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Original Article

Evaluation of Partial Pulpotomy Treatment in Cariously Exposed Immature Permanent Molars: Randomized Controlled Trial

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ABSTRACT

Background and Aims: This study aimed to assess the outcomes of partial pulpotomy treatments using different biocompatible materials which were Biodentine®, mineral trioxide aggregate (MTA), and calcium hydroxide (CH) in cariously exposed pulp tissue in immature permanent molars. **Materials and Methods:** Fifty-four teeth of 50 patients, which had cariously pulp exposures were randomly divided into Biodentine®, MTA, and CH groups for partial pulpotomy treatments and finally restored with stainless steel crowns at the same appointment. Clinical and radiographical success was evaluated by the absence of any clinical and radiographical signs and symptoms for 12 months. Also, Image J was used for the quantitative assessment of length developments for mesial and distal roots. *P* value of less than 0.05 was considered statistically significant. **Results:** Partial pulpotomy treatments showed high overall success rate (87%). On the other hand, Biodentine and MTA showed higher success rates compared to CH without any statistical significance ($P = 0.09$). Besides, mesial and distal root lengths displayed a continuous and significant increase in each group at sixth month follow-up ($P = 0.01$; $P = 0.03$). **Conclusions:** Favorable results demonstrated that Biodentine, MTA, and CH might be recommended as suitable agents for partial pulpotomy treatment in cariously exposed immature molars with clinical diagnosis of normal pulp or reversible pulpitis.

KEYWORDS: *Biodentine, immature permanent teeth, mineral trioxide aggregate, partial pulpotomy*

INTRODUCTION

Management strategies for treatment of the cariously exposed pulp are shifting with avoidance of pulpectomy and re-emergence of vital pulp treatment techniques.[1-3] Pulp–dentin complex exhibits a broad spectrum of responses against caries progression that represents a summation of injury, defense, and repair events. During the initial stage of caries process which is in enamel, pulpal responses and changes are lower. However, in deep carious lesions, pulp–dentin complex shows more or less reversible or irreversible changes.[4,5] If the cause of the inflammation is removed and bacterial microleakage is prevented, the inflamed pulp might heal.[1-3] Treatment options of pulp exposure such as direct pulp capping and partial pulpotomy following complete caries removal allow clinicians to assess pulpal conditions subjectively based on appearances such as color and occurrence of bleeding.[6,7] Partial pulpotomy treatment is performed to treat reversible pulpal

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inflammation to promote root development and apical closure.

The most common material used in partial pulpotomy of immature permanent teeth has been calcium hydroxide. Three years follow-up of partial pulpotomy treatments with CH has been reported for cariously exposed immature permanent teeth with high clinical success rates.[8,9] However, choosing hydraulic calcium silicate-based materials (tricalcium silicate cements) with well-accepted biocompatibility and tissue repair promoting properties, such as MTA and Biodentine could probably be an appropriate option for partial pulpotomy. A clinical study reported 95.2% and 96% success rates through CH and MTA for partial pulpotomy treatments of cariously exposed pulp tissue in immature permanent teeth up to 1–2 years.[10] Also, another study presented successful clinical and histological outcomes of partial pulpotomy using Biodentine® and ProRoot MTA.[11]

This randomized controlled clinical study aimed to compare the success of partial pulpotomy treatment using Biodentine®, MTA, and CH in cariously exposed asymptomatic immature permanent teeth with vital pulps and evaluate root developments because of the limited number of long-term observational studies with tricalcium silicate types of cement. The hypothesis was Biodentine® and MTA will show a particularly significant difference in clinical and radiographical success rates and progression of root development compared to CH.

Materials and Methods

Procedures followed during the study were in accordance with the Helsinki Declaration, written consents were taken and ethical approval was obtained with the number 36290600/36 from Clinical Research Ethical Clearance Committee of ……. University, Faculty of Dentistry,……..,……. following power analysis, which included a total sample size of 48 (16 per group) to detect with a power of 80% at the 5% significance level and 0.4 effect size.

