EUROPEAN ENDODONTIC JOURNAL

ORIGINAL ARTICLE

Efficacy of Calcium Enriched Mixture Cement, Mineral Trioxide Aggregate and Calcium Hydroxide Used as Direct Pulp Capping Agents in Deep Carious Lesions - A Randomised Clinical Trial

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ABSTRACT

Objective: The primary objective of this randomised clinical trial was to evaluate the efficacy of Calcium Enriched Mixture (CEM) cement compared to Mineral Trioxide Aggregate (MTA) and Calcium Hydroxide (CH) in maintaining pulp vitality when used for direct pulp capping (DPC) of deep carious lesions with reversible pulpitis and secondary objective was to assess the overall success of DPC in carious exposures.

Methods: One hundred and fifty patients diagnosed with reversible pulpitis with deep carious lesions were included in this study. Patients were randomly allocated into three groups (n=50), Group C: CEM group, Group M: MTA group, and Group D: CH (Dycal) group. After caries removal by mechanical excavation except for one carious spot, the removal of which resulted in the exposure of the pulp, the final carious spot was removed with a sterile no.2 round carbide bur. After haemostasis, the pulpal wound was dressed by a capping agent, followed immediately by permanent restoration. Patients were assessed for successful outcomes based on positive vitality tests, absence of clinical signs and symptoms, and PAI scores after 1, 3, 6, 12, and 18-month follow-up periods. The ANOVA test was employed to analyse quantitative variables, and the Pearson Chi-square test was used for qualitative variables. A Bonferroni Test was employed as the post hoc test for intergroup comparison. The significance level was set at $p \leq 0.05$ within all tests.

Results: The percentage of success in Group C was 86.7%, Group M was 77.3%, and Group D was 57.9%. This study's overall success rate after direct pulp capping of deep carious lesions was 74.8%. A statistically significant difference in PAI score was found between Groups C and D. Pain on percussion and response to vitality tests also showed significant differences among the three groups at the one-month follow-up.

Conclusion: CEM cement had comparable efficacy to MTA and was superior to CH in maintaining pulpal vitality following DPC in teeth with reversible pulpitis. An overall success rate of 74.8% indicated that DPC in deep carious lesions with reversible pulpitis could yield favourable clinical outcomes.

Keywords: Calcium-enriched mixture cement, calcium hydroxide, dental caries, mineral trioxide aggregate, pulp capping, pulpitis

HIGHLIGHTS

- The novel biomaterial Calcium-Enriched Mixture cement (CEM cement) has comparable efficacy to Mineral Trioxide Aggregate (MTA) in maintaining pulpal vitality following direct pulp capping in deep carious lesions.
- Calcium Hydroxide has the least efficacy in maintaining pulpal vitality following direct pulp capping when compared to CEM and MTA.
- The overall success rate of 74.8% in this study indicates that direct pulp capping of carious exposures with reversible pulpitis can yield favourable outcomes.

Please cite this article as:
Parameswaran M, Vanaja Madanan K, Kumar Maroli R, Raghunathan D. Efficacy of Calcium Enriched Mixture Cement, Mineral Trioxide Aggregate and Calcium Hydroxide Used as Direct Pulp Capping Agents in Deep Carious Lesions - A Randomised Clinical Trial. Eur Endod J 2023; 8: 253-61

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Received November 21, 2022,
Revised January 25, 2023,
Accepted April 17, 2023

Published online: July 13, 2023
DOI 10.14744/eej.2023.83007

INTRODUCTION

Strategies in vital pulp therapy (VPT) aim to maintain the vitality and function of the dentine-pulp complex. This ensures that pulp tissue is preserved, thus maintaining its physiological and defensive functions, less hard tissue is removed and, therefore, less weakening of the tooth (1). According to the American Association of Paediatric Dentistry, teeth exhibiting pain of a short duration that is relieved upon removal of stimulus with analgesics or by brushing and without signs and symptoms of irreversible pulpitis have a clinical diagnosis of reversible pulpitis and are candidates for VPT (2). Direct pulp capping is a procedure in which a medicament is placed directly over the exposed dental pulp to maintain pulp vitality and health (3). Controversies in the literature exist regarding DPC of carious pulpal exposures (4, 5). However, VPT has been successful in carious exposures using newer biomaterials in many recent studies (6–8). Overall success rates of 72.9–99.4 % have been reported for VPT in vital permanent teeth with caries-exposed pulp (9). Studies have reported a decrease in success rates when calcium hydroxide (CH) has been used for pulp capping (10, 11). Although a promising bioactive material, mineral trioxide aggregate (MTA) is expensive with difficult handling characteristics, long setting time (12–14), and the potential to discolour teeth (15). A recently introduced bioactive material called calcium-enriched mixture (CEM) is reported to have appropriate setting time, handling characteristics, chemical properties, colour and sealing ability (16). Major components of CEM cement powder are 51.75% calcium oxide, 9.53% sulphite, 8.49% phosphorous-pentoxide, and 6.32% silica, and minor components are aluminium oxide, sodium oxide, magnesium oxide, and chlorides which provide a bioactive calcium- and phosphate-enriched material when mixed with a water-base solution (13). CEM has a setting time of less than one hour, more flow, and less film thickness than MTA and is capable of hydroxyapatite formation over the material in normal saline solution (13, 17).

We could not find any randomised clinical trials that evaluated the efficacy of CEM for DPC of deep carious lesions in mature permanent teeth with reversible pulpitis. Our primary objective was to evaluate the efficacy of CEM compared to MTA and CH in maintaining pulp vitality when used for DPC in deep carious lesions with reversible pulpitis, and the secondary objective was to assess the overall success of DPC in carious exposures.

MATERIALS AND METHODS

This study was done in the Department of Conservative Dentistry and Endodontics, Government Dental College Kozhikode. The study protocol was reviewed and approved by the Institutional Ethics Committee (Reg. No. ECR/673/Inst/KL/2014/RR-20) and was registered under the ISRCTN registry (ISRCTN44317435). Study details were explained verbally, and written informed consent was obtained from patients. The study was conducted following the Declaration of Helsinki (18).

A total of one hundred and fifty patients (Fig. 1) who were clinically diagnosed with reversible pulpitis concerning deep carious lesions with permanent mature teeth were included in this study. All patients were free of any systemic diseases and in the age group of 14–60 years. There was no history of spontaneous pain or pain on percussion (POP) with the carious tooth. All the selected teeth showed a positive response to the cold test and electric pulp test (EPT) and a periapical index score (PAI) of one (19, 20).

