and RetroMTA	OrthoMTA 94.7% RetroMTA	ProRoot MTA,	OrthoMTA 94.7% RetroMTA	ProRoot MTA,
			94.70%	100%,	94.70%	100%,
Zhao *et al*. [16]	20 Children who had at least one pair of carious primary molars	iRoot BP Plus and mineral trioxide aggregate (MTA)	iRoot BP Plus	MTA	iRoot BP Plus	MTA
			87%	96%	87%	96%
Bani and Odabaş *et al*. [17]	primary molars from 32 children of 4- to 9-year-olds	Biodentine™ and mineral trioxide aggregate (MTA)	Biodentine	MTA	Biodentine	MTA
			96.80%	96.80%	93.60%	87.10%
Erdem *et al*. [18]	32 healthy 5- to 7-year-old children with 128 carious primary molars	Mineral trioxide aggregate (ProRoot MTA),	ferric sulfate 100%	ProRoot MTA	ferric sulfate 100%	ProRoot MTA
		ferric sulfate (15.5 % FS), formocresol (1:5 dilution of Buckley's FC) and zinc oxide eugenol (ZOE)	formocresol	100%	formocresol	
			100%		100%	
			ZOE 92%		ZOE 92%	
Liu *et al*. [41]	40 primary molars of 4- to 9-year-old children	MTA and CH	CH	MTA	CH	MTA
			64.70%	94.10%	64.70%	94.10%
Fernández *et al*. [19]	total of 90 primary molars in children aged 4–9 years	mineral trioxide aggregate and Biodentine	Biodentine	MTA	Biodentine	MTA
			97%	92%	95%	97%
Yilmaz *et al*. [20]	96 primary second molars from 32 children aged 5 to 9 years	RetroMTA, OrthoMTA, and ferric sulfate	O-MTA 96.4%	75% for FS	O-MTA	50% for FS
			R-MTA 92.8%		85.80%	
					R-MTA 82.2%	
Rasteh *et al*. [21]	42 children aged 4-9 years old	mineral trioxide aggregate and cold ceramic	cold ceramic	MTA	cold ceramic	MTA
			100%	100%	97%	100%
Hassanpour *et al*. [22]	90 bilateral primary molars from 45 healthy	TheraCal and MTA	TheraCal	MTA	TheraCal	MTA
	5- to 8-year-old children		99:4±3:8%	100%	97:2 ± 11:6%	98:8±7:7%
Rajashekharan *et al*.[23]	Fifty-eight patients (82 teeth) in patients above 3 years of age	Biodentine; ProRoot White Mineral Trioxide Aggregate (WMTA);	Biodentine	ProRoot WMTA	Biodentine	ProRoot WMTA
		Tempophore	95.24%	100%	94.40%	90.90%
			Tempophore		Tempophore	
			95.65%		82.40%	
Randa *et al*. 2020 [24]	72- second primary molars in 4 to 8 years old children	Nanohydroxyapatite (NHA), Mineral Trioxide Aggregate (MTA), Formocresol	NanoHA	MTA	NanoHA	MTA

		(FC)				
			54.20%	87.50%	41.70%	79.20%
			Formocresol		Formocresol 75 %	
			87.50%			
Eshghi *et al*. **[25]**	52 children aged 3–6 years	MTA and Biodentine	88.46%	88.46%	88.46%	88.46%
Guven *et al*. **[26]**	29 healthy 5- to 7-year-old children	ProRoot MTA [PR-MTA], MTA-Plus [MTA-P], and Biodentine [BD]) and ferric sulfate [FS]	ferric sulfate [FS] 82.75%	PR-MTA	ferric sulfate [FS] 82.75%	PR-MTA
				93.10%		93.10%
				MTA-P		MTA-P
				96.55%		96.55%
				Biodentine		Biodentine
				89.65%		89.65%
Sakai *et al*. **[27]**	36 primary mandibular	mineral trioxide aggregate (MTA) and Portland cement (PC)	Portland cement (PC)	MTA	Portland cement (PC)	MTA
	molars of children aged 5-9 years old		100%	100%	100%	78.60%
Noorollahian *et al*. **[28]**	60 lower second primary molars of 46 children 5-7 years of age	mineral trioxide aggregate and formocresol	Formocresol	MTA	Formocresol	MTA
Holan *et al*. **[29]**	64 primary molars in 35 children4 to 12 years	mineral trioxide aggregate and formocresol	mineral trioxide aggregate	Formocresol	mineral trioxide aggregate	Formocresol
			97%	83%	58%	52%
Moretti *et al*. **[30]**	45 primary mandibular molars in 23 children between 5 and 9 years old	mineral trioxide aggregate, calcium hydroxide and formocresol	CH 36 %	FC 100%	CH 36 %	FC 100%
				MTA 100%		MTA 100%
Olatosi *et al*. **[31]**	50 primary molars in 37 children aged 4-7 years	mineral trioxide aggregate and formocresol	FC 81%	MTA 100%	FC 81%	MTA 96%
Agamy *et al*. **[32]**	72 primary molars in 24 children	Mineral Trioxide Aggregate and Formocresol	Formocresol	White MTA	Formocresol	White MTA
			90%	80%	90%	80%
				Gray MTA		Gray MTA
				100%		100%
Carti *et al*.**[33]**	25 children (50 human primary molar teeth) aged between 5 and 9 years	Mineral Trioxide Aggregate and Biodentine	Biodentine	MTA	Biodentine	MTA
			96%	96%	60%	80%
Juneja *et al*. **[34]**	51 primary molars of children aged 5–9 years old	Biodentine, mineral trioxide aggregate and formocresol	Biodentine 100%	MTA	Biodentine	MTA
			formocresol 73.3%	100%	86.60%	100%
					Formocresol	
					73.3	
Sirohi *et al*. **[35]**	Fifty primary molar in children aged 4 to 8 years	Ferric Sulfate (FS) and Bioactive Tricalcium Silicate Cement	FS	Biodentine	FS	Biodentine
			96%	100%	84%	92%