Study design

Healthy patients aged between 6 and 13 years who referred to …. University, Pediatric Dentistry Clinics, were included in the study. Written consents were obtained from all participating children and their parents before the treatment procedure. One-hundred-nineteen asymptomatic immature permanent first and second mandibular molar teeth with deep dentine carious lesions with asymptomatic vital pulps were treated with vital pulp treatments during the study period. After complete caries removal if there is no pulp exposure, the recommended clinical protocol is to place a protective liner at the bottom of the cavity to treat with indirect pulp therapy. When pulp exposure was smaller than half mm, and hemostasis could be achieved, teeth were treated with direct pulp therapy. However, if there was pulp exposure, but hemostasis could not be achieved, teeth were treated with apexification. As a result, 54 teeth of 50 patients were treated with partial pulpotomy and included in this study; however, the remaining 65 teeth which were treated with other vital pulp treatments, such as indirect pulp treatment and direct pulp treatment, were excluded. Figure 1 shows the flow chart of this study.

Inclusion criteria for selected cases were immature permanent molar teeth with cariously pulp exposures larger than half mm and less than 2 mm, which happened during the treatment procedure, and hemostasis could be controlled within 2 min. with 1.25% sodium hypochlorite (NaOCl). Other criteria was that only mandibular permanent molar teeth with only one mesial and distal roots were included to standardize and minimize the risk of wrong measurements with Image J. Also, if the included teeth had any dental anomalies such as dilaceration, taurodontism, the teeth were excluded during preoperative radiographic evaluation.

Treatment procedure

Partial pulpotomy technique

Following block local anesthesia using articaine hydrochloride with 4% epinephrine (Ultracaine® D-S Forte ampule, Sanofi-Aventis, Germany), the teeth were isolated with a rubber dam. After isolation, sharp fractured edges and caries at lateral walls of the cavity were removed with diamond fissure bur (no. 12 or 14/ISO) with a high-speed handpiece under water cooling**.** Large round bur used to remove carious dentine tissue in the periphery of the cavity and in proximity to the pulp.

If the pulp exposure smaller than 2 mm diameter occurred during the caries removal procedure with a low-speed handpiece, exposed pulp and surrounding dentine were cleaned with isotonic saline solution. The superficial layer of the exposed pulp and surrounding dentine were excised to a depth of approximately – 2–3 mm using a high-speed diamond round bur (no. 20/ISO) with a light touch under water cooling. Pulp bleeding was stopped with cotton pellets moistened with 1.25% NaOCl.

After hemostasis, a randomly chosen biocompatible pulp medicament was condensed to partial pulpotomy cavity without pressure. Block randomization technique was used for random distribution of three different medicament groups. These biocompatible pulp medicaments were CH powder (Merck, Darmstadt, Germany), MTA (ProRoot MTA®, Dentsply, Tulsa, USA), and a hydraulic calcium

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silicate-based material (Biodentine®, Septodont, Saint Maur-des-Fossees, France).

After randomization, the chosen medicament was used as pulpotomy dressing and prepared according to the manufacturers' instructions and condensed to the partial pulpotomy cavities. Then glass ionomer cement (Kavitan Pro, Spofa Dental, Jicin, Czech Republic) was placed over these materials as a liner and, finally, restored with stainless steel crowns (3M ESPE, St. Paul, Minn., USA). Stainless steel crowns were cemented with a different glass ionomer cement (Cavitan CEM, Spofa Dental, Jicin, Czech Republic) at the same appointment.

Follow-up periods

Patients were scheduled for clinical examinations at 1, 3, 6, and 12 months and radiographical evaluations at 3, six, and 12 months. In clinical evaluation, percussion tenderness of teeth and palpation of soft tissue around the teeth, the formation of abscess and fistula were examined. Postoperative pain and type and duration of the pain were recorded. If postoperative pain or any clinical symptom was detected, it was considered as clinical failure.

