ORIGINAL ARTICLE

Clinical and radiographic evaluation of two different apexification protocols in traumatized immature permanent incisors

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ABSTRACT

BACKGROUND: Dental trauma can cause damage to the pulp tissue in immature teeth. Revascularization therapy is a possible option in the treatment of non-vital, immature permanent teeth with a history of trauma. The aim of this prospective study was to evaluate the radiographic and clinical results of immature teeth with a history of trauma treated by regenerative endodontic procedures and mineral trioxide aggregate apexification techniques.

METHODS: Forty-one patients aged between 7 and 12 years with traumatized immature permanent maxillary incisors were included in the study. These patients were divided into two groups: those who had previously received endodontic treatment and those who had not. Twenty-four patients who applied directly to the university clinic and had not received endodontic treatment before were included in the regenerative endodontic protocol group (Group 1). Seventeen patients who had previously undergone endodontic intervention on their relevant teeth were included in the mineral trioxide aggregate apexification group (Group 2). The patients were followed for a period of 24 months. Clinical success rates were evaluated, and pre-treatment and control radiographs were analyzed to calculate the percentage increase in root dentin width and root length.

RESULTS: After 24 months of follow-up, positive periapical healing was detected in the radiographic findings in the majority of cases. In Group 1, a limited increase in root length and root dentin width was observed, while a narrowing in the apical opening was evident. The radiographic evaluation of two of the cases, which could be accessed 11 years later, emphasized the importance of long-term follow-up in assessing the effectiveness of the chosen methods.

CONCLUSION: The revascularization method is a treatment option that has positive results in terms of root development in teeth with necrotic pulp as a result of trauma.

Keywords: Immature permanent teeth; regenerative endodontic protocol; mineral trioxide aggregate.

INTRODUCTION

Traumatic injuries to permanent teeth are common in both children and young adults,[1] and during this period, the most traumatized region is the anterior maxilla.[2] Damage to immature permanent teeth may occur through bacterial invasion and/or dental trauma. In this situation, if the inflamed pulp tissue is not treated, necrosis will develop. Odontoblast death resulting from necrosis leads to deterioration in root development[3] and teeth become more fragile. Such results may develop due to the possibility of damage to the vascular system and Hertwig's epithelial root sheath in the periapical region, even if the crown dentin and enamel remain intact.[4-6]

Infected pulp treatments in immature permanent teeth pose a

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number of clinical challenges. The wide apex opening creates difficulty in root canal debridement and obturation. In an immature tooth, the apical opening is closed by the apexification method to create a calcified barrier or to maintain the apical development of the tooth root with necrosed pulp, where root development has not been completed. These teeth have been conventionally treated with either long-term calcium hydroxide treatment[7-9] or apexification procedures with mineral trioxide aggregate (MTA).[10] In fact, although these approaches relieve negative signs and symptoms, their beneficial effects on root development are insufficient.[11] Therefore, it is accepted that immature teeth treated with these methods cannot continue their development. It should not be expected that root growth will continue, pulpal nociception, and immune defense will be normal in these teeth. All these reasons bring regenerative endodontic procedures (REP) to the forefront in etiological trauma injuries.

The clinical results of the revitalization method used in the treatment of teeth with necrosis due to trauma and ongoing root development are not clear. Although there are studies on the timing in periapical wound healing, increased dentin thickness on the canal walls, and increase in root length after revitalization applied to immature teeth with necrotic pulps, the proportional results are unclear.[12-13] However, in traumatized teeth, such endodontic approaches are important in helping the functionality and vitality of the tooth.[14]

The aim of the present study is to evaluate the clinical and radiographic outcomes over a 24-month period in patients with traumatic immature permanent incisors treated with regenerative endodontic protocol or MTA apexification techniques.

MATERIALS AND METHODS

This prospective study was conducted at the Pediatric Dentistry Department of Istanbul University, Faculty of Dentistry, from January 2012 to June 2014. The study protocol was approved by the Ethics Committee of Istanbul University Faculty of Dentistry (ref. 2012/851).

