CASE SERIES

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Endodontic retreatment and apexification of a tooth previously treated with a regenerative endodontic procedure: A case report

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In this case report, the treatment procedure and follow-up of a left maxillary central incisor that previously underwent a regenerative endodontic procedure is presented. After a thorough anamnesis, clinical and radiographical examination, a non-surgical endodontic retreatment was applied. Apexification treatment included intensive irrigation, Ca(OH)2 administration and finally, creating an apical plug with MTA. Follow-up radiographic and clinical examination showed healing of the periapical area and reduction of initial symptoms, keeping the tooth in function. As regenerative endodontic procedures can be recognized as the best option for permanent teeth with immature apices, there are always alternatives that can be implemented following failure.

Keywords: Calcium hydroxide; mineral trioxide aggregate; regenerative endodontics; root canal therapy; tooth apex.

Introduction

Regenerative endodontic procedure (REP) is a treatment approach that aims to resume physiological root development and maintain apical closure in immature, necrotic permanent teeth (1). REP procedures are widely accepted treatment strategies, especially by American Association of Endodontics, European Society of Endodontics and European Academy of Paediatric Dentistry. Traumatic dental injuries to the permanent dentition occur frequently in 25% of children and 33% of adults, with most of the injuries taking place before 19 years of age (2). Trauma may induce pulp and periradicular pathosis, and in teeth with immature apices, this may lead to the disruption of the root development. REP contributes to the thickening of the dentin walls and normal maturation of the root, thus maintaining long-term tooth functionality (3). However, the desired outcome may not be achieved in every case, and post-treatment complications such as the development of periapical lesions could occur (4).

According to recent systematic reviews, the clinical success rates of REPs are on par with those of traditional non-surgical endodontic treatments (NSETs). Variability in follow-up periods, however, seems to have an impact on these results. Specifically, short-term results might not accurately represent long-term clinical success, highlighting the significance of proper follow-up in assessing treatment effectiveness (5,6).

Periapical healing is the most commonly attained outcome, and pooled clinical success rates exceeding 90% have been reported in recent quantitative meta-analyses

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assessing the results of regenerative endodontic therapy (REP). These results support the clinical feasibility of REP, especially when appropriate disinfection is guaranteed and protocols are closely adhered to (7).

In unsuccessful REP cases, retreatment is necessary, and careful planning of the treatment strategy is crucial. In these type of situations, traditional apexification stands out as a safe treatment alternative, especially in teeth with incomplete root development due to failed revitalization (8). The selection between apexification and REPs should be based on the clinical context, root development stage, and patient-related factors. Apexification is a well-established endodontic procedure aimed at inducing a calcified barrier at the apex of an immature permanent tooth with a necrotic pulp. This treatment is especially indicated in teeth that exhibit open apices, which render conventional root canal obturation techniques challenging (9). Prevention of the extrusion of root canal filling material and allowing proper apical sealing is the chief objective of apexification (1).

Calcium hydroxide [$Ca(OH)_2$] has been popularized as the material of choice for this procedure back in 1972 by Cvek et al. (10), due to its ability to stimulate hard tissue formation. Conversely, its application needs multiple visits and periodical monitorization, ranging from 6 to 24 months (11). The hard tissue barrier created by $Ca(OH)_2$ is often porous, increases the risk of root fracture due to long-term $Ca(OH)_2$ exposure and the extended treatment duration may not often be well accepted by the patients (12).

In recent years, Mineral Trioxide Aggregate (MTA) has emerged as a reliable alternative, offering the advantage of a one- or two-visit apexification procedure (13). MTA is a frequently preferred material in endodontics, used in many areas like vital pulp therapy, perforation repair, creating an apical plug, root canal sealer, and has been reported in the literature due to its biocompatibility, antimicrobial effect, and ideal microleakage resistance (14). Studies have reported high success rates with MTA apexification, with healing outcomes exceeding 90% in many cases (15). The clinical protocol typically involves thorough debridement of the root canal system, followed by the placement of MTA at the apical portion to create an artificial apical barrier. Once the material sets, the remainder of the canal can be obturated conventionally. Radiographic follow-up is essential to monitor periapical healing and confirm apical closure over time.

