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Original Article

Evaluating the radiographic results of apexification treatment in children

Ebru Akleyin[1], Yelda Polat[1], Elif Burcu Harman[1], Sema Çelenk[1]

[1] Dicle University, Faculty of Dentistry, Department of Pediatric Dentistry, Diyarbakır, Turkey

Abstract

Aim: This retrospective study aimed to evaluate the radiographic success of apexification treatments applied with different materials and techniques.

Methodology: Periapical radiographs of 224 maxillary incisors in patients between 6 and 12 years of age who had undergone apexification treatment at the Dicle University, Faculty of Dentistry, Department of Pediatric Dentistry were retrospectively examined. Each apex was scored using the periapical index (PAI) on X-rays obtained at 12 months of follow-up after treatment, and the presence or absence of the apical barrier was evaluated. The Kruskal-Wallis H, Mann-Whitney U, and chi-square tests were used for the statistical analysis ($p < 0.05$).

Results: In the maxillary incisors, apexification was most commonly performed on the maxillary right central teeth (74.11%). The cause for this treatment was trauma in 97.77% of the patients. Enlargement in the periodontal space (95.98%), the presence of lesions (60.71%), loss of lamina dura (54.46%), and external resorption (43.75%) were observed. At 12 months of follow-up after treatment, apical closure (87.95%) was observed in all teeth with open apexes, and the ratio of patients with a PAI of < 2 was 89.35% for calcium hydroxide (CH) apexification and 92.73% for mineral trioxide aggregate (MTA) apexification.

Conclusion: The radiographic success of apexification treatments with CH and MTA was found to be high in 224 immature upper incisors.

Keywords: Apexification, calcium hydroxide, mineral trioxide aggregate, periapical index

Correspondence:

Dr. Ebru AKLEYİN
Dicle University, Faculty of Dentistry,
Department of Pediatric Dentistry,
Diyarbakır, Turkey.
E-mail: dt.eakleyin@gmail.com

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Introduction

In immature permanent teeth, if the pulp loses its vitality because of caries or trauma, necrotic pulp can lead to the death of cells that are important for root development. This affects root development in immature teeth, leading to outcomes such as open apexes, wide root canals, and fragile root walls. It can also make traditional root canal treatment difficult (1, 2). In immature teeth with pulp necrosis with or without periapical lesions, the most common treatment is apexification (3, 4). The aim of apexification treatment is to form a calcified barrier at the root apex by placing a material that is biocompatible with periapical tissues in the root canal (5). Calcium hydroxide (CH) and mineral trioxide aggregate (MTA) are the preferred materials for apexification procedures (6).

By placing CH in the canal during one or more monthly sessions, the apexification procedure promotes hard tissue induction, antibacterial healing, and tissue repair. Thus, root canal treatment can be performed by providing apical closure with traditional techniques using gutta-percha and canal filling paste (7, 8). Treatment times for apical barrier formation range from 3 to 24 months, with an average of 12 months. The duration of the treatment may vary according to factors such as the patient's age, apex width, and the presence of radiolucent lesions in the periradicular region. CH apexification exacerbates the risk of tooth fractures and requires a long treatment duration that requires patient compliance (1).

Due to its high biocompatibility, superior sealing, and antibacterial properties, MTA can be successfully used as an apical plug in a single session of apexification without waiting for calcific barrier formation (9, 10). However, there are some disadvantages to MTA, such as its long curing time, difficulty in use due to low fluidity, risk of discoloring the tooth structure, and high cost (11, 12). This retrospective study aimed to evaluate and compare the radiological success of CH and MTA apexifications in 224 immature permanent maxillary incisors.

Materials and Methods

Local ethics committee approval was received for this study from Dicle University, Faculty of Dentistry Ethics Committee (2022-01).

In this retrospective study, the clinical records of patients who had visited the Dicle University, Faculty of Dentistry, Department of Pediatric Dentistry between 2017 and 2021 were examined, and the patients who had undergone apexification treatment were determined. The study was limited to children aged 6–12 years with mixed dentition. Pediatric patients without systemic diseases were included in the study. Radiographically visible maxillary incisors with an open apex were included in the evaluation. Patients with advanced periodontal disease and those scheduled for apical surgery on the relevant teeth were excluded from the study. Before beginning treatment, the initial, final, and control radiographs of all teeth were obtained digitally, primarily using the parallel technique with the aid of a film holder and a phosphorus plague.

