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ORIGINAL ARTICLE

Treatment outcomes of pulpotomy in permanent molars with irreversible pulpitis using biomaterials: A multi-center randomized controlled trial

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Abstract

Objective. To conduct a randomized clinical trial to compare the post-operative pain experience as well as clinical and radiographic outcomes of pulpotomy in human permanent molars with irreversible pulpitis using calcium enriched mixture (CEM) cement or mineral trioxide aggregate (MTA). ***Materials and mcethods.*** A total of 413 patients met the inclusion criteria and consented to participate. The patients were randomly allocated into two study arms: MTA pulpotomy (PMTA: $n = 208$) and CEM pulpotomy (PCEM: $n = 205$). Numerical rating scale questionnaires were utilized by the patients to record pain intensity (PI) over 7 days post-operatively. The patients were followed-up for 12 months to assess the clinical and radiographic outcomes of treatment. The data was analyzed using Chi-square, Cohen's kappa and *t*-tests. ***Results.*** There was no significant difference in the mean PI recorded during the 7 post-operative days between the two study arms ($p = 0.221$). The clinical and radiographic success rates for PMTA at 12-month follow-up were 98 and 95%, respectively; and 97 and 92% for PCEM, respectively. There was no significant differences in clinical ($p = 0.7$) and radiographic ($p = 0.4$) success rates between the two arms. ***Conclusions.*** Excellent treatment outcomes occurred in molar teeth with irreversible pulpitis undergoing pulpotomy with MTA and CEM biomaterials.

Key Words: *calcium enriched mixture, CEM, human, permanent tooth, pulpitis, pulpotomy*

Introduction

There is a range of treatment options for the management of pulpitis in teeth with extensive carious lesions. When a carious pulp exposure has occurred, the clinician may decide to cover the exposed pulp by direct pulp capping, remove the coronal part of the pulp (pulpotomy) or to carry out root canal treatment [1]. The ultimate treatment decision is affected by several variables including patient factors such as age and medical history and tooth factors such as whether it is a permanent or primary tooth, pulps were cariously exposed, contaminated by saliva, previously restored and/or periodontally involved [2].

Pulpotomy is well established and a common treatment modality for cariously exposed pulps in primary molars with well documented positive results [3]. This procedure can be defined as the surgical removal of the coronal portion of the pulp and the placement of a therapeutic agent to preserve the health of the remaining tissue [4].

In the permanent dentition, one of the most commonly adopted emergency treatment protocols for pain relief for irreversible pulpitis is complete or partial extirpation of the dental pulp [5]. The excellent prognosis of root canal treatment is well established (95% CI; 82.8 ± 1.19%) [6]; however, the procedure is complicated and time-consuming. Unfortunately, the only other feasible treatment option may be extraction due to financial restrictions in some areas of the world [7].

Recently, the use of conservative and simple pulpotomy techniques with one of the two biomaterials: (1) mineral trioxide aggregate (MTA) [8,9] and (2) calcium enriched mixture (CEM) cement [10-12] was suggested. Their rationale is based on the healing potential of the remaining radicular pulp of mature permanent molar teeth.

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MTA has become a widely used biomaterial for vital pulp therapy (VPT) [13] due to its ability to induce hard-tissue formation in pulpotomy treatment [14,15]. There is also a growing body of evidence that demonstrates the favorable success rates of MTA when used in primary molar pulpotomies [16,17]. Moreover, partial pulpotomy is also recommended for cariously pulp exposures in immature permanent teeth [18]. However, there are as yet only two case series that have investigated the use of MTA for conventional pulpotomy in mature permanent human teeth with partial irreversible pulpitis [8,9].

Recently, a new endodontic biomaterial (CEM cement) has been introduced ([19], USPTO Number: 7,942,961). Although the laboratory study on sealing ability [20] and the *in vivo* investigations on VPT in animals [21–23] revealed comparable results for CEM and MTA, this novel cement offered some advantages over MTA. These include characteristics such as superior antibacterial effect [24], improved handling, shorter setting time, decreased film thickness and improved flow [19]. Furthermore, CEM has the ability to form hydroxyapatite over it's surface in normal saline solution [25] and exhibits similar surface characteristics as the surrounding dentine [26].