Teeth subjected to traumatic occlusion, non-carious destructions, developmental defects, mobility, clinical or radiographic evidence of pulp degeneration, symptoms of irreversible pulpitis, profuse haemorrhage from exposure site >5 minutes, presence of serous or purulent exudates from exposure site and pregnant patients were excluded.

The sample size was calculated by the formula $n=\frac{(z\alpha+z\beta)^2 XpXqX2)}{d^2}$ where, n=sample size in each group, zα=1.96 for an α error 5%, zβ=0.84 for a power of 80% and p=average percentage of outcome calculated as $\frac{(p1+p2)}{2}$ where p1 and p2 were the expected successful outcome in the MTA and CH groups, respectively, and *q=100-p and d=p1-p2*.

A successful outcome of DPC was 78% for MTA and 60 % for CH, according to a similar study (21). These were taken as p1 and p2, respectively, for sample size calculation in this study. The total sample size was divided into three groups, Group C (Experimental Group), Group M (Control group) and Group D (Control group), in which DPC was done with CEM (Bionique Dent Tehran, Iran), white MTA (Proroot, Dentsply, Johnson City, USA) and CH (Dycal, Dentsply Johnson City, USA), respectively.

The number of patients in each group was calculated as 36. However, considering the possibility of dropouts, the sample size was rounded off to 50 in each group. All patients were randomly assigned to each group using a simple lot method. Patient demographic data, chief complaint, medical-dental history, results of baseline examinations, and follow-up examinations were entered into the patient information sheet, and scores were assigned for clinical and radiographic criteria.

Clinical criteria included evaluation of response to cold test and EPT, POP, tooth mobility, sinus tract, root canal treatment (RCT), or extraction conducted during any follow-up examinations. Radiographic criteria included assessment of the periradicular condition of teeth using PAI.

Analogic intraoral periapical radiographs were taken using the long-cone paralleling technique (Asahi x-ray unit GX-60N; Kyoto, Japan). Kodak DF-57 films (Eastman Kodak, Rochester, NY) which were automatically developed and fixed (Level 360; Flat Co, Kobe, Japan), were used in this study. Viewing conditions are standardised using a slide viewer with magnification (6.6×). Films were examined in a darkened room using an illuminated viewer box with magnification (3.5×) while mounted in a cardboard slit to block off ambient light emanating from the viewer. Scores were assigned based on visual references for the 5 categories within the PAI scale (19). Multirooted teeth were assessed according to the highest-scored root.

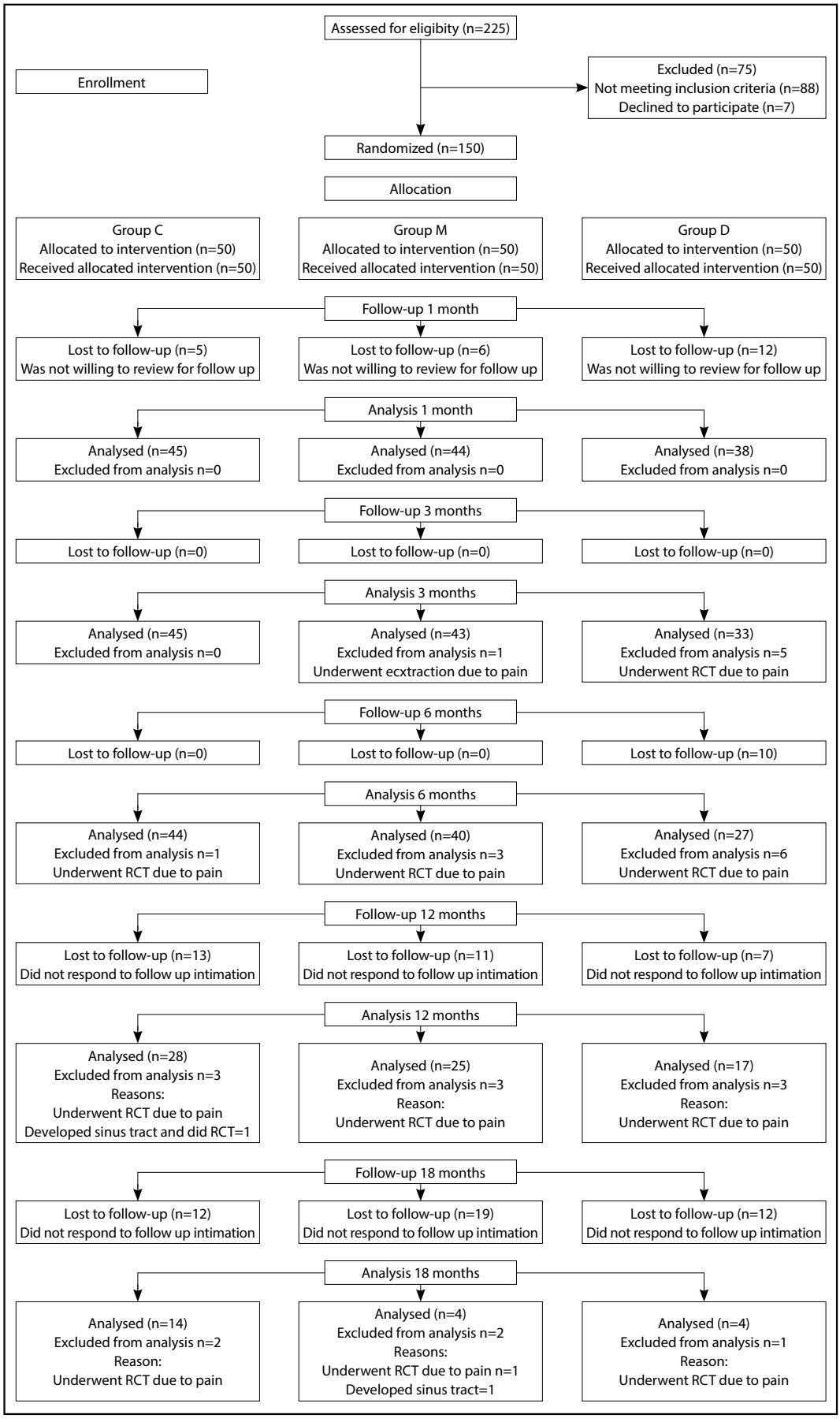

Figure 1. CONSORT flow diagram

Group C: Calcium enriched mixture Group, Group M: Mineral trioxide aggregate group, Group D: Dycal group, RCT: root canal treatment

