Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 10:2026
DOI: 10.5281/zenodo.23434850

EFFECT OF ENAMEL MATRIX DERIVATIVE ON CLINICAL AND RADIOGRAPHIC OUTCOMES IN REGENERATIVE ENDODONTIC TREATMENT OF NON-VITAL IMMATURE PERMANENT TEETH: A RANDOMIZED CLINICAL TRIAL

ABRAR HAMED HABIB YOUSEF*

Teaching Assistant, Pediatric Dentistry, Preventive Dentistry and Dental Public Health Faculty of Dentistry, Horus University, Damietta, Egypt. *Corresponding Author Email: Ahabib@horus.edu.eg

ADEL FATHY AHMED HUSSEIN

Professor, Pedodontics and Oral Health, Faculty of Dental Medicine, Al-Azhar University (Boys- Cairo), Egypt. Email: adelfathy@azhar.edu.eg, ORCID: 0000-0002-0066-1496

WALEED OMAR AMIN KADOUR

Lecturer, Pedodontics and Oral Health, Faculty of Dental Medicine, Al-Azhar University (Boys- Cairo), Egypt. Email: WaleedKadour.209@azhar.edu.eg**,** ORCID: 0009-0003-8354-0888

Abstract

Objective: This study aimed to compare the clinical and radiographic outcomes of enamel matrix derivative (Emdogain®) and blood clot scaffold in regenerative endodontic treatment of non-vital immature permanent anterior teeth. **Materials and Methods:** twenty-six children with immature non-vital anterior teeth were randomly allocated into two equal groups (n=13). Group I received conventional blood clot regenerative treatment and Group II received Emdogain. Clinical evaluation was performed at baseline, 3, 6, and 12 months, while digital periapical radiographs were assessed at the same follow-up intervals. **Results:** Clinical findings improved progressively in both groups, with complete resolution of the evaluated clinical signs observed by the 3-month follow-up. Radiographic assessment demonstrated a gradual reduction in PDL widening and periapical radiolucency over the follow-up period, with no evidence of root resorption in either group. No statistically significant differences were detected between the groups at any assessment point ($p > 0.05$). Nevertheless, both groups exhibited significant radiographic improvement over time. **Conclusion:** Both regenerative protocols demonstrated favorable clinical and periapical radiographic outcomes throughout the 12-month follow-up period, with no significant differences between the two groups.

Keywords: Regenerative Endodontics; Enamel Matrix Derivative; Emdogain; Blood Clot Scaffold; Immature Permanent Teeth; Pulp Necrosis.

INTRODUCTION

The management of non-vital immature permanent teeth represents a significant clinical challenge because incomplete root formation results in thin dentinal walls and a wide apical foramen, increasing the risk of root fracture and complicating conventional endodontic treatment. Conventional apexification techniques can establish an apical barrier; however, they do not reliably promote continued root development or reinforcement of the immature root [(1)].

Regenerative endodontic treatment (RET) has consequently emerged as a biologically based approach for the management of immature permanent teeth with pulp necrosis [(2)].

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 10:2026
DOI: 10.5281/zenodo.23434850

Its main objectives are to control intracanal infection, facilitate the ingrowth of vital tissues, and promote continued root development and maturation. An appropriate scaffold within the disinfected root canal is considered a key component of the regenerative process, providing a three-dimensional framework that supports tissue ingrowth and regeneration [(3)].

The induced blood clot is the most commonly used scaffold in regenerative endodontic procedures. It provides a fibrin-based three-dimensional matrix containing platelets, growth factors, and cells that may contribute to tissue repair and continued root development. However, the amount and quality of the blood clot may vary between cases, which has encouraged investigation of alternative biological scaffolds [(4)].

Enamel matrix derivative (Emdogain®) is a biologically active protein-based material that has been investigated as a scaffold in regenerative endodontics. Its components have been reported to promote cell proliferation, differentiation, angiogenesis, and mineralization, potentially supporting regenerative and reparative processes [(5)].

Although different scaffolds have demonstrated promising outcomes, comparative clinical evidence remains limited. Therefore, the present randomized clinical trial was designed to compare the clinical and periapical radiographic outcomes of regenerative endodontic treatment using conventional blood clot and Emdogain® scaffold in non-vital immature permanent anterior teeth.

MATERIALS AND METHODS

This study was conducted on a total of twenty-six Egyptian child patients with immature non-vital anterior teeth. Patients were selected from the outpatient clinic of the Pedodontics and Oral Health Department, Faculty of Dental Medicine, Al-Azhar University (Boys' Branch, Cairo) after obtaining the approval of The Research Ethics Committee.