Periapical radiographs were obtained preoperatively and postoperatively to assess the condition of periradicular tissues with Image Plate System (Digora®, Soredex, Helsinki, Finland). Root development continuity, integrity, and/or discontinuity of lamina dura and presence of radiolucency in bifurcation or periapical area were evaluated radiographically during follow-up. If root development or integrity of lamina dura discontinue or presence of radiolucency was seen in the bifurcation or periapical area, it was considered as radiographic failure. But, if clinical symptoms accompanied with the one of the radiographic failures, it was considered as failure and treated with apexification. However, if radiographic failure was seen without any clinical symptoms, it was not treated with apexification, continue to follow-up until the observation of any clinical signs or symptoms.

Apical closure stages were graded at seventh, eighth, and ninth stages based on Nolla's classification.[12] Then, root development stages at preoperative and 12 month follow-up were compared according to these Nolla stages and considered as success or failure. Also, overall success of this study was defined when there are no signs or symptoms of any clinical or radiographical failure.

Mesial and distal root developments were also evaluated in a 12 month follow-up period using Image J program (V. 1.44p; National Institutes of Health, Bethesda, Maryland, USA). A plug-in program for Image J called Turbo-Reg (Biomedical Imaging Group, Swiss Federal Institute of Technology, Lausanne, Switzerland) was used for image alignment of non-standardized preoperative and postoperative plate images, and Image J was used for the evaluation of the progress of root developments during follow-up in terms of pixel value.[13-16]

First step of the Image J measurements was to convert the taken images for each case to 8-bit TIFF files [Figure 2-a]. After subpixel image alignment with Turbo-Reg [Figure 2-b], a measuring scale was set in Image J for each set of radiographs to obtain a calibrated "output" image [Figure 2-c]. This calibrated "output" image and other images were evaluated for root lengths with Image J, quantitatively. For evaluations of root lengths, a "straight-line" was drawn between bifurcation point and apical area for both mesial and distal roots. The red straight line drawn between the lowest bifurcation point and middle of the apical area of the distal root can be seen in Figure 2-d. Also, each measurement was repeated three times to prevent or reduce the number of faulty measurements for each root. These pixel values were saved as excel tables and compared root developments quantitatively for each group as time-dependent and between other groups.

Statistical analysis

Data analysis was performed by using IBM SPSS Statistics version 17.0 software (IBM Corp., Armonk, NY, USA). While the descriptive statistics for ages were expressed as mean ± standard deviation (SD), otherwise, medians (interquartile range-IQR) were used for mesial and distal root lengths. The number of cases and percentages were used for categorical data. In addition, the mean differences in ages among groups were analyzed by one-way ANOVA, otherwise, the Kruskal–Wallis test was applied for comparisons in terms of mesial and distal root lengths. When *P* values from the Kruskal–Wallis test statistics were statistically significant, Conover's multiple comparison test was used to know which group differed from the others. Whether the differences in mesial and distal root lengths among follow-up times were statistically significant or not was evaluated by the Friedman test. When the *P* values from the Friedman test statistics were statistically significant, Bonferroni adjusted multiple comparison test was used to know which time differed from the others. *P* value of less than 0.05 was considered to statistically significant.

Results

One-hundred-nineteen immature permanent molar teeth were treated in this study period. However, only 54 of them were treated with partial pulpotomy according to