A recent Cochrane report evaluating pulp management in carious teeth in adults was not able to reach a conclusion regarding the maintenance of pulp vitality in permanent carious teeth with inflamed pulp [1]. They stated that: Further well designed randomized clinical trials are needed. It is recognized that it is difficult to establish the 'ideal' clinical study when ethical approval for new materials must be sought, not easy to recruit sufficient numbers of patients. The present study protocol aimed to provide further data by performing a quadruple blind, multi-centered, randomized clinical trial. Moreover, the purpose of this trial was to compare pain alleviation as well as radiographic and clinical outcomes of pulpotomy treatment using CEM (PCEM) or MTA (PMTA) in permanent human molar teeth.

Materials and methods

This report is part of a larger ongoing study, which has been registered at IRCT (Number: 138706131191N1). The study protocol was approved by the Iranian Ministry of Health as well as the Ethics Committee of Dental Research Center of Shahid Beheshti Medical University, Tehran, Iran. The trial was conducted in compliance with the ethical principles of The Helsinki Declaration. The trial was managed by the Iranian Center for Endodontic Research (ICER). The study was a 36-week multicenter, randomized, parallel-grouped and blinded design conducted by general dentists (GDP). Several studies on human subjects were performed as pilot studies prior to the clinical trial [9-11]; similar methods to our previous report were employed [12].

The 30 GDPs who volunteered to take part in this study worked in primary healthcare centers throughout Iran. They attended a training workshop at ICER and a total of 23 GDPs passed the final exam and qualified for the trial. Study subjects were recruited from a pool of patients referred to five Medical Universities in four different States of Iran. For standardization of the participants, the inclusion/exclusion criteria were adopted.

Subjects were included if they (1) had toothache from a molar tooth; (2) requested extraction for pain relief; (3) were 9–65 years old; (4) agreed to attend for recall appointment; and (5) provided written informed consent (patients < 18, the parents provided consent). Signs and symptoms of teeth had to include pain indicating partial irreversible pulpitis, i.e. have a history of (a) spontaneous pain for a few seconds to several hours with extensive caries, (b) pain exacerbated with hot and cold fluids and/or (c) radiating pain [27]. Moreover, teeth had to respond to cold vitality testing and bleeding from all canal orifices had to be observed during access cavity preparation.

Subjects were excluded if they had (1) active systemic disease; (2) physical or mental disability and/or (3) patients who were pregnant or nursing. In addition, subjects whose teeth showed signs of (a) moderate/severe marginal periodontitis; (b) were non-restorable; (c) had internal or external root resorption; (d) had root canal calcification; and (e) had associated abscesses.

The study was explained to the patients by the GDPs. Demographic data were recorded before treatment. Upon enrolment patients were randomly assigned by a computer-based randomization schedule to receive either PMTA (tooth-colored ProRoot MTA; Dentsply, Tulsa Dental, Tulsa, OK) or PCEM (CEM cement; BioniqueDent, Tehran, Iran). The allocation took place on a central basis in ICER to ensure concealment.

For sample size determination, 98 and 90% success rate were considered for patients in PMTA and PCEM, respectively. To obtain 90% power with a 2-sided α equal to 0.05, ~ 180 patients per treatment groups were required to establish the equivalency of PCEM compared with PMTA. Around 10% drop-out per year was taken into consideration; therefore, ~ 400 patients were required.

