ORIGINAL RESEARCH

Clinical and Radiographic Outcomes of Mineral Trioxide Aggregate Pulpotomies in Vital Permanent Teeth with Carious Pulp Exposure: A Pioneering Retrospective Study

Margarita Yoshpe[1], Arieh Y Kaufman[2], Shaul Lin[3], Mikhal Malul[4], Malka Ashkenazi[5]

Abstract

Purpose: Vital partial pulpotomy (PP) or cervical pulpotomy (CP) in carious pulp-exposed permanent teeth preserves tooth vitality, promotes pulp healing, decreases treatment costs, and shortens treatment duration, which is a significant factor in treating noncooperative children. The aim of this retrospective study was to compare clinical and radiographic outcomes of partial and CP in vital carious-exposed permanent teeth.

Materials and methods: All vital permanent teeth with carious pulp exposure, treated by pulpotomy using mineral trioxide aggregate (MTA) during 2017–2019, by two operators in one dental center, were included in the study. Around 118 permanent teeth in 97 children and adolescents (mean age 10.9 years) were evaluated 6–57 months postoperatively.

Results: The total success rates of CP and PP were 82.5 and 80.8%, respectively (p = nonsignificant). The only factor that significantly affected the success rate was the presence of preoperative periapical pathology. Teeth without such pathology showed an 87.3% success rate compared to 74.1 and 58.3% in teeth with preoperative enlarged periodontal ligament (PDL) or with periapical radiolucency, respectively (p = 0.0301). Demographic variables, maturation state of the tooth, type of tooth (incisor, premolar, molar), postoperative variables, such as the presence of radiographic dentinal bridge, partial or full obliteration of the pulp during the follow-up period, and the integrity of the final restoration during the recall examinations did not affect the success rate of the treatment.

Conclusion: Partial and CP in vital permanent teeth with carious pulp exposure in children and adolescents might be a reliable alternative to full root canal treatment (RCT).

Keywords: Immature teeth, Mature teeth, Molar, Open apex, Periapical radiolucency, Pulpotomy, Pulp therapy.

International Journal of Clinical Pediatric Dentistry (2023): 10.5005/jp-journals-10005-2483

Introduction

Vital permanent teeth with carious pulp exposure are usually treated by full RCT. This approach can be challenging when treating uncooperative young children, especially when they suffer dental pain or previously experienced an unsuccessful dental treatment.[1] Moreover, obturating immature roots with an open apex is complicated and time-consuming. These factors may subsequently decrease the quality and outcome of the RCT and shorten the survival rate of the treated teeth. PP or CP are minimal invasive pulp treatments that preserve the radicular pulp vitality and promote its healing, thus, enabling the continuation of root development, reduction in treatment costs, and shortening the treatment duration compared to RCT. These advantages are significant factors in treating noncooperative children and can even prevent the need for treatment under general anesthesia.[2–4] Moreover, these treatments are currently recommended by the American Association of Endodontists (AAE) in teeth with the traditional classification of irreversible pulpitis on the condition that the bleeding of their amputated pulp stops within a few minutes.[5] In previously published studies, the clinical success rate of pulpotomy in vital carious molars ranged from 66 to 93%.[6–10] Notwithstanding, the results of these studies were based on evaluations of limited and random case reports (ranging from 27 to 49 cases).

[1]Faculty of Dental Medicine, Hebrew University of Jerusalem, Jerusalem, Israel; Department of Endodontics, Hadassah Medical Center, Jerusalem, Israel; Dental Medical Center, Ashdod, Israel

[2]Department of Endodontology, (Professor Emeritus) The Maurice and Gabriela Goldschleger School of Dental Medicine, Tel Aviv University (TAU), Tel Aviv, Israel

[3]Department of Endodontic, School of Graduate Dentistry, Rambam Health Care Campus, Ruth & Bruce Rappaport Faculty of Medicine, Technion-Israel Institute of Technology, Haifa, Israel; The Israeli National Center for Trauma Emergency & Emergency Medicine Research, Gertner Institute; Sheba Medical Center, Tel Hashomer, Israel