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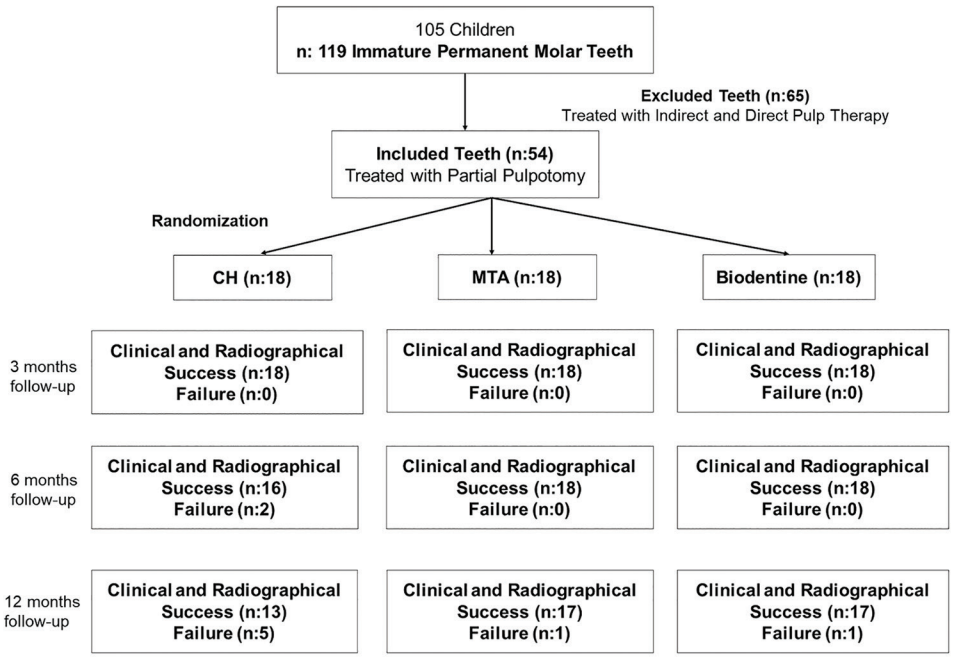


Figure 1: Consort flow diagram of randomized clinical study

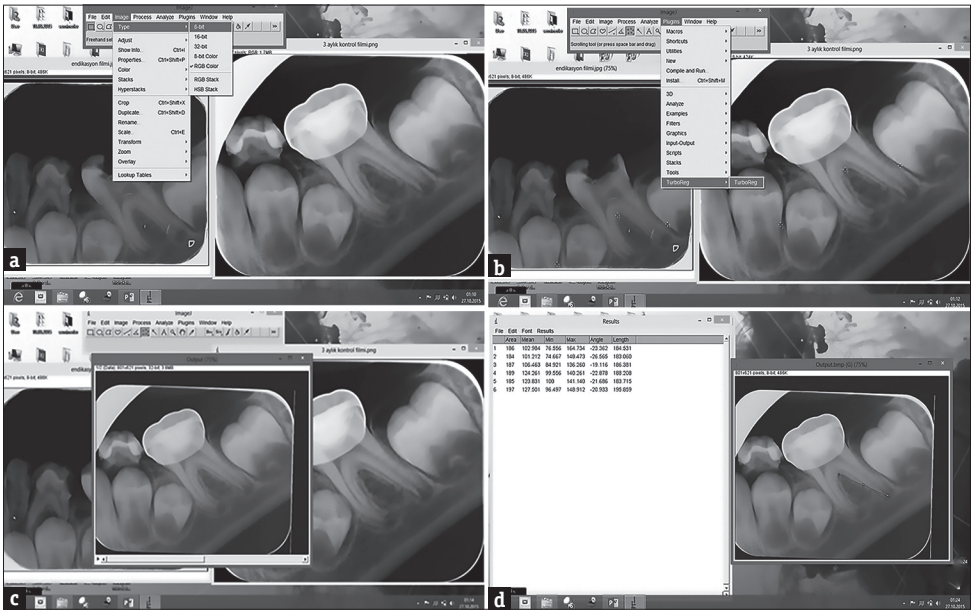


Figure 2: (a-d): Image J analysis illustrations showing steps for measurement of mesial and distal root lengths, (a) each image was converted to 8-bits; (b) subpixel image alignment with Turbo-Reg; (c) calibrated output image; (d) straight-line between the bifurcation and apical area of distal root and table of the repeated measurements of root lengths

the inclusion criteria. These 54 teeth were randomly distributed in three groups (*n*: 18) and treated by using CH, MTA, and Biodentine materials and evaluated for 12-months in this clinical study [Figure 1]. There was no statistically significant difference between these three groups according to patients' average ages ($P = 0.46$), gender ($P = 0.51$), or tooth numbers ($P = 0.89$) [Table 1].