Age, sex, tooth number (11, 12, 21, 22), cause of apexification (caries and trauma), duration of the apexification (<3 months, 3-6 months, 6-12 months, and ≥ 12 months), number of periapical radiographs acquired during the study period, and superstructure (filling, direct restoration, and crown) were recorded on a customized data form for each patient. The status of the periapical tissues (lamina dura loss, expansion of the periodontal space, presence of lesions, and external resorption), as revealed by the initial diagnostic X-ray, was evaluated.

In general, the clinical procedure for CH apexification involves removal of the pulp necrosis in the maxillary incisor with a canal file, followed by mechanical cleaning of the root canal walls with X-ray confirmation throughout the procedure. After completing the irrigation and shaping process between the files, the final irrigation of the canals is performed, and the canals are dried up to the root tip with paper cones. Distilled water and CH powder are mixed in the form of a medicament between the sessions and sent to the root canals with the help of a lentulo. The access cavity is isolated with cotton pellets and temporarily sealed with zinc oxide eugenol cement. The canal is reopened after three weeks, and the CH medicament is reinserted into it. This step is repeated every two months until a hard tissue barrier is formed at the apex. Once the barrier is formed, gutta-percha and canal sealer are used for canal filling. The clinical procedure in MTA apexification generally involves completing disinfection and root canal shaping and then applying CH to the root canal in the form of intracanal medicament during the first session.

CH was removed during the second session, which was three weeks after the application of intracanal medicament to all patients. If the dental findings were asymptomatic and if there was no fistula or exudate in the canals, control X-rays are taken with the final file and the plug was applied with MTA to the root tip in the same session. After the final irrigation, the channels were dried with sterile paper cones. Subsequently, in accordance with the manufacturer's recommendation, MTA was mixed and condensed by pushing it to the root tip with the help of a plugger. To form an apical plug, MTA was placed at the apex with a thickness of at least 3 mm. To complete the curing reaction of MTA, moistened paper points were placed in the canal cavity, and the entrance cavities were temporarily closed with glass ionomer cement. The next session was held 2–5 days later. The temporary filling was removed, and in teeth with sufficient dentin thickness, the canal cavity was filled with gutta-percha and resin-based canal sealer. In teeth with very thin dentin, the canal cavity was filled using fiber post and resin cement. Sometimes, MTA was used to create an apical plug in teeth where the barrier could not be created with CH despite long sessions. Follow-up appointments were made with all patients for 3, 6, and 12 months after the completion of the canal filling (Fig. 1).

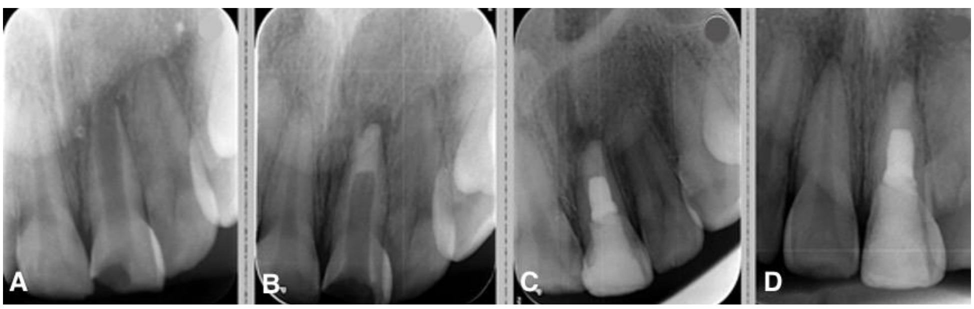

Figure 1. (A) Diagnostic X-ray of the immature left upper central with pulp necrosis as a result of trauma, (B) Creation of apical plug with MTA in the second session, (C) Root canal filling and cavity filling, (D) Control X-ray of the tooth 12 months later