Patient selection and Grouping

Patients aged 7–11 years were included if they had at least one restorable immature permanent anterior tooth with pulp necrosis, with or without a periapical lesion, and radiographic evidence of an open apex (≥1 mm apical foramen width). Patients were required to have cooperative behavior and parental/guardian informed consent. Teeth with root fractures, root resorption, periodontal pockets, developmental anomalies, periapical radiolucency >10 mm, or grade III mobility were excluded [(6)].

The eligible patients were randomly assigned using a computer-generated sequence to one of two equal groups (n = 13 per group). Group I (Conventional group) underwent regenerative endodontic treatment using an induced blood clot as the scaffold, whereas Group II (Emdogain group) received regenerative endodontic treatment with Emdogain® as the scaffold.

Pre-Operative Phase

A thorough personal, medical, and dental history was obtained from each participant, followed by clinical and radiographic examination. Clinically, the suspected teeth were

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 10:2026
DOI: 10.5281/zenodo.23434850

examined for caries, previous restorations, or crown fractures, along with percussion testing. Digital periapical radiographs were obtained to assess root morphology and confirm the presence of periapical radiolucency, while pulp necrosis was confirmed by negative responses to cold and electrical pulp sensitivity tests.

Operative Phase

At the first visit, local anesthesia was administered using 4% articaine hydrochloride with epinephrine, followed by rubber dam isolation. An access cavity was prepared using a high-speed #4 bur under water coolant *(figure 1-a)*, and the working length was determined with an electronic apex locator and confirmed radiographically. No mechanical canal enlargement was performed to preserve the integrity of the thin dentinal walls.

Canal debridement was carried out using H-files to remove necrotic debris and residual pulp tissue. Passive irrigation was performed according to the American Association of Endodontists guidelines using 20 mL/canal of 1.5% sodium hypochlorite, followed by sterile saline and 20 mL/canal of 17% EDTA, delivered with a side-vented needle positioned 2 mm short of the working length *(figure1-b)*. The canals were then dried with sterile paper points, and calcium hydroxide (Metapaste) was placed as an intracanal medicament for two weeks *(figure 1-c)*. Finally, the access cavity was temporarily sealed with a glass ionomer restoration.

The second visit was scheduled after confirming the absence of signs or symptoms of persistent infection; when infection persisted, intracanal medication was maintained for an additional period. Following administration of 4% articaine hydrochloride without vasoconstrictor and rubber dam isolation, the tooth was re-opened. The irrigation protocol was repeated using 20 mL/canal of 1.5% sodium hypochlorite, followed by sterile saline and 20 mL/canal of 17% EDTA. The canals were then dried with sterile paper points, and bleeding was induced by intentional over-instrumentation with an H-file approximately 2 mm beyond the apical foramen to initiate blood clot formation *(figure 1-d)*.

Following blood clot formation to the level of the cementoenamel junction, the regenerative procedures were performed according to the assigned group. In Group I (Conventional group), a 3-mm layer of Bio-MTA was placed over the blood clot without an additional scaffold. In Group II (Emdogain® group), 0.15 mL of Emdogain® was introduced into the canal and mixed with the blood clot, followed by placement of a 3-mm Bio-MTA layer in the coronal third of the canal *(figure 1-e&f).* In both groups, the access cavity was sealed with glass ionomer cement followed by Beautifil resin composite restoration. Postoperative periapical radiographs and clinical photographs were obtained for all patients.

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 10:2026
DOI: 10.5281/zenodo.23434850