Clinical success rates of CH, MTA, and Biodentine® were 72.2%, 94.4%, and 94.4%, respectively. Achieved overall success rate was 87% at 12 months, and the difference between groups was not statistically significant ($P = 0.09$; $P \geq 0.05$). The overall success rates and degree of significance of pulp medicaments used in the study are given in Table 2. According to the preoperative distribution, the eighth stage of Nolla for the included teeth was 55.5%, 77.8%, and 66.7% for CH, MTA, and Biodentine® groups, respectively. At 12 months follow-up, the distribution of the ninth

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stage of Nolla for the teeth that showed overall success was 53.8%, 64.7%, and 52.9% for CH, MTA, and Biodentine® groups, respectively [Table 3].

Table 1: Demographic data of the patients

	CH (*n*: 18)	MTA (*n*: 18)	Biodentine (*n*: 18)	*P*
Age	7.5±1.2	8.0±1.4	8.1±1.9	0.46†
Gender				0.51‡
♂	8 (44.4%)	11 (61.1%)	8 (44.4%)	
♀	10 (55.6%)	7 (38.9%)	10 (55.6%)	
Tooth number				0.89
36	11 (61.1%)	11 (61.1%)	10 (55.6%)	
37	0 (0.0%)	1 (5.6%)	1 (5.6%)	
46	6 (33.3%)	5 (27.8%)	5 (27.8%)	
47	1 (5.6%)	1 (5.6%)	2 (11.1%)	

†Average ages were analyzed with One-Way ANOVA. Gender distribution was analyzed with ‡Pearson's Chi-Square Test. Tooth localisations were analyzed with the ¶Likelihood Ratio Test. *Significance between the groups in all demographic data shown as $P<0.05$

Table 2: Overall success rates of CH, MTA, and Biodentine groups at 12-months follow-up

	CH (*n*=18)	MTA (*n*=18)	Biodentine (*n*=18)	*P*	Total (*n*=54)
Success	13 (72.2%)	17 (94.4%)	17 (94.4%)	0.09†	47 (87%)
Failure	5 (27.8%)	1 (5.6%)	1 (5.6%)		7 (13%)

*Data, sample number were shown as %, †One Way Anova, $P<0.05$

Abscess formation was observed in two patients between 3 and 6 months follow-up and three patients between 6 and 12 months follow-up in the CH group, and only one patient between 6 and 12 months follow-up in both MTA and Biodentine® groups. Also, lack of continuity of lamina dura, root development, and presence of radiolucent area at the apical third of the roots were signs of failure that were present in the radiographical evaluation, so these cases were treated with apexification.

Table 4 shows mesial and distal root developments of the groups during the follow-up period. There was no statistically significant difference between CH, MTA, and Biodentine® groups in terms of mesial root lengths at preoperative ($P = 0.75$; $P \geq 0.05$) and third month follow-up ($P = 0.07$; $P \geq 0.05$). However, the difference between the groups in terms of the mesial root lengths at the 6th and 12th month follow-up was statistically significant ($P = 0.02$, $P = 0.01$; $P < 0.05$). The increase in the mesial root lengths at 6th-month follow-up was significantly higher in the CH group than in the MTA and Biodentine® groups ($P < 0.05$); however, there was no significant difference between MTA and Biodentine® groups ($P \geq 0.05$). Also, the increase in the mesial root length at 12th month follow-up