[4]Dental Medical Center, Ashdod, Israel

[5]Pediatric Dentistry Clinic, Oral Medicine Unit, Sheba Medical Center, Tel Hashomer, Israel

Corresponding Author: Margarita Yoshpe, Department of Endodontics, Faculty of Dental Medicine, The Hebrew University of Jerusalem, Jerusalem, Israel, Phone: +972542892976, e-mail: rita.yoshpe@gmail.com

How to cite this article: Yoshpe M, Kaufman AY, Lin S, *et al.* Clinical and Radiographic Outcomes of Mineral Trioxide Aggregate Pulpotomies in Vital Permanent Teeth with Carious Pulp Exposure: A Pioneering Retrospective Study. Int J Clin Pediatr Dent 2023;16(4):555–559.

Source of support: Nil

Conflict of interest: None

The AAE has recommended using a microscope to clinically analyze the pulp condition (2001). However, to the best of our knowledge to date, no study has evaluated the impact of diagnosing the pulp by means of a microscope on the success rate of pulpotomy.

Moreover, in a literature search in PubMed and Google Scholar using the keywords "pulpotomy, permanent, mature and immature molars, and apical radiolucency," no data were found that compare the clinical outcome of PP vs CP or mature vs immature permanent teeth with or without periapical radiolucency. Moreover, only one study and two case reports evaluated the potential application of PP or CP for treating permanent teeth with apical radiolucency.[11–13] Although, Linsuwanont et al.[14] reported a success rate of 76–84% when performing pulpotomy in teeth with apical radiolucency.

Calcium hydroxide [$Ca(OH)_2$] has been previously used for pulpotomy in permanent carious molars. Recently, MTA has been suggested as a replacement for $Ca(OH)_2$ in PP or CP. MTA is a water-based material that is composed of tricalcium silicate, tricalcium aluminate, bismuth oxide, and tetra-calcium aluminoferrite.[15] Though this material, has an antimicrobial effect comparable to $Ca(OH)_2$, it promotes pulpal cell proliferation, significantly reduces bacterial invasion, and sets in moisture. Nevertheless, MTA has a long setting time, poor handling properties, and induces tooth discoloration due to the bismuth oxide, which is included in its composition as a radiopaque agent. The literature review reveals that the clinical superiority of MTA over $Ca(OH)_2$ is still in controversy. A meta-analysis conducted by Taneja and Singh concluded that in spite of the bactericidal property of $Ca(OH)_2$, MTA showed superior clinical and radiologic results when it was used as a capping material for pulpotomy in carious permanent molars.[10,16] In contrast Qudeimat et al.[16] and Jiang et al.[11] showed equivalent clinical and radiologic outcomes with both materials.

The null hypothesis of the present study was that the success rate of pulpotomy with MTA in mature and immature molars, when treated by means of PP or CP, will be comparable. However, the success rate of teeth with periapical radiolucency will be lower than that of teeth with healthy PDL.

Accordingly, the aims of the present study were to compare the effects of the type of pulpotomy (PP vs CP), the maturation status (mature vs immature), and the presence of preoperative periapical radiolucency on the success rate of the MTA-pulpotomy in carious-exposed vital permanent teeth.

Materials and Methods

Ethics

The present study was approved by Institutional Review Board (#0604-20-RMB-D). Upon diagnosis of pulp exposure, the parents were offered two treatment options (RCT or pulpotomy). Parents who preferred the pulpotomy option were asked to give their written consent for the treatment, which also included a commitment to arrive for the follow-up appointments.

Population

The present study included all patients who were treated by means of PP or CP at a dental center, during the period beginning from 1st January 2017 to 31st December 2019 and gave their written consent to participate in the study. Most of the patients were referred by health maintenance organizations or by general practitioners solely for the treatment of a specific permanent molar (s), which they considered difficult to manage. The patients were treated by either one certified pediatric dentist (without the aid of a microscope) or by one certified endodontist (with the aid of a microscope) according to the availability of the dentist at the time of the emergency.