In conclusion, apexification continues to be a valuable treatment modality in contemporary endodontics. With the introduction of bioactive materials such as MTA, the prognosis of necrotic immature teeth has significantly improved. An MTA apexification intervention of a maxillary central incisor that was unsuccessfully treated with REP is presented in this case report.

Case Report

This manuscript has been written according to Preferred Reporting Items for Case reports/or randomized clinical trials/or animal studies in Endodontics.

A 19-year-old systemically healthy female patient presented to the Department of Endodontics at Başkent University, Faculty of Dentistry with complaint of pain on her maxillary left central incisor. According to the anamnesis, the patient had received a REP on right and left maxillary central incisors at an external clinic approximately 10 years ago following a traumatic incident. Her chief complaint involved spontaneous pain as well as pain during mastication.

Clinical examination revealed percussion and palpation sensitivity on the left maxillary central incisor. In addition, pulp vitality tests yielded negative responses. Radiographic evaluation of the periapical area showed incomplete root development of the left maxillary central incisor and a radiolucency consistent with a periapical lesion was observed. Furthermore, structural defects were detected in the MTA material that had been placed during the previous REP (Fig. 1).

The clinician explained the treatment options in detail, repetition of the REP, apexification with MTA or root canal treatment. The patient and the clinician decided to commence with the apexification treatment using MTA. Before proceeding, the patient's written informed consent was taken.

Under local anesthesia and rubber dam isolation, an access cavity was prepared to reach the root canal system. Using a #80 stainless steel K-file, the working length was determined to be 22 mm and the root canal walls were mechanically shaped (Fig. 2). Irrigation was carried out sequentially with 20 ml of 5.25% sodium hypochlorite (NaOCl), 20 ml of 17% EDTA, and finally another 20 ml of 5.25% NaOCl. After drying the root canal with sterile paper points, $Ca(OH)_2$ was placed and a temporary restoration was applied.

At the second appointment given 10 days later, clinical symptoms had subsided, and the same irrigation protocol was repeated. After drying the root canal with sterile paper points, an apical plug was created using Bio MTA (CERKAMED, Stalowa Wola, Poland). The preparation and application of MTA followed the instruction manual provided by the manufacturer. A Schilder plugger (Dentsply Maillefer, Ballaigues, Switzerland) was used to create an apical barrier that was 4 mm thick, to allocate an adequate marginal adaptation and apical sealing (16). To ensure con-

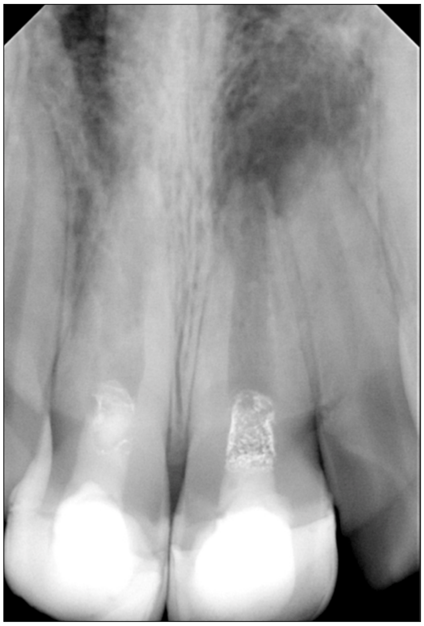

Fig. 1. Initial periapical radiograph.