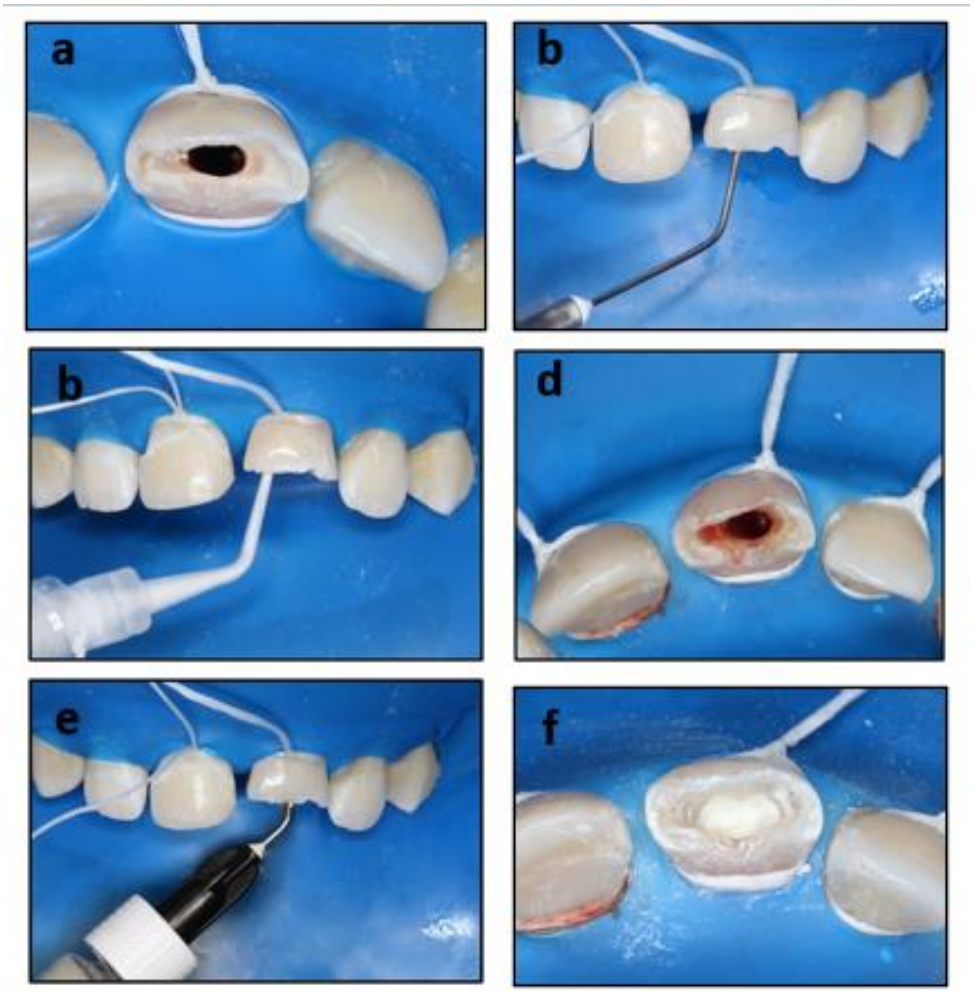


Figure 1: (A) Access Cavity Preparation, (B) Irrigation Protocol, (C) Metapaste Placement, (D) Bleeding Initiation, (E) Emdogain Placement, (F) MTA Placement

Evaluation and Assessment

Clinical and radiographic outcomes were evaluated at baseline and at 3, 6, and 12 months postoperatively. Clinical assessment was performed according to the criteria described by Johns et al. [7], including the presence of pain, tooth mobility, sinus tract or swelling, tenderness to palpation of the surrounding soft tissues, and tenderness to percussion. Standardized digital periapical radiographs were obtained at the same follow-up intervals and evaluated for changes in periodontal ligament space width, the presence of internal or external root resorption, and the presence or absence of periapical radiolucency.

RESULTS

A total of twenty -six subjects were included in this study with an age ranged from 7 to 11 years with immature non-vital anterior teeth. They were divided into two main groups; group I in which 13 patients were enrolled and received regenerative endodontic

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 10:2026
DOI: 10.5281/zenodo.23434850

treatment of the necrotic immature anterior teeth using conventional blood clot technique, whereas group II included 13 patients who received regenerative endodontic treatment of the necrotic immature anterior teeth using Emdogain as regenerative scaffold.

The statistical analysis was performed to assess and compare the differences in clinical and radiographic parameters between the tested groups. Data were analyzed using computer software Statistical Package for Social Science SPSS (IBM-SPSS version 29.0). Data were collected, checked, and organized in tables and figures using Microsoft Excel 2016.

Qualitative data were conveyed as frequencies and percentages. Whereas, quantitative data were tested for normality by Shapiro-Wilk test then presented as mean and standard deviation as data are normally distributed.

The appropriate statistical test was applied according to data type. Intergroup comparisons of nominal variables between the two study groups were performed using the Chi-Square test. Intragroup comparisons across more than two time points for dichotomous outcomes were assessed using Cochran's Q test. Significance of the obtained results was judged at the 0.05 level

I. Demographic Data

Twenty-six patients diagnosed with immature non-vital anterior teeth participated in this study (19 males, and 7 females). They were randomly divided into two equal groups (13 patients each).

The age of the patients ranged from 7-11 years with mean age in the group I was 8.54 ± 0.88 years, eight of them were males and five were females while the mean age in the group II was 8.77 ± 0.93 years, eleven of them were males and two were females. No significant difference was noticed between groups regarding age (p= 0.521), and gender (p=0.378) as shown in (**Table.1**), (**Fig 2)**

Table 1: Age and Gender Distribution in the Tested Groups

Group	Gender		P-value	Age (Years)Mean ±SD	P-value
	MaleN (%)	FemaleN %)			
Group I (n= 13)	8 (61.5%)	5 (38.5%)	**0.378** ^{Ns}	8.54 ± 0.88	**0.521**^{Ns}
Group II (n= 13)	11 (84.6%)	2 (15.4%)		8.77 ± 0.93	

Independent t-test was done comparing age**,** while **Fisher's Exact test** was performed comparing gender between groups

P; p value,

*: Statistically significant at p ≤ 0.05

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 10:2026
DOI: 10.5281/zenodo.23434850

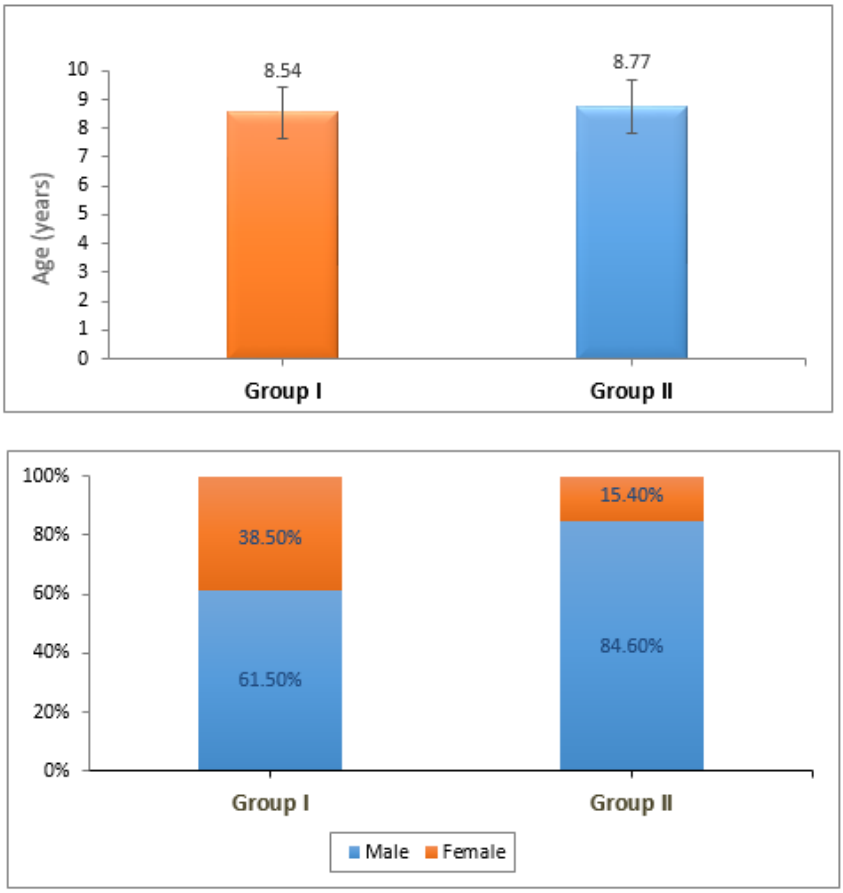


Figure 2: Bar Charts Showing Age Distribution among the Tested Groups and Gender Distribution among the Tested Groups

II. Clinical Assessment

Clinical assessment of both groups is summarized in (Table 2), both groups showed comparable baseline prevalence of clinical symptoms, with no statistically significant intergroup differences ($p > 0.05$).

At baseline, pain was present in 84.6% of Group I and 69.2% of Group II, with no significant intergroup difference ($p = 0.645$). Pain resolved completely by the 3-month follow-up and remained absent at subsequent intervals ($p = 1.000$).

Within-group analysis using Cochran's Q test demonstrated a highly significant reduction across time (Group I: $Q = 33.000$, $p < 0.001$; Group II: $Q = 27.000$, $p < 0.001$). Mobility was observed in 69.2% of Group I and 53.8% of Group II at baseline ($p = 0.420$), but resolved entirely by 3 months and remained absent thereafter. Cochran's Q confirmed significant improvement over time (Group I: $Q = 27.000$, $p < 0.001$; Group II: $Q = 21.000$, $p < 0.001$).

Associated sinus tract/swelling was present in 38.5% of both groups at baseline ($p = 1.000$), with complete resolution by 3 months and sustained absence thereafter (Group I:

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 10:2026
DOI: 10.5281/zenodo.23434850

Q = 15.000, p = 0.002; Group II: Q = 15.000, p = 0.002). Tenderness to palpation was recorded in 38.5% of Group I and 30.8% of Group II (p = 0.680), with complete resolution by 3 months.

Significant within-group reductions were observed (Group I: Q = 15.000, p = 0.002; Group II: Q = 12.000, p = 0.007 tenderness to percussion showed higher baseline prevalence (69.2% vs. 46.2%, p = 0.234), but also resolved completely by 3 months, with significant improvement across time (Group I: Q = 27.000, p < 0.001; Group II: Q = 18.000, p < 0.001). Collectively, both treatment modalities achieved comparable clinical success, with no significant differences between groups at any time point, while demonstrating highly significant improvements within each group across the follow-up period.

Table 2: Comparison of both Groups Regarding Clinical Parameters at Different Follow-Up Intervals

	Group I (n= 13) N (%)	**Group II (n= 13) N (%)**	**P Value**
Pain			
Baseline	11 (84.6%)	9 (69.2%)	0.645 Ns
3 Months	0 (0%)	0 (0%)	1.000 Ns
6 Months	0 (0%)	0 (0%)	1.000 Ns
12 Months	0 (0%)	0 (0%)	1.000 Ns
Cochran's Q	33.000	27.000	
P Value	**<0.001***	**<0.001***	
Mobility			
Baseline	9 (69.2%)	7 (53.8%)	0.420 Ns
3 Months	0 (0%)	0 (0%)	1.000 Ns
6 Months	0 (0%)	0 (0%)	1.000 Ns
12 Months	0 (0%)	0 (0%)	1.000 Ns
Cochran's Q	27.000	21.000	
P Value	**<0.001***	**<0.001***	
Associated Sinus Tract/Swelling			
Baseline	5 (38.5%)	5 (38.5%)	1.000 Ns
3 Months	0 (0%)	0 (0%)	1.000 Ns
6 Months	0 (0%)	0 (0%)	1.000 Ns
12 Months	0 (0%)	0 (0%)	1.000 Ns
Cochran's Q	15.000	15.000	
P Value	**0.002***	**0.002***	
Tenderness to Palpation			
Baseline	5 (38.5%)	4 (30.8%)	0.680 Ns
3 Months	0 (0%)	0 (0%)	1.000 Ns
6 Months	0 (0%)	0 (0%)	1.000 Ns
12 Months	0 (0%)	0 (0%)	1.000 Ns
Cochran's Q	15.000	12.000	
P Value	**0.002***	**0.007***	
Tenderness to Percussion			
Baseline	9 (69.2%)	6 (46.2%)	0.234 Ns
3 Months	0 (0%)	0 (0%)	1.000 Ns

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 10:2026
DOI: 10.5281/zenodo.23434850

6 Months	0 (0%)	0 (0%)	1.000 Ns
12 Months	0 (0%)	0 (0%)	1.000 Ns
Cochran's Q	27.000	18.000	
P Value	**<0.001***	**<0.001***	

Inter-group comparisons were performed using **Chi-square test**, while intra-group comparisons over time were assessed using **Cochran's Q test**.

*: Statistically significant at p ≤ 0.05 Ns: non-significant

III. Radiographic Assessment

Radiographic assessment of both groups is summarized in (Table 3), At baseline, widening of the periodontal ligament (PDL) space was observed in 76.9% of Group I and 76.9% of Group II, with no significant intergroup difference (p = 1.000). The prevalence decreased progressively to 69.2% vs. 61.5% at 3 months (p = 0.680), 23% vs. 15.4% at 6 months (p = 0.619), and was completely absent at 12 months (p = 1.000). Within-group analysis using Cochran's Q test confirmed a highly significant reduction across time (p < 0.001 for both groups). Internal and external root resorption was not detected in either group at any time point, with consistently non-significant values (p = 1.000). Periapical radiolucency was present in 69.2% of Group I and 61.5% of Group II at baseline (p = 0.680), and persisted at 3 months with the same prevalence (p = 0.680). By 6 months, the prevalence had decreased to 23% vs. 15.4% (p = 0.619), and was completely absent at 12 months (p = 1.000). Cochran's Q test demonstrated a highly significant reduction across time in both groups (p < 0.001). Collectively, both treatment modalities achieved comparable radiographic success, with no significant differences between groups at any time point, while showing highly significant improvements within each group across the follow-up period.

Table 3: Comparison of both Groups Regarding Radiographic Parameters at Different Follow-Up Intervals

	Group I (n= 13) N (%)	**Group II (n= 13) N (%)**	**P Value**
Widening of PDL Space			
Baseline	10 (76.9%)	(76.9%)10	1.000 Ns
3 Months	9 (69.2%)	8 (61.5%)	0.680 Ns
6 Months	3 (23%)	2 (15.4%)	0.619 Ns
12 Months	0 (0%)	0 (0%)	1.000 Ns
P Value	<0.001*	<0.001*	
Presence of Internal /External Root Resorption			
Baseline	0 (0%)	0 (0%)	1.000 Ns
3 Months	0 (0%)	0 (0%)	1.000 Ns
6 Months	0 (0%)	0 (0%)	1.000 Ns
12 Months	0 (0%)	0 (0%)	1.000 Ns
P Value	1.000 Ns	1.000 Ns	
Presence of Periapical Radiolucency			
Baseline	9 (69.2%)	8 (61.5%)	0.680 Ns
3 Months	9 (69.2%)	8 (61.5%)	0.680 Ns

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 10:2026
DOI: 10.5281/zenodo.23434850

6 Months	3 (23%)	2 (15.4%)	0.619 Ns
12 Months	0 (0%)	0 (0%)	1.000 Ns
P Value	<0.001*	<0.001*	

Inter-group comparisons were performed using **Chi-square test**, while intra-group comparisons over time were assessed using **Cochran's Q test**.

*: Statistically significant at p ≤ 0.05 Ns: non-significant

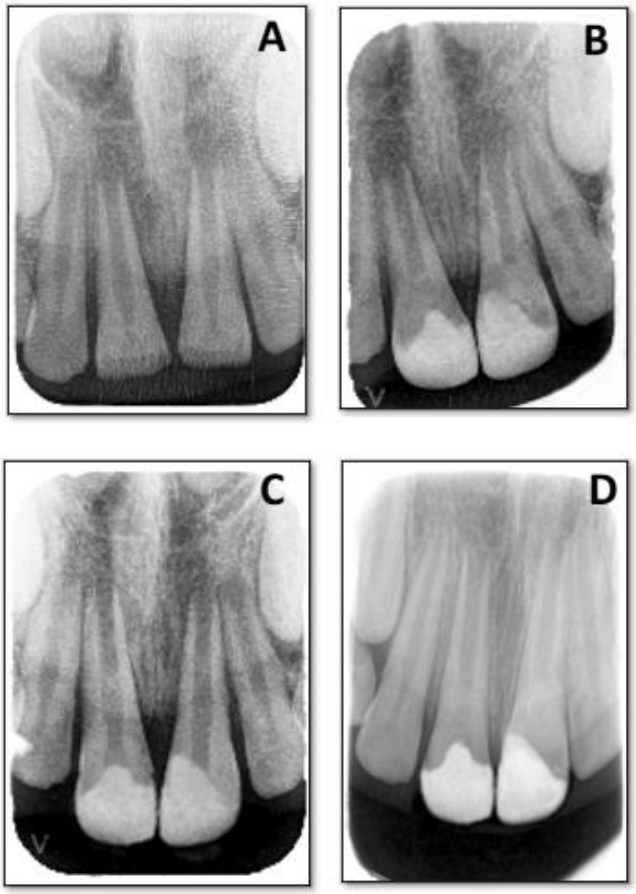


Figure 3: Radiographic 3, 6, 12 Months Follow Up of A Case With Two Teeth Treated With Emdogain Scaffold For Right Tooth And Blood Clot Technique for Left Tooth

DISCUSSION

The management of non-vital immature permanent teeth remains a clinical challenge due to the structural limitations associated with incomplete root development. Although traditional approaches, such as long-term calcium hydroxide apexification and mineral trioxide aggregate (MTA) apical barrier techniques, are effective in controlling infection and establishing an apical barrier, they do not predictably promote further root maturation. Consequently, despite successful resolution of infection, the persistence of thin dentinal

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 10:2026
DOI: 10.5281/zenodo.23434850

walls may leave the treated teeth susceptible to fracture. These limitations have provided the rationale for the development of regenerative endodontic treatment, which aims to promote continued root development and strengthen the immature root [8].

The age range of 7–11 years was selected to correspond with the developmental stage of permanent maxillary central incisors, which may remain incompletely developed during this period. In addition, children within this age range are considered at increased risk of traumatic dental injuries, which represent a common etiological factor for pulp necrosis in immature permanent teeth. This rationale is consistent with the findings of *El-Kenany et al.* [9], who reported the highest incidence of dental trauma among children aged 8–12 years.

Only teeth with an apical diameter greater than 1 mm were included, as this dimension provides adequate space for tissue ingrowth, revascularization, and migration of stem cells from the apical papilla [10]. In addition, teeth that did not require post-and-core restorations were selected. This was based on the use of an MTA coronal plug over the scaffold to achieve an adequate coronal seal, which occupies part of the cervical canal and consequently limits the available space for post placement [11].

Effective canal disinfection is a fundamental prerequisite for successful regenerative endodontic procedures. In the present study, 1.5% sodium hypochlorite (NaOCl) was selected as the irrigant rather than higher concentrations. This concentration was chosen based on evidence that higher concentrations of NaOCl may adversely affect the viability of stem cells of the apical papilla (SCAP) and alter dentin-derived matrix proteins that play an important role in tissue regeneration [12].

Despite its lower concentration, 1.5% NaOCl has demonstrated adequate antimicrobial efficacy against endodontic pathogens, as reported by Karkehabadi et al. Following NaOCl irrigation, sterile saline was used to remove residual irrigant and minimize its potential cytotoxic effects on the regenerative environment [13].

Calcium hydroxide intracanal medication was used between visits because it has demonstrated superior compatibility with SCAPs survival and proliferation compared to triple antibiotic paste (TAP). Moreover, in-vitro studies raised concerns regarding the cytotoxic effects TAP on SCAPs, as well as the possibility of development of bacterial resistance. Previous research has shown that SCAPs exhibit the highest survival rates when cultured on dentine exposed to Ca (OH), compared to dentine exposed to 1 mg/mL or higher of TAP concentration [14].

At the second treatment visit, local anesthesia without a vasoconstrictor was used before bleeding induction. This approach prevents vasoconstrictor-induces ischemia, which could compromise the ability to achieve adequate intracanal bleeding, a critical step for forming a natural scaffold and delivering stem cells into the canal space [15].

Through the follow up periods, a complete and sustained resolution was observed across all clinical parameters, with no patients showing residual symptoms. This favorable outcome was sustained at 6 and 12 months, reflecting the stability of the clinical response.

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 10:2026
DOI: 10.5281/zenodo.23434850

These findings are in accordance with those of ***Khalil et al.*** [16], who reported a 100% clinical success and survival rate in teeth treated with Enamel Matrix Derivative (EMD) after one year. The uniform improvement and early disappearance of clinical signs across both groups confirms the effectiveness and reliability of the interventions.

The favorable radiographic healing observed in both groups may be attributed primarily to adequate canal disinfection and effective control of periapical infection, which are considered essential factors for successful regenerative endodontic treatment. The progressive resolution of PDL widening and periapical radiolucency may therefore reflect reduction of the inflammatory process and subsequent periapical healing.

The lack of significant differences among the three groups is consistent with previous evidence showing comparable clinical and radiographic outcomes among different scaffold approaches. This may be explained by the biological potential of the naturally formed blood clot, which provides a fibrin matrix, mesenchymal stem cells, and platelet-derived growth factors that can support tissue repair [17].

Furthermore, the absence of root resorption may be related to adequate infection control and the conservative nature of regenerative protocols, which emphasize minimal instrumentation of the dentinal walls. Although Emdogain® may provide additional biological components, their potential advantages did not result in a significant radiographic benefit in the present study [17].

CONCLUSION

Both regenerative endodontic approaches demonstrated favorable and comparable clinical and radiographic outcomes over the 12-month follow-up period. Emdogain® did not provide a significant clinical or radiographic advantage over the conventional blood clot technique.

Author's Contributions

AFA and AHH conceived the idea and designed the study. WOA wrote the main manuscript text. AHH prepared the figures. All listed authors participated in experiments and data collection. All authors have read and approved the final manuscript.

Data availability

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

References

1) Alagl A, Bedi S, Hassan K, AlHumaid J, Alagl R. Use of platelet-rich plasma for regeneration in non-vital immature permanent teeth: clinical and cone-beam computed tomography evaluation. J Int Med Res. 2017;45(2):583-593.