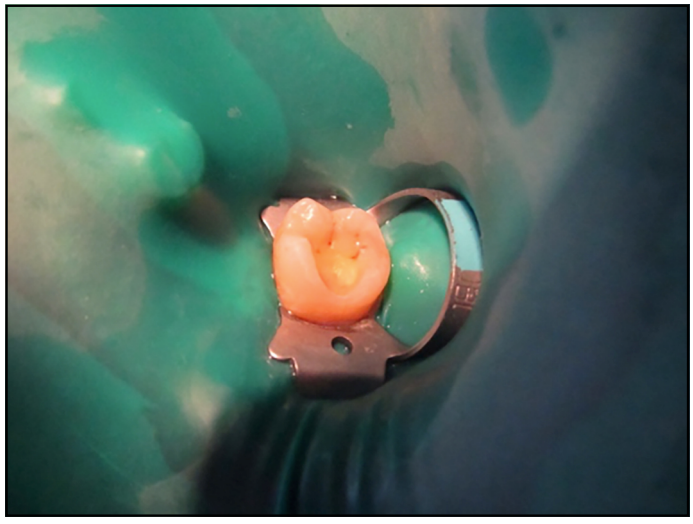

Figure 2. Preoperative view after peripheral caries removal

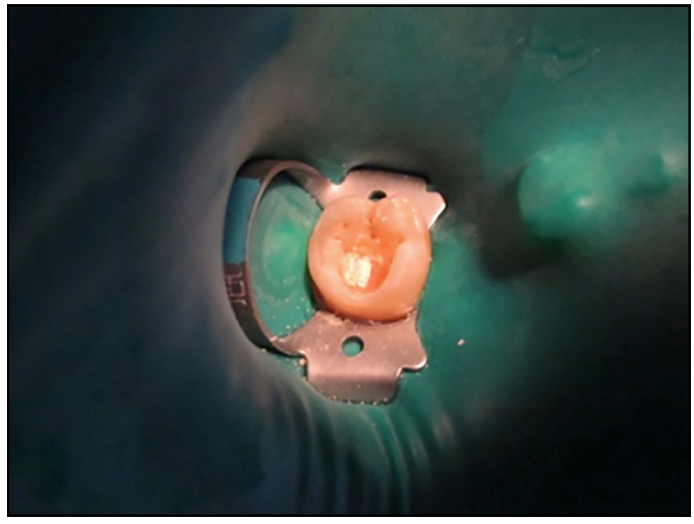

Figure 4. Direct pulp capping agent applied to the exposure site

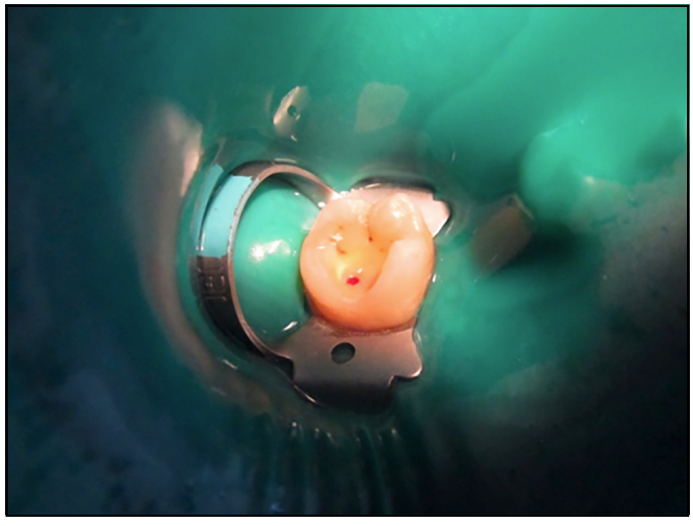

Figure 3. Pulp exposure site after complete caries removal

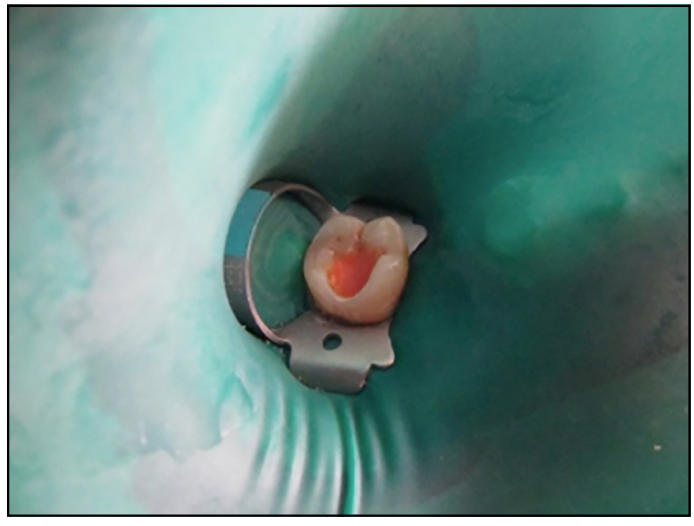

Figure 5. Capping agent covered with Glass ionomer liner

Under local anaesthesia (Lignox 2%A, IndoCo Remedies, Thane, India) and dental dam isolation (Fig. 2), entire peripheral caries were removed by mechanical excavation with slow-speed rose-head bur before excavation from cavity walls near to pulp, except for one carious spot, removal of which caused exposure of the pulp. The final carious spot was removed with sterile no.2 round carbide bur (SS White, Lakewood, New Jersey) having a head diameter of 0.9 mm to standardise the size of the pulpal wound (Fig. 3). Sodium hypochlorite (NaOCl) 5.25% (Septodont, São Paulo, Brazil) was used for haemostasis and disinfection of the cavity for 5–10 minutes. The resolution of bleeding from the exposure site within 5 minutes was considered reversible inflammation, and the pulpal wound was dressed in a capping agent. Capping material selected by simple lot method was mixed according to the manufacturer's instructions and placed and adapted to the wound gently (Fig. 4). Capping material was overlaid with a thin layer of self-cure glass-ionomer base (3M ESPE, St. Paul, USA) (Fig. 5), and permanent restoration was done using direct posterior composite resin (Filtek Z-250, 3M ESPE, St. Paul, USA) (Fig. 6). No postoperative analgesics or antibiotics were prescribed. Patients were advised to report any discomfort postoperatively. In case of extensive caries involvement of the pulp chamber or if haemostasis was not achieved within 5 minutes, irreversible

