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Case Report

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CLINICAL APPLICATIONS OF MINERAL TRIOXIDE AGGREGATE IN ENDODONTICS: A CASE SERIES

Introduction: In recent years, mineral trioxide aggregate (MTA) has been used extensively in endodontic treatment applications and satisfactory results have been obtained. This case series aims to describe the recovery of patients with the nonsurgical endodontic management of different endodontic cases using MTA.
Case Report: Case 1. A 72-year-old female patient presented with cold and sweet sensitivity. A reversible pulpitis diagnosis was made, and direct pulp capping with MTA was performed. A 12-month follow-up showed positive clinical outcomes. Case 2. A 16-year-old female patient presented with prolonged throbbing pain and a history of episodic severe pain. Diagnosed with irreversible pulpitis and an immature apex, apexification was performed using MTA. A 14-month follow-up revealed successful healing. Case 3. A 14-year-old male patient presented with a broken tooth, intermittent swelling, and pain. Diagnosed with chronic apical periodontitis, root canal treatment was conducted on tooth 21, while regenerative endodontic treatment was applied to tooth 22. A 15-month follow-up showed lesion healing. **Conclusion:** These cases suggest that MTA may be a substitute material for the treatment of endodontic problems (vital and necrotic conditions); however, more clinical studies with larger sample size and longer follow-ups are needed.
Key words: mineral trioxide aggregate, direct pulp capping, apexification, regenerative endodontic treatment

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МИНЕРАЛДЫ ТРИОКСИД АГРЕГАТЫНЫҢ ЭНДОДОНТИЯДАҒЫ КЛИНИКАЛЫҚ ҚОЛДАНЫСЫ: КЛИНИКАЛЫҚ ЖАҒДАЙЛАР СЕРИЯСЫ

Кіріспе. Соңғы жылдары минералды триоксид агрегаты (МТА) эндодонтияда кеңінен қолданылып, әртүрлі стоматологиялық ауруларды емдеуде қанағаттанарлық нәтижелер көрсетуде. Бұл мақалада МТА қолдану арқылы эндодонтиялық мәселелерді хирургиялық емес емдеу барысында пациенттердің сәтті қалпына келуін көрсететін клиникалық жағдайлар сипатталған.
Клиникалық жағдайлар сипаттамасы.
1-жағдай. 72 жастағы әйел салқын және тәтті тағамға тісінің сезімталдығына шағымданды. Қайтымды пульпит диагнозы қойылып, МТА қолдану арқылы пульпаны тікелей жабу жүргізілді. 12 айлық бақылау кезінде оң клиникалық нәтижелер тіркелді.
2-жағдай. 16 жастағы қыз бала ұзаққа созылған пульсация тәрізді ауырсыну және эпизодтық қатты ауырсынуға шағымданды. Қайтымсыз пульпит және жетілмеген апекс диагнозы қойылды. МТА көмегімен апексификация жасалды. 14 айлық бақылау кезінде сәтті жазылу және рецидивтердің болмауы анықталды.
3-жағдай. 14 жастағы ер бала сынған тіс, мезгіл-мезгіл ісіну және ауырсыну туралы шағымданды. Созылмалы апикальді периодонтит диагнозы қойылды. 21-тіске түбірлік каналдарды емдеу жүргізілді, ал 22-тіске регенеративті эндодонтиялық ем қолданылды. 15 айлық бақылау кезінде зақымдалған аймақтың толық жазылғаны байқалды.
Қорытынды. Бұл клиникалық жағдайлар сериясы МТА материалының эндодонтиялық мәселелерді (витальді және некротикалық жағдайларды) емдеуде тиімділігі жоғары екенін көрсетеді. Алайда, тиімділікті толық растау үшін үлкенірек үлгімен және ұзақ мерзімді бақылау арқылы қосымша клиникалық зерттеулер қажет.
Түйінді сөздер: минералды триоксид агрегаты, пульпаны тікелей жабу, апексификация, регенеративті эндодонтиялық ем.