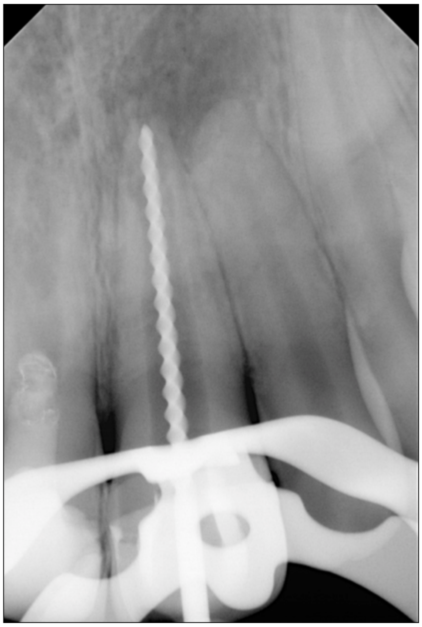

Fig. 2. Working length determination.

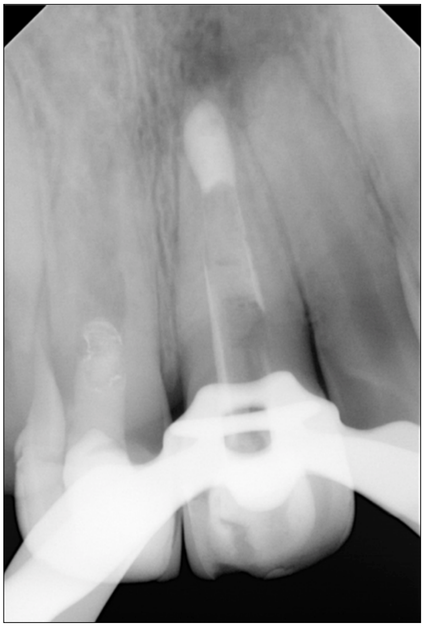

Fig. 3. Forming an apical plug with MTA.

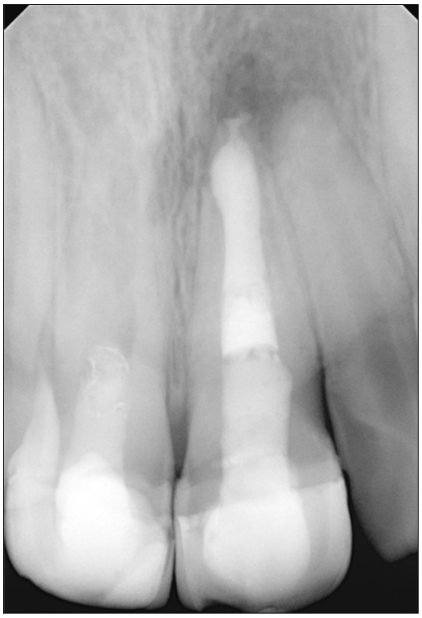

Fig. 4. Root canal obturation.

Fig. 5. 11-month follow-up.

Fig. 6. 21-month follow-up.

trolled placement and compaction of the apical plug, the initial working length was set at 22 mm, and the plugger was gradually shortened by 1 mm per step until a final stop at 18 mm was reached (Fig. 3). The remaining canal space was backfilled with gutta-percha and AH Plus (Dentsply, Germany) sealer using the cold lateral condensation technique. The access cavity was sealed with a composite restoration (Fig. 4).

At the 11-month follow-up, the tooth was found to be asymptomatic and in function (Fig. 5). In the follow-up radiograph taken at 21 months, significant healing of the lesion was observed, and the periradical area appeared to have approached a normal configuration with bone healing (Fig. 6).

Discussion

REP is a cell-based modern therapeutic approach targeted at re-constructing the dentin-pulp complex and promoting root development in immature permanent teeth affected by pulp necrosis (1). Although long-term success rates have been reported to exceed 80% in numerous studies (17), REP procedures may fail for various reasons in clinical practice.