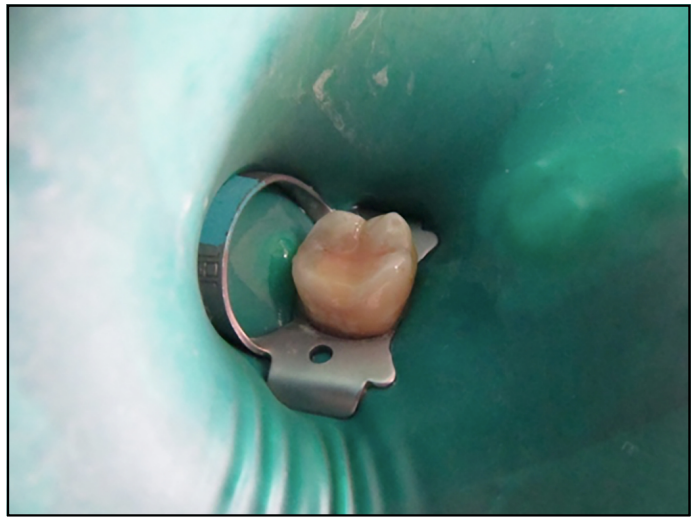

Figure 6. Immediate Restoration with direct composite resin

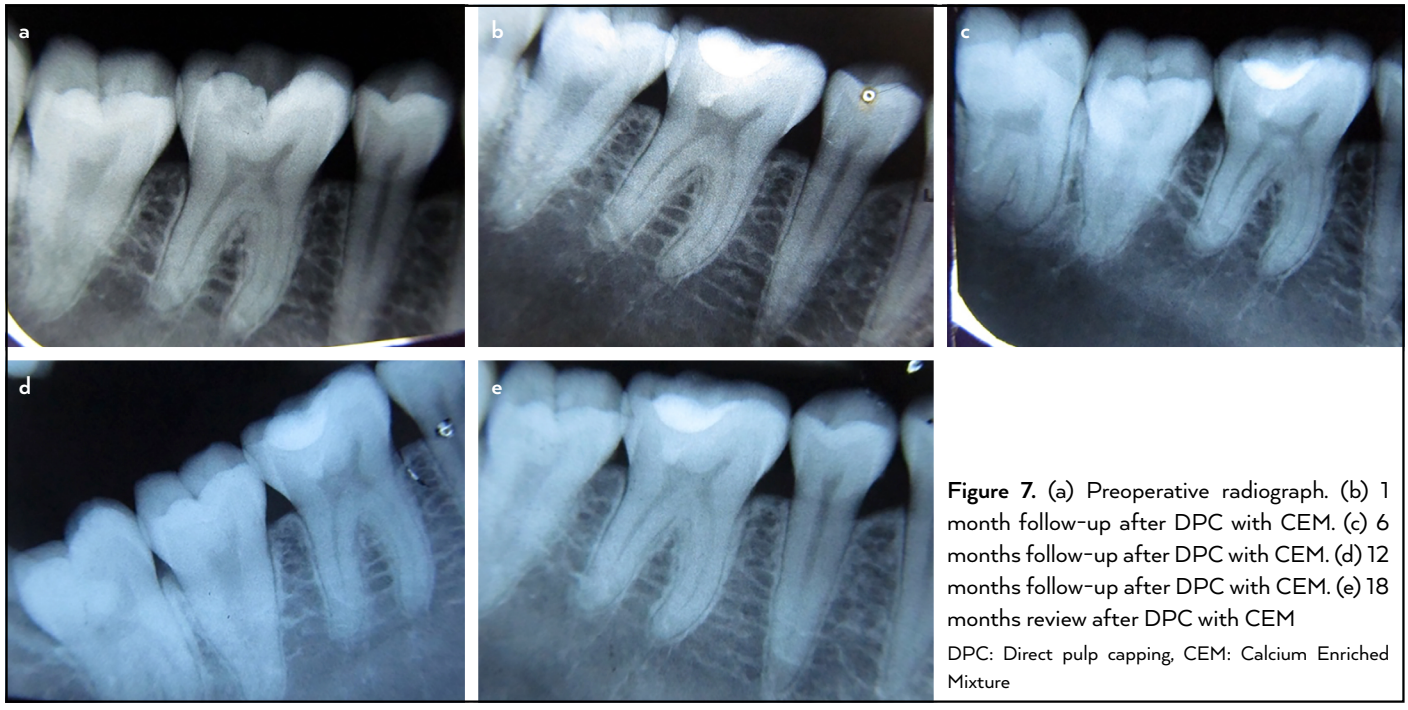

Figure 7. (a) Preoperative radiograph. (b) 1 month follow-up after DPC with CEM. (c) 6 months follow-up after DPC with CEM. (d) 12 months follow-up after DPC with CEM. (e) 18 months review after DPC with CEM

DPC: Direct pulp capping, CEM: Calcium Enriched Mixture

pulpitis was assumed, and RCT was initiated. Such cases were subsequently excluded from the study sample.

Follow-up evaluation was done at 1, 3, 6, 12, and 18 months postoperatively (Fig. 7a-e), and scores were entered into the patient information sheet. Success criteria were a positive response to vitality tests, absence of clinical signs and symptoms, and PAI 1. Outcome considered as a failure when tenderness to palpation, POP, negative response to vitality tests, presence of sinus tract, mobility, RCT or extraction of the pulp-capped tooth, and PAI score>1 was noted in any follow-up examinations.

Statistical Analysis

All analyses were done in SPSS software (Version 16; SPSS, Inc, Chicago). As the objective is to compare the efficacy of three different materials in treating deep pulpal caries by assessing the quantitative PAI scores, the ANOVA test is employed (22). A Bonferroni test is followed by ANOVA as a post hoc procedure to determine the experiment-wise error rate (23). Further variables determining the overall success rate, such as 'pain on percussion' and 'response to vitality tests', are qualitative (24). Hence, the chi-square test was employed to determine the difference in the success rate (qualitative variable) among the three groups. A p-value less than or equal to 0.05 was statistically significant.

RESULTS

Final analysis and interpretation were done with 127 patients (Fig. 1). Forty-eight males and seventy-nine females participated in this study. The chi-square test of the sex distribution in the three groups showed a p-value of 0.374 which was not statistically significant (p>0.05). The mean age in Group C was 29.00, in Group M was 28.61 and in Group D was 30.53. The ANOVA test showed a p-value of 0.728 which was statistically insignificant (p<0.05).