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КЛИНИЧЕСКОЕ ПРИМЕНЕНИЕ МИНЕРАЛЬНОГО ТРИОКСИДНОГО АГРЕГАТА В ЭНДОДОНТИИ: СЕРИЯ КЛИНИЧЕСКИХ СЛУЧАЕВ

Введение. Минеральный триоксидный агрегат (МТА) в последние годы получил широкое применение в эндодонтии, продемонстрировав удовлетворительные результаты при лечении различных стоматологических заболеваний. Настоящая работа представляет серию клинических случаев, иллюстрирующих успешное восстановление пациентов при нехирургическом лечении эндодонтических проблем с использованием МТА.

Описание клинических случаев.

Случай 1. 72-летняя пациентка обратилась с жалобами на чувствительность зуба к холоду и сладкому. Поставлен диагноз обратимого пульпита, выполнено прямое покрытие пульпы с применением МТА. При 12-месячном наблюдении выявлены положительные клинические результаты. **Случай 2.** 16-летняя пациентка жаловалась на длительную пульсирующую боль и эпизодические острые боли. Диагностированы необратимый пульпит и незрелый апекс. Проведена апексификация с использованием МТА. Через 14 месяцев наблюдения отмечено успешное заживление и отсутствие рецидивов. **Случай 3.** 14-летний пациент обратился с жалобами на сломанную коронку зуба, периодическую отечность и боль. Диагностирован хронический апикальный периодонтит. Выполнено лечение корневых каналов зуба 21, а зубу 22 проведено регенеративное эндодонтическое лечение. На 15-й месяц наблюдения отмечено полное заживление пораженной области.

Заключение. Данная серия случаев подтверждает, что МТА является перспективным материалом для лечения эндодонтических проблем как при витальных, так и при некротических состояниях. Однако для окончательного подтверждения эффективности требуются дальнейшие клинические исследования с участием большего числа пациентов и более длительным периодом наблюдения.

Ключевые слова: минеральный триоксидный агрегат, прямое покрытие пульпы, апексификация, регенеративное эндодонтическое лечение.

Introduction

Endodontics has gone through several changes and significant improvements in recent decades. Among the most important developments is the use of mineral trioxide aggregate (MTA) in a variety of endodontic treatments. It was introduced by Mahmoud Torabinejad in the 1990s [1-3]. MTA is a radiopaque Portland cement, patented as a structural material specifically for use in clinical dentistry [3, 4]. This material consists of a powder that includes trioxides such as tricalcium oxide, silicon oxide, and bismuth oxide [5]. The chemical and physical properties of MTA are primarily attributed to hydrophilic particles like tricalcium silicate and tricalcium aluminate, which work synergistically to enhance the material's performance in dental applications [5, 6]. Notably, it exhibits excellent sealing properties and biocompatibility, making it suitable for a variety of endodontic procedures, including root canal fillings, root-end fillings, regenerative treatments, and pulp capping [7].

Moreover, MTA hardens in the presence of moisture, resulting in the formation of a colloidal gel with a pH of 12.5 that solidifies within approximately 3 to 4 h. This alkaline pH creates an antibacterial environment by regulating cytokine production. When in direct contact with human tissues, It can release calcium ions, promoting cell proliferation and further enhancing its regenerative capabilities [8]. In addition to these positive properties of MTA, studies show that MTA facilitates faster pulp healing, promotes the formation of thicker dentin bridges, and is associated with reduced inflammation, hyperemia, and necrosis. These favorable effects are attributed to MTA's high biocompatibility, low permeability, and superior ability to prevent bacterial infiltration into the pulp, thereby reducing the activation of inflammatory responses [9]. The exceptional biological properties of MTA have been substantiated both in vitro and in vivo studies, as well as clinical trials that compare it with calcium hydroxide (CH). These studies underscore MTA's biocompatibility, its capacity to promote tissue healing, and its clinical efficacy, affirming MTA as a dependable and effective choice in dental applications [9, 10].

Direct pulp capping (DPC) is performed when a healthy pulp is exposed due to trauma, caries, or iatrogenic causes [11]. During DPC, a biocompatible material is placed over the exposed area. The most used material for direct pulp capping is CH which was introduced to dentistry in 1921 and has been regarded as the "gold standard" for several decades [11-14]. CH possesses excellent antibacterial properties, which can minimize irritation to the pulp tissue caused by bacterial penetration and contamination. However, CH has several disadvantages, including inflammation and necrosis at the pulp surface, tunnel defects in the dentin bridge, high solubility, lack of adhesion, and resorption over time [15]. Due to these drawbacks, MTA has recently emerged as a popular alternative to CH. Studies have shown that the formation of dentin bridges over the pulp tissue after MTA application is more homogeneous and contains fewer tunnel defects compared to those formed after CH application [16]. Histological evaluations have indicated a thicker dentin bridge formation and a lower inflammatory response with MTA. Therefore, MTA may be a favorable material option for dental pulp capping procedures [16, 17].

Endodontic treatment of immature necrotic permanent teeth presents significant challenges when approached with traditional methods. Two primary strategies are generally employed in such cases: apexogenesis, which focuses on preserving pulp vitality to enable natural root development, and apexification, a technique using appropriate materials to form a barrier and close the root apex [18].

Regenerative endodontic therapy (RET), rooted in biological engineering principles, aims to repair the pulp-dentin complex damaged by caries, trauma, or structural anomalies. RET is regarded as the most appropriate treatment approach for young permanent teeth with necrotic pulp and periapical periodontitis. In most RET procedures, a blood clot within the root canal system acts as a biological scaffold, promoting successful regenerative outcomes [19]. In the process of revitalization, the interaction between calcium silicates and the blood clot saturates the blood with calcium and phosphate ions. The contact between calcium silicate cement and tissue fluid promotes the formation of carbonate apatite and hydroxyapatite crystals on its surfaces, both of which serve a bioactive function [20]. During the cement's setting reaction, CH is released, which contributes to the formation of these apatite crystal elements characteristic of mineralized biological tissues [21]. The formation of these crystals has shown bioactivity in vitro, demonstrating antibacterial effects and the potential to induce mineralization [22].

During these treatment procedures (DPC, apexification, apexogenesis, and RET) using MTA has gained prominence as a single or 2-visit procedure and has demonstrated a consistently high clinical success rate over many years.

This case series aims to describe the recovery of patients with the nonsurgical endodontic management of different endodontic cases (DPC, apexification, and RET) using MTA.

Case Report

Case 1

A 72-year-old female patient presented to the Department of Endodontics at Akdeniz University Faculty of Dentistry, reporting sensitivity to hot and cold stimuli, as well as pain in the mandibular right region during the consumption of sweet foods. Her medical history was unremarkable, with no systemic diseases or allergies noted. Intraoral examination revealed a cavitated carious lesion in the mandibular right first molar (tooth 46). Vitality tests yielded positive responses, while percussion and palpation tests were negative. Radiographic examination showed a deep carious extending toward the pulp chamber, leading to a diagnosis of reversible pulpitis.

Afterwards, the informed consent was obtained. A local anesthetic (Maxicaine, Vem Drugs, Istanbul, Turkiye) was administered via the inferior alveolar nerve block technique. Following the onset of anesthesia, indicated by numbness in the right lower lip and associated teeth, a rubber dam was applied to isolate the affected tooth. Carious tissue was removed from tooth 46 using high-speed handpieces with water cooling and diamond burs. As the procedure approached the pulp chamber, low-speed handpieces with tungsten carbide burs were used to remove caries from the periphery toward the center. During this process, the pulp was exposed. The cavity was irrigated with sterile saline, revealing slight bleeding from the exposed pulp. Hemostasis and disinfection of the healthy pulp tissue were achieved by placing a cotton pellet soaked in 5.25% SH (Chloraxid; Cerkamed, Stalowa Wola, Poland) in the cavity for 5 min. MTA (Bio MTA; Cerkamed) was prepared by mixing the powder and liquid on a sterile mixing pad and was subsequently placed over the exposed pulp using an MTA carrier. The MTA was carefully condensed with an end plugger, and residual particles were removed from the cavity with a slightly moistened cotton pellet soaked in sterile saline. Glass ionomer cement (Ketac Molar, 3M ESPE) was applied as a base layer. The enamel was selectively etched with 37% orthophosphoric acid (K-Etchant Syringe Gel, Okayama, Japan) for 15 sec. Following the application of a bonding agent (G-Premio Bond; GC Co., Tokyo, Japan), the tooth was permanently restored with composite resin (Estelite Sigma Quick, Tokuyama, Japan).