The trial included 45 children (18 girls and 27 boys) aged 7 to 12 years (average age of 10.5±2.7 years) who had at least one non-vital upper permanent incisor with an open apex where root development was affected as a result of trauma. During the clinical examination, the patient's spontaneous pain status, presence or absence of a sinus tract, sensitivity to palpation, and response to cold and electric pulp tests were determined. An informed consent form was obtained from the parents regarding the possible consequences and complications of the proposed treatment approach. In this study, in the power analysis performed with G*Power 3.1 software (alpha error p=0.05), the sufficient number for the sample size was calculated as 40. A sample size of 46 teeth was calculated to detect differences at the 5% significance level, with an expected loss to follow-up of 10%, using the Mann-Whitney U test to compare independent means.

Fifty single-rooted teeth (1 or 2 per patient) with apical lesions, with or without previous endodontic intervention, were included in both treatment groups. Twenty-five patients who first came to the university clinic without consulting any dentist before were included in the regenerative endodontic protocol group (Group 1). Meanwhile, 25 patients who had previously received endodontic treatment were included in the MTA apexification group (Group 2).

In the REP group, one patient was excluded from the study at the 6-month follow-up due to re-traumatization of the same tooth, and in the MTA apexification group, eight patients were excluded from the study at the 12-month follow-up for the same reason. Forty-one teeth were included in the statistical analysis.

Only healthy and cooperative patients were included in this study. Teeth with vertical fractures, serious periodontal problems, and teeth that could not be restored were excluded from the study. Exclusion criteria from the study were poor cooperation, new trauma or new complications, and development of disease leading to termination of the study.

In order to have reproducible film position at all experimental time points, a film holder was used to take periapical radiographs (Endo-Bite Senso Anterior, Kerr, Switzerland). The digital films were exposed to the same X-ray source (Trophy ETX System, Kodak Dental Systems, France) set at 60 kV, 4 mA , 0.25 s. The same clinician (GK) treated both groups of teeth according to the following protocol: pulpal sensitivity was assessed by a carbon dioxide negative test (-50°C) (EndoFrost; Roeko, Langenau, Germany) and an electric pulp tester (Analytic Technology, Redmond, WA); local anesthesia without vasoconstrictors was used during the anesthesia of the teeth (Citanest® 2% plain, AstraZeneca, Istanbul, Türkiye). After rubber dam isolation, the access cavity was prepared with a round diamond and Endo-Z bur (Dentsply Maillefer, Ballaigues, Switzerland), and the working length was estimated with an apex locator (Sybron Endo, Orange, CA).

Group 1

Passive positive pressure irrigation was used to disinfect the canals with 20 mL of 5% sodium hypochlorite (NaOCl), 20 mL saline, and 20 mL of 0.2 % chlorhexidine (CLX) solution with no instrumentation via a Max-i-Probe® needle (Dentsply Rinn, Elgin, IL). Care was taken to ensure that the irrigation was 3 mm shorter than the working length to eliminate chemical interaction with periapical stem cells. The canals were then dried using paper points, and to eliminate or reduce discoloration, a bonding agent was applied to the cavity walls. Commercially prepared chemotherapeutic agents, namely metronidazole (500 mg tablets, Nidazol®, İ.E. Ulagay, Topkapı, İstanbul), ciprofloxacin (500 mg tablets, Cipro®, Biofarma, Sancaktepe, Istanbul), and minocycline (500 mg tablets, Minocycline®, Ratiopharm, Germany) were used. The preparation procedures of the triple antibiotic paste (TAP) have been described elsewhere.[14-16] In short, after removing

the materials covering the drugs, each was crushed with a pestle in a porcelain mortar into a fine powder. It was then stored separately in tightly closed porcelain containers to prevent exposure to light and moisture. A small amount of silica gel was added to reduce humidity in the environment, and the drugs were used within a month.

The TAP was transferred into the canal spaces to protect the root canal walls using a 25-gauge lentulo spiral up to 8 mm in size (Medin, Nave Mesto Moravia, Czech Republic), attached to achieve a paste-like consistency. Glass ionomer cement was used to seal the access cavity (3M Single bond®, Minneapolis, MN, USA), and the patients were recalled for control after 4 weeks.