Each GDP was asked to recruit 18 patients with irreversible pulpitis of a permanent molar tooth, i.e. nine patients treated in each group. The teeth were anesthetized with 2% Lidocaine and 1/80,000 epinephrine (Darou Pakhsh, Tehran, Iran). Subsequently, a 0.2% chlorhexidine (Shahre Daru, Tehran, Iran) oral rinse was used by each patient. Under rubber dam isolation, pulpotomy was performed with a large sterile round-end bur in a high-speed

handpiece with copious irrigation; pulp tissue was then removed to the orifice level. Hemostasis was achieved by irrigation of the cavity with sterile normal saline and application of small pieces of wet sterile cotton pellets. Cases where hemostasis could not be achieved were excluded. The blood clot-free pulpal wound was covered with an ~ 2 mm layer of pulpotomy agent (CEM or MTA). As the nature of the two pulp capping biomaterials was water-based, the GDP performing the treatment were blinded to the material used. A sterile wet cotton pellet was then placed over the pulpotomy agent and the cavity sealed temporarily with Cavit (ESPE, Norristown PA). In all cases, the Cavit was replaced with amalgam after 7 days.

Patients were recalled for clinical examination 1 day, 1 week and then 12 months post-operatively. The primary outcome was determined using the long-term (1-year) clinical and radiographic measure. The secondary (short-term) outcome was determined by the pain-relief achieved during the post-operative 7 days. The blinded GDP assessed the clinical symptoms; and the radiographic assessments were made by four blinded specialist examiners.

Similar to our previous report [12], on completion of pulpotomy, pain assessments were carried out using the pain Numerical Rating Scale (NRS) with ratings between 0–9. Pain assessments were made at baseline, 6, 12, 18 h and then after at 1, 1.5 (36 h), 2, 2.5 (60 h) 3, 4, 5, 6 and 7 days post-operatively. One NRS form was given to each patient to complete at home at the specified times.

Clinical failure was determined by the following criteria: subjective reports of symptoms by patient. Objective signs noted by the clinician included abscess, swelling, sinus tract, redness and tenderness associated with the tooth. Clinical outcome assessments were performed by the GDPs at baseline, 7 days and 12 months post-treatment. Radiographic examination, however, was carried out at baseline and 12 months only. The outcome of radiographic success was classified by using a modification of the Strindberg [28] criteria for periapical status. Teeth with normal contour and width of PDL were judged as 'healed'. Teeth with a clearly decreased size of the periapical radiolucency were judged as 'healing'. Teeth with unchanged, increase in size of the periapical radiolucency or appearance of a new periapical radiolucency were judged as 'failed'. Internal/external root resorption and pulp obliteration were also assessed radiographically. The radiographs were assessed by a total of four independent experienced endodontists ($n = 2$) and oral radiologists ($n = 2$). All the examiners were calibrated prior to their assessment through individual evaluation of 20 radiographs independent from this study. When disagreement arose, a consensus approach was adopted. Intra-rater and inter-rater agreement between the evaluators was measured.

The means of pain intensity (PI) at baseline and at all the other time intervals in the two study arms were compared using a *t*-test. The clinical and radiographic outcomes between the two study arms were compared using Chi square tests. Inter- and intra-rater agreement on radiographic assessment was measured using Cohen's kappa statistic. First type statistical error was considered as 0.05. Statistical analysis was set up using SPSS version 13.

Results

A total of 413 patients who met the inclusion criteria consented to participate in the trial. They were recruited and randomized from 23 healthcare centers in four states and five Medical Universities of Iran. Follow-up for 7-day and 12-month end-points were completed for all and 84% of the subjects, respectively.

The two groups of patients were well balanced with regards to baseline data, with 179 remaining subjects in PMTA and 167 in PCEM arm (Table I). The statistical analyses revealed no differences between treatment arms with respect to demographic

Table I. Patient demographics and baseline characteristics at the beginning and 1-year follow-up.

	Baseline		1-year	
	PCEM ($n = 205$)	PMTA ($n = 208$)	PCEM ($n = 167$)	PMTA ($n = 179$)
Mean age, years ± SD	27 ± 8	26 ± 9	28 ± 8	27 ± 9
Sex, *n* (%)				
Male	72 (35.1%)	75 (36.0%)	58 (34.7%)	65 (36.3%)
Female	133 (64.9%)	132 (64.0%)	109 (65.3%)	114 (63.6%)
Pre-operative pain				
PI, cm, mean ± SD	4.03 ± 1.87	4.09 ± 1.93	—	—
Periapical involvement, *n* (%)	63 (30.7%)	55 (26.4%)	12 (7.2%)	9 (5.0%)

PCEM, Pulpotomy with Calcium Enriched Mixture; PMTA, Pulpotomy with MTA; PI, Pain Intensity.