The REP protocol generally consists of disinfection, induction of apical bleeding and a hermetically sealed coronal restoration. During the disinfection step, minimal mechanical instrumentation is performed, and irrigants such as 1.5% NaOCl followed by 17% EDTA are used to prepare root canal surfaces. Typically, triple antibiotic paste (TAP) or $Ca(OH)_2$ is placed as an intracanal medicament. At the follow-up appointments, if the tooth is asymptomatic, a traumatic bleeding is induced by using a K-file extended approximately 2 mm beyond the apex to advocate the migration and proliferation of mesenchymal stem cells from the periapical tissues. Once bleeding stabilizes, a collagen sponge is placed over the clot, followed by a biocompatible material, and then the final restoration is completed. This protocol is described in detail in AAE's 2021 clinical guidelines (18).

Reasons for failure include inadequate sterilization, inability to eliminate infection, unfavorable root canal morphology, limited stem cell migration in the apical tissues, and issues related to patient compliance. In a study by Lee and Song (19) involving 111 cases, persistent infection was reported as the primary cause of failure in 81.3% of cases; anatomical factors like canal morphology were also listed as significant contributors to treatment outcomes.

Unsuccessful REP cases are not uncommon in clinical settings and necessitate a reassessment of the treatment protocol. According to the Mahidol Study published in 2024, 10.8% of regenerative procedures were classified as failures, being labeled "diseased" rather than "healed" (20). Additionally, systematic reviews have associated REP failure with persistent symptoms, unchanged periapical radiolucency, and development of internal or external resorption (21).

The choice of irrigation solution and intracanal medicament significantly impacts the canal environment and promotes cellular regeneration, thereby affecting the success of REPs. NaOCl, the most commonly used irrigant, effectively decomposes tissues and has a potent antimicrobial action but can exhibit cytotoxic effects on stem cell viability at high concentrations. Notably, SCAP (stem cells of the apical papilla) viability has been reported to decrease by over 50% after exposure to 5–6% NaOCl (22). Therefore, lower concentrations, such as 1.5% NaOCl are recommended in REP, followed by a final irrigation with 17% EDTA to demineralize the dentin matrix and release growth factors.

Intracanal medicaments are another critical factor in treatment outcomes. Although traditional TAP offers a broad-spectrum antibacterial activity, it may induce tissue toxicity and cause permanent discoloration of dentin at high concentrations. In 2021, an in vitro study on SCAPs showed that TAP had both cytotoxic and genotoxic effects at high concentrations, significantly reducing stem cell viability (23).

As an alternative, $Ca(OH)_2$ has been proposed as another medicament; however, it may be less effective than TAP in eliminating infection. Meta-analyses from 2021 and 2022 reported that TAP exhibited a significantly greater antimicrobial efficacy against resistant microorganisms like Enterococcus than $Ca(OH)_2$. For example, in one systematic review, TAP's effect on E. faecalis biofilm was reported as (SMD=–3.82, 95% CI: –5.44 to –2.21; $p<0.001$), demonstrating superiority over $Ca(OH)_2$ (24). Conversely, $Ca(OH)_2$ has been shown to exert less tissue toxicity and more favorable effects on stem cell survival compared to TAP (25). Thus, balancing biocompatibility and antimicrobial efficacy with the use of irrigants and medicaments is vital for the long-term success of REP.

After regenerative endodontic therapy (REP) fails, a number of treatment approaches have been suggested, including extraction, nonsurgical root canal therapy, repeated RET, calcium hydroxide apexification, or surgical procedures. However, there is currently inadequate clinical data to support the efficiency and long-term results of these secondary approaches (26).

Both apexification with an MTA apical plug and REPs may be regarded as effective treatment options in cases with advanced root development (stage 4 according to Cvek's classification) (27). However, the viability of stem cells and tissue-forming cells in the periapical area may be compromised by prior infection, making successful revascularization uncertain. Additionally, mechanical instrumentation was intentionally minimized to avoid further weakening of the already thin dentinal walls (28), although limited instrumentation has also raised concerns regarding the completeness of disinfection in REPs (29,30). Considering these biological and technical limitations, apexification was selected as the more predictable and conservative approach in this case.