If there were no symptoms in the tooth, it was isolated with a rubber dam, and the antibiotic mixture was removed from the canal by washing with 5.25% NaOCl. The canal was dried with paper points to confirm that there was no exudate. An endo spreader was inserted into the canal until vital tissue was felt, and this tissue was gently stimulated, initiating some bleeding. It was observed that the bleeding reached approximately 3 mm below the enamel-cement junction, and another 15 minutes were waited for the blood clot to form. A wet cotton pellet with NaOCl was placed on the blood clot for 1 minute. Mineral trioxide aggregate (MTA Angelus White, Londrina, Brasil), prepared in accordance with the manufacturer's instructions, was gently placed over the blood clot. Afterwards, a wet cotton pellet was placed on the MTA for 15-30 minutes, and the cavity was temporarily sealed with conventional glass ionomer cement. After 4 weeks, the tooth was restored with composite.

Group 2

For disinfection, the canals were irrigated without pressure with 20 mL of 0.5% sodium hypochlorite and infused with 20 mL of saline using a Maxiprobe (Dentsply Rinn, Elgin, IL). During the irrigation, the needle was placed 1 mm shorter than the radiographic apex of the tooth.

The canals were then dried with paper points, and to eliminate or reduce discoloration, a bonding agent was applied to the cavity walls. Calcium hydroxide (Ca(OH)2) (Merck, Darmstadt, Germany), prepared in paste consistency, was transferred into the root canal cavities using a low-speed spiral, and the cavity was temporarily closed with conventional glass ionomer cement. The patient was then scheduled for an appointment 1 week later. At the next visit, under rubber dam isolation, the canals were washed with sterile saline to remove calcium hydroxide residues and dried with paper points. Mineral trioxide aggregate, prepared in accordance with the manufacturer's recommendations, was moved into the canal and placed with the appropriate plugger to fill the apical one-third (4-5 mm) of the canal. The correct placement of the material was confirmed with a periapical radiography. If the apical barrier was inadequate, the procedures were repeated. A cotton pellet moistened with sterile water was placed at the canal opening for 15-30 minutes, then a dry cotton pellet was placed, and the access cavity was filled with thermoplasticized gutta-percha. Finally, the coronal access cavity was restored with glass-ionomer cement, and composite restorations (3M ESPE Filtek® Z550, St. Paul, USA) were placed. Patients in Group 1 and Group 2 were scheduled for recall appointments at thirty days, three months, six months, one year, and two years for further clinical and radiographic evaluation.

Clinical and Radiographic Follow-up

Both groups were called back for control periods at 1, 3, 6, 12, and 24 months. The data collected during these periods were compared with the initial examination findings. Both clinical and radiographic findings were detected by the same qualified clinicians (GK, GA). When evaluating clinical findings, the following criteria were considered: pulp sensitivity, presence of spontaneous pain, presence of pain on percussion and palpation, condition of the sinus tract, and discoloration of the enamel. Pulp sensitivity was evaluated via cold thermal testing and electric pulp testing. Among the criteria in the radiographic examination were complete bone healing of the periapical lesion, increase in root length, and radiographic apex formation. RVG images before and after treatment were recorded in JPEG format. The root length and root width were measured and recorded by transferring to Morita imaging software (Morita®, 3D Accuitomo, Kyoto, Japan). All radiographs were taken by the same clinician using a film holder. The method of subtracting the pulp cavity from the canal width was preferred to measure the root width.

Statistical Analysis

The analysis of the data was evaluated using NCSS (Number Cruncher Statistical System) 2007 and PASS (Power Analysis and Sample Size) 2008 Statistical Software (NCSS, LLC, Utah, USA).

In the analysis of clinical and radiographic parameters, the difference between Group 1 and Group 2 was evaluated using the McNemar test and Chi-square test at a significance level of $p<0.05$. The percentage change in root length and dentin thickness was analyzed by the t-test, and the difference between groups was determined using the Mann-Whitney U test. A p value <0.05 was accepted as significant, and mean values are reported.