Table II. The distribution of post-operative pain intensity (PI) during the 7 days in two study arms.

		Pain intensity category					
Day	Arm	Pain free (0)	Mild (1–3)	Moderate (4–6)	Severe (7–9)	% reporting pain	Mean PI ± SD
Baseline	PCEM	0	82	96	27	100	4.0 ± 1.9
	PMTA	0	76	105	27	100	4.1 ± 1.9
1	PCEM	150	47	8	0	26.8	0.5 ± 1.1
	PMTA	157	43	7	1	24.5	0.5 ± 1.2
2	PCEM	173	28	4	0	15.6	0.3 ± 0.8
	PMTA	166	32	9	1	20.2	0.5 ± 1.3
3	PCEM	173	30	2	0	15.6	0.3 ± 0.7
	PMTA	180	20	7	1	13.5	0.4 ± 1.2
4	PCEM	174	28	3	0	15.1	0.3 ± 0.8
	PMTA	179	23	4	2	13.9	0.3 ± 1.1
5	PCEM	177	26	2	0	13.6	0.2 ± 0.7
	PMTA	178	23	5	2	14.4	0.4 ± 1.1
6	PCEM	180	23	2	0	12.2	0.2 ± 0.6
	PMTA	177	26	3	2	14.9	0.3 ± 1.1
7	PCEM	184	21	0	0	10.2	0.1 ± 0.5
	PMTA	183	21	2	2	12.0	0.2 ± 1.0

PCEM, Pulpotomy with Calcium Enriched Mixture; PMTA, Pulpotomy with MTA.

characteristics as well as pre-operative pain experience and periapical status.

The distributions of pain intensity (PI) for 413 patients at baseline and over the 7 days post-operatively in two study arms are illustrated in Table II. There was no significant difference in the mean of PI between the two study arms at any time point.

At 7-day recall, clinical examination of buccal and lingual mucosa revealed the absence of abscess, swelling, sinus tract, redness and tenderness related to all treated teeth.

Sixty-seven patients, 29 in the PMTA and 38 in the PCEM arms, did not attend due to lack of compliance or for personal reasons in the 12-month follow-up session. Overall there were 346 cases for primary outcome analysis (long-term outcome); no significant difference was observed between clinical success rates of the two groups.

Mean follow-up times were 12.90 ± 0.66 and 12.93 ± 0.69 months in the PCEM and PMTA groups, respectively; these were not significant ($p = 0.716$). At the 12-months follow-up, clinical examination revealed signs of periapical disease in 2.4% ($n = 4$) and 1.7% ($n = 3$) of the cases in PCEM and PMTA groups, respectively (Table III); no significant difference was found ($p > 0.05$).

Radiographic intra-rater and inter-rater reliability for all four raters ranged between 0.77–0.91. Radiographic evaluations by the four examiners at the 12-month follow-up revealed no significant difference in the treatment outcomes between the two study arms ($p = 0.435$) (Table IV).

Overall, the percentage of teeth with successful treatment (absence of symptoms, clinical/radiographic signs of pulpal/periapical disease) was 92 and 95% in PCEM and PMTA arms, respectively. All the failed cases were associated with a radiographic lesion.

Table III. The results of clinical examination at 12 months follow-up stratified by the two tested biomaterials.

	Symptoms			
Group	Abscess/swelling	Sinus tract	Tooth tenderness to percussion	Failed
PCEM ($n = 167$)	0	1	3	4
	0.0%	0.6%	1.8%	2.4%
PMTA ($n = 179$)	0	1	2	3
	0.0%	0.6%	1.1%	1.7%

PCEM, Pulpotomy with Calcium Enriched Mixture; PMTA, Pulpotomy with MTA.

