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Limitations and Management of Static-Guided Endodontics Failure

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ABSTRACT

Endodontic treatment in severely calcified canals is always a challenging task because it can result in accidents such as deviations or perforations. Recently, guided endodontics has become an alternative approach for pulp canal calcification, facilitating the location of root canals more predictably through the combined use of cone-beam computed tomography, oral scanning, and endodontic access guides. Although several reports have shown that guided endodontics is safer, faster, and can be performed without an operating microscope and by less experienced operators, the technique has limitations, and iatrogenesis may occur. This article describes the limitations of static-guided endodontics and possible causes of failures. In the present case, not fixing the guide to the bone and inaccuracies generated by manually performing mesh merger software led to root perforation. | Endodontic microsurgery was effective in resolving this case and should be considered the treatment of choice where guided endodontics cannot be employed safely or when it fails.

KEYWORDS: Dental trauma; endodontics; endodontic microsurgery; guided endodontics; pulp canal obliteration.

INTRODUCTION

Pulp canal obliteration (PCO), also known as pulp canal calcification or calcific metamorphosis, is associated with dental trauma (1), vital pulp therapy (2), caries and restorations (3), and physiological changes in elderly patients (4,5), causing a significant reduction in root canal space due to the apposition of secondary dentin over time along the canal walls.

Endodontic treatment in severely calcified canals, in which the tooth has symptoms or radiographic signs of periapical disease, is always challenging, and deviations from the original path should be avoided because they can result in perforations (6,7). Incomplete instrumentation, bacterial persistence, and debris may result in endodontic failure (8). According to the American Association of Endodontists, teeth with PCO are considered a high level of difficulty (9).

Nowadays, the use of modern technology, such as magnification and illumination with a dental operating microscope (10), ultrasonic tips (11), cone beam-computed tomographic (12) (CBCT), and guided endodontic access, has increased the precision involved in planning and performing treatment of calcified canals as well as allowed practitioners to overcome some of these challenges (13).

Guided endodontics is an alternative solution for teeth with the canal partially or entirely obliterated (13,14). The advantages of three-dimensional (3D) planning and the creation of guided models for locating the root canal system outweigh the high cost of the technique (15). A special software (coDiag-nostix; Dental Wings Inc, Montreal, Canada) aligned with the CBCT and 3D digital scanning facilitates virtual planning to access a cavity in the canal. Subsequently, a 3D model can be produced to guide the drill in the calcified root canal (16).

The virtual planning and guided access procedure for calcified root canals can preserve the dental structure and prevent accidents such as deviations and perforations, leading to an improvement in long-term prognoses (17). Procedural errors might negatively impact endodontic treatment success and contribute to infections in inaccessible apical areas. In such circumstances, surgical intervention is required (18,19). The present case report aimed to describe the limitations and management of a static-guided endodontics failure employed in a severely calcified root canal.

CASE REPORT

A 38-year-old male patient was referred to a post-graduate educational institution for endodontic treatment of the upper left central incisor. The patient had no history of medication or systemic diseases. It was reported that there was a history of trauma involving tooth 9 a couple of years ago, resulting in a yellowish coloration. A previous attempt to locate the canal by another professional was unsuccessful. Periodontal probing depths were within normal limits. The tooth did not respond to thermal (cold) or electrical tests, and both percussion and palpation elicited normal responses. High-resolution CBCT was performed using the following settings: 0.2-mm voxel, grayscale 14 bits, 26.9-second x-ray exposure, 120 kV, and 37 mA (iCAT; Imaging Sciences International, Hatfield, PA, USA). The CBCT and radiographic examination revealed a severe PCO and a suggestive image of the periapical lesion (Fig. 1-A), confirming the diagnosis of previous initiated therapy with asymptomatic apical periodontitis.

After the treatment planning options were presented and discussed with the patient, guided endodontics was chosen as the most appropriate treatment approach. The patient fully agreed with the proposed treatment and signed informed consent.

An intraoral scan was performed, aligned, and processed using software, with images of the CBCT previously performed (Fig. 1). Two guides were made for endodontic access to the root canal: the first guide was intended for access to the middle-cervical third and the second to the apical third. The tooth presented 23 mm of total length; nevertheless, merely 4 mm of the visible canal was found in the CBCT. A virtual copy of a drill with a diameter of 1.3 mm and a length of 20 mm (Neodent Drill for Tempimplants, Ref: 103179; JJGC Indústria e Comércio de Materiais Dentários SA, Curitiba, Brazil) was superimposed on the scans in a position that allowed access to the root canal system through the palatal surface of the tooth, as recommended by Tavares et al. (14). The drill position was verified in virtually three dimensions in a depth of 19.00 mm. Subsequently, the 3D model was sent to a 3D printer.