Table 3: Stage of root developments of based on Nolla's classification at preoperative for all teeth and at 12-months follow-up evaluations for teeth with the overall success

Classification	Preoperative			12-months follow-up		
	CH	MTA	Biodentine	CH	MTA	Biodentine
Nolla 7	3 (16.7%)	3 (16.7%)	5 (27.8%)	-	-	-
Nolla 8	10 (55.5%)	14 (77.8%)	12 (66.7%)	-	-	-
Nolla 9	5 (27.8%)*	1 (5.5%)*	1 (5.5%)*	7 (53.8%)	11 (64,7%)	9 (52.9%)
Nolla 10	-	-	-	6 (46.2%)	6 (35.3%)	8 (47.1%)
Total teeth number (percentage)	18-100%	18-100%	18-100%	13 (72.2%)	17 (94.4%)	17 (94.4%)

*Refers subjects with overall failure and excluded from the study

Table 4: Comparisons of mesial and distal root lengths between CH, MTA, and Biodentine® groups and follow-up times

	CH		MTA		Biodentine		*P*†
	Mean±SD	Median (IQR)	Mean±SD	Median (IQR)	Mean±SD	Median (IQR)	
Mesial root							
Preop	154.841±40.976	148.251 (58.423)	176.826±61.083	156.357 (115.227)	154.056±39.743	142.844 (31.776)	0.75
3rd month	206.440±59.561	215.530 (75.095)	200.911±67.725	205.235 (104.176)	172.249±45.311	161.830 (65.403)	0.07
6th month	259.844±67.102	287.367 (89.385)	216.250±55.185	224.914 (109.787)	197.654±55.087	182.172 (97.810)	0.01*
12th month	302.383 ±69.255	295.514 (93.477)	256.660±62.371	257.664 (93.661)	232.402±49.095	215.473 (80.015)	0.02*
Distal Root							
Preop	168.915 ±51.656	164.840-32.487	192.902±61.827	174.505 (108.224)	177.743±50.815	163.013 (57.904)	0.88
3rd month	217.116±61.934	240.276 (99.022)	218.166±62.588	204.425 (105.523)	196.322±53.457	177.918 (61.638)	0.16
6th month	276.459±84.586	264.775 (107.278)	243.912±65.865	237.991 (108.328)	213.103±55.959	201.452 (82.434)	0.03*
12th month	322.154±87.985	314.775 (144.223)	283.001±69.764	290.625 (139.458)	262.967±51.613	249.477 (81.070)	0.09

Data are shown as mean±standard deviation (sd); medians (interquartile range-IQR), †Comparisons between the groups for each follow-up time were evaluated with Kruskal Wallis, Bonferroni correction. *$P<0.05$ accepted as significant

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showed no significant difference between CH, MTA, and Biodentine® groups ($P \geq 0.05$).

There was no statistically significant difference between the CH, MTA, and Biodentine® groups in terms of distal root lengths at preoperative ($P = 0.88$; $P \geq 0.05$), third ($P = 0.16$; $P \geq 0.05$), and 12th month follow-up ($P = 0.09$; $P \geq 0.05$). However, at 6th month follow-up, there was a statistically significant increase in root developments regarding the group difference ($P = 0.03$; $P < 0.05$).

Discussion

If the tooth is vital, with a diagnosis of normal pulp or reversible pulpitis, partial pulpotomy might be a valid alternative to apexification or conventional root canal treatment for cariously exposed immature permanent teeth.[8] The results of this study showed high success rates for partial pulpotomy treatments with three different medicaments without statistical significance between the groups on cariously exposed teeth. After 12 month follow-up, the overall success rate of 87% may be related to the standardization of inclusion criteria for teeth; hemostasis and use of biocompatible pulp medicaments as well as hermetic permanent restoration of the treated teeth. However, root developments of the teeth during the 12 month follow-up were not completed because of being at different Nolla classification stages at the preoperative stage. Interestingly, all failure subjects were at the ninth stage of Nolla, where the apical closure had nearly completed, pointing out that inadequate blood supply for pulp healing might be the reason for failure. This result supports researchers' idea that the healing ability of pulp in immature permanent teeth is due to increased apical perfusion, which can be directly related to apical closure stage.[12,17]