Table IV. Consensus radiographic outcome (number and percentage) in the two study groups.

	Periapical status			Root canal			Overall outcome	
Group	Healed	Healing	Failed	Internal resorption	External resorption	Obliteration	Success	Failure
PCEM (n = 167)	154	1	12	0	1	0	155	12
	92.2%	0.6%	7.2%	0.0%	0.6%	0.0%	92.8	7.2%
PMTA (n = 179)	170	0	9	0	1	0	170	9
	95.0%	0.0%	5.0%	0.0%	0.5%	0.0%	95.0%	5.0%

PCEM, Pulpotomy with Calcium Enriched Mixture; PMTA, Pulpotomy with MTA.

Discussion

The incidence of post-operative pain and the clinical and radiographic outcomes are the major interest when evaluating endodontic treatment alternatives [29]. This clinical trial involving over 400 participants demonstrated that pulpotomy treatment with CEM or MTA was equally effective for pain relief and had high clinical and radiographic success after 1 year; however, it is worth noting that the pain relief effects of CEM pulpotomy was reported to be significantly superior to root canal therapy [12]. The results of the present quadruple blind, multi-centered, randomized clinical trial can be classified as a grade 1 level of evidence [30].

In this trial, complete coronal pulpotomy instead of partial pulpotomy was adopted in order to standardize the treatment technique and therefore reduce heterogeneity in the data. However, research has shown comparable histological responses to complete or partial pulpotomies in immature permanent molars [31]. Partial pulpotomy is a less invasive method that preserves the coronal part of the pulp and may be able to avoid possible root canal obliteration. This would in turn evade complications such as negotiating calcified root canals should the pulpotomy fail. Therefore, partial pulpotomy for teeth with irreversible pulpitis may be a reasonable treatment option that should be explored in future clinical trials.

The mean age of patients was ≈ 27 years. Although aging of the pulp tissue reduces the success rate of VPT [32], this trial revealed that the use of an appropriate material and technique may allow the pulp to heal in adults, at least as seen radiographically and clinically.

Calcium hydroxide (CH) had been considered the gold standard material for pulp-capping as it allows dentine bridge formation; however, studies have shown the results to be variable and unpredictable [33]. MTA has become the new gold standard for pulp capping due to its predictable pulp tissue regeneration [34]. There are several reports demonstrating the successful use of MTA for pulpotomies in primary [16,17] or immature permanent teeth [8,18]; however, only one study investigated a similar role in molars with closed apices and irreversible pulpitis [9]. Nevertheless, the outcomes of pulpotomies with CH [35], MTA [9] and CEM [10,11] were favorable.

The primary long-term outcome measures in this trial were clinical and radiographic success in 12 months post-treatment. The high clinical success rates (>97%) are probably due to the evaluations being based on patient symptoms. Since chronic apical periodontitis as well as internal/external root resorption may be asymptomatic clinically, the root and periapical status were also examined radiographically. As expected, the radiographic examination revealed slightly lower success rates for both materials under investigation (92% PCEM and 95% for PMTA). Interestingly, the success rate for pulpotomy as an alternative simple treatment is comparable with the treatment outcome expected from root canal treatment which ranges up to 89% [6,36].

When the pulp tissue of permanent teeth is infected, initially the superficial section of the pulp is affected [37]. The long-term radiographic evaluations demonstrated that removing the inflamed coronal part of the pulp and covering it with a suitable biomaterial will create favorable conditions for healing of the remaining pulp. Various studies have suggested that the key factor in VPT is the sealing ability of the material [38]. In addition, Massler [39] demonstrated that the most important cause of failure is bacterial recontamination during the healing process. CEM prevents microleakage and has a sealing ability superior to IRM and comparable to MTA [20]. Moreover, CEM is an effective antibacterial agent [24]. The results of the present trial were consistent with the reports from previous studies evaluating the outcome of pulpotomy in mature permanent human teeth [9-11,40,41].