In cases of failure, apexification is an alternative treatment approach, intending to create an apical barrier in teeth with open apices to enable safe obturation of the canal system. Traditionally, this procedure is done by placing $Ca(OH)_2$ in the root canal over multiple sessions. However, single-visit apexification using MTA has become a faster, tissue-friendly, and clinically reliable alternative (13,31).

MTA is a calcium silicate-based material that sets in moist environments and exhibits biocompatible and tissue-regenerating properties (32). This material exerts antimicrobial effects by creating a high-pH environment parallel to $Ca(OH)_2$ upon direct contact with tissue and enhances apical sealing through a hydroxyapatite-like surface layer (33). A recent systematic review has shown that single-visit MTA apexification procedures yield success rates exceeding 90% and offer comparable or superior clinical outcomes in a shorter timeframe compared to $Ca(OH)_2$ protocols (34). However, appropriate case selection and strict follow-up protocols are crucial for the success of such revision treatments. In this context, unsuccessful REP cases require a comprehensive analysis of clinical, biological, and patient-centered dynamics.

In the presented case, apexification was performed on a previously REP-treated but non-healing central incisor using the single-visit MTA apical plug technique. MTA was carried with a metal spatula and carrier into the root canal, placed with a plugger under controlled conditions, and a moist cotton pellet was inserted to allow proper setting. After 24 hours, the MTA plug was assessed, and the coronal restoration was completed. At 11- and 21-month follow-ups, the tooth remained clinically asymptomatic, and radiographic healing of the periapical area was observed. These results align with findings reported in the literature regarding MTA-based apexification cases (35,36).

Although alternative materials such as Biodentine and EndoSequence Root Repair Material have been developed, many recent studies highlight MTA's superiority in terms of apical sealing, setting depth, and tissue compatibility. For instance, an in vivo experiment found that MTA showed better marginal adaptation and histological response compared to BioDentine (37). Clinically, after drying the root canal with sterile paper points, MTA is inserted using a moist cotton pellet and a carrier instrument, aiming to form a 4–5 mm thick apical barrier (38). According to a study done by Pereira et al. (16), a 4-mm thick apical barrier ensures a significantly suitable seal and marginal adaptation (39) Nonetheless, some laboratory studies report that Biodentine demonstrates lower porosity and faster setting, which may provide better adaptation in in vitro models (38). Clinical and in vivo comparisons largely support the preference for MTA due to its stable tissue integration and long-term performance. Histological analyses have shown that apical barriers formed with MTA support cementum-like mineralization and positively impact periapical healing. For example, a 2024 study using a Wistar albino rat model reported superior calcific barrier formation and minimal inflammation after 28 days using modified MTA formulations (40).

Conclusion

In conclusion, single-visit apexification with MTA emerges as a biologically and clinically reliable option in failed REP cases. However, prevention of such failures hinges upon patient compliance, sterilization, control of irrigation, and strict adherence to protocols. Further clinical studies should be undertaken to compare the treatment options in cases with failed REPs.

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References

1. American Association of Endodontists. Clinical considerations for a regenerative procedure. Available at: https://www.aae.org/specialty/wp-content/uploads/sites/2/2021/08/ClinicalConsiderationsApprovedBy-REC062921.pdf. Accessed Apr 17, 2025.
2. Levin L, Day PF, Hicks L, et al. International Association of Dental Traumatology guidelines for the management of traumatic dental injuries: General introduction. Dent Traumatol 2020; 36(4): 309–13. [CrossRef]
3. Nazzal H, Ainscough S, Kang J, et al. Revitalisation endodontic treatment of traumatised immature teeth: A prospective long-term clinical study. Eur Arch Paediatr Dent 2020; 21(5): 587–96. [CrossRef]
4. Bose R, Nummikoski P, Hargreaves K. A retrospective evaluation of radiographic outcomes in immature teeth with necrotic root canal systems treated with regenerative endodontic procedures. J Endod 2009; 35(10): 1343–9. [CrossRef]
5. Nangia D, Saini A, Sharma S, et al. Treatment outcome of regenerative endodontic procedures in mature permanent teeth compared to nonsurgical endodontic treatment: A systematic review and meta-analysis. J Conserv Dent 2021; 24: 530–8. [CrossRef]
6. Torabinejad M, Corr R, Handysides R, et al. Outcomes of