Pulpotomy Procedure

Before treatment, local anesthetics were administered, and a rubber dam was placed over the teeth. The treatment began with the removal of caries. Upon diagnosis of pulp exposure, the pulpotomy was initiated. The decision whether to perform PP or CP was determined according to the intensity of the bleeding from the pulp. If the bleeding continued >6 minutes after initiating PP, despite the pressure with a cotton pellet soaked in sodium a 3% solution of hypochlorite, CP was performed. When bleeding continued even after the performance of CP, an RCT was initiated.

The detailed clinical treatment modality of PP and CP were described previously.[7] Briefly, PP was performed by penetrating the exposure site with a sterile diamond round bur to a depth of 2 mm and removing the most infected pulp tissue. The site was then rinsed for 2–3 minutes using 3% sodium hypochlorite (NaOCl) until the bleeding stopped and dressed with MTA Angelus White (Londrina, Brazil). The MTA was then covered with glass ionomer cement (GC Fuji IX GP FAST).

Cervical pulpotomy (CP) was performed by removing all the pulp tissue in the pulp chamber using a big round diamond bur, the residual radicular pulp was then rinsed for 2–3 minutes using 3% NaOCl until the bleeding stopped and dressed with MTA Angelus White (Londrina, Brazil). The MTA was then covered with glass ionomer cement (GC FUJI IX GP FAST). Subsequently, the final restoration, composite (P60, 3M), stainless steel (SS) crowns, or amalgam restoration, was immediately placed.

Data Collection

A structured form was designed to anonymously collect all demographic and dental variables, such as age, gender, tooth number, maturation stage of the tooth, (apex opened up to 1 mm diameter or closed apex), type of pulpotomy (partial or cervical), type of final restoration (composite on top of glass ionomer in the majority of the treated teeth), and amalgam or SS crown.

Postoperative Follow-up

Clinical and radiographic follow-up examinations were performed following 6 months in the 1st year and every year thereafter. During follow-up, the clinical examinations included mobility and sensitivity to cold and percussion tests. Moreover, the clinical follow-up included an evaluation of the integrity of the final restoration. The clinical evaluations were performed by the operator. All periapical radiographs which were taken during diagnosis and during the follow-up appointments were performed by means of a parallel technique. For radiographic evaluation of the treatment results, postoperative radiographs were compared to the preoperative radiograph by one of the operators and by an independent observer (AK). Their evaluations were compared. When disagreements existed, a discussion was made until consensus was achieved. The evaluated radiographic variables during the followed up appointments included absence or healing of the radiolucent area around the apices, apex closure, continuous root development in immature teeth, and dentin response, such as thickening of root walls or obliteration.

Statistical Analysis

Associations between categorical variables were tested using Chi-squared and Fisher's exact tests. Associations between continuous and categorical variables were assessed using the *t*-test with unequal variance (when the number of levels of the categorical variable was L = 2) or the analysis of variance test (when L > 2).

The potential effects of study variables on tooth survival were assessed using Cox regression. In all tests performed, $p < 0.05$ was considered statistically significant. All the data processing, visualization, and statistical analyses were performed using R (version 3.6.0).[17]

Results

Demographic Characteristics of the Patients

From a total of 252 carious-exposed permanent teeth in 186 children and adolescents that were treated by means of pulpotomy during 2017–2019, 118 (63.4%) in 97 children and adolescents were available for evaluation following 6–57 months. The distribution of the treated teeth according to their duration of follow-up is presented in Figure 1.

The mean age of the participants was 10.9 years (range—6.1–17.9 years, median age—10.7 years), of whom 47 (48.5%) were boys (the female:male ratio was 1.06:1). Among these patients, 80 had one tooth treated, 15 had two teeth treated, and two had four teeth treated. Of them, 78 teeth were treated with partial and 40 by CP. The treatments were performed by one certified pediatric dentist (71 teeth) or by one certified endodontist (47 teeth). Only the certified endodontists used a microscope for further clinical evaluation. No significant statistical difference was found between the success rate of teeth treated by the certified pediatric dentist or by the certified endodontist ($p = 0.9$).

Characteristics of the Treated Teeth

Of the 118 permanent teeth treated, 102 were permanent molars (38 upper; 64 lower), six were premolars (two upper; four lower), and 10 were upper incisors (six central; four lateral).

Success Rate of the Treatment

The total success rates of PP and CP in the present study were 77 and 81%, respectively (p = nonsignificant). The overall survival curve is shown in Figure 2. The statistical analysis of the radiographic findings revealed that the success rate of the pulpotomy was not affected by the following variables—demographic variables, such as age and gender; maturation state of the roots during treatment (Table 1); type of treated tooth (incisor, premolar, molar); type of treatment—PP or CP; operators; postoperative variables such as—presence of radiographic dentinal bridge, partial or full obliteration of the pulp during the follow-up period; integrity and type of the final restoration. We further modeled the effect of those variables on tooth survival using Cox proportional hazards regression which led to an identical conclusion (no significant effect).

The integrity and the type of final restoration did not affect the success rate (Fisher's test, $p = 0.22$). However, it should be noted that the majority of the teeth were treated by means of GC Fuji as a base with a composite restoration on top, and only a few teeth were treated by means of either amalgam or SS crowns (five and six, respectively) and thus our data is limited with reference to the effect of the type of final restoration.

The only factor that significantly affected the success rate was the preoperative presence of pathology. Teeth without pathology showed an 87.3% success rate as compared to 74.1 and 58.3% in teeth with preoperative enlarged PDL or with periapical radiolucency [$p = 0.0301$ (χ^2-test) and 0.0297 (Fisher's test), Fig. 3]. However, the effect of this variable on survival in the Cox proportional hazards model did not reach statistical significance ($p = 0.089$).

Discussion

The goal of the present study was to evaluate the success rate of pulpotomy performed in children and adolescents in carious-exposed permanent teeth when the main indication for the treatment was healthy bleeding at the exposure site, regardless presence or absence of preoperative pain. The total success rates of both CP and PP were 82.5 and 80.8%, respectively. No differences in the success rates were found between the two operators, although only one used a microscope for diagnosis and treatment. The success rates in the present study support the mean success rate of previously published data of CP and PP which ranges between 42 and 100%.[6,8,18]

Interestingly, our results are comparable with other published data, even though in the present study we also included vital teeth with preoperative enlarged PDL (74% success rate) or with

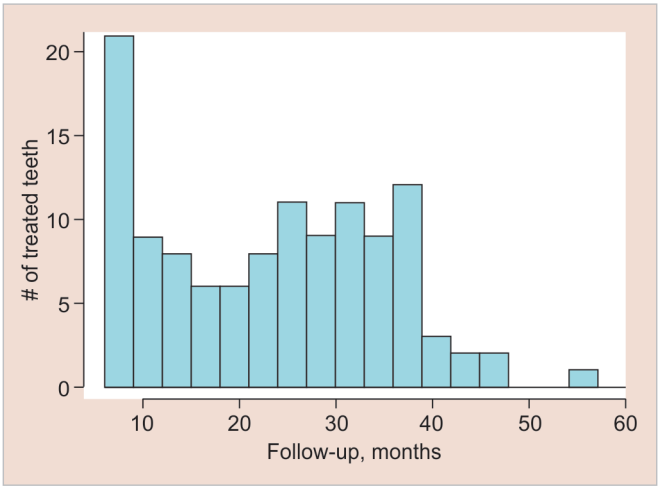

Fig. 1: Distribution of treated teeth according to duration of follow-up in months