The patient was monitored, and at the 12-month follow-up, no adverse symptoms were reported. The vitality of the treated tooth continues to be assessed, with positive outcomes maintained over the monitoring period.

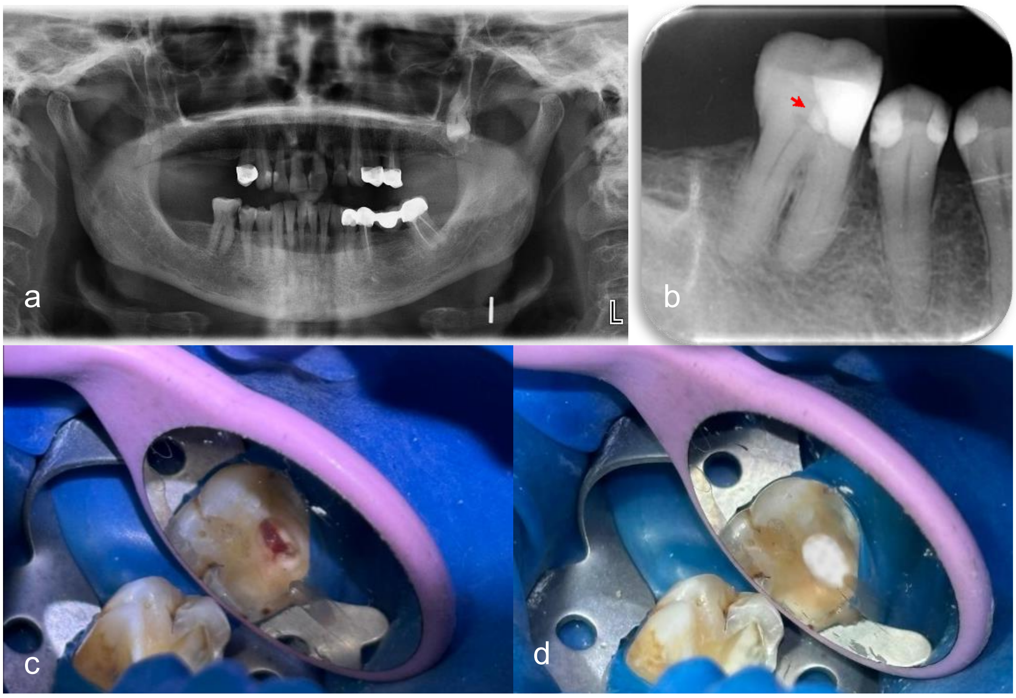

Figure 1 - **(a) preoperative panoramic radiograph, (b) postoperative periapical radiograph, red arrow indicates MTA, (c) pulpal bleeding control and (d) after MTA placement**

Case 2

A 16-year-old female patient presented to the Department of Endodontics at Akdeniz University Faculty of Dentistry, reporting prolonged, throbbing sensitivity to hot and cold stimuli in the mandibular right region, accompanied by episodes of sudden severe pain. Her medical history was unremarkable, with no underlying diseases or allergies. Intraoral examination revealed a large cavitation in the mandibular right second molar (tooth 47). Radiographic analysis indicated the presence of an old restoration fragment and extensive carious tissue involving the pulp chamber, with an open apex suggesting incomplete root development. Vitality testing elicited an early and severe painful response from tooth 47, which was also positive on percussion. A diagnosis of irreversible pulpitis was made and RCT was recommended.