A randomized clinical study reported a high incidence of unfavorable outcomes of partial pulpotomy treatment with CH and MTA in permanent molar teeth with pulp exposure areas larger than 5 mm^2.[18] Therefore, in this study, the superficial layer of the cariously exposed pulp and surrounding dentine were excised to a depth of about two or three mm, as provided by the guideline[8] for cavity standardization and protection of ideal healing capacity of pulp in order not to take risks about the critical wound surface. Our results showed that exposure of pulp larger than half mm and less than 2 mm, which was cariously infected, can be treated with partial pulpotomy with high overall success (87%).

Hemostasis and disinfection are also important factors that affect prognosis in VPTs. NaOCl is the most widely used hemostatic antibacterial agent in this sense. Different concentrations and application times of NaOCl evaluated in histological studies reported that pulp tissue contact with NaOCl forms a modified environment that emerges as an intermediate region that reduces the cytotoxic effects of the restorative materials in the first period of application.[19,20] Another study[21] showed high success with the application of 1.25% NaOCl within 1 min. for hemostasis. Considering all these studies, 1.25% NaOCl moistened cotton pellets were used within 2 min. for hemostasis in this study.

Material selection is another important parameter for successful VPTs. Calcium hydroxide was the historical gold standard pulp capping material; however, clinical studies on VPT for cariously exposed pulps treated with CH have shown poor outcomes. So, nowadays, hydraulic calcium silicate-based materials, such as MTA and Biodentine, have shown higher clinical and radiographical outcomes compared with CH. These materials induce the formation of thicker and less porous hard tissue barrier than CH after VPTs. However, these hydraulic calcium silicate-based materials also have advantages over each other. MTA is still the gold standard among the hydraulic calcium silicate-based materials but, Biodentine has been an alternative pulp capping material due to long setting time, expense and discoloration problems of MTA.[22,23]

Previous studies[22-25] have reported that Biodentine® is a promising hydraulic calcium silicate-based material, with non-staining fast set (12 min.), no cytotoxic effect on pulp tissue, has induction on dentinogenesis mechanism in animal studies. The clinical and radiographical success of Biodentine® has been demonstrated in DPT and apexification treatments of immature permanent teeth in case reports and studies.[26-28] However, most of the pulpotomy studies with Biodentine® were on primary teeth.[29-31] According to the overall results of the present study, MTA and Biodentine® groups had similar and better outcome than CH, but the result was not statistically significant. Similar results for MTA and Biodentine® have been shown in another study and, the overall success of both the materials was 90% and 92%, respectively.[32]

According to the clinical studies,[6,10,11,18,22,32-34] CH, MTA, and Biodentine showed similar success results for partial pulpotomy treatments when compared to each other for reversible or irreversible pulpitis and for permanent teeth with open or close apices. Even though hydraulic calcium silicate-based materials provide better quality and thicker hard tissue barrier in a short time, the results of comparative clinical studies showed similar clinical success of partial pulpotomy treatments with CH, MTA, and Biodentine materials. Cox *et al*.[1] reported that tunnel defects in dentine bridges

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under calcium hydroxide dressings can act as pathways for microleakage and material might dissolve over the time. Therefore, follow-up time and final restoration have an important impact on the prognosis of these treatments.

In deep carious lesions specially with cariously exposed pulp, pulp–dentin complex shows reversible or irreversible changes with the different degrees of inflammation and first diagnosis might be misleading and the prognosis cannot be known exactly. However, according to the today's developments on these pulp capping materials, partial pulpotomy might show greater clinical success than expected specially for irreversible pulpitis cases.[4,5,33,35] So, we might say that partial pulpotomy treatments done with one of these, biocompatible pulp capping materials, providing good hemostasis with NaOCl and hermetic sealing with final restoration, give the ability of the inflamed pulp to recover and maintain the vitality of permanent teeth.