The 12-month post-operative follow-up in the present trial was longer than previous reports [42,43]. The majority of researchers have used short duration of follow-up as the end-point due to the problems in patient attendance in clinical trials. VPT failures tend to occur during the first post-operative months (<2 months) [44,45]. Matsuo et al. [46] reported similar success rates for VPT after 3 months and

18 months post-operatively. Francischone [47] followed the cases for 6 years and reported that most failures occurred during the first 45 days after treatment; they therefore suggested that 2–3 months follow-up was adequate. The 12-month follow-up period (mean of > 12.9) adopted in the present trial should therefore be adequate for evaluation of clinical and radiographic success rates.

The biological mechanism by which CEM or MTA promotes healing is currently unknown. This characteristic is likely to be the result of several properties such as their sealing ability [20], dentinogenesis [21,23], cementogenesis [48–50], apexogenesis [8,51,52], low cytotoxicity [53,54] or high alkalinity [19]. In addition, other favorable treatment outcomes utilizing CEM, such as management of inflammatory external root resorption [55] and regenerative endodontics [56], have also been mentioned.

Conclusion

There was no significant difference in the favorable outcomes of permanent molar teeth with irreversible pulpitis undergoing pulpotomy using CEM cement or MTA.

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References

[1] Miyashita H, Worthington HV, Qualtrough A, Plasschaert A. Pulp management for caries in adults: maintaining pulp vitality. Cochrane Database Syst Rev 2007;2:CD004484.

[2] Stanley HR. Pulp capping: conserving the dental pulp-can it be done? Is it worth it? Oral Surg Oral Med Oral Pathol 1989; 68:628–39.

[3] McDonald RE, Avery DR, Dean JA. Treatment of deep caries, vital pulp exposure and pulpless teeth. Dentistry for the child and adolescent. In: McDonald RE, Avery DR; 8th ed. St. Louis, Mo: Mosby Co; 2004. p 389–412.

[4] Nadin G, Goel BR, Yeung CA, Glenny AM. Pulp treatment for extensive decay in primary teeth. Cochrane Database Syst Rev 2003:CD003220.

[5] Hasselgren G, Reit C. Emergency pulpotomy: pain relieving effect with and without the use of sedative dressings. J Endod 1989;15:254–6.

[6] Kojima K, Inamoto K, Nagamatsu K, Hara A, Nakata K, Morita I, et al. Success rate of endodontic treatment of teeth with vital and nonvital pulps. A meta-analysis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2004;97:95–9.

[7] Bender IB. Reversible and irreversible painful pulpitis: diagnosis and treatment. Aust Endod J 2000;26:10–14.

[8] Witherspoon DE, Small JC, Harris GZ. Mineral trioxide aggregate pulpotomies: a case series outcomes assessment. J Am Dent Assoc 2006;137:610–18.

[9] Eghbal MJ, Asgary S, Baglue RA, Parirokh M, Ghoddusi J. MTA pulpotomy of human permanent molars with irreversible pulpitis. Aust Endod J 2009;35:4–8.

[10] Asgary S, Ehsani S. Permanent molar pulpotomy with a new endodontic cement: a case series. J Conserv Dent 2009;12: 31–6.

[11] Asgary S. Calcium-enriched mixture pulpotomy of a human permanent molar with irreversible pulpitis and condensing apical periodontitis. J Conserv Dent 2011;14:90–3.

[12] Asgary S, Eghbal MJ. The effect of pulpotomy using a calcium-enriched mixture cement versus one-visit root canal therapy on postoperative pain relief in irreversible pulpitis: a randomized clinical trial. Odontology 2010;98: 126–33.

[13] Aeinehchi M, Eslami B, Ghanbariha M, Saffar AS. Mineral trioxide aggregate (MTA) and calcium hydroxide as pulp-capping agents in human teeth: a preliminary report. Int Endod J 2003;36:225–31.

[14] Dominguez MS, Witherspoon DE, Gutmann JL, Opperman LA. Histological and scanning electron microscopy assessment of various vital pulp-therapy materials. J Endod 2003;29:324–33.