Informed consent was obtained from both the patient and her guardian. During the initial visit, local anesthesia was administered and after a rubber dam was applied for isolation. Carious tissue was removed from tooth 47 using high-speed handpieces with water cooling and diamond burs. As the procedure approached the pulp chamber, low-speed handpieces with tungsten carbide burs were used for precise caries removal, proceeding from the periphery toward the center. An endodontic access cavity was established, and the root canal orifices were identified. Working length (WL) was determined with an electronic apex locator (EndoRadar Pro (Woodpecker, Guilin, China) using a #10 K-type file. Sequential root canal shaping was performed using ProTaper Next (Dentsply Maillefer, Ballaigues, Switzerland) NiTi rotary files X1-X4, with irrigation achieved through 5.25% SH (Chloraxid). CH (Metapaste, Meta Biomed, Chungbuk, Korea) was applied within the root canals, and a resin-modified glass ionomer cement (Riva Light Cure, SDI, Australia) was used as temporary filling material. A follow-up visit was scheduled for 2 weeks later.

At the second visit, the patient reported resolution of all symptoms. After rubber dam isolation, the temporary restoration was removed, and the CH was eliminated from the root canals using EDTA (Endo-Solution, Cerkamed) in activation with a sonic activator (EndoActivator; (Dentsply Maillefer). Final preparation of the distal canal, characterized by a wide, open apex, was completed using ProTaper X5 and ISO 55-60 H-type hand files. Final irrigation included 6 mL of SH and 2 mL of EDTA per canal, with activation provided by EndoActivator. The mesiobuccal and mesiolingual canals were filled using a bioceramic-based canal sealer (Ceraseal; MetaBiomed) and ProTaper X4 gutta-percha (Dentsply Maillefer). The distal canal was filled with MTA (Bio MTA). MTA was prepared by mixing powder and liquid on a sterile mixing pad and then applied to the distal root canal using an MTA carrier. The MTA was condensed to approximately 5 mm thickness in the apical region with an end plugger. The remaining root canal was filled using the warm vertical compaction technique with the Fi-G Obturation Gun (Woodpecker Obturation System; Woodpecker Medical Instrument Co., Guilin, China). Root canal filling was confirmed through periapical radiographs. The enamel was selectively etched with 37% phosphoric acid (K-Etchant Syringe Gel) for 15 sec. Following the application of a bonding agent (G-Premio Bond), the final restoration was completed with composite resin (Estelite Sigma Quick).

The patient was monitored, and at the 14-month follow-up, no adverse symptoms were reported, with positive clinical outcomes maintained throughout the observation period.