Table 2: Summary statistics: percentage clinical and radiographic success and 95% CI - all studies

Intervention	No of studies	Sample size	REM/ FEM	% Success	Confidence Interval
		CLINICAL			
MTA	33	2219	REM	97.02	95.46, 98.26
Formocresol	8	542	REM	91.90	82.66, 97.84
Ferric sulfate	4	303	REM	90.86	71.67, 99.72
Biodentine	8	491	REM	95.82	92.16, 98.36
Ca hydroxide	5	206	REM	76.37	50.95, 94.38
Ca enriched mixture	3	216	FEM	99.67	97.71, 99.99
Ca silicate	2	126	FEM	99.08	95.494, 99.96
		RADIOGRAPHIC			
MTA	33	2219	REM	94.21	91.20, 96.63
Formocresol	8	542	REM	88.17	73.25, 97.51
Ferric sulfate	4	303	REM	79.23	42.23, 99.31
Biodentine	8	491	REM	88.47	81.40, 94.02
Ca hydroxide	5	206	REM	73.35	50.09, 91.24
Ca enriched mixture	3	216	FEM	99.67	97.71, 99.99
Ca silicate	2	126	FEM	97.67	93.32, 99.52

The values are percent success.
REM- Random effect model/ FEM- fixed effect model; CI- Confidence Interval

Table 3: Summary statistics: Odds ratios – various pulpotomy agents vs MTA (percentage clinical and radiographic success and 95% CI - all studies)

Intervention Vs. MTA	No of studies	Sample size	REM/ FEM	Odds ratio	Confidence Interval
		CLINICAL			
Ca hydroxide	5	206	FEM	0.046	0.02, 0.13
Biodentine	8	491	REM	2.858	1.06, 7.67
Formocresol	8	542	REM	0.304	0.06, 1.47
Ferric sulfate	5	378	FEM	0.191	0.10, 0.36
		RADIOGRAPHIC			

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Ca hydroxide	5	206	FEM	0.049	0.02, 0.13
Biodentine	8	491	FEM	0.976	0.63, 1.51
Formocresol	8	542	REM	0.779	0.22, 2.77
Ferric sulfate	5	378	FEM	0.201	0.13, 0.32

The values are Odds Ratios
REM- Random effect model/ FEM- fixed effect model; CI- Confidence Interval

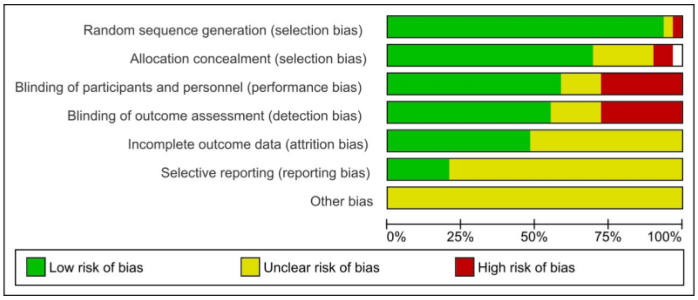

Figure 2: Risk of bias assessment summary.