A significant difference in POP was noticed only at the 1-month follow-up (Table 1), where four patients in Group D had severe POP. There was a statistically significant difference in the number of patients with a negative response to vitality tests and who underwent RCT at the first- and third-month follow-up sessions (Table 1). ANOVA test showed a significant difference in PAI scores at the first- and third-month follow-up sessions (Table 2).

At one month, one patient in Group M and five in Group D had a PAI Score>1. Since the ANOVA test showed a p-value of 0.015 within the groups Bonferroni test was done for intergroup comparison (Table 2). The result indicated a statistically significant difference in PAI between Groups C and D. Success rate in Group C, M, and D was 100%, 97.7%, and 86.8%, respectively (p<0.05). The overall success rate of 95.3% was statistically significant (Fig. 8).

At 3 months, one patient in Group D developed a sinus tract, although statistically insignificant (p-value 0.212). Group C had one patient having a PAI score of 2. Group M had 3, and Group D had 6 patients having a PAI>1. The success rate in Group C, M, and D were 97.8%, 90.9%, and 71.1%, respectively (p<0.05). The overall success rate was 87.4 % (Fig. 9). At six months, 1 patient in Group C developed a sinus tract. Two patients in Group C and 3 patients each in Groups M and D had a PAI>1. The success rate at six months in Group C, M, and D were 93.3%, 81.8%, and 63.2%, respectively (p<0.05). Overall success at six months was 80.3%. (Fig. 10). At twelve months, one patient in Group M developed a sinus tract, two patients in Group C had PAI>1, and the highest score was 3. One patient in Group M had a PAI of 5. One patient in Group D had a PAI of 3. The success rate in Group C, M, and D were 88.9%, 77.3% and 60.5%, respectively (p<0.05). The overall success was 76.4% (Fig. 11).

At eighteen months, one patient in the C group had a PAI of 4, and one in Group D had a PAI of 3. The success rate

TABLE 1. Comparison of pain on percussion and response to vitality tests at different follow-up periods among the groups using the chi-square test. (Number of cases and percentages)

Pain on percussion	Group C: CEM		Group M: MTA		Group D: Dycal		p	Response to vitality tests	Group C: CEM	Group M: MTA	Group D: Dycal	p
	n	%	n	%	n	%			n	n	n	
1 month												
Mild	0	0	0	0	1	2.6	0.029*	Negative	0	1	5	0.012*
Moderate	0	0	1	2.3	0	0		Positive	45	43	33	
Severe	0	0	0	0	4	10.5						
3 months												
Mild	1	2.2	1	2.3	1	3	0.212	Negative	1	3	6	0.038*
Moderate	0	0	1	2.3	3	9.1		Positive	44	40	27	
Severe	0	0	1	2.3	2	6.1						
6 months												
Mild	0	0	0	0	1	3.7	0.481	Negative	2	4	3	0.530
Moderate	2	4.5	1	2.5	1	3.7		Positive	42	36	24	
Severe	0	0	2	5	1	3.7						
12 months												
Mild	1	3.6	1	4	0	0	0.641	Negative	2	1	1	0.885
Moderate	0	0	1	0	0	0		Positive	26	24	16	
Severe	0	0	0	0	0	0						
18 months												
Mild	0	0	0	0	1	2.5	0.265	Negative	1	0	1	0.43
Moderate	1	7.1	0	0	0	0		Positive	13	4	3	
Severe	0	0	0	0	0	0						

*: p<0.05 statistically significant. CEM: Calcium enriched mixture, MTA: Mineral trioxide aggregate

in Group C, M, and D were 86.7%, 77.3% and 57.9%, respectively (p<0.05). Overall success CEMs rate at 18 months was 74.8 %. The chi-square test showed a p-value of 0.010 which was statistically significant. Intergroup comparison was made between the experimental and control groups (Table 3), and there was a statistically significant difference in success rate only between Group C (86.7%) and Group D (57.9%) (p<0.05). Overall success and failure within the groups were assessed, and the result was statistically significant (p<0.05) (Fig. 12).

DISCUSSION

The study findings reflect the capability and the superiority of calcium-enriched bio-mixture in treating deep pulpal caries. Assessing the pulpal status remains challenging owing to the non-availability of a reliable tool to evaluate the progression of inflammation to the pulp. The pulpal status plays a key role in determining the success or failure of vital pulp therapy (9). The overall success rate at eighteen months in this group was 86.7%, much higher than other groups. The 18-month follow-up was chosen as it is the ideal time to detect the failure of direct pulp capping procedures (24). The evaluation time remains a matter of controversy. A study by Matsuo et al. (25) suggested that three months was sufficient to determine the prognosis of vital pulpal therapy, as the success rates at three and eighteen months were similar. Our study showed a gradual decline in success rate from 1–18 months follow-up. This can be attributed to the loss of follow-up incurred in our study towards the 3, 6, 12, and 18-month follow-up periods. Literature has elicited that pre-existing clinical findings had no role in the success rate of the treatment (25). Thus, the type of capping material is pertinent in determining the success of vital pulpal therapy (26).

Materials used for direct pulp capping should be capable of stopping bacterial growth, creating an adequate seal, and facilitating mineralisation and root development (27). The common materials used were calcium hydroxide and mineral trioxide aggregate (MTA) (27). CEM, an endodontic cement comprising calcium compounds, was introduced recently owing to the superior properties of the compound in comparison with MTA (16). Shorter setting time, adequate film thickness and flow, good handling properties, and similar pH are the characteristic features of CEM (16). Besides, CEM was also found to be hard tissue friendly, dentinogenic, cementogenic and osteogenic (28, 29). These superior properties were proven to facilitate remineralisation and aid in improving the overall success rate of the direct pulp capping procedure, as reflected in the study.