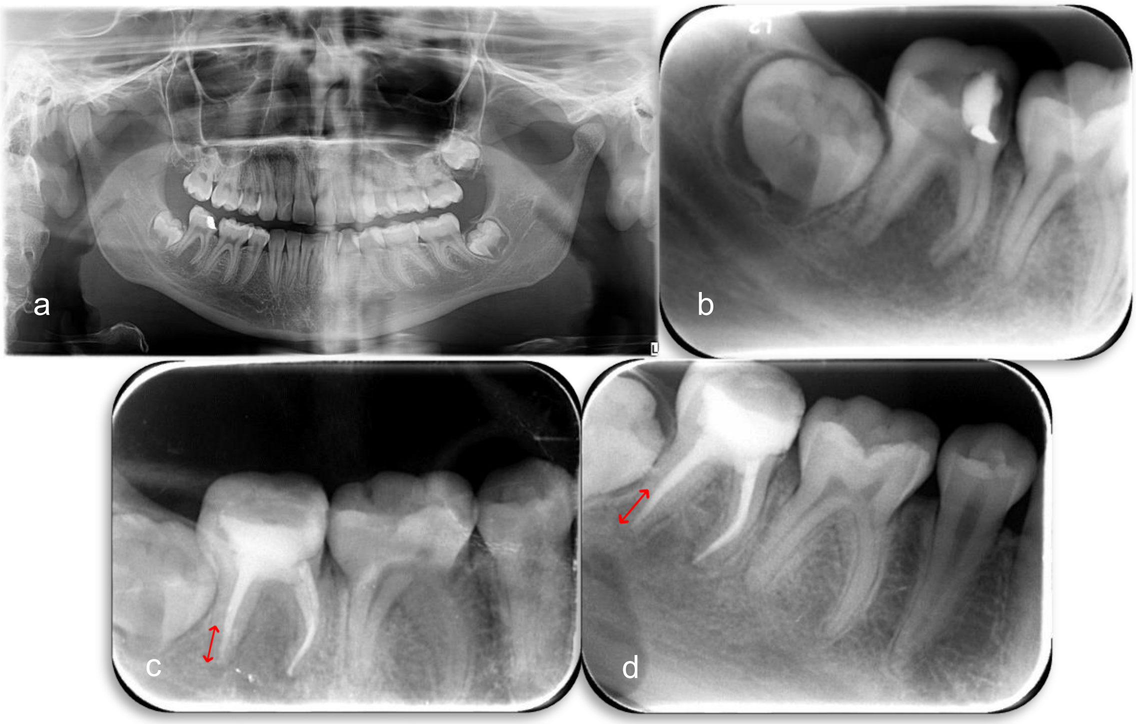

Figure 2 - **Preoperative (a) panoramic and (b) periapical radiographs, (c) after filling, red arrow indicates the level of MTA, (d) 14-month follow-up image**

Case 3

A 14-year-old male patient presented to the Endodontics Department of Akdeniz University Faculty of Dentistry with complaints of a fracture in the maxillary left incisors, along with intermittent swelling and pain. Medical history revealed no underlying diseases or allergies. Dental history indicated a trauma that occurred one year prior. Vitality tests returned negative results for teeth 21 and 22, and periapical radiographs showed that tooth 22 had not completed development, while tooth 21 exhibited a periapical lesion. A diagnosis of chronic apical periodontitis was made for both teeth, leading to an endodontic treatment plan: RCT for tooth 21 and regenerative endodontic treatment for tooth 22.

Informed consent was obtained from both the patient and his guardian. During the first visit, local anesthesia was administered and then rubber dam isolation was achieved for teeth 21 and 22. Access cavities were created using high-speed handpieces with water cooling and diamond burs. WL was determined using an electronic apex locator (EndoRadar Pro, Woodpecker). Root canal shaping for tooth 21 was performed sequentially with ProTaper Next (Dentsply Maillefer) NiTi rotary files. For tooth 22, no root canal reparation was performed. Only, a K-type hand file was positioned meticulously to minimize any potential harm to the canal walls. Prior to drying the canal using paper points, the canal was irrigated with 10 mL of 1% SH, 2 mm from the WL. CH (Metapaste) was placed as a root canal medicament in both teeth, and the canal orifices were sealed with sterile Teflon tape. A resin-modified glass ionomer cement (Riva Light Cure) was used as a temporary filling material, and the patient was scheduled for a follow-up visit in 2-week.

Upon arrival for the second visit, the patient reported that all symptoms had resolved. The temporary restoration was removed under rubber dam isolation. CH was removed from the root canals using sterile saline, EDTA (Endo-Solution), and an EndoActivator (Dentsply Maillefer). For tooth 21, final preparation was completed using ProTaper X4. After, final irrigation and drying the root canal, a bioceramic-based root canal sealer (Ceraseal) and X4 gutta-percha (Dentsply Maillefer) were used for canal filling. After sealing the canal orifice with glass ionomer cement, the patient was referred to the restorative dentistry department for permanent aesthetic restoration. Following treatment, the patient was monitored.

Approximately 6 mL of EDTA was used to irrigate the tooth 22, and the root canals were dried with sterile paper points (Dentsply Maillefer). A sterile ISO 30 K-type hand file was used to create bleeding from the apical region by extending into the alveolar bone. MTA (Bio MTA) was prepared by mixing powder and liquid on a sterile mixing pad and placed into the canal using an MTA carrier. The MTA was gently condensed with an end plugger, and 3-4 mm of MTA was placed in the cervical region to contact the blood clot within the canal. Glass ionomer cement (Ketac Molar) was placed over the MTA, sealing the canal orifice.

During the 15-month follow-up, periapical radiographs of teeth 21 and 22 showed healing of the apical lesion, and the patient reported complete resolution of symptoms.