nonsurgical retreatment and endodontic surgery: A systematic review. J Endod 2009; 35(7): 930–7. [CrossRef]
7. Ong TK, Lim GS, Singh M, et al. Quantitative assessment of root development after regenerative endodontic therapy: A systematic review and meta-analysis. J Endod 2020; 46(12): 1856–66.e2. [CrossRef]
8. Shabahang S. Treatment options: Apexogenesis and apexification. Pediatr Dent 2013; 35(2): 125–8. [CrossRef]
9. Mishra N, Narang I, Iqbal MdJ, et al. Apexification of the mineral trioxide aggregate in nonvital immature anterior teeth with and without platelet-rich plasma: A preliminary clinical study. Saints Int Dent J 2023; 7(1): 20–6. [CrossRef]
10. Cvek M. Treatment of non-vital permanent incisors with calcium hydroxide. I. Follow-up of periapical repair and apical closure of immature roots. Odontol Revy 1972; 23(1): 27–44.
11. Sheehy EC, Roberts GJ. Use of calcium hydroxide for apical barrier formation and healing in non-vital immature permanent teeth: A review. Br Dent J 1997; 183(7): 241–6. [CrossRef]
12. Soumya S, Karunakar P, Siddhartha P, et al. Membrane-assisted mineral trioxide aggregate apical plug for management of traumatized immature anterior teeth: Clinical case reports. J Oral Res Rev 2014; 6(1): 14. [CrossRef]
13. Witherspoon DE. Vital pulp therapy with new materials: New directions and treatment perspectives—Permanent teeth. Pediatr Dent 2008; 30(3): 220–4. [CrossRef]
14. Torabinejad M, Parirokh M. Mineral trioxide aggregate: A comprehensive review Part II. J Endod 2010; 36(2): 190–202. [CrossRef]
15. Simon S, Rilliard F, Berdal A, et al. The use of mineral trioxide aggregate in one-visit apexification treatment: A prospective study. Int Endod J 2007; 40(3): 186–97. [CrossRef]
16. Pereira IR, Carvalho C, Paulo S, et al. Apical sealing ability of two calcium silicate-based sealers using a radioactive isotope method: An in vitro apexification model. Materials 2021; 14(21): 6456. [CrossRef]
17. Cheng J, Yang F, Li J, et al. Treatment outcomes of regenerative endodontic procedures in traumatized immature permanent necrotic teeth: A retrospective study. J Endod 2022; 48(9): 1129–36. [CrossRef]
18. AAE. Clinical considerations for a regenerative procedure. American Assosiation of Endodontists.
19. Lee C, Song M. Failure of regenerative endodontic procedures: Case analysis and subsequent treatment options. J Endod 2022; 48(9): 1137–45. [CrossRef]
20. Theekakul C, Banomyong D, Osiri S, et al. Mahidol study 2: Treatment outcomes and prognostic factors of regenerative endodontic procedures in immature permanent teeth. J Endod 2024; 50(11): 1569–78. [CrossRef]
21. Zeng Q, Zhang J, Guo J, et al. Preoperative factors analysis on root development after regenerative endodontic procedures: A retrospective study. BMC Oral Health 2022; 22(1): 374. [CrossRef]
22. de Oliveira MCV, Silva MA, de Farias ZBBM, et al. Viability of human mesenchymal stem cells from the periradicular region at different concentrations of sodium hypochlorite: A systematic review. J Pre Clin Clin Res 2023; 17(4): 251–5. [CrossRef]
23. Jamshidi D. Cytotoxicity and genotoxicity of calcium hydroxide and two antibiotic pastes on human stem cells of the apical papilla. Eur Endod J 2021; 6(3): 303–8. [CrossRef]
24. Vatankhah M, Khosravi K, Zargar N, et al. Antibacterial efficacy of antibiotic pastes versus calcium hydroxide intracanal dressing: A systematic review and meta-analysis of ex vivo studies. J Conserv Dent 2022; 25(5): 463. [CrossRef]
25. Singh J, Nihar P, Kashwani R, et al. Assessing the cytotoxic effects of calcium hydroxide and triple antibiotic paste on SCAP: A systematic review. Bioscan 2025; 20(1): 63–73. [CrossRef]
26. Keinan D, Nuni E, Bronstein Rainus M, et al. Retreatment of failed regenerative endodontic therapy: Outcome and treatment considerations. Cureus 2024; 16(12): e75147. [CrossRef]
27. Cvek M. Prognosis of luxated non-vital maxillary incisors treated with calcium hydroxide and filled with gutta-percha: A retrospective clinical study. Dent Traumatol 1992; 8(2): 45–55. [CrossRef]
28. Karp JM, Leng Teo GS. Mesenchymal stem cell homing: The devil is in the details. Cell Stem Cell 2009; 4(3): 206–16. [CrossRef]
29. Lin LM, Shimizu E, Gibbs JL, et al. Histologic and histobacteriologic observations of failed revascularization/revitalization therapy: A case report. J Endod 2014; 40(2): 291–5. [CrossRef]
30. Kim SG, Malek M, Sigurdsson A, et al. Regenerative endodontics: A comprehensive review. Int Endod J 2018; 51(12): 1367–88. [CrossRef]
31. Andreasen JO, Farik B, Munksgaard EC. Long-term calcium hydroxide as a root canal dressing may increase risk of root fracture. Dent Traumatol 2002; 18(3): 134–7. [CrossRef]
32. Dong X, Xu X. Bioceramics in endodontics: Updates and future perspectives. Bioengineering 2023; 10(3): 354. [CrossRef]
33. Refaei P, Jahromi MZ, Ali A, et al. Comparison of the microleakage of mineral trioxide aggregate, calcium-enriched mixture cement, and biodentine orthograde apical plug. Dent Res J 2020; 17(1): 66–72. [CrossRef]
34. Shaik I, Dasari B, Kolichala R, et al. Comparison of the success rate of mineral trioxide aggregate, endosequence bioceramic root repair material, and calcium hydroxide for apexification of immature permanent teeth: Systematic review and meta-analysis. J Pharm Bioallied Sci 2021; 13(Suppl 1): 43–7. [CrossRef]