RESULTS

Trauma was the primary contributory etiology in both groups, and the number of patients whose treatment procedures were completed totaled 50 cases meeting the eligibility criteria, of which 41 cases had at least 24 months follow-up for a recall rate of 82%. These 41 cases included 24 regenerative endodontic protocol cases and 17 MTA apexification cases. Table 1 summarizes the patient data for this study population. One patient in the REP group and eight patients in the MTA apexification group were excluded from the study because

Table 1. Summary of patient demographics and clinical characteristics of the study population

	Group REP		Group MTA	
	Teeth	%	Teeth	%
Sex				
Male	16	66.6%	12	70.5%
Female	8	33.3%	5	29.4%
Signs and Symptoms				
Absent	4	16.6%	10	58.82%
Present	20	83.3%	7	41.7%
Apical Lesion				
Absent	13	54.16%	14	82.35%
Present	11	45.83%	3	17.65%
Age		10.5±2.7		
Follow-up Time		2 years		

they did not attend the 6-month follow-up.

At the 3rd month, all teeth in Group 1 were asymptomatic and periradicular radiolucency areas were observed to heal radiographically. In clinical evaluation, a decrease in palpation, pain, sensitivity to percussion, and sinus tract was observed in both treated groups (REP and MTA), and the difference between the groups was not statistically significant ($p>0.05$).

Crown discoloration was obvious in 24 teeth (100%) in Group REP and seven teeth (41.18%) in Group MTA, and the difference was not significant ($p=0.01$). All clinical findings before and after treatment for the groups are detailed in Table 2.

In terms of tooth survival analysis, the REP group had similar survival rates (24/24 teeth [100%]) compared to teeth treated in the MTA apexification group (17/17 teeth [100%]) ($p<0.05$).

On radiographic examination, repair of periapical lesions was seen in both groups, but there were no statistically significant differences between the groups ($p=0.305$). Apical closure results were significant in both groups ($p<0.05$).

No significant difference was observed between the groups regarding the increase in root length ($p=0.304$), and group analyses are presented in Table 3. Although the number of immature teeth was higher in the revascularization group, the groups did not differ in terms of root development.

Analysis of radiographic findings revealed that revascularization treatment had a significant effect on the root tip width in the apical 1/3 ($p<0.0001$).

Representative cases for the groups are presented in Figures 1 and 2. As shown in Figure 2a, REP treatment in immature teeth resulted in significant percentage increases in root tip width (31.43%) compared to MTA apexification techniques (19.33%). The same case 12 months after MTA apical plug

Table 2. Clinical findings before and after treatment for groups undergoing regenerative endodontic procedure (REP) and mineral trioxide aggregate (MTA) apexification protocol

	Group REP (n=24)			Group MTA (n=17)		
Clinical Aspects	**Before**	**After**	**P value**	**Before**	**After**	**P value**
Pulp Vitality	0 (0%)	20 (83.33%)	¶	0 (0%)	0 (0%)	
Mobility	17 (70.83%)	1 (4.17%)	¶	4 (23.53%)	0 (0%)	¶
Pain on Percussion	20 (83.33%)	1 (4.17%)	¶	7 (41.18%)	0 (0%)	¶
Spontaneous Pain	19 (79.17%)	1 (4.17%)	¶	9 (52.94%)	0 (0%)	¶
Sinus Tract	11 (45.83%)	0 (0%)	¶	3 (17.65%)	0 (0%)	¶
Crown Discoloration	0 (0%)	24 (100%)	¶	0 (0%)	7 (41.18%)	¶

¶ Statistical reduction of clinical aspects before and after treatments in groups REP and MTA (Chi-square and McNemar test, $p<0.05$).

Table 3. Pre- and post-treatment radiographic analysis data for regenerative endodontic procedure (REP) and mineral trioxide aggregate (MTA) apical plug applied groups

	Group REP (n=24)	Group MTA (n=17)	
Radiographic Aspects	**Before-After**	**Before-After**	**p value**
Root Length	-7.52±8.33	-9.36±10.31	0.255‡
Root Tip Width	31.97±15.17	19.11±18.91	0.039‡
Root Canal Width	0.98±7.35	-0.78±10.42	0.721‡
Pulp Space	3.73±17.87	-16.56±16.56	0.001‡
Dentin Thickness	-2.76±14.12	8.97±21.35	0.039‡

¶ Statistical reduction of clinical aspects before and after treatments in groups REP and MTA (Chi-square and McNemar test, p<0.05).