[15] Asgary S, Parirokh M, Eghbal MJ, Ghoddusi J, Eskandarizadeh A. SEM evaluation of neodentinal bridging after direct pulp protection with mineral trioxide aggregate. Aust Endod J 2006;32:26–30.

[16] Fallahinejad Ghajari M, Mirkarimi M, Vatanpour M, Kharrazi Fard MJ. Comparison of pulpotomy with formocresol and MTA in primary molars: a systematic review and metaanalysis. Iran Endod J 2008;3:45–9.

[17] Malekafzali B, Shekarchi F, Asgary S. Treatment outcomes of pulpotomy in primary molars using two endodontic biomaterials. A 2-year randomised clinical trial. Eur J Paediatr Dent 2011;12:189–93.

[18] Barrieshi-Nusair K, Qudeimat MA. A prospective clinical study of mineral trioxide aggregate for partial pulpotomy in cariously exposed permanent teeth. J Endod 2006;32: 731–5.
[19] Asgary S, Shahabi S, Jafarzadeh T, Amini S, Kheirieh S. The properties of a new endodontic material. J Endod 2008;34: 990–3.
[20] 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;87:706–9.
[21] Asgary S, Eghbal MJ, Parirokh M, Ghanavati F, Rahimi H. A comparative study of histologic response to different pulp capping materials and a novel endodontic cement. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008; 106:609–14.
[22] Asgary S, Parirokh M, Eghbal MJ, Ghoddusi J. SEM evaluation of pulp reaction to different pulp capping materials in dog's teeth. Iran Endod J 2006;4:117–22.
[23] Tabarsi B, Parirokh M, Eghbal MJ, Haghdoost AA, Torabzadeh H, Asgary S. A comparative study of dental pulp response to several pulpotomy agents. Int Endod J 2010; 43:565–71.
[24] Asgary S, Kamrani FA. Antibacterial effects of five different root canal sealing materials. J Oral Sci 2008;50:469–74.
[25] Asgary S, Eghbal MJ, Parirokh M, Ghoddusi J. Effect of two storage solutions on surface topography of two root-end fillings. Aust Endod J 2009;35:147–52.
[26] 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;35:243–50.
[27] Carrotte P. A clinical guide to endodontics. London: British Dental Association; 2003.
[28] Strindberg LZ. The dependence of the results of pulp therapy on certain factors. Acta Odontol Scand 1956;14(Suppl 21): 1–175.
[29] DiRenzo A, Gresla T, Johnson BR, Rogers M, Tucker D, BeGole EA. Postoperative pain after 1- and 2-visit root canal therapy. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2002;93:605–10.
[30] Torabinejad M, Kutsenko D, Machnick TK, Ismail A, Newton CW. Levels of evidence for the outcome of nonsurgical endodontic treatment. J Endod 2005;31:637–46.
[31] Cleaton-Jones P, Duggal M, Parak R, Williams S, Setzer S. Equivalency study of histological responses to complete or partial pulpotomies in inflamed baboon immature first permanent molars. SADJ 2007;62:062–5.
[32] Camp JH, Fuks AB. Pediatric endodontics. In Cohen S, Hargreaves KM, editors. Pathway of the pulp. 9th ed. St. Louis, MO: CV Mosby; 2006. p 838.
[33] Auschill TM, Arweiler NB, Hellwig E, Zamani-Alaei A, Sculean A. Success rate of direct pulp capping with calcium hydroxide. Schweiz Monatsschr Zahnmed 2003; 113:946–52.
[34] Nair PN, Duncan HF, Pitt Ford TR, Luder HU. Histological, ultrastructural and quantitative investigations on the response of healthy human pulps to experimental capping with mineral trioxide aggregate: a randomized controlled trial. Int Endod J 2008;41:128–50.
[35] Calişkan MK. Pulpotomy of carious vital teeth with periapical involvement. Int Endod J 1995;28:172–6.