Therefore, CH is one of the preferred pulp capping materials, however, the root development stage, hemostasis, and final restoration play an important role for prognosis. It is critical to avoid bacterial contamination of the pulp tissue because of any leakage after restoration. Many studies have shown that stainless steel crowns have the most successful results for long-term clinical success.[36,37] Therefore, stainless steel crowns were preferred as the final restoration for this study. In this study, it is found that there was no statistically significant difference between CH, MTA, and Biodentine in terms of clinical and radiographical success. As a result, calcium silicate-based materials might be recommended in partial pulpotomies because of their superior properties than CH for long-term clinical studies.

Image J with Turbo-Reg plug-in transforms radiographical analysis from nonstandardized radiographs and provides quantitative values as pixels to represent treatment outcomes. This method is mostly used to evaluate the increase in root length and thickness after revascularization treatments for immature teeth.[13-16] Bose *et al*.[13] and Cehreli *et al*.[16] stated that standardized radiographs of a tooth might be taken significantly hard in a child patient so, authors stated that Turbo-Reg plug in of Image J Software provides an image correction to transform nonstandardized preoperative and postoperative radiographs into mathematically aligned radiographic images. Also, authors indicated that they could measure the changes in root dimensions from the calibrated radiograph and commented about the estimated radiographic success. Therefore, according to the increased pixel values obtained from Image J during the follow-up time, we might comment on the progress of root developments because of pulp capping materials or time dependency. Therefore, only immature mandibular permanent molar teeth were included in the study for proper standardization also, permit the root length evaluation because of the long straight root shapes of mandibular molar teeth.

In this study, the results of Image J showed that an increase in both mesial and distal root lengths in the 6th month in CH group Çeviri hatasıwere found to be significantly higher than MTA and Biodentine® groups. While there was no significant difference in the preoperative, third, and 12th month for CH, MTA, and Biodentine® groups considering root development. However, it is not possible to be sure about the ideal lengths for root development for both mesial and distal roots. Thus, we adopted the idea of "each case is normalized to its own preoperative or postoperative measurement, as this evaluation technique minimizes the potential source of systematic errors."[13-16] Furthermore, the results for root length measurement with Image J were supported with Nolla classification in this study to reduce the possibility of measurement errors.

The first limitation of this study was that we could not determine the root thickness in a way that it could be compared to other Image J studies. Partial pulpotomy, like the other VPTs, induces root formation naturally, so we focused on the increase in root development, not thickness. Also, dentine bridge formation is one of the radiographical signs of success after VPTs. Although some studies[8,10,18,38] have measured the thickness of dentine bridge after pulp healing with different biocompatible materials, all teeth were restored with stainless steel crowns as final restorations, so dentine bridge formation after treatment could not be measured in this study. Also, root canal calcification during or after the root development was not seen in any of the included cases, so future studies with more than 12 month follow-up might be more reliable for evaluating overall success rates of partial pulpotomy treatments. Since the treatments and outcome evaluations were done by the same reseacher, blinding was not ensured and this was the other limitation of this study.

Conclusions

Cariously exposed pulp during the treatment of deep dentine caries in immature permanent molar teeth is a big challenge for pediatric dentists. According to these results, partial pulpotomy treatment is a good option and 12-month high success rates with CH, MTA, and Biodentine® might encourage pediatric dentists for this treatment. Considering the pulpal status at the time of

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treatment and applying optimal technique by using CH, MTA, or Biodentine® may have contributed to the successful outcome of partial pulpotomy cases on cariously exposed asymptomatic vital pulps. However, it should be remembered that, case selection and apical closure stage were found to be important for successful clinical results in this treatment option.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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