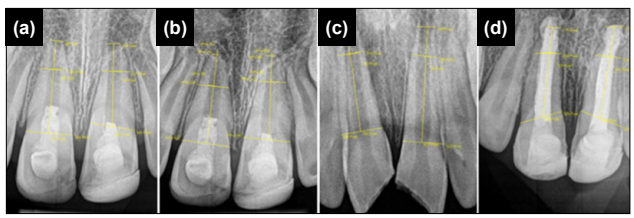

Figure 1. (a) The measurence of the root length, the root tip width, the pulp space and the dentin thickness of REP group from the CEJ to the radiographic apex on first visit. **(b)** Measurement on 24 month. **(c)** The measurence of the root length, the root tip width, the pulp space and the dentin thickness of grup 2 from the CEJ to the radiographic apex on first visit. **(d)** Measurement on 24th month.

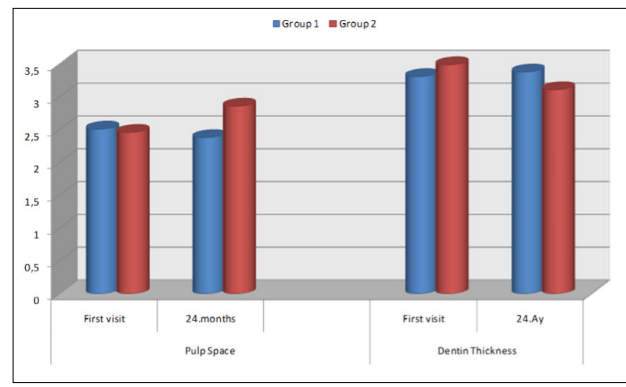

Figure 3. Comparison of radiographic analysis of the findings of the groups in terms of pulp space and dentin thickness.

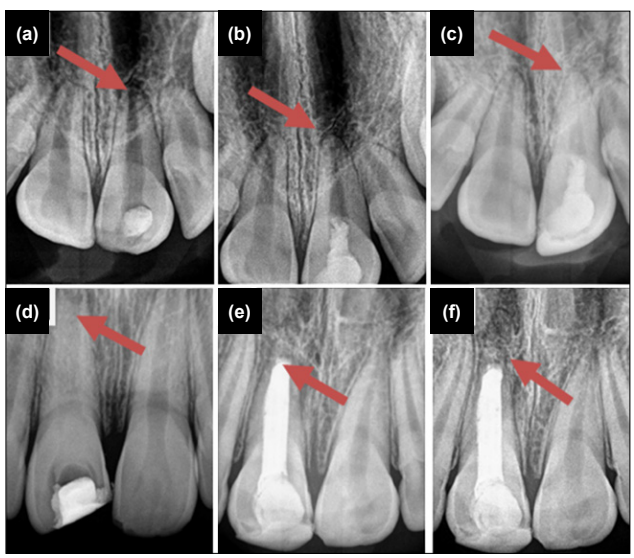

Figure 2. (a) The RVG of maxillary permanent incisor teeth after 3Mix-MP, **(b)** 12 months after MTA apical plug apexification, **(c)** Apical closure and increasing lenght of the rooth after 24 months. **(d)** First visit, Ca $(OH)_2$ application, **(e)** After 12 months dentinal barrier formation, **(f)** After 24 monts apical closure of the rooth.

application is shown in Figure 2b. The apical closure of the case and the increase in root length after 24 months can be seen in Figure 2c.

Follow-up radiographs of the case in Group 2, for which the MTA apexification technique was applied, at the beginning, 12th and 24th months are shown in Figure 2A-B-C. In the present study, 83.33% of the teeth recovered pulp sensitivity in the REP group. Figure 3 shows the radiographic analysis results of the groups.

After 11 years, one case from each study group that could be reached was called for a follow-up and was evaluated radiographically.

The clinical presence of periapical healing and its radiographic observation, radiographic monitoring of root development, and positive developments in the pulp vitality test were the expected positive results of the treatment.