35. Chang SW, Oh TS, Lee W, et al. Long-term observation of the mineral trioxide aggregate extrusion into the periapical lesion: A case series. Int J Oral Sci 2013; 5(1): 54–7. [CrossRef]
36. Dabbagh B, Alvaro E, Vu DD, et al. Clinical complications in the revascularization of immature necrotic permanent teeth. Pediatr Dent 2012; 34(5): 414–7.
37. Radeva E, Uzunov T. Comparative SEM study of the marginal adaptation of MTA and biodentine after apical resection (in vitro study). Folia Med 2023; 65(2): 269–76. [CrossRef]
38. Panjwani P, Banga K, Atram J, et al. The effect of varying thicknesses of mineral trioxide aggregate (MTA) and biodentine as apical plugs on the fracture resistance of teeth with simulated open apices: A comparative in vitro study. PeerJ 2024; 12: e18691. [CrossRef]
39. Lertmalapong P, Jantarat J, Srisatjaluk RL, et al. Bacterial leakage and marginal adaptation of various bioceramics as apical plug in open apex model. J Investig Clin Dent 2019; 10(1): e12371. [CrossRef]
40. Fathima A, Ravindran V, Jeevanandan G, et al. Histologic assessment of a fast-set mineral trioxide aggregate (MTA) and two novel antibacterial-enhanced fast-set MTAs for apexification and periapical healing of teeth with incomplete root formation in a rat model: An in vivo animal study. Cureus 2024: 16(4): e59064. [CrossRef]