Local anesthesia was achieved with 2% lidocaine with epinephrine 1:100,000 (Nova DFL, Rio de Janeiro, Brazil), and conventional opening access was initiated with a high-speed spherical diamond bur 1014 (Komet, South Carolina, USA). The adjustment of the guides was verified in the mouth. The drill was attached to an X-Mart Plus endodontic motor (Dentsply Maillefer, Ballaigues, Switzerland) with a torque of 4N and 950 rpm. Once the first guide was adapted, penetration started with a 1.3 mm drill to the middle third of the root canal under abundant irrigation with saline solution (Fig. 2-E). Subsequently, the second guide was adapted to finalize the access to the apical third. After access to the root canal was reached, a rubber

dam was placed, and exploration was carried out using a K-file #8 (Dentsply Maillefer, Ballaigues, Switzerland).

After reaching the estimated working length, a K-file #15 (Dentsply Maillefer, Ballaigues, Switzerland) was introduced into the canal, and the working length was confirmed using the apex locator (Romi Apex A15, Romidan, São Paulo, Brazil). The tooth was instrumented with the Logic NiTi rotary system until size 30.05 (Easy Equipamentos Odontológicas, Belo Horizonte, MG, Brazil) and irrigated with 2.5% sodium hypochlorite (NaOCL) and 17% ethylenediaminetetraacetic acid (EDTA) using a 30-gauge needle (NaviTip®, Ultradent, USA).

During the master gutta-percha radiograph, it was possible to observe a deviation in the path of the canal, with consequent perforation in the apical region (Fig. 2-F). The canal was dried with sterile paper points (Dentsply Maillefer, Ballaigues, Switzerland), filled with gutta-percha (Odous de Deus, Belo Horizonte, MG, Brazil) and bioceramic cement (BioCSealer Angelus, Londrina, Paraná, Brazil) using the warm vertical condensation technique. The tooth was restored with Filtek Z350 XT (3M Oral Care, St. Paul, MN, USA). For all procedures, a range of 3X to 16X magnification was used with a surgical microscope (DF Vasconcelos, Valença, Rio de Janeiro, Brazil). The patient was informed about the root canal deviation. After careful explanation of the possible surgical treatment options, the patient agreed to undergo endodontic microsurgery.

Endodontic microsurgery

Local anesthesia was achieved using 2% lidocaine with epinephrine 1:100,000 (Nova DFL, Rio de Janeiro, Brazil). A horizontal submarginal incision using a No. 67 microblade (Swann-Morton, Sheffield, England) was carried out within the attached gingiva followed by two vertical reliefs (Fig. 3-A), and a full-thickness mucoperiosteal flap was reflected. The osteotomy was performed with a tungsten carbide bur in slow-speed size 6 (Komet, South Carolina, USA) under copious saline solution irrigation. The periapical lesion was completely enucleated (Fig. 3-B), followed by 3 mm of a root-end resection using an ultrasonic tip Blade Sonic (Helse Ultrasonic, Ocoee, FL, USA) under copious saline solution irrigation (Fig. 3-C).

The anatomical canal was located with the aid of a surgical microscope (DF Vasconcelos, Valença, Rio de Janeiro, Brazil) using 16X magnification and a microprobe (Kit Camargo, Millennium, São Caetano do Sul, SP, Brazil). The retro-preparation was carried out with an ultrasonic tip (Dental Trinks, São Paulo, Brazil) under copious saline solution irrigation

up to a limit of 3 mm (Fig. 3-D). Retro-filling was performed with bioceramic cement PBS (CIMMO, Pouso Alegre, MG, Brazil) (Fig. 3-E). A heterologous bone graft was performed with lyophilized bovine bone (Lumina Bone, Criteria Biomaterials, São Paulo, SP, Brazil) (Fig. 3-F). The graft region was covered with a collagen membrane (Lumina Coat, Criteria Biomaterials, São Paulo, SP, Brazil). The flap was repositioned and sutured with Vicryl 6.0 (Ethicon, Ohio, USA).

The patient was reassessed after seven days for suture removal and later for a 6-month and 2-year follow-up. The patient reported no symptoms or discomfort. The radiographic and CBCT exams showed complete bone repair (Fig. 4 C-D)

DISCUSSION

It has been reported that guided endodontics is practical and safe, optimizes the time taken to access severely calcified canals, eliminates the need for the operating microscope, and can be performed by less experienced operators (15,17,20). The guided access procedure and virtual planning can significantly reduce access cavity size, preserve the tooth structure, and avoid accidents such as deviations or perforations (21).