2) Kim SG, Malek M, Sigurdsson A, Lin LM, Kahler B. Regenerative endodontics: a comprehensive review. Int Endod J. 2018;51(12):1367-1388.

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online):0493-2137
E-Publication: Online Open Access
Vol: 59 Issue: 10:2026
DOI: 10.5281/zenodo.23434850

3) Albuquerque MTP, Valera MC, Nakashima M, Nör JE, Bottino MC. Tissue-engineering-based strategies for regenerative endodontics. J Dent Res. 2014;93(12):1222-1231.

4) Ducret M, Costantini A, Gobert S, Farges JC, Bekhouche M. Fibrin-based scaffolds for dental pulp regeneration: from biology to nanotherapeutics. Eur Cell Mater. 2021; 41:1-14.

5) Haugen HJ, Basu P, Sukul M, Mano JF, Reseland JE. Injectable biomaterials for dental tissue regeneration. Int J Mol Sci. 2020;21(10):3442.

6) Wikström, A., Brundin, M., Lopes, M. F., El Sayed, M., Tsilingaridis, G. What is The Best Long-Term Treatment Modality for Immature Permanent Teeth with Pulp Necrosis and Apical Periodontitis? European Archives of Paediatric Dentistry. 2021; 22(3): 311-340.

7) Johns DA, Varughese JM, Thomas K, et al. Clinical and Radiographical Evaluation of The Healing of Large Periapical Lesions Using Triple Antibiotic Paste, Photo Activated Disinfection and Calcium Hydroxide When Used as Root Canal Disinfectant. J Clin Exp Dent 2014; 6(3): 230 -236.

8) Aksoy D, Kocak S. Management Strategies for Teeth with Open Apex: From Apexification to Regenerative Endodontics. Cumhuriyet Dent J. 2025; 28(3): 462-468.

9) El-Kenany MH, Awad SM, Hegazy SA. Prevalence and Risk Factors of Traumatic Dental Injuries to Permanent Anterior Teeth Among 8-12-Year-Old School Children in Egypt. Pediatr Dent J. 2016; 26(2): 67-73.

10) Murray PE. Review Of Guidance for The Selection of Regenerative Endodontics, Apexogenesis, Apexification, Pulpotomy, And Other Endodontic Treatments for Immature Permanent Teeth. Int Endod J. 2023; 56(3):188-199.

11) Grayli, E., Dashtban, A., Shadan, L., Behnampour, N., & Afshari, E. Effect of MTA Versus CEM Apical Plugs on Fracture Resistance of Endodontically Treated Simulated Immature Teeth Restored with Cast Metal Posts: An In Vitro Study. BMC Oral Health. 2021; 21(1): 280- 95.

12) Martin D, De Almeida, J., Henry, M., Khaing, Z., Schmidt, E., Teixeira, F. B., & Diogenes, A. Concentration-Dependent Effect of Sodium Hypochlorite on Stem Cells of Apical Papilla Survival and Differentiation. J Endod. 2014; 40(1): 51-55.

13) Karkehabadi H, Yousefifakhr H, Zadsirjan S. Cytotoxicity of Endodontic Irrigants on Human Periodontal Ligament Cells. Iran Endod J. 2018; 13(3): 390-394.

14) Tantawy, D. A., Abu-Seida, A. M., Soliman, A. H., Obeid, M. F., Mahran, A. H. Regenerative endodontics in mature teeth: a comprehensive review. Ain Shams Dent J. 2026; 42(2): 127-142.

15) Guimaraes, C., Lopes, L., Bergamaschi, C., Ramacciato, J., Silva, M., Araujo J, Motta, R. Local Anaesthetics Combined with Vasoconstrictors in Patients with Cardiovascular Disease Undergoing Dental Procedures: systematic review and meta-analysis. BMJ Open. 2021; 11(7): 344-357.

16) Khalil, A., El-Batouty, K., Nagy, M. Influence of The Use of Scaffold on The Regeneration Potential of Necrotic Immature Human Permanent Anterior Teeth: Clinical Study. Egyptian Dental Journal, 2022; 68(1): 1107-1121.

17) Thakkar S, Naik S, Nadig B, Bellal S, Thaliyil A. A comparative clinico-radiographic analysis of regenerative endodontic procedure on immature necrotic permanent teeth using blood clot and PRF as scaffold: a retrospective study. Saudi Dent J. 2023;35(6):753-759.