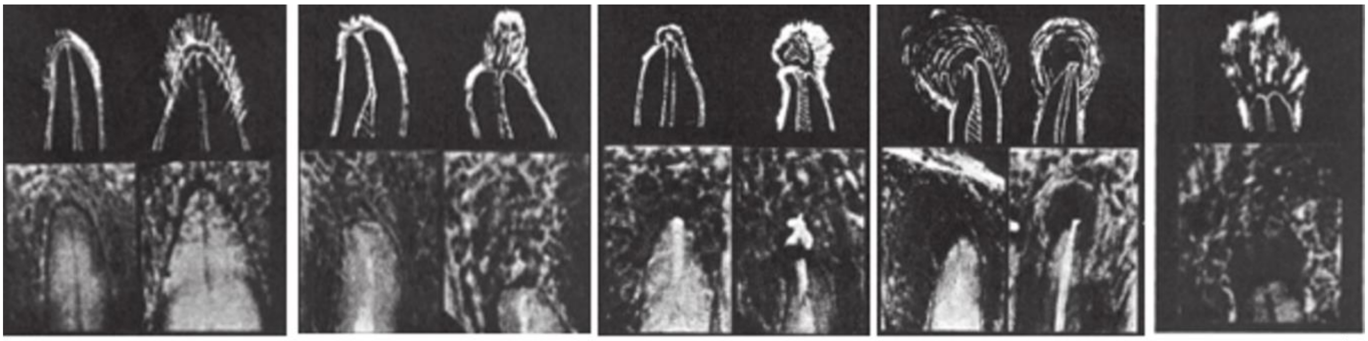

Figure 2. Periapical Index (PAI) categories

The apical barrier status of the involved tooth and the alterations in the periapical tissues were evaluated on radiographs taken after 12 months. In order to determine the changes in periapical bone density, radiographs taken at baseline and after 12 months were evaluated by two independent observers using the Periapical Index (PAI), a five-point scoring index developed by Ørstavik et al. (13) in 1986 (Fig. 2). This scoring system facilitates a more detailed assessment of the extent of the disease compared with the conventional binary approach (healthy/diseased). In previous studies, the original five categories of PAI (the full scale) were classified into two categories: PAI 1 and 2 were categorized as "successful" or "healthy," and PAI 3, 4, and 5 were categorized as "unsuccessful" or "diseased" (14, 15). In the present study, PAI 1 and 2 were also categorized as "improved" if the score decreased compared with that of the baseline. A four-stage scoreboard was used for apical closure in radiographs. Stage 1 showed no change in X-ray, and Stages 2–4 showed closure or barrier formation at the root tip with or without a change in the canal size (16).

Statistical analysis

Analyses were performed with SPSS 20.0 (IBM Corp., Armonk, NY, USA) software. Normality was investigated using the Shapiro-Wilk and Kolmogorov-Smirnov tests. Chi-square analysis was performed to examine the relationship between nominal variables. Kruskal-Wallis H and Mann-Whitney U tests were used to evaluate the between-group differences. Post hoc tests with Bonferroni correction were used for multiple comparisons. $p < 0.05$ was considered statistically significant in all analyses. Cohen's Kappa analysis was performed to check the reliability of the agreement between the two raters.

Results

A total of 224 patients aged 6–12 who underwent apexification treatment for maxillary incisors owing to trauma or caries between 2017 and 2021 were included in the study. Of these patients, 33.45% were female and 66.55% were male. The mean age of the patients was 9.48 ±1.32 years. The cause of apexification was trauma in 97.77% and caries in 2.23% of the patients. Apexification was most commonly performed on the first maxillary central incisor (74.11%), followed by the left maxillary central (19.64%), right maxillary lateral (4.91%), and left maxillary lateral (1.34%) incisors. Diagnostic radiographs of the teeth revealed loss of lamina dura in 54.46%, enlargement of the periodontal space in 95.98%, presence of lesions in 60.71%, and external resorption in 43.75% of the patients (Table 1). Agreement between the two independent observers was high (κ = 0.816).