Although the literature shows high levels of success achieved with guided endodontics (10), there is a lack of information regarding safety and limitations. Practitioners must be aware that possible failures may occur, and precautions should be taken to avoid iatrogenesis (22).

Over the last four years, our team has gained experience in guided endodontics (13,23,24); this method can be a general solution for most cases. On the other hand, there are limitations, and in specific circumstances, guided endodontics is not recommended. Patients with a limited mouth opening might have this technique as a counterindication. Patient underuse of aligners can modify the teeth position and make it impossible to use the guide. In those situations, the patient must stop using the aligner after oral scanning and CBCT until guided endodontic Treatment is performed. Furthermore, new restorations after treatment planning must be avoided to maintain the original teeth configuration.

The evolution of intraoral scanning has provided benefits, as it allows for greater accuracy in the models required for 3D planning (23). However, the professional must be mindful when performing this step and 3D virtual planning and printing the guide. Any distortion or error in these steps will compromise the results of the technique. Nevertheless, the quality of these steps will be verified in a crucial moment when testing the fit of the prototyped guide in the mouth. If the adaption is not perfect, it is necessary to repeat the planning and

printing. A good practice that can be adopted in the design of the guide is to perform windows in the template to permit the visualization of the perfect fit in the teeth and avoid any errors (13).

A well-adapted prototyped guide will fit the teeth very precisely. If a gap is observed between the guide and the teeth, the adaptation was not perfectly executed. Likewise, the guide must not show any tipping movement. Fixing the guide to the bone with the aid of screws can be virtually planned to prevent movement of the guide during access. In the present case, this step was not followed; lack of complete guide stability and design inaccuracies potentially led to the iatrogenic incident.

A small field of view CBCT should be performed according to the correct protocol. Thus, it is essential to move the lip away for an accurate technique of obtaining images. The complete arc must be scanned. In the case of maxillary teeth, the palate must be included in the scan to better match the image meshes with the 3D file of the computed tomography and the guide-making software.

The printing of the guides is also a critical factor. It must be calibrated correctly. It is imperative to use the original and manufacturer-specified entries with regular changes. After the printing process, in the post-treatment of the guide, washing and curing will be carried out, which are fundamental for the dimensional stabilization of the guide.

The guide washer, where the drill will be inserted, must have a length of 8 mm for better precision of the drill. Washers with shorter lengths will enable instability of the cutter used. Therefore, when planning the case, the professional must keep in mind that the active part of the instrument must be subtracted from the 8 mm of the washer. If the root canal is not visible up to this length in the CBCT during digital planning, there will be a limitation of the technique. In the present case, the drill used was 20 mm, and the root canal was only observed beyond the 12 mm that provided a safety margin for the procedure.

Regarding the difference in diameter of the drill and the root canal space, the diameter of the drill utilized in guided endodontics ranges from 0.85 to 1.3mm, while the diameter of calcified root canals is eventually reduced when compared to those of non-calcified teeth (1,25). This means that the clinician must be aware and cautious when achieving the virtual position of the root canal space. K -files #8 or #10 can be pre-curved and used to negotiate the patent canal after copious irrigation to remove debris caused by the drill. The use of the

operating microscope is crucial to check the cleanliness and locate the canal. If the location of the root canal is unsuccessful, one alternative is to take a new CBCT to verify its position.

In severe calcifications up to the apical third, as in the present case, it is necessary to plan and print two templates. Depending on the software utilized, the guides are designed differently, which increases the chance of errors. The software with the best mesh matching features employs artificial intelligence technology. However, the software used in the present case, the mesh merger, was still performed manually, which could have compromised the planning and maybe the justification for the deviation of the canal.

As demonstrated by Choi et al. (26), an accuracy error in the CBCT settings, low-quality images, section thickness larger than 1 mm, and an incorrect threshold value can compromise the guided endodontic planning and lead to deviations.

When a complete absence of root canal space is observed in the CBCT, the chances of failure rise. Virtually, the professional will plan the position of the bur in contact with the visible lumen of the root canal. In some circumstances, the calcification process is so severe that this may not be easily detectable. In those cases, the operator must avoid inserting the instrument beyond the limits of the 3D planning, and other strategies must be conducted to improve root canal disinfection (24,27,28).

Apical surgery should be considered the treatment of choice in the cases of PCO in which a straight line to the patent canal cannot be achieved by the bur with guided endodontics in severely curved canals in order to remove unreachable infected areas and seal the root canal (27,28). Over the last 20 years, modern endodontic microsurgery have improved the prