CASE REPORT

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Integrative Structural, Functional and Aesthetic Rehabilitation of Fractured Non-vital Maxillary Central Incisor with Open Apex: A Case Report

Harshitha Ramana Priya Maddimsetti*, Madhu Varma Kanumuri, Praveen Dalavai, Jagapathi Babu Mavidi, Durga Prasad Naik Ketavatu, Kalyani Redrouthu

Department of Conservative Dentistry and Endodontics, Vishnu Dental College, Bhimavaram, Andhra Pradesh, India.

***Corresponding author:**
Harshitha Ramana Priya Maddimsetti
Department of Conservative Dentistry and Endodontics, Vishnu Dental College, Bhimavaram, Andhra Pradesh, India.
Email: harshithapriya65@gmail.com

Abstract

Anterior teeth, due to their prominent visibility during smiling, speech, and other facial expressions, are integral to dental aesthetics, phonetics, psychosocial confidence and self-esteem. Traumatic injuries sustained before the closure of the apex interrupt root development and result in incomplete apical closure. Management of fractured nonvital permanent anterior teeth with open apex remains challenging owing to thin radicular dentin and structurally compromised crowns, necessitating a strategic approach. This case report highlights a meticulously coordinated, conservative strategy to rehabilitate a fractured nonvital maxillary central incisor with an open apex. A 23-year-old male patient presented with a fractured, nonvital maxillary central incisor with an open apex resulting from trauma at the age of 9 years. Initial endodontic management includes access cavity preparation, followed by which the root canal system was thoroughly debrided using conventional cleaning and shaping protocols, augmented with laser-assisted disinfection to enhance microbial control and optimize canal cleanliness. Due to the presence of an open apex, a mineral trioxide aggregate (MTA) apical plug was placed to establish an apical seal, induce an artificial apical barrier and promote periapical healing. Given the thin root canal walls, a custom-fabricated anatomic post was created to provide reinforcement and improve internal adaptation, reducing the risk of root fracture. Advanced digital techniques were incorporated through intraoral scanning and CAD/CAM design, enabling precise fabrication of a zirconia crown, ensuring excellent fit, strength, and aesthetics. This case illustrates that combining biomaterials, laser technology and digital dentistry can provide a conservative structural, functional, and aesthetic outcome in the management of structurally compromised permanent anterior teeth with open apex.

Keywords: Anatomic post, CAD-CAM, Dental trauma, Diode lasers, MTA apical plug, Zirconia.

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1. Introduction

Traumatic dental injuries frequently affect the anterior teeth, with the maxillary central incisors being the most commonly involved. Among these cases, approximately 16% consist of complicated crown fractures that extend to involve the pulp. Severe traumatic injuries can lead to pulpal inflammation, which may eventually progress to pulpal necrosis and apical periodontitis [1].

The primary challenge in managing nonvital teeth with open apices is achieving thorough elimination of microorganisms from the root canal system. Since extensive mechanical instrumentation can further weaken the already fragile canal walls, disinfection is primarily accomplished using irrigating solutions such as sodium hypochlorite (NaOCl) and intracanal medicaments like calcium hydroxide [2]. In addition to NaOCl, diode lasers also play a pivotal role in achieving thorough disinfection [3].

Dental caries and trauma pose the greatest threats to a tooth's integrity during development, as both can lead to pulpal necrosis. If the pulp becomes non-vital before root formation, it results in incomplete apical closure and cessation of normal root development [4].

An open apex presents a significant clinical challenge in achieving a predictable apical seal due to the absence of an anatomical constriction against which to compact traditional filling materials. This deficiency necessitates specialized techniques to create a stable apical barrier, typically employing modern biomaterials, including mineral trioxide aggregate (MTA) or Biodentine [5].

Mineral trioxide aggregate (MTA) is a very effective root filling material for sealing root canals with open apices that could otherwise impose challenges in obtaining adequate obturation and apical seal [6]. Teeth with significant loss of crown structure and enlarged/ flared root canals with thin, weakened dentinal walls need adequate reinforcement. Prefabricated posts are commonly used because they are easy to place and require minimal chairside time. However, in such cases, prefabricated posts, whether metal or fibre, do not accurately conform to the natural root canal anatomy. A better alternative is the chairside fabrication of a customized fibre post by relining it with a composite, which offers superior adaptation, aesthetics, and retention [7].

A full-veneer crown is often indicated for structurally compromised teeth because it provides complete coverage that substantially improves fracture resistance and stress distribution [8]. CAD/CAM zirconia restorative prostheses offer excellent biocompatibility, cause minimal wear on opposing teeth, and provide long-term aesthetics with stable colour. Owing to these advantages, CAD/CAM zirconia restorations can enhance a patient's self-esteem and confidence, facilitating a return to a satisfying social life [9].

2. Case report

The current case report describes the comprehensive management of a fractured nonvital discoloured maxillary right central incisor with an open apex. A 23-year-old male patient reported to the Department of Conservative Dentistry & Endodontics with a chief complaint of a fractured, discoloured upper front tooth, which is associated with pain upon biting for 20 days, with a history of trauma that happened at the age of 9 years (Figure 1A). The patient's medical history was non-contributory. Clinical examination revealed tenderness to percussion in tooth 11. Periodontal assessment demonstrated a 5-mm probing depth on the distal aspect of tooth 11, accompanied by Grade I mobility. The concerned tooth did not respond to pulp sensibility tests using an electric pulp tester (PARKELL, Farmingdale, New York, USA) and cold test (Endo-Frost; Coltene/Whaledent, Langenau, Germany). Upon intraoral periapical radiograph (IOPAR) examination, there was an ill-defined radiolucency involving enamel, dentin pulp of the coronal portion with an open apex and widening of the periodontal ligament space in the periapical region of 11 (Figure 1B).

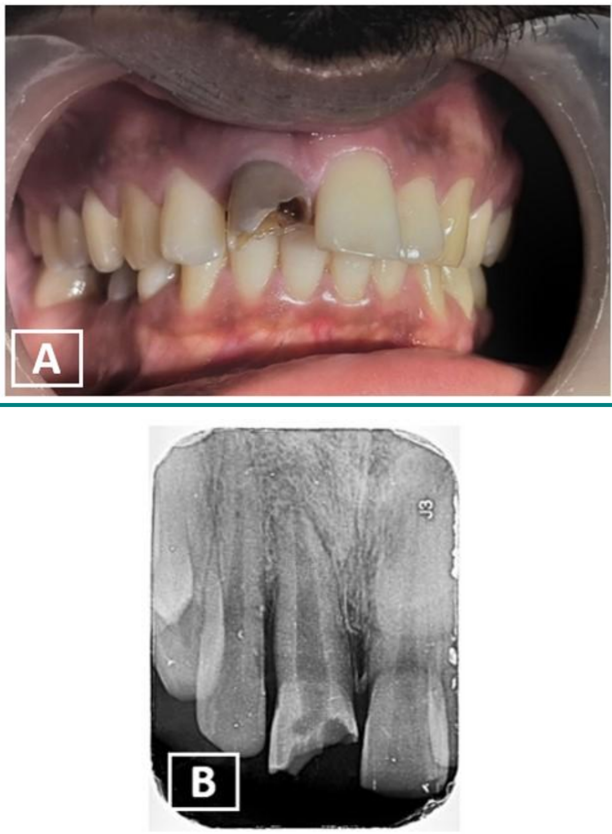

Figure 1. A. Preoperative clinical photograph, and B. Pre-operative intraoral periapical radiograph of tooth 11.

Tooth 11 was diagnosed as pulpal necrosis with symptomatic apical periodontitis. The patient was informed that the treatment involves thorough cleaning and disinfection of the root canal, placement of a biocompatible apical barrier, followed by post-placement and crown restoration to restore function and esthetics. After discussing the treatment plan with the patient, informed consent was obtained.

3. Management

3.1 First appointment

Before commencing endodontic treatment, A thorough scaling and root planning of tooth 11 was performed followed by which Initial endodontic management included administration of local anaesthesia (LIGNOX 2% A Santacruz, Mumbai, India), rubber dam isolation, caries excavation, access cavity preparation (Figure 2A) and working length determination (Figure 2B). Biomechanical preparation was performed with no. 60 K-file (Mani, Tokyo, Japan) using circumferential filing motion. Root canal debridement was performed using alternate irrigation with 3% NaOCl (Prime Dental products Pvt Ltd, Maharashtra, India) and saline. Final irrigation was performed with 2% chlorhexidine solution (Safe Endo Hexachlor, SafeEndo Dental India Pvt.Ltd, Gujarat, India). A 27-gauge side-vented needle (Orikam Health Care Pvt.Ltd, India) was used for the irrigation. Calcium hydroxide (RC CAL, Prime Dental products Pvt Ltd, Mumbai, India) was placed as an intracanal medicament (Figure 2C) in the root canal, and the patient was recalled after one week.

3.2 Second appointment

At the subsequent appointment after removal of intracanal dressing, the root canal was completely debrided with 10ml of 3% NaOCl for 2-3minutes, followed by which intracanal irradiation was performed with 810nm diode laser (DenLase, Fona, China), 200 µm tip with power of 1W in continuous mode. Fibre optic tip (200 µm) was placed 1mm short of working length, and the tip was removed from the canal in helicoidal motion at 2mm/sec speed. This was repeated 4 times at intervals of 20sec [10] (Figures 3A and B). After completion of irradiation, the canal was irrigated with 17% EDTA (Prevest DenPro Limited, India) and flushed with sterile distilled water. Canal was dried with paper points, collagen plug (Coloplug, Cologenesis Healthcare Pvt. Ltd, Tamilnadu, India) was placed as an apical barrier and then Mineral trioxide aggregate (BioStructure MTA, SafeEndo Dental India Pvt. Ltd, Gujarat, India) was placed in the apical portion of the canal by condensing with the hand pluggers till a thickness of 5mm. MTA apical plug density, position and extension were checked radiographically (Figure 3C). A wet cotton pellet was placed, and the access cavity was sealed with temporary cement (Orafil-G, Prevest DenPro, India).

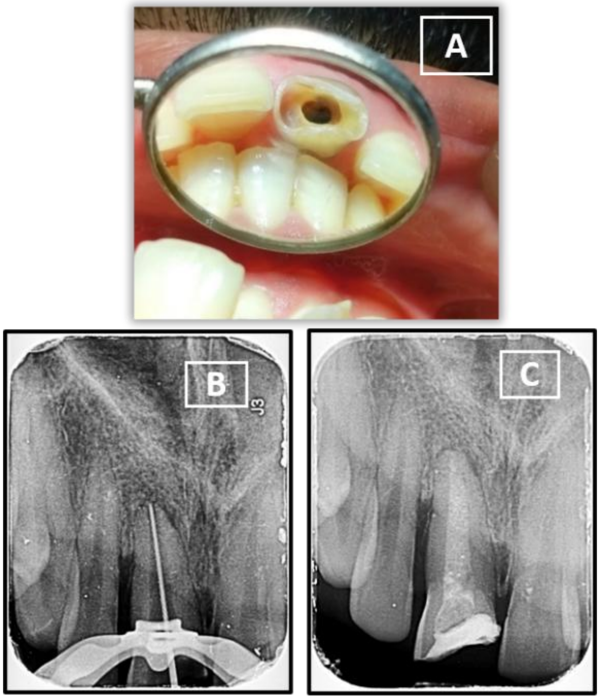

Figure 2. A. Caries excavation and access cavity preparation, B. Working length determination, and C. Periapical radiograph showing calcium hydroxide intracanal medicament placement and temporary coronal seal.

Figure 3. A and B. 810nm Diode laser irradiation of tooth 11, and C. Periapical radiograph showing MTA apical plug of 5mm and temporary coronal seal.

3.3 Third appointment

In the subsequent appointment, the post space was refined, and the desired fibre post was selected (Selfpost, Medicept UK Ltd, UK) (Figure 4A). The glycerin was applied as a separator to the canal walls and layering on fiber post was done in increments with packable nanohybrid composite resin (Tetric® N-Ceram, Ivoclar Vivadent, Liechtenstein) to replicate the anatomic form of root canal (Figure 4B), then the anatomic post was gently pulled out of the canal and additional light curing of 20 sec was performed to completely polymerize relining composite resin. This procedure continued in increments until the post had a snug fit inside the canal.

The root canal walls were etched with 37% phosphoric acid for 15 seconds and then thoroughly rinsed with water and gently air-dried. The glycerine used as a separator was removed at this stage. Bonding agent was applied to the root canal with a micro-brush applicator and cured for 20 seconds. Finally, the anatomical post was cemented with dual-cure resin cement (Rely-X ARC, 3M ESPE, St. Paul, USA), followed by core buildup using packable nanohybrid composite incrementally (Tetric® N-Ceram, Ivoclar Vivadent, Liechtenstein) (Figure 4C).

Later, tooth preparation was performed to receive a zirconia crown, a shoulder margin with a rounded internal angle was established, ensuring a smooth and continuous finish line to facilitate optimal seating, minimize stress concentrations on both the tooth structure and the restoration, and to provide adequate material bulk. A gingival retraction cord was placed on the prepared tooth to ensure gingival deflection and better visibility of the preparation margin (Figure 5A).

The patient's dentition was digitized with an intraoral scanner (Medit i700, Medit Corp, Seongbuk-gu, Seoul, Korea) (Figures 5B, C, and D) and exported in standard tessellation language (STL) format. The standard tessellation language files obtained from the intraoral scanner were imported into the CAD software (Exocad v2.3 DentalCAD; exocad GmbH) (Figures 6A and B). Based on the data, a zirconia crown was designed (Figures 6C, D and E) and milled with a computer-aided manufacturing (CAD-CAM) machine (PrograMill, Ivoclar Vivadent, Schaan, Liechtenstein) (Figure 6F).

Subsequently, the zirconia crown was fitted, adjusted for occlusion, and cemented using dual-cure resin cement (Figure 7). The patient was satisfied with both the function and esthetics of the restoration.

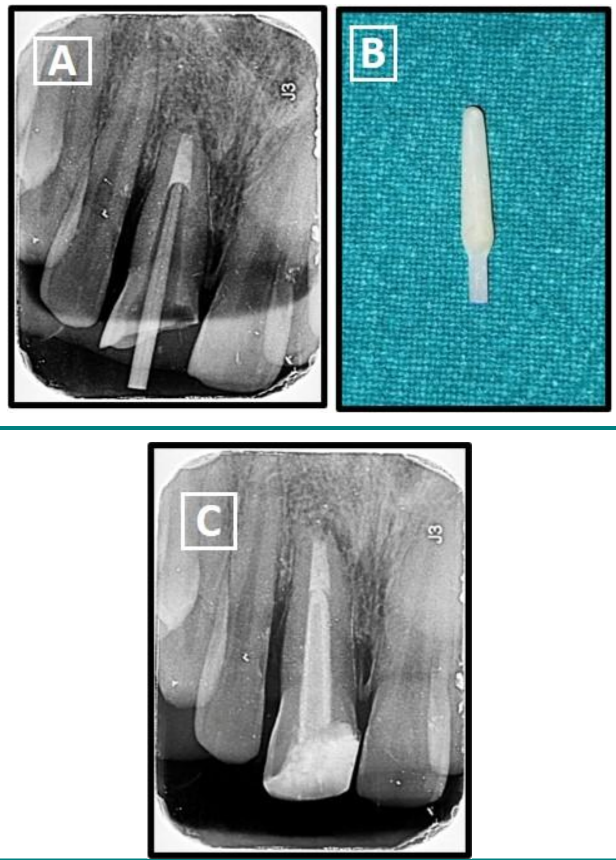

Figure 4. A. Selection of fibre post into the canal, B. Layering of the fibre post with nanohybrid composite to replicate the anatomy of the root canal, and C. Anatomic post cementation with core build-up.

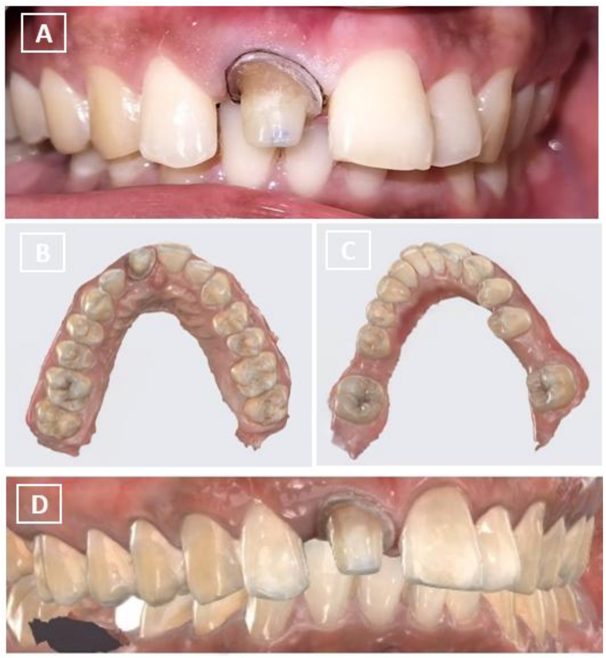

Figure 5. A. Tooth preparation with gingival retraction, and B-D. Intraoral scans of the patient's dentition were obtained after tooth preparation.

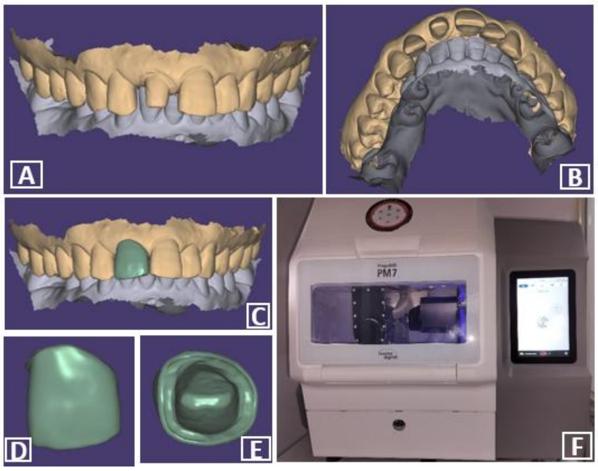

Figure 6. A-B. Designs developed using STL files. C-E. Designing of full veneer crown with CAD software. And F. Milling of the zirconia crown.

Figure 7. Immediate post-operative clinical photograph showing final cementation of zirconia crown with optimal fit, occlusion and aesthetics.

3.4 Follow-up evaluation at 6 months

At 6 months postoperatively, follow-up evaluation demonstrated the absence of symptoms, a satisfactory apical seal, adequate reinforcement of the remaining tooth structure, and restoration of esthetics and function, contributing to improved patient confidence and satisfaction (Figures 8A and B).

4. Discussion

Considering the clinical evaluation, vitality test and radiographic examination tooth was diagnosed as pulp necrosis due to the previous trauma, which resulted in symptomatic apical periodontitis. The therapeutic goal of endodontic treatment is to create a sterile, bacteria-free environment both within the tooth and at the apex [11].

Studies have shown that bacterial contamination of the root canal system, along with the presence of necrotic tissue and bacterial penetration deep within the dentinal tubules (up to 1.1 mm), are major factors contributing to the long-term failure

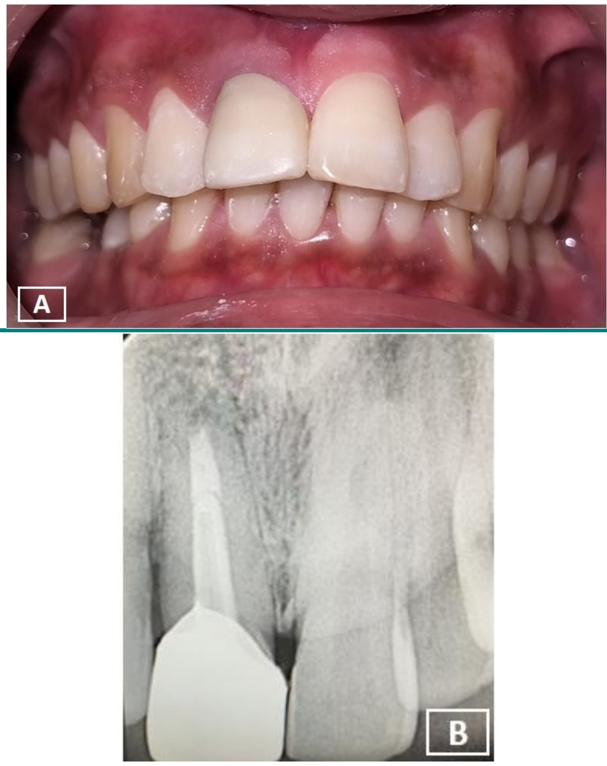

Figure 8. A. Postoperative clinical photograph at 6 months follow-up, and B. Intraoral periapical radiograph of tooth 11 at 6 months follow-up.

of endodontic therapy. Ideally, performing root canal treatment before extensive bacterial colonization occurs provides patients with the best chance for long-term success. Unfortunately, early intervention is not always feasible. Notably, microorganisms such as E. faecalis have been detected as deep as 800–1100 µm within dentinal tubules [12].

Successful endodontic treatment of non-vital teeth is primarily dependent on effective disinfection of the root canal system. Pulp necrosis provides a favourable environment for microbial colonization, and persistent intra-radicular infection is the main etiological factor in the development and maintenance of apical periodontitis [13]. Mechanical instrumentation alone is insufficient to eliminate microorganisms. Therefore, chemo-mechanical preparation using antimicrobial irrigants is essential to achieve adequate microbial reduction.

Sodium hypochlorite remains the gold standard irrigant due to its broad-spectrum antimicrobial activity and tissue-dissolving properties. Inadequate disinfection has been directly associated with endodontic treatment failure, emphasizing that optimal microbial control is a prerequisite before considering adjunctive disinfection methods such as laser-assisted techniques [14].

Various types of lasers have demonstrated promising antimicrobial effects, and numerous studies have evaluated different laser systems and wavelengths for their effectiveness in root canal disinfection. Diode lasers, in particular, have shown significant antibacterial activity, likely due to their ability to penetrate up to 1000 μm into dentinal tubules—substantially deeper than sodium hypochlorite, which reaches only about 100 μm [15].

Along with the use of traditional irrigants and intracanal medicaments, in this case 810nm diode laser was employed for disinfection. According to Shirani et.al 810nm diode laser was found superior to the 980nm diode laser in the reduction of E. faecalis colonies [16].

Following thorough disinfection, the open apex in this case was managed using the MTA apical plug technique. Recently, the one-visit MTA apical plug approach has been recommended as an effective alternative to long-term apexification for the management of nonvital immature permanent teeth [17].

The major problem in the presence of a wide-open apex is the need to limit the material to the apex. In this case, a collagen plug was used as an apical matrix to prevent over-extrusion of MTA, ensure adequate compaction of MTA and promote healing of the periapical tissues [18].

MTA is a bioactive material characterized by minimal leakage, superior antibacterial properties, excellent marginal adaptation, a relatively short setting time (~4 hours), a high pH of 12.5 and excellent biocompatibility [19]. It provides a scaffold for hard tissue barrier formation and stimulates the release of interleukins and cytokines, thereby promoting hard tissue regeneration [19,20]. Not only the choice of material but also the thickness of the apical MTA barrier plays a crucial role in clinical success. A 5-mm-thick apical MTA barrier is significantly stronger and exhibits less leakage than a 2-mm barrier [21,22]. In the present case, a well-condensed 5-mm apical MTA plug was placed.

Anatomical posts demonstrate a highly favourable prognosis in cases with thin radicular dentin and flared root canals. Moreover, glass fibre posts provide a more uniform distribution of stress in both the occlusal and radicular regions compared to metal posts. With the increasing demand for esthetics, metal-free restorations, the use of anatomical posts where a glass fibre post is relined with composite has emerged as a practical and effective approach for managing wide and flared root canals in routine clinical practice [23].

This technique offers several advantages, including single-visit customization of the post and core, precise adaptation to canal anatomy, minimal resin cement thickness, reduced polymerization shrinkage, and enhanced chemical bonding with the resin. The composite resin can be secondarily cured both intracanal and externally before final cementation. Anatomic posts have also been shown to resist bending under oblique loads by efficiently transferring stresses along the root [24].

The limitations associated with introducing fibre post alone in wide root canals include poor adaptation to canal walls and the need for a thick layer of luting cement, which increases the risk of adhesive failure and post debonding. On the other hand, custom cast posts also present challenges, as their rigid design can create a wedging effect on the root dentin, potentially leading to root fracture [25]. Due to the compromised structural integrity of the tooth in this case, a CAD/CAM-designed zirconia full-veneer crown was deemed the most appropriate definitive restoration. CAD/CAM technology has transformed modern dentistry by improving precision, efficiency, and overall patient outcomes. This integrated system combines digital scanning, advanced design software, and automated milling to streamline the fabrication of dental restorations. It allows analogue clinical data to be captured digitally, followed by virtual design (CAD) and precise material fabrication (CAM) [26]. CAD/CAM technology has enhanced multiple aspects of prosthesis quality, particularly by reducing the risk of errors through the elimination of traditional impression techniques [27].

A zirconia full crown was selected due to its excellent clinical longevity and high survival rate. Compared with other all-ceramic systems, zirconia offers superior opacity, making it especially suitable for masking dark underlying tooth structure. In addition to its aesthetic benefits, zirconia provides exceptional strength and durability. It is also highly biocompatible and well-tolerated by the body. Furthermore, zirconia crowns are minimally invasive, requiring less tooth reduction and preserving more natural tooth structure [28].

The primary limitation of this case report lies in the relatively brief follow-up duration of 6 months. Extended longitudinal monitoring is necessary to substantiate the long-term stability and predictability of treatment outcomes.

5. Conclusion

This case report highlights integration of a strategic approach through a comprehensive protocol involving laser technology for disinfection, MTA apical plug for open apex management, anatomic post, intraoral scanning and CAD-CAM designed final restoration, ensuring precise and efficient treatment in managing a non-vital fractured non-vital maxillary central incisor with open apex, while promoting patient-centred care through improved clinical outcomes and enhanced comfort.

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