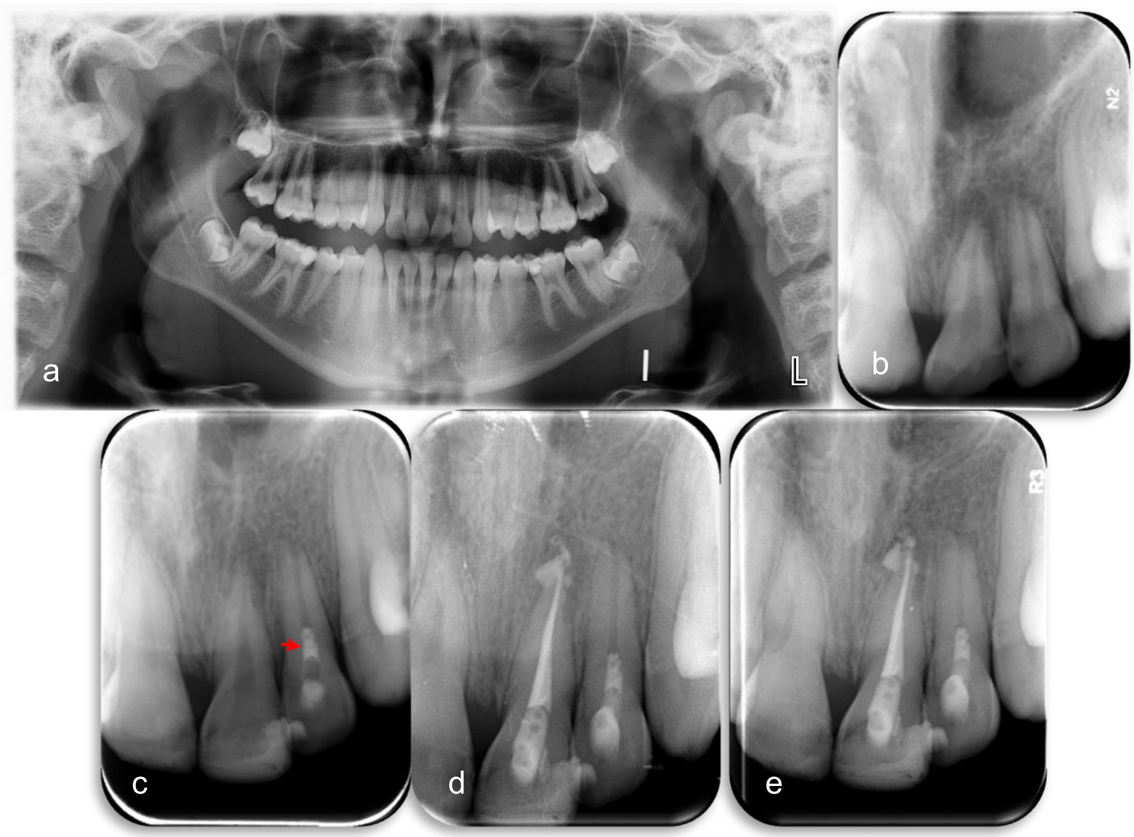

Figure 3 - **Preoperative (a) panoramic and (b) periapical radiographs, (c) periapical radiograph taken during the RET of tooth 22, red arrow indicates the MTA, (d) root canal filling of the tooth 21, (e) 17-month follow-up image**

Discussion

Vital pulp therapies encompass various techniques focused on minimal intervention and the preservation of healthy pulp tissue. Interestingly, these methods are not new; reports from the 18th century attributed to Pfaff indicate that placing gold on injured pulp has a long-standing history. This highlights the evolution of dental practices aimed at maintaining pulp vitality and underscores the importance of preserving natural dental structures [23]. The conservative treatment of deep caries and exposed pulp remains a fundamental aspect of operative dentistry. However, the clinical decision-making process in vital pulp therapy has become increasingly complex. Various research groups [24,25] and recent Endodontic position statements [26,27] present conflicting recommendations, leading to ongoing debates in the field. The ESE's position statement primarily addresses concerns related to caries management and invasive treatments like pulp exposure and RCT. However, it does not sufficiently tackle the management of exposed pulp when discussing the treatment of deep caries near the pulp. The ESE statement suggests that selective caries removal (using either a 1-step or 2-step technique) is appropriate for teeth with reversible pulpitis, provided that radiographic evaluation shows the caries have not progressed deeper than a quarter of the dentin and that a layer of dentin separates the carious lesion from the pulp chamber [27]. In contrast, the AAE emphasizes the necessity of completely removing infected tissues, including all infected pulp tissue, in cases where the pulp is exposed. They argue that leaving residual carious tissue can lead to more severe pulp responses and significant pulp inflammation in the future [26]. Consequently, in our first case, after thoroughly removing the carious tissue, a partial pulpotomy was performed by removing a portion of the pulp at the level of the pulp horn. In addition, MTA was selected over CH as a biocompatible material for pulp capping in this case, reflecting an increasing recognition of MTA's advantages in enhancing healing outcomes in endodontic procedures.