Table 1. Frequency and percentage values of the variables of the teeth to be treated with apexification before treatment [n(%)]

Frequency and percentage values			
		n	%
Tooth number	11	166	74.11
	12	11	4.91
	21	44	19.64
	22	3	1.34
	Total	**224**	**100**
Reason for apexification	Trauma	219	97.77
	Tooth decay	5	2.23
	Total	**224**	**100**
Lamina dura loss	No	102	45.54
	Yes	122	54.46
	Total	**224**	**100**
Widening of the periodontal space	No	9	4.02
	Yes	215	95.98
	Total	**224**	**100**
Presence of lesion	No	88	39.29
	Yes	136	60.71
	Total	**224**	**100**
Resorption	No	126	56.25
	External	98	43.75
	Total	**224**	**100**

When the duration of the apexification treatment was examined, it was observed that 32.14% of the patients completed the treatment in less than 3 months and 31.70% completed it in 3-6 months. After apexification, 95.98% of the patients received a filling with direct restoration, and 4.02% received crowns as the upper structure. Apexification was performed with CH in 75.54% and MTA in 24.46% of the patients. When the apical closure was examined after the apexification, barrier formation at or near the apex was observed in 66.52%, root tip closure without any change in canal size was observed in 20.09%, and continued root development with apex closure was observed in 1.34% of the patients. The root tip was not closed in 12.05% of the patients. When the periapical index was examined, normal periapical tissues were present in 61.61% of the patients. Small changes were observed in the periapical tissues in 27.68% of the patients, and PAI<2 in the periapical tissues was considered successful (89.29%) (Table 2). The PAI scores (PAI<2) were found to be healthy after CH apexification (89.35%) and MTA apexification (92.73%) (Table 3).

Table 2. Frequency and percentage values of teeth [n(%)]

Frequency and percentage values			
		n	%
Duration of treatment	<3 months	72	32,14
	3-6 months	71	31,70
	6-12 months	53	23,66
	≥12 months	28	12,50
	Total	**224**	**100**
Superstructure	Filling direct restoration	215	95,98
	Crown	9	4,02
	Total	224	100
Apical plug formation	MTA apexification	55	24,46
	$Ca(OH)_2$ apexification	169	75,54
	Total	**224**	**100**
Apical closure	No radiographic change	27	12,05
	Barrier at or near the apex area observed radiographically	149	66,52
	Root end closed with no change in canal size	45	20,09
	Root development continued and apex closed	3	1,34
	Total	**224**	**100**
Periapical index	Normal periapical tissues	138	61,61
	Minor changes in periapical bone tissue	62	27,68
	Mineral loss with changes in periapical bone structure	19	8,48
	Periodontitis with demarcated radiolucent area	3	1,34
	Severe apical periodontitis with exacerbation features	2	0,89
	Total	**224**	**100**

Table 3. Relationship between apexification and periapical index (PAI) [n(%)]

Periapical Index	MTA	CH	Total	Test Statistics	p*
Normal periapical tissues (PAI 1)	32 (58,18)	105 (63,91)	138 (61,61)	4,713	0,318
Minor changes in periapical bone tissue (PAI 2)	19 (34,55)	43 (25,44)	62 (27,68)		
Mineral loss with changes in periapical bone structure (PAI 3)	4 (7,27)	16 (9,47)	19 (8,48)		
Periodontitis with demarcated radiolucent area (PAI 4)	0 (0)	3 (1,78)	3 (1,34)		
Severe apical periodontitis with exacerbation features (PAI 5)	0 (0)	2 (1,18)	2 (0,89)		
Total	**55 (100)**	**169 (100)**	**224 (100)**		

*Pearson Chi-Square test

Discussion

In studies on the results of endodontic treatment, success criteria often include the normal radiographic appearance of the treated tooth and periradicular tissues and the absence of signs and symptoms of apical pathology. The use of radiographs is the most objective method to evaluate endodontic treatment results. Generally, intraoral radiographs are evaluated using various criteria to determine the health of the periapical region (17, 18, 19). The most commonly used criterion is the PAI, which comprises five categories (13). There are many studies in the literature that have used PAI scoring for the evaluation of immature teeth (20, 21). PAI has also been used in some MTA apexification studies (22, 23). Therefore, the PAI score was used in the present study as a measure of the radiographic outcome to evaluate periapical health and the healing process.