TABLE 2. Comparison of Periapical index score among the three groups using ANOVA followed by Bonferroni *Post hoc*

Periapical index score	Groups	N	Mean	SD	p	Between the 2 groups	p
1 month	CEM	45	1.00	0.000	0.015*	C-M	1.000
	MTA	44	1.02	0.151		C-D	0.022*
	Dycal	38	1.21	0.622		M-D	0.052
3 months	CEM	45	1.02	0.149	0.058	C-M	p-values are not relevant as no statistically significant
	MTA	43	1.14	0.639		C-D	difference was obtained between the three groups
	Dycal	33	1.33	0.777		M-D	
6 months	CEM	44	1.05	0.211	0.393	C-M	p-values are not relevant as no statistically significant
	MTA	40	1.15	0.483		C-D	difference was obtained between the three groups
	Dycal	27	1.15	0.456		M-D	
12 months	CEM	28	1.11	0.416	0.946	C-M	p-values are not relevant as no statistically significant
	MTA	25	1.16	0.800		C-D	difference was obtained between the 3 groups
	Dycal	17	1.12	0.485		M-D	
18 months	CEM	14	1.21	0.802	0.661	C-M	p-values are not relevant as no statistically significant
	MTA	4	1.00	0.000		C-D	difference was obtained between the three groups
	Dycal	4	1.50	1.000		M-D	

*: p<0.05 statistically significant. ANOVA: Analysis of variance, CEM: Calcium enriched mixture, MTA: Mineral trioxide aggregate, SD: Standard deviation

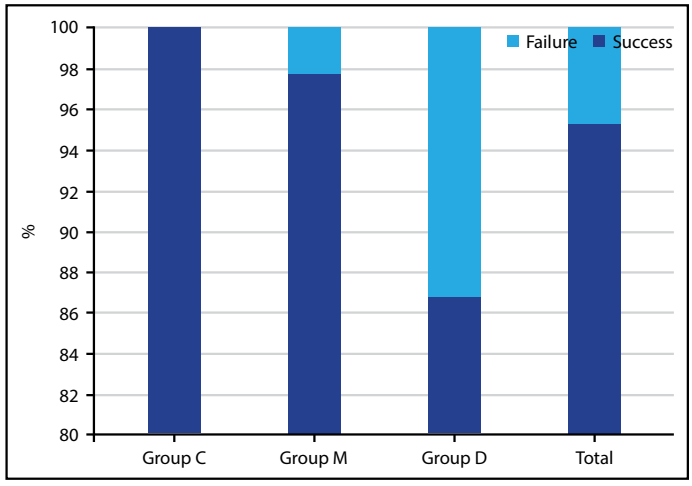

Figure 8. Success versus failure at one month

p=0.012<0.05=Statistically significant

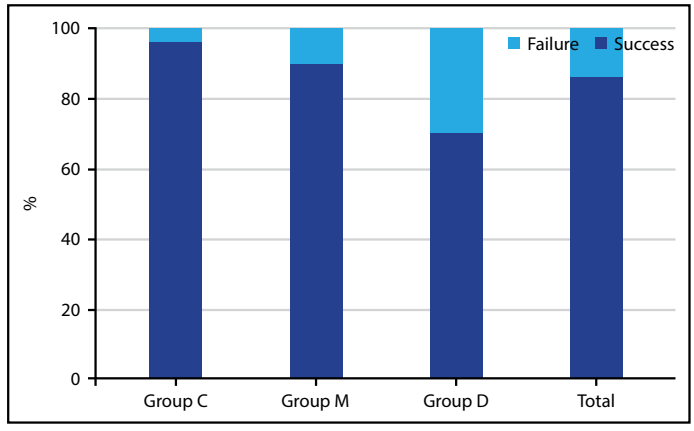

Figure 9. Success versus failure at three months

p=0.001<0.05=Statistically significant

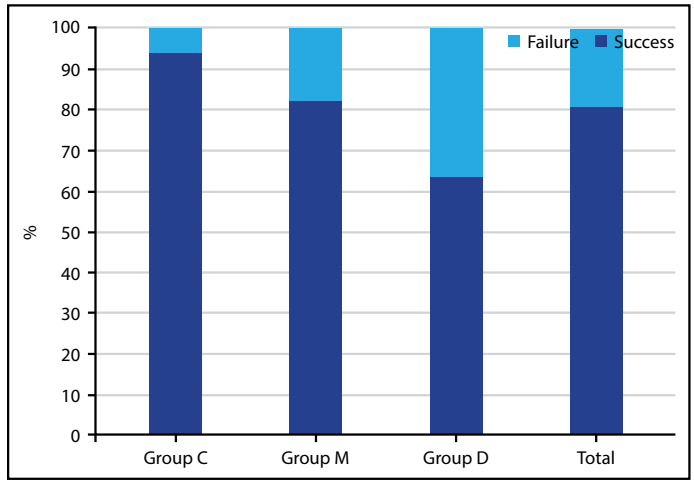

Figure 10. Success versus failure at six months

p=0.003<0.05=Statistically significant

The clinical success rate of CEM and MTA in our study was similar to another study (30). In a randomised clinical trial to compare clinical and radiographic outcomes of pulpotomy using CEM and MTA, there was no significant difference between the two experimental groups, similar to our study results (31). CH has shown a constant decline in success rate at all periods, reflecting this material's inferior properties as reported by similar studies that compared CH with calcium silicate materials like Biodentine and MTA (32, 33) and CH in comparison with MTA (34, 35).

A study comparing Biodentine, CEM, and MTA showed that the thickness of the dentine bridge is higher in the Biodentine group, with less pulpal inflammation (36). The formation of a calcified bridge is 66.7% in CEM and 80% in Biodentine (36). Histology showed the superior property of Biodentine to CEM. Thus, more studies comparing the efficacy of Biodentine with CEM and MTA with a cost-effective analysis component are essential for improving the prognosis of direct pulp capping.

CEM was also effective in a one-year follow-up study of indirect pulp therapy, demonstrating maintained pulp vitality, absence of pain or tenderness to percussion, and a healing

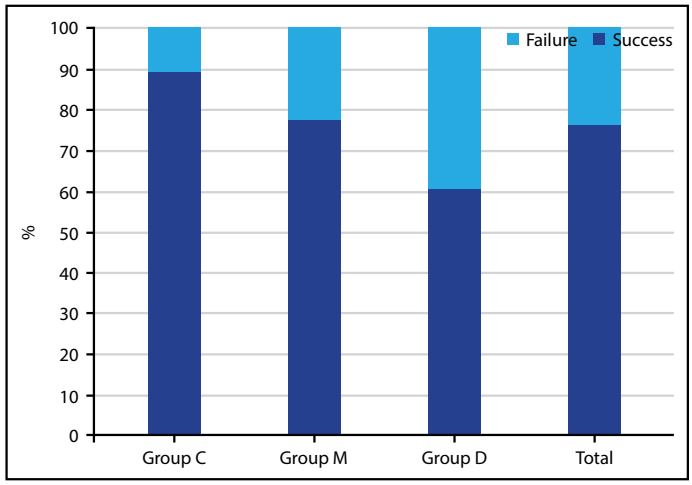

Figure 11. Success versus failure at twelve months

p=0.010<0.05=Statistically significant

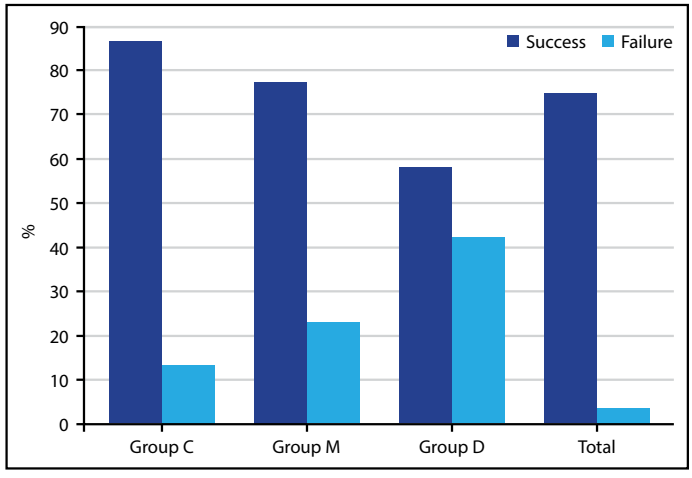

Figure 12. Overall success versus failure within the groups

p=0.010<0.05=Statistically significant

periradicular lesion in the periapical radiograph (37). However, this aspect of CEM was not explored in our study, as our main aim was to assess the efficacy of different materials in direct pulp capping.

Another factor influencing the outcome of direct pulp capping was the degree of bleeding from the exposure site (25). The presence of extra pulpal blood clots could cause contamination of the exposure site (38) and interfere with the formation of adequate coronal seals (39). Hence, the patient selection criteria in our study were chosen based on the degree of bleeding from the exposure. NaOCl is reported as the most effective agent in removing cavity biofilm and haemostasis before DPC (40) and is hence used in this trial.

In this study, a successful outcome was strictly defined by radiographic and clinical findings of the pulp-capped tooth. The diagnosis of reversible pulpitis may not correlate with the actual histologic condition of the pulp (41). Hence studies with more objective diagnostic tests will be of immense value in appropriate case selection for DPC. In this study, we have not considered variables like gender, age, and tooth type for assessing the outcome of direct pulp capping, which needs further evaluation. As we did not account for the high rates of loss to follow-ups, conducting studies with a larger sample size in different study settings can yield more reliable results. Hence, the external validity of the study is limited.

TABLE 3. Intergroup comparison of overall success versus failure

Compared group	Comparing groups	p
Group C	Group M	0.72
	Group D	0.01*
Group M	Group C	0.72
	Group D	0.18
Group D	Group C	0.01*
	Group M	0.18

*: p<0.05: Statistically significant. Group C: Calcium enriched mixture Group, Group M: Mineral trioxide aggregate group, Group D: Dycal group C to M p-value 0.24 uncorrected – with correction - 0.72, C to D: P-value 0.00308 uncorrected - with correction - 0.01, M to D: P-value 0.06 uncorrected – with correction -0.18. The Chi-square test was done taking into consideration the multiple alternate hypotheses and correcting the p-value cut-off based on the number of alternate hypotheses

CONCLUSION

CEM cement has comparable efficacy to MTA in maintaining pulpal vitality following DPC. CH has the least efficacy in maintaining pulpal vitality compared to CEM and MTA. The ability to maintain pulpal vitality following DPC of deep carious lesions declined with an increased follow-up period and was marked for CH compared to CEM and MTA groups. The overall success rate of 74.8% indicates that DPC in carious exposures can yield favourable outcomes.

Disclosures

Conflict of interest: The authors deny any conflict of interest.

Ethics Committee Approval: This study was approved by The Department of Conservative Dentistry and Endodontics, Government Dental College Kozhikode Ethics Committee (Date: 10/01/2011, Number: ECR/673/Inst/KL/2014/RR-20).

Peer-review: Externally peer-reviewed.

Financial Disclosure: This study did not receive any financial support.

Authorship contributions: Concept – M.P., K.V.M., R.K.M., D.R.; Design – M.P., K.V.M., R.K.M., D.R.; Supervision – M.P., K.V.M., R.K.M., D.R.; Funding - M.P., K.V.M., R.K.M.; Materials - M.P., K.V.M.; Data collection and/or processing – M.P., K.V.M.; Analysis and/or interpretation – M.P., K.V.M., D.R.; Literature search – M.P., K.V.M.; Writing – M.P.; Critical Review – M.P., K.V.M., R.K.M., D.R.

REFERENCES

1. 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(9):825–9.
2. American Academy on Pediatric Dentistry Clinical Affairs Committee-Pulp Therapy subcommittee, American Academy on Pediatric Dentistry Council on Clinical Affairs. Guideline on pulp therapy for primary and young permanent teeth. Pediatr Dent 2008-2009; 30(Suppl 7):170–4.
3. Camps J, Fuks AB. Pediatric endodontics: endodontic treatment for the primary and young permanent dentition. In: Cohen S, Hargreaves K, Keiser K, editors. Pathways of the pulp. 9th ed. St Luois: Mosby Elsevier; 2006. p. 822–82.
4. Tronstad L, Mjör IA. Capping of the inflamed pulp. Oral Surg Oral Med Oral Pathol 1972; 34(3):477–85. [CrossRef]