DISCUSSION

Trauma is more common in the immature teeth of young people,[2,15,16] and apexification therapy is also commonly used

in the treatment of these teeth.[6,17] Apexification is a procedure performed for the treatment and protection of immature permanent teeth with necrotic pulp.[18]

Calcium hydroxide [$Ca(OH)_2$] is widely used in apexification, capable of providing physiological closure of immature pulpless teeth.[9,19,20] The traditional $Ca(OH)_2$ technique has several drawbacks, including the unpredictability of apical barrier formation, long treatment times that require frequent monitoring,[9,21-23] and the need for complete removal of the paste. These disadvantages have led to the use of mineral trioxide aggregate, which plugs the apical end and does not require calcific barrier formation.[18] Although MTA apexification shortens the treatment time, it is costly. In addition, its widespread use may be limited due to the need for clinical skill in issues such as the thinness of the dentin walls or delivery of material to the apical 3-4 mm.[24-26]

Pulp damage due to trauma or caries in teeth with incomplete apical development has made it possible to investigate the regenerative potential in endodontics.[27] In this study, REP was preferred among the treatment options for the immature non-vital teeth of patients coming directly to the university clinic. Mineral trioxide aggregate apexification was the method of choice in the treatment of immature teeth that had previously undergone endodontic intervention.

In the REPs, disinfection is applied at a very high level.[28-29] In the disinfection of root canals, the use of $Ca(OH)_2$ or antimicrobial dressing after sodium hypochlorite (NaOCl) and chlorhexidine irrigation is common.[30-32]

However, chlorhexidine is not used in this protocol after it was reported that it is cytotoxic on stem cells.[33] Basrani et al.[34] advocate the application of sterile saline between NaOCl and chlorhexidine rinses to lower the potential chlorhexidine precipitation in the canal if chlorhexidine is used. Successful results have been obtained this way.[35,36] In this study, the reaction between NaOCl and chlorhexidine was tried to be reduced by this method.

In preliminary studies on successful revascularization, metronidazole and ciprofloxacin were preferred to disinfect the canal.[37]

This was later followed by the success of the TAP containing 1:1:1 ciprofloxacin, metronidazole, and minocycline.[28,38-40] It has been suggested that TAP containing minocycline allows better results to be obtained than other pastes in terms of their positive effects on root wall thickness.[12] Also, it has been observed that it can effectively disinfect the deep layers of root canal dentin throughout the entire dentin thickness.[41-43] In a study conducted on the effectiveness of the antiseptic effects of antibiotic combinations, Sato et al.[41] emphasized that cefaclor has similar effects to minocycline in triple antibiotic paste. The toxic effects of antibiotic pastes on human dental cells are another important issue.[44-48] It was stated by Althumairy et al.[46] that there is a concentration-dependent effect in this toxicity. Balanced use of selected products during canal disinfection is an important point. This importance is not only for the dentin matrix that releases growth factors but also for the survival and proliferation of stem cells from the apical papilla (SCAP).[49]

The American Association of Endodontists (AAE) protocol[50] recommends that triple antibiotic pastes should not be used in concentrations above 0.1 mg/mL. In this study, TAP containing 1:1:1 ciprofloxacin, metronidazole, and minocycline was used as an intracanal disinfectant. However, color change due to minocycline content after treatment is a serious disadvantage of this treatment step.[51,52]

According to Kim et al.,[51] although the use of dentin bonding agents before antibiotic application can reduce discoloration, it does not prevent it. Therefore, in this study, dentin bonding agents were used to reduce discoloration of the cavity walls. However, almost all teeth medicated with the regenerative endodontic protocol demonstrated various degrees of crown color change (100%) due to the presence of the minocycline component. Cervical staining was observed in seven teeth (41.18%) of Group 2 MTA apical plug in this study. Reynolds et al.[36] stated that the dentin walls in the access space should be sealed with a flowable composite before the paste is placed in the canal. They stated that color change could be prevented by acting in this way.

Revascularization enables the delivery of mesenchymal stem cells to the canal of necrotic immature teeth through the open apex after the regenerative endodontic approach.[53] Therefore, it can form new tissues in the root canal of the host cell.[54] Immature permanent teeth with a history of trauma and an apex diameter of 1.1 mm or more are the best candidates for regenerative endodontic procedures.[14] In this study, the root tip dimensions of the teeth in both groups were found to meet this requirement. Even if there is currently limited data, regenerative endodontic procedures are not recommended for children younger than 7 years of age or older than 16 years of age unless they have thin dentin walls at risk of fracture and an open apex.[14] Although not necessary or achievable, healing of the periapical lesion, increase in root length and root dentin wall thickness, and formation of the radiographic apex are desired results.[50] Improvement of the periapical lesion on radiography is an important finding in terms of infection control. In addition, repair will begin only in the organized and uninfected tissue at the apex of immature teeth and will enable the development of the root tip.[55] When root tip development is evaluated, most teeth have only apical closure. A similar result was observed in teeth that underwent apexification; there was no increase in root length and no narrowing of the root canal space. This may be due to the fact that Hertwig's epithelial root sheath, apical papilla, or periodontal ligament cells are alive and therefore root development is continuous.[56,57] Kahler et al.[58] suggested from this perspective that longer examination periods would be more meaningful in regeneration cases because root matura-