Pulp necrosis and apical periodontitis in immature teeth are mostly caused by traumatic dental injuries (24). In the present study, trauma was the predominant cause (97.77%) for apexification treatment. Central and lateral maxillary incisors were evaluated. These teeth encounter more traumatic dental injuries, and their apical diameters are larger than those of the mandibular incisors (25). According to the results obtained in the present study, apexification was performed mostly in the right central maxillary incisor (74.11%).

Previously, Dominguez Reyes et al. (26) (100%), Ghose et al. (27) (96%), and Morfis et al. (28) (87.5%) achieved apical closure with apexification treatment using CH. In MTA apexification studies conducted by Felippe et al. (29) (100%) and Shabahang et al. (30) (93%), apical closure with an apical calcified barrier was reported. In the present study, apical closure was achieved in 87.95% of the teeth that underwent apexification with CH and MTA. Although the sessions were performed by different assistant physicians in the university hospital, this rate was consistent with the results obtained by other researchers. The mean period required for apical closure was reported to be 18 months by Cvek (31), 12 months by Dominguez et al. (26) and 5–6 months by Ghose et al. (27). In the present study, apexification treatment lasted >12 months in only 12.5% of the patients, which could be attributed to the use of MTA as an apical plug.

In the literature, the rate of periapical improvement in apexification with CH was found to be between 77% and 98% (32, 33). Using the PAI score, Simon et al. (20) 81% and Büche et al. (22) 90% reported radiographic success after MTA apexification. El-Meligy and Avery et al. documented 100% apical healing in MTA apexification (34). In a study based on the PAI scores, Chen et al. (21) did not observe a significant difference in apical healing after apexification treatments using CH and MTA.

Similar to other studies, the PAI scores were determined to be 89.35% for CH and 92.73% for MTA. No significant difference was found in apical healing between the two materials. The apexification treatments were radiographically successful even in the presence of external resorption. In their MTA apexification follow-up study, Pace et al. (35) noted that the PAI score decreased between 1 and 5 years in terms of periapical healing and that there was no significant difference between years 5 and 10. In the present study, several immature incisors with apexification, a total of 224 teeth, were examined, and it was decided to jointly evaluate the 12-month follow-up period that allowed access to radiographs taken from the patients. It was concluded that the PAI scores were healthy during this follow-up period.

In a study involving 242 patients in whom long-term CH use was evaluated, 90% of the teeth diagnosed with pulp necrosis and apical periodontitis were evaluated at the last follow-up visit and reported to be healthy according to the PAI score. It was concluded that CH was the most appropriate inter-appointment dressing (36). In the present study, CH also remained the most preferred material for apexification (75.54%) owing to its cost-effectiveness and high accessibility. CH is widely used in apexification because of its antimicrobial properties, biocompatibility, organic tissue dissolving capacity, and anti-inflammatory effects. However, Falakaloğlu et al. (37) stated that none of the irrigation solutions had wholly removed the remaining CH in the dentin walls. Moreover, they reported that it affects the accuracy of electronic apex locators and may lead to root canal sealer microleakage.

MTA is the most suitable material for single-visit apexification treatments to obtain an apical barrier because of its high antimicrobial efficacy, biocompatibility, and impermeability. During the placement of MTA in the wide apical region, resorbable barriers can be used to prevent it from overflowing into the periapical area (38). In the present study, the use of MTA was preferred, especially in patients who did not respond to apexification treatment after multiple CH sessions, because it was costly.

The use of two-dimensional imaging to evaluate the changes in the periapical region may be a limitation of the present study. In addition, owing to the COVID-19 pandemic, long-term follow-up data could not be accessed for most patients who had undergone apexification treatment at our university hospital in the last 4 years, and the follow-up period was limited to 12 months.

Conclusions

In conclusion, periradicular tissues of 224 immature permanent maxillary incisors, of which 169 were treated with CH and 55 treated with MTA apexification, were evaluated in this study. CH and MTA apexification showed high radiographic success at the 12-month follow-up.

Ethical Approval: Ethics committee approval was received for this study from Dicle University, Faculty of Dentistry Ethics Committee, in accordance with the World Medical Association Declaration of Helsinki with the approval number: 2022-01.

Peer-review: Externally peer-reviewed.

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