5. Langeland K. Management of the inflamed pulp associated with deep carious lesion. J Endod 1981; 7(4):169–81. [CrossRef]
6. Eghbal MJ, Asgary S, Baglue RA, Parirokh M, Ghoddusi J. MTA pulpotomy of human permanent molars with irreversible pulpitis. Aust Endod J 2009; 35(1):4–8. [CrossRef]
7. Asgary S, Ehsani S. Permanent molar pulpotomy with a new endodontic cement: a case series. J Conserv Dent 2009; 12(1):31–6. [CrossRef]
8. Chueh LH, Chiang CP. Histology of Irreversible pulpitis premolars treated with mineral trioxide aggregate pulpotomy. Oper Dent 2010; 35(3):370–4.
9. Aguilar P, Linsuwanont P. Vital pulp therapy in vital permanent teeth with cariously exposed pulp: a systematic review. J Endod 2011; 37(5):581–7.
10. Barthel CR, Rosenkranz B, Leuenberg A, Roulet JF. Pulp capping of carious exposures: treatment outcome after 5 and 10 years: a retrospective study. J Endod 2000; 26(9):525–8. [CrossRef]
11. Haskell EW, Stanley HR, Chellemi J, Stringfellow H. Direct pulp capping treatment: a long-term follow-up. J Am Dent Assoc 1978; 97(4):607–12.
12. Fuks AB. Current concepts in vital primary pulp therapy. Eur J Paediatr Dent 2002; 3(3):115–20.
13. Asgary S, Shahabi S, Jafarzadeh T, Amini S, Kheirieh S. The properties of a new endodontic material. J Endod 2008; 34(8):990–3. [CrossRef]
14. Torabinejad M, Hong CU, McDonald F, Pitt Ford TR. Physical and chemical properties of a new root-end filling material. J Endod 1995; 21(7):349–53.
15. Watts JD, Holt DM, Beeson TJ, Kirkpatrick TC, Rutledge RE. Effects of pH and mixing agents on the temporal setting of tooth-colored and gray mineral trioxide aggregate. J Endod 2007; 33(8):970–3. [CrossRef]
16. Asgary S, Eghbal MJ, Parirokh M. Sealing ability of a novel endodontic cement as a root-end filling material. J Biomed Mater Res A 2008; 87(3):706–9. [CrossRef]
17. Asgary S, Eghbal MJ, Parirokh M, Ghoddusi J, Kheirieh S, Brink F. Comparison of mineral trioxide aggregate's composition with Portland cements and a new endodontic cement. J Endod 2009; 35(2):243–50. [CrossRef]
18. World Medical Association. WMA Declaration of Helsinki – Ethical Principles for Medical Research Involving Human Subjects. Available at: https://www.wma.net/policies-post/wma-declaration-of-helsinki-ethical-principles-for-medical-research-involving-human-subjects/. Accessed Dec 21, 2022.
19. Orstavik D, Kerekes K, Eriksen HM. The periapical index: a scoring system for radiographic assessment of apical periodontitis. Endod Dent Traumatol 1986; 2(1):20–34. [CrossRef]
20. AAE Consensus Conference Recommended Diagnostic Terminology. J Endod 2009; 35(12):1634. [CrossRef]
21. Mente J, Geletneky B, Ohle M, Koch MJ, Friedrich Ding PG, Wolff D, et al. Mineral trioxide aggregate or calcium hydroxide direct pulp capping: an analysis of the clinical treatment outcome. J Endod 2010; 36(5):806–13.
22. Larson MG. Analysis of variance. Circulation 2008; 117(1):115–21.
23. Armstrong RA. When to use the Bonferroni correction. Ophthalmic Physiol Opt 2014; 34(5):502–8. [CrossRef]
24. McHugh ML. The chi-square test of independence. Biochem Med (Zagreb) 2013; 23(2):143–9. [CrossRef]
25. Matsuo T, Nakanishi T, Shimizu H, Ebisu S. A clinical study of direct pulp capping applied to carious-exposed pulps. J Endod 1996; 22(10):551–6.
26. Cho SY, Seo DG, Lee SJ, Lee J, Lee SJ, Jung IY. Prognostic factors for clinical outcomes according to time after direct pulp capping. J Endod 2013; 39(3):327–31. [CrossRef]
27. Witherspoon DE. Vital pulp therapy with new materials: new directions and treatment perspectives--permanent teeth. Pediatr Dent 2008; 30(3):220–4. [CrossRef]
28. Asgary S, Nosrat A. Concurrent intentional replantation of maxillary molars using a novel root-end filling. Gen Dent 2014; 62(3):30–3.
29. Asgary S, Eghbal MJ, Ehsani S. Periradicular regeneration after endodontic surgery with calcium-enriched mixture cement in dogs. J Endod 2010; 36(5):837–41. [CrossRef]
30. Fallahinejad Ghajari M, Asgharian Jeddi T, Iri S, Asgary S. Direct pulp-capping with calcium enriched mixture in primary molar teeth: a randomized clinical trial. Iran Endod J 2010; 5(1):27–30.
31. Nosrat A, Seifi A, Asgary S. Pulpotomy in caries-exposed immature permanent molars using calcium-enriched mixture cement or mineral trioxide aggregate: a randomized clinical trial. Int J Paediatr Dent 2013; 23(1):56–63. [CrossRef]
32. Matsuura T, Ziauddin SM, Kawata-Matsuura VKS, Sugimoto K, Yamada S, Yoshimura A. Long-term clinical and radiographic evaluation of the effectiveness of direct pulp capping materials: a meta-analysis. Dent Mater J 2021; 40(1):1–7. [CrossRef]
33. Brizuela C, Ormeño A, Cabrera C, Cabezas R, Silva CI, Ramírez V, et al. Direct pulp capping with calcium hydroxide, mineral trioxide aggregate, and biodentine in permanent young teeth with caries: a randomized clinical trial. J Endod 2017; 43(11):1776–80. [CrossRef]
34. Li Z, Cao L, Fan M, Xu Q. Direct pulp capping with calcium hydroxide or mineral trioxide aggregate: a meta-analysis. J Endod 2015; 41(9):1412–7.
35. Hilton TJ, Ferracane JL, Mancl L; Northwest Practice-based Research Collaborative in Evidence-based Dentistry (NWP). Comparison of CaOH with MTA for direct pulp capping: a PBRN randomized clinical trial. J Dent Res 2013; 92(Suppl 7):16S–22. [CrossRef]
36. Hoseinifar R, Eskandarizadeh A, Parirokh M, Torabi M, Safarian F, Rahmanian E. Histological evaluation of human pulp response to direct pulp capping with MTA, CEM cement, and biodentine. J Dent 2020; 21(3):177–83.
37. Asgary S, Torabzadeh H. Indirect pulp therapy in a symptomatic mature molar using calcium enriched mixture cement. J Conserv Dent 2013; 16(1):83. [CrossRef]
38. Schröder U. Effects of calcium hydroxide-containing pulp-capping agents on pulp cell migration, proliferation, and differentiation. J Dent Res 1985; 64(Spec):541–8. [CrossRef]
39. Hilton TJ. Keys to clinical success with pulp capping: a review of the literature. Oper Dent 2009; 34(5):615–25. [CrossRef]
40. Garcia-Godoy F, Murray PE. Systemic evaluation of various haemostatic agents following local application prior to direct pulp capping. Available at: https://tspace.library.utoronto.ca/handle/1807/8596. Accessed Sep 12, 2022.
41. Akhlaghi N, Khademi A. Outcomes of vital pulp therapy in permanent teeth with different medicaments based on review of the literature. Dent Res J 2015; 12(5):406–17. [CrossRef]