[36] Weiger R, Axmann-Krcmar D, Löst C. Prognosis of conventional root canal treatment reconsidered. Endod Dent Traumatol 1998;14:1–9.
[37] Yamasaki M, Kumazawa M, Kohsaka T, Nakamura H, Kameyama Y. Pulpal and periapical tissue reactions after experimental pulpal exposure in rats. J Endod 1994;20:13–17.
[38] Tobias RS, Plant CG, Browne RM. Reduction in pulpal inflammation beneath surface-sealed silicates. Int Endod J 1982;15:173–80.
[39] Massler M. Preserving the exposed pulp. J Pedodont 1978;2: 217–27.
[40] McDougal RA, Delano EO, Caplan D, Sigurdsson A, Trope M. Success of an alternative for interim management of irreversible pulpitis. J Am Dent Assoc 2004;135: 1707–12.
[41] Nosrat IV, Nosrat CA. Reparative hard tissue formation following calcium hydroxide application after partial pulpotomy in cariously exposed pulps of permanent teeth. Int Endod J 1998;31:221–6.
[42] Oliveira MAF, Busato ALS. Pulpotomia com e sem isolamento absoluto. Avaliaçã o clínica e radiográfica. Rev Gaúcha Odontol 1996;44:262–4.
[43] Estrela C, Zina O, Borges AH. Correlaçã o entre o diagnostic clínico da polpa dental inflamada eo reparo após pulpotomia. Rev Odontol Brasil Cent 1996;6:4–8.
[44] Zilberman U, Mass E, Sarnat H. Partial pulpotomy in carious permanent molars. Am J Dent 1989;2:147–50.
[45] Mejare I, Cvek M. Partial pulpotomy in young permanent teeth with deep carious lesions. Endod Dent Traumatol 1993; 9:238–42.
[46] Matsuo T, Nakanishi T, Shimizu H, Ebisu S. A clinical study of direct pulp capping applied to carious-exposed pulps. J Endod 1995;22:551–6.
[47] Francischone CE. Avaliaçã o clínico e radiográfica, feita a curto e longo prazo, de uma técnica de pulpotomia em funçã o da idade do paciente, do grupo de dentes e da propedêutica. PhD Thesis. Bauru, Brazil: University of São Paulo; 1978.
[48] Asgary S, Eghbal MJ, Ehsani S. Periradicular regeneration after endodontic surgery with calcium-enriched mixture cement in dogs. J Endod 2010;36:837–41.
[49] Samiee M, Eghbal MJ, Parirokh M, Abbas FM, Asgary S. Repair of furcal perforation using a new endodontic cement. Clin Oral Investig 2010;14:653–8.
[50] Asgary S. Furcal perforation repair using calcium enriched mixture cement. J Conserv Dent 2010;13:156–8.
[51] Nosrat A, Asgary S. Apexogenesis treatment with a new endodontic cement: a case report. J Endod 2010;36: 912–14.
[52] Nosrat A, Asgary S. Apexogenesis of a symptomatic molar with calcium enriched mixture. Int Endod J 2010;43:940–4.
[53] Mozayeni MA, Salem Milani A, Alim Marvasti L, Asgary S. Cytotoxicity of calcium enriched mixture cement compared with mineral trioxide aggregate and intermediate restorative material. Aust Endod J 2010;In press (doi:10.1111/j.1747-4477.2010.00269.x).
[54] Ghoddusi J, Tavakkol Afshari J, Donyavi Z, Brook A, Disfani R, Esmaeelzadeh M. Cytotoxic effect of a new endodontic cement and mineral trioxide aggregate on L929 line culture. Iran Endod J 2008;3:17–23.
[55] Asgary S, Nosrat A, Seifi A. Management of inflammatory external root resorption by using calcium-enriched mixture cement: a case report. J Endod 2011;37:411–13.
[56] Nosrat A, Seifi A, Asgary S. Regenerative endodontic treatment (revascularization) for necrotic immature permanent molars: a review and report of two cases with a new biomaterial. J Endod 2011;37:562–7.