tion continued in two cases during the 36-month follow-up period in their study.

In this study, periapical lesions decreased in both groups, and periapical healing was proven radiographically in the majority of cases. There were no statistically significant differences between groups in the development of root length (p=0.304). No difference was observed between the REP and MTA groups in terms of root development, but teeth showed less development in terms of maturation in the revascularization group. Analysis of radiographic data showed that revascularization treatment had a significant effect (p<0.05) on root tip width in the apical third. In Group 1, a positive improvement in root tip width and a narrowing in apical diameter were observed in the apical 1/3.

Reaching the correct diagnosis in pediatric patients should be based on existing clinical symptoms, history of these symptoms, tests used for diagnosis, and clinical findings,[59] because younger patients may not respond reliably to clinical symptoms. Regarding clinical examination, the literature shows that signs and symptoms generally regress after the revascularization procedure, and in some cases, pulp sensitivity returns.[6] In this study, patients in both groups reported a decrease in clinical complaints but increased pulp sensitivity in 83.33% of teeth in the REP group.

Although the desired results such as healing of the apical lesion and continuation of root development are often achieved in REPs, the observation of coronal color change due to minocycline is a negative effect. In this study, the induced bleeding technique was used in REPs. Researchers have reported that this technique has a more positive effect on the results in traumatic teeth.[60] Although its effect on periapical healing could not be clearly determined in our study, it is thought to be positive.

In this study, the recall periods of the groups were similar (1, 3, 6, 12, and 24 months) and were consistent with those of other studies in this field.[12] However, it would be appropriate to emphasize that more definitive results will be obtained from longer follow-up periods. The clinical radiographs of two patients whom we could reach 11 years later for control purposes confirmed this (Figures 4 and 5).

The strength of this study is that it presents the results of different endodontic approaches in traumatized immature permanent teeth with a two-year prospective follow-up.

Given the prospective nature of this study, attention should be paid to reliability limitations in the selection of cases and their distribution into groups. Another limitation is the use of 2D images for radiographic evaluation. Additionally, differences in the severity and duration of apical lesions and differences in root development stages of the pediatric patients included in the study may have affected the results. The unpredictability of these effects is another limitation.

The results of this study showed that patients with a history of trauma treated with REP and MTA protocols presented similar clinical and radiographic findings. However, when these two methods were compared, the color change observed in the teeth after treatment in the REP-applied group created a serious aesthetic problem.

Figure 4. Radiographic image of MTA apical plug application on tooth number 21, 11 years later.

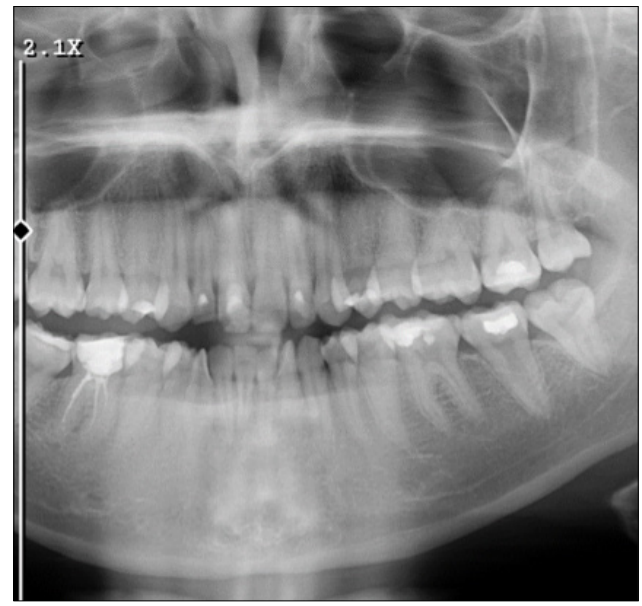

Figure 5. Radiographic image of tooth number 11, which underwent REP, 11 years later.