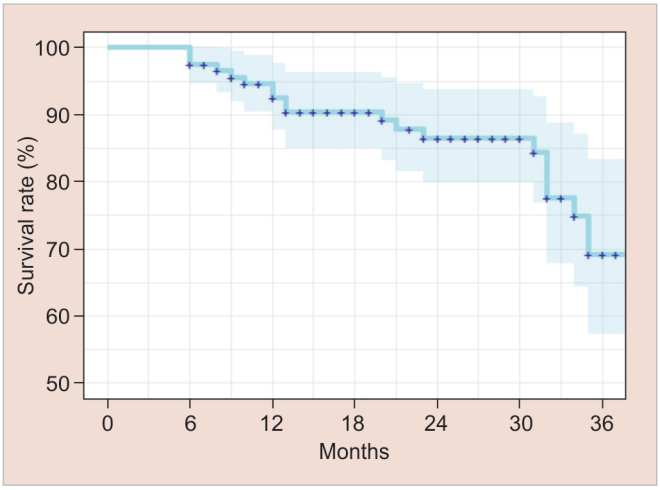

Fig. 2: Percentage of survival rate of treated teeth according to their duration of follow-up in months

Table 1: Distribution of treated teeth according to their maturation stage and type of pulpotomy

Variable examined		*Success*	*Failure*	*p-value*
Age				*t*-test: $p = 0.203$
Gender	Female	51	9	χ^2-test: 0.425/Fisher's test: 0.35
	Male	45	13	
Tooth maturation	Mature	56	10	χ^2-test: 0.39/Fisher's test: 0.343
	Immature	40	12	
Type of treated tooth	Incisors	8	2	χ^2-test: 0.484/Fisher's test: 0.0753
	Premolars	6	0	
	Molars	82	20	
Partial or cervical	Partial	63	15	χ^2-test: 1/Fisher's test: 1
	Cervical	33	7	
Different operators				χ^2-test: 1/Fisher's test: 1
Type of restoration	GI	87	20	χ^2-test: 0.237/Fisher's test: 0.218
	Amalgam	6	0	
	SS crowns	3	2	
Presence of radiographic pathology on the day of the procedure	No pathology	69	10	χ^2-test: 0.0301/Fisher's test: 0.0297
	PDL enlargement	20	7	
	Apical radiolucency	7	5	
Postoperative radiographic pulp findings	Dentinal bridge formation	1	0	χ^2-test: 0.69/Fisher's test: 0.599
	Partial obliteration	18	2	
	Pulp obliteration	4	1	
	No change	73	19	
Integrity of Fuji restoration during the follow-up period	Failed	9	0	χ^2-test: 0.192/ Fisher's test: 0.291
	Reperformed	10	1	
	Intact	68	19	
Total		96	22	

GI, glass ionomer

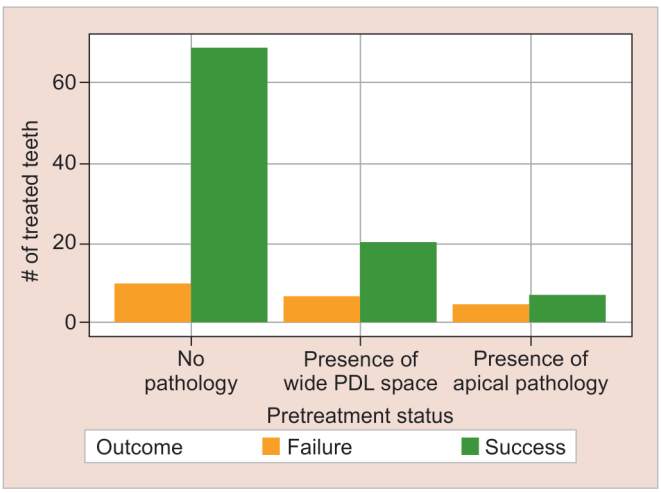

Fig. 3: Percentage of clinical and radiographic success of pulpotomy according to pretreatment radiographic status

periapical radiolucency (58% success rate). The reasons for these results are not completely clear. Perhaps, reducing the bacterial load in the pulp chamber during the treatment enables the pulp to deal with the infection. Alternatively, periapical radiolucency in the preoperative radiograph represents, at that time, inflammation without infection, a healing process as in periapical breakdown or reaction to low-grade infection. Accordingly, removing the main infected pulp tissue during pulpotomy assists the immune system to resolve the residual infection.