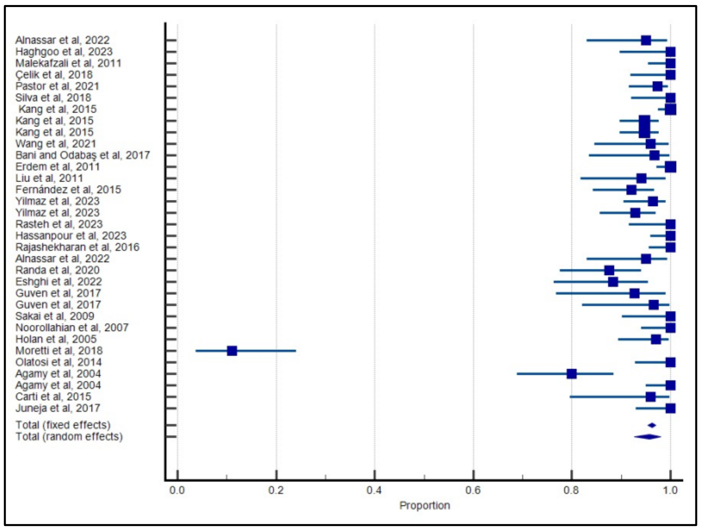

Figure 3: Forest plot – clinical success MTA

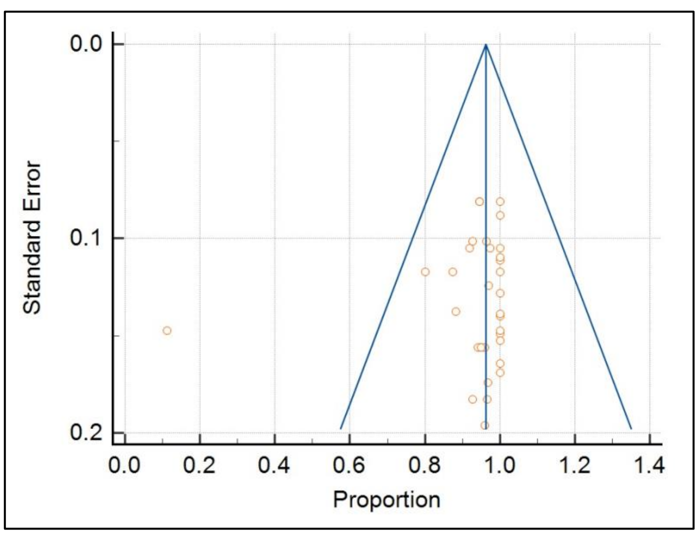

Figure 4: Funnel plot – clinical success MTA

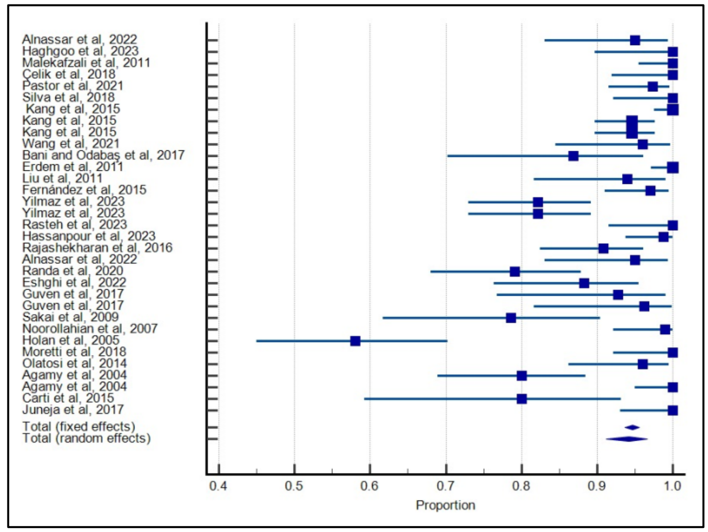

Figure 5: Forest plot – radiographic success MTA

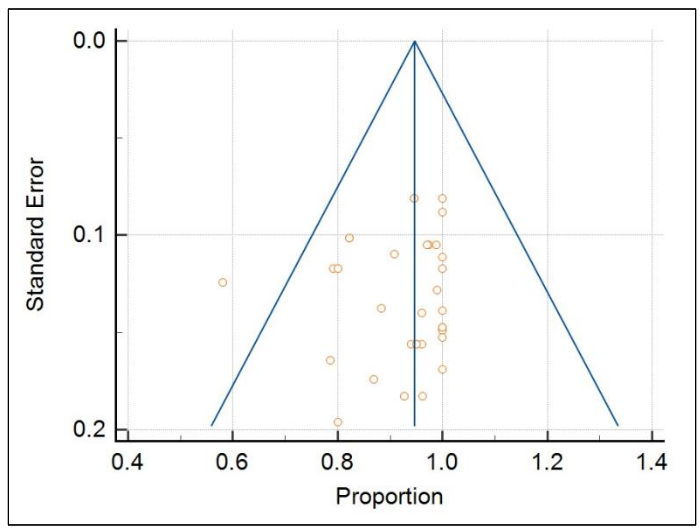

Figure 6: Funnel plot – radiographic success MTA

Discussion:

Irreversible pulpitis is when the dental pulp becomes inflamed and damaged to the point where it cannot heal independently. This condition is usually a result of deep decay, trauma, or repeated dental procedures that irritate the pulp **[35]**. Key characteristics of irreversible pulpitis include severe, intense, lingering pain, especially in response to hot or cold stimuli. The pain may also be spontaneous, without any external trigger. Severe inflammation leads to irreversible damage. As the condition progresses, the pulp may become necrotic, potentially leading to infection and an abscess at the root tip. Irreversible pulpitis is believed to require more invasive treatments than pulpotomy because the pulp cannot recover independently **[36]**. The standard therapy for irreversible pulpitis is to remove the inflamed and damaged pulp to prevent further complications. In primary teeth, this is usually done through pulpotomy (removal of the pulp from the coronal portion) or pulpectomy (removal of the entire pulp), followed by filling the space with a suitable material **[11]**. If left untreated, irreversible pulpitis can lead to more severe dental issues, including abscess formation, bone loss around the tooth and potentially needing tooth extraction. The emergence of calcium silicate-based materials, particularly MTA and newer materials like Biodentine, has significantly transformed the practice of pulpotomy, especially in pediatric dentistry **[37]**. These materials have introduced a paradigm shift in the management of dental pulp therapy, primarily due to their superior biological properties (includes the inductive ability leading to dentin formation), clinical efficacy and long-term success rates **[13]**. These materials have revolutionized pulpotomy procedures by offering more biocompatible, effective and durable solutions for managing irreversible pulpitis in primary teeth. These materials have set a new standard in dental pulp therapy, leading to better patient outcomes and transforming the approach to pediatric dental care. Pulpotomy was used initially as a devitalisation procedure for inflamed pulp just for the pain to subside which is an obsolete concept now. We now prefer preservation/ regeneration approach to the earlier mummification/ devitalization practice **[38]**. Devitalization, preservation and regeneration reflect the evolution of the procedure from a focus on simply managing symptoms to promoting long-term dental health and natural healing. These approaches offer more sustainable outcomes, especially in pediatric patients, by maintaining the function and health of the affected tooth until it can naturally exfoliate or continue to develop (as in the case of permanent teeth) . Although several randomised controlled trials have been available reporting success of these materials, some of these with recent evidence are available with sufficient follow-up. Pulpotomy treatment failures resulting in inflammation could be noticed over a period of 1 year and beyond; hence, our study assessed the success of pulpotomy with an inclusion criterion of minimum 1-year follow-up while assessing both individual and comparative performance of various materials. We found that calcium enriched mixture, calcium silicate, MTA and Biodentine cements to have the best clinical success followed by formocresol and ferric sulfate and was lowest for calcium hydroxide. Radiographically, a similar trend was observed. In general, both the clinical and radiographic success of these materials is comparable to that of reported studies for pulp therapies of primary teeth without irreversible pulpitis. Junior *et al*. **[38]** reported that the success rate of MTA was higher than that of formocresol, with a statistically significant difference. Formocresol pulpotomy success was not statistically different from ferric sulphate or electrosurgery. Tewari *et al*. **[37]** reported that pulpotomy medicaments, except calcium hydroxide, showed success rates of more than 80%, whereas most comparisons revealed no differences. MTA, however, was found to be better than calcium hydroxide and formocresol. In comparison to MTA, calcium hydroxide, formocresol and ferric sulfate pulpotomies showed lower clinical and radiographic success. Biodentine exhibited superior clinical success however; radiographically the success was not significantly different. Junior *et al*. **[38]** reported that overall clinical and radiographic success rates Biodentine vs. MTA did not differ statistically in the 6-month follow-up. Coll *et al*. **[39]** reported that two calcium silicate cement pulpotomies success using mineral trioxide aggregate (MTA) and Biodentine were 94 percent and 90 percent, respectively. The current SRMA has a few limitations such as inclusion of fewer studies of direct comparison, Unavailability of trials with longer follow-up *i.e.* more than 2-3 years, variations in the identification of different calcium silicate materials. Despite such limitations, this study confirms the possibility of success of pulpotomy in primary teeth with irreversible pulpitis.

Conclusion:

Calcium silicate-based materials are superior to formocresol and ferric sulfate. Amongst calcium silicate-based materials, CEM and calcium silicate cement shows best outcomes followed by MTA and Biodentine. Hence, we conclude our findings; pulpotomy has potential for success over 90% in primary teeth with irreversible pulpitis using calcium silicate-based materials.

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