Studies are continuing to increase the effectiveness of regenerative endodontic treatments. However, the lack of long-term evidence supporting regenerative endodontic procedures in traumatized teeth with open apices is an important gap in this field.[61]

Today, the number of studies on cell-free and cell-based approaches based on the regeneration of pulp tissue is increasing. However, the implementation difficulties of cell-based approaches are quite obvious. On the other hand, complete clarity has not been achieved in the cell-free approach using biological signaling molecules. It is of great importance to increase the number of clinical studies on regenerative endodontic procedures that offer positive results in the clinic.

CONCLUSION

The results of this prospective study provided very satisfactory treatment results in traumatized immature permanent necrotic teeth with REPs. While the effect of REPs on apical diameter can be predicted, it can be said that this effect is not sufficiently evident on root length. The induced bleeding technique in REP may have a positive effect on the treatment of traumatized immature teeth.

Ethics Committee Approval: This study was approved by the Istanbul University Ethics Committee (Date: 13.04.2012, Decision No: 2012/632-1035).

Peer-review: Externally peer-reviewed.

Authorship Contributions: Concept: G.A.; Design: G.K.; Supervision: G.A.; Resource: G.K.; Materials: G.K.; Data collection and/or processing: G.K.; Analysis and/or interpretation: G.K.; Literature search: G.K.; Writing: G.A.; Critical review: G.A.

Conflict of Interest: None declared.

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ORİJİNAL ÇALIŞMA - *ÖZ*

Travmalı genç sürekli kesici dişlerde iki farklı apeksifikasyon protokolünün klinik ve radyografik değerlendirilmesi

AMAÇ: Diş travması, olgunlaşmamış dişlerde pulpa dokusuna zarar verebilir. Revaskülarizasyon tedavisi, travma öyküsü olan, non-vital, olgunlaşmamış sürekli dişlerin tedavisinde olası bir seçenektir. Bu prospektif çalışmanın amacı, rejeneratif endodontik prosedürler ve mineral trioksit agregat apeksifikasyon teknikleriyle tedavi edilen travma öyküsü olan olgunlaşmamış dişlerin radyografik ve klinik sonuçlarını değerlendirmektir.
GEREÇ VE YÖNTEM: Yaşları 7 ile 12 arasında değişen, travmatize immatür sürekli üst kesici dişlere sahip 45 hastadan oluşan gruptan 41 hasta çalışma kapsamına alındı. Hastalar daha önce endodontik tedavi görmüş olanlar ve görmemiş olanlar olmak üzere iki gruba ayrıldı. Üniversite kliniğine doğrudan başvuran ve daha önce endodontik tedavi görmemiş 24 hasta rejeneratif endodonti protokol grubuna (grup 1) dahil edildi. Daha önce ilgili dişlerine endodontik müdahale yapılmış 17 hasta mineral trioksit agregat apeksifikasyon grubuna (grup 2) dahil edildi. Hastalar 24 ay süreyle takip edildi. Klinik başarı oranları değerlendirilirken, kök dentin genişliği ve kök uzunluğundaki yüzde artış miktarını hesaplamak için tedavi öncesi ve kontrol radyografileri değerlendirildi.
BULGULAR: 24 aylık takip sonrasında vakaların çoğunda radyografik bulgularda pozitif periapikal iyileşme tespit edildi. Grup 1'de kök uzunluğunda ve kök dentin genişliğinde sınırlı bir artış gözlenirken, apikal açıklıkta daralma belirgindi. 11 yıl sonra ulaşılabilen iki olgunun radyografik değerlendirmesi, seçilen yöntemlerin etkinliğinde uzun süreli takibin önemini vurgular tarzda idi.
SONUÇ: Revaskülarizasyon yöntemi travma sonucu nekrotik pulpalı dişlerde kök gelişimi açısından olumlu sonuçları olan bir tedavi seçeneğidir.

Anahtar sözcükler: Genç sürekli dişler; rejeneratif endodontik protokol; mineral trioksit agregat.

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