Several teeth in the failure group were immature teeth with an open apex that closed their apex completely or partially during the follow-up period, despite their final failure outcome. The biological explanation for the failures associated with continuous apex development in these teeth is not completely clear and may be attributed to late bacterial leakage of the final restoration or to the fact that in these teeth the Hertwig's epithelial root sheath was not degraded by the pulp infection and continued to function after the treatment. It should be pointed out however, that although these teeth showed failure following 21, 34, 35, 35, and 45 months; they can still be considered as, at least partial success, since performing RCT in teeth with a closed apex is easier and faster as compared to immature teeth. Moreover, these teeth increased their dentinal walls during the follow-up period and thus may improve their tooth survival. From the behavioral perspective, postponing RCT in young children increased their ability to cooperate and receive higher-quality treatment.

The success rate in mature and immature teeth was found to be similar in the present study. To the best of our knowledge, no previous study has compared the success rate between mature and immature teeth. The reason for these results may be attributed to the fact that the success of the treatment depends mainly on factors related to the blood supply and infection load and not on the maturity of the teeth.

Interestingly, in the present study, no differences in the success rates were found between CP and PP. These findings are in accordance with other studies that reported success rates of 66–93% in PP and 82–92% in CP.[6,13,18,19] Nevertheless, these studies evaluated only 17 and 52 teeth, respectively, and included also adults, who

cooperate usually better than children. In contrast, in the present study, we included only children and adolescents who usually cooperate less than adults, a fact that may implicate the success rate. However, the decision whether to perform PP or CP was determined per tooth during treatment, according to the presence, amount, nature, and color of bleeding from the amputated radicular pulp, which may correlate with inflammation or infection, respectively. These results may indicate that CP may be beneficial even in teeth with flooded increased bleeding following PP.

One of the unexpected results was that the integrity of the final composite restoration at the recall appointments did not statistically reduce the success rate of the treatments. These results are in contrast to the results of Ray and Trope who found that the success rate of endodontically treated teeth is related more to the quality of the coronal restoration and less to the quality of the root filling.[20] The reason for this discrepancy may be attributed to the fact that in our study, the pulp stump was obturated with 2 mm thick MTA, which served as second-line protection from bacterial invasion until restoration during the follow-up examination or the frequent follow-ups of the patient which enable immediate restoration repair and thus prevent bacterial invasion. Accordingly, it may be recommended that a 2 mm thick layer of MTA be used to serve as protection in cases of marginal breakdown of the restoration and frequent follow-up appointments.

Historically, the formation of the dentinal bridge following pulpotomy with $Ca(OH)_2$ was considered one of the most pathognomonic findings which represent pulpotomy success. In the present study, the success rate of the teeth with or without a dentinal bridge or obliteration was comparable. The reason may be contributed to the low pulp irritation of MTA compared to $Ca(OH)_2$.

In conclusion, PP and CP may be a reliable alternative to full RCT in vital permanent teeth with carious pulp exposure in children and adolescents. Nonetheless, additional long-term studies with larger samples of teeth are required to validate these findings. Moreover, in light of the fact that no differences were found between the success rates of the two operators, although only one used a microscope for diagnosis and treatment, warrants more controlled studies in this regard to verify and further examine this interesting result. Finally, our novel finding regarding the relative high success rate in teeth with preoperative enlarged PDL or with periapical radiolucency also calls for further long-term studies to extend these findings to other populations.