The most significant issue associated with classical apexification using CH is the prolonged treatment duration, which can vary between 3 to 21-month due to a variety of factors. During apexification, since the access cavity is sealed with temporary restorative materials, there is a risk of reinfection of the canal [28-30]. Additionally, it has been shown that prolonged exposure to CH increases the likelihood of cervical fractures [30]. Increasing evidence supports the use of MTA apical barriers as a viable alternative in apexification procedures [28-30,32]. MTA-based apexification can often be completed within 2 visits, enabling timely restoration without compromising the mechanical properties of root dentin, as can occur with CH apexification [30]. Beyond MTA's excellent biocompatibility, its ability to stimulate the production of bone morphogenetic protein-2 and transforming growth factor beta-1 may further enhance the biological response in periapical tissues, promoting tissue repair through these critical cytokines [33]. Consequently, in our second case demonstrates that MTA functions effectively as an apical barrier, providing a reliable material choice for regenerating apical tissues and achieving apical closure in open-apex, infected, and immature teeth. Both clinical and radiographic follow-ups confirm MTA's efficacy in promoting optimal healing of apical periodontitis and stimulating new hard tissue formation. Consequently, MTA apical plugs offer advantages such as more predictable apical closure, reduced treatment duration, and decreased dependency on patient compliance, affirming MTA's role in endodontic success.

RET is a biologically based alternative approach for treating immature necrotic teeth, allowing for continued root development, unlike apexification and artificial apical barrier techniques [34]. The endodontic treatment of open-apex permanent teeth presents clinical challenges due to factors such as the difficulty of mechanical instrumentation of the root canal caused by the tooth's anatomy, the inability to achieve a hermetic seal in the root canal when traditional root canal filling methods are used due to the lack of an apical stop, and the susceptibility of immature teeth with thin root canal walls to fracture [35]. For these reasons, the disinfection of the canal system relies solely on irrigants and intracanal medications. In our third case of regeneration, CH was used as the intracanal medicament. As reported in numerous previously published case reports [36-38], we also used 1% SH and 17% EDTA as chemical irrigants. EDTA has been suggested as the sole irrigant used in the second visit for teeth planned for pulp regeneration because Trevino et al. [39] demonstrated that EDTA supports the survival of apical papilla stem cells (SCAP) with an 89% viability rate. They reported that the use of both SH and EDTA resulted in a lower cell viability rate of 74%. Furthermore, it has been shown that the final irrigation with EDTA can stimulate the release of growth factors embedded in the dentin matrix and enhance the odontogenic differentiation and angiogenesis of migrating cells [40]. For this reason, only EDTA was used in the second visit of our regeneration case.

Conclusion

MTA is a versatile and highly effective material in endodontic applications, demonstrating significant success across vital pulp therapy, regenerative endodontics, and root canal filling. Its excellent biocompatibility, sealing ability, and capacity to promote hard tissue formation make it particularly advantageous for vital pulp treatments and regenerative procedures, where tissue preservation and regeneration are essential. Clinical and radiographic evidence consistently supports the effectiveness of MTA in achieving favorable outcomes, including reduced inflammation, enhanced dentin bridge formation, and reliable apical closure. These qualities underscore MTA's value as a reliable material that enhances healing potential and treatment success across diverse endodontic therapies.

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