References

1. Jälevik B, Klingberg GA. Dental treatment, dental fear and behaviour management problems in children with severe enamel hypomineralization of their permanent first molars. Int J Paediatr Dent 2002;12(1):24–32. DOI: 10.1046/j.0960-7439.2001.00318.x
2. Bjørndal L, Simon S, Tomson PL, et al. Management of deep caries and the exposed pulp. Int Endod J 2019;52(7): 949–973. DOI: 10.1111/iej.13128
3. Sadaf D. Success of coronal pulpotomy in permanent teeth with irreversible pulpitis: an evidence-based review. Cureus 2020;12(1):e6747. DOI: 10.7759/cureus.6747
4. Zanini M, Hennequin M, Cousson PY. A review of criteria for the evaluation of pulpotomy outcomes in mature permanent teeth. J Endod 2016;42(8):1167–1174. DOI: 10.1016/j.joen.2016.05.008
5. AAE position statement on vital pulp therapy. J Endod 2021;47(9): 1340–1344. DOI: 10.1016/j.joen.2021.07.015
6. Mass E, Zilberman U. Clinical and radiographic evaluation of partial pulpotomy in carious exposure of permanent molars. Pediatr Dent 1993;15(4):257–259.
7. Mass E, Zilberman U, Fuks AB. Partial pulpotomy: another treatment option for cariously exposed permanent molars. ASDC J Dent Child 1995;62(5):342–345.
8. Barrieshi-Nusair KM, Qudeimat MA. A prospective clinical study of mineral trioxide aggregate for partial pulpotomy in cariously exposed permanent teeth. J Endod 2006;32(8):731–735. DOI: 10.1016/j.joen.2005.12.008
9. Alqaderi HE, Al-Mutawa SA, Qudeimat MA. MTA pulpotomy as an alternative to root canal treatment in children's permanent teeth in a dental public health setting. J Dent 2014;42(11):1390–1395. DOI: 10.1016/j.jdent.2014.06.007
10. Taneja S, Singh A. Evaluation of effectiveness of calcium hydroxide and MTA as pulpotomy agents in permanent teeth: a meta-analysis. Pediatr Dent J 2019;29(2):90–96. DOI: 10.1016/j.pdj.2019.04.001
11. Jiang S, Wu H, Zhang CF. Partial pulpotomy of immature teeth with apical periodontitis using bioceramics and mineral trioxide aggregate: a report of three cases. Chin J Dental Res 2016;19(2):115–120. DOI: 10.3290/j.cjdr.a36182
12. Tran XV, Ngo LTQ, Boukpessi T. BiodentineTM full pulpotomy in mature permanent teeth with irreversible pulpitis and apical periodontitis. Healthcare (Basel) 2021;9(6):720. DOI: 10.3390/healthcare9060720
13. Simon S, Perard M, Zanini M, et al. Should pulp chamber pulpotomy be seen as a permanent treatment? Some preliminary thoughts. Int Endod J 2013;46(1):79–87. DOI: 10.1111/j.1365-2591.2012.02113.x
14. Linsuwanont P, Wimonsutthikul K, Pothimoke U, et al. Treatment outcomes of mineral trioxide aggregate pulpotomy in vital permanent teeth with carious pulp exposure: the retrospective study. J Endod 2017;43(2):225–230. DOI: 10.1016/j.joen.2016.10.027
15. Tawil PZ, Duggan DJ, Galicia JC. Mineral trioxide aggregate (MTA): its history, composition, and clinical applications. Compend Contin Educ Dent 2015;36(4):247–252.
16. Qudeimat MA, Barrieshi-Nusair KM, Owais AI. Calcium hydroxide vs mineral trioxide aggregates for partial pulpotomy of permanent molars with deep caries. Eur Arch Paediatr Dent 2007;8(2):99–104. DOI: 10.1007/BF03262577
17. R Core Team 'R: A language and environment for statistical computing'. Vienna, Austria: R Foundation for Statistical Computing. 2018. Available at: https://www.r-project.org.
18. Mejàre I, Cvek M. Partial pulpotomy in young permanent teeth with deep carious lesions. Endod Dent Traumatol 1993;9(6):238–242. DOI: 10.1111/j.1600-9657.1993.tb00279.x
19. Taha NA, Ahmad MB, Ghanim A. Assessment of mineral trioxide aggregate pulpotomy in mature permanent teeth with carious exposures. Int Endod J 2017;50(2):117–125. DOI: 10.1111/iej.12605
20. Ray HA, Trope M. Periapical status of endodontically treated teeth in relation to the technical quality of the root filling and the coronal restoration. Int Endod J 1995;28(1):12–18. DOI: 10.1111/j.1365-2591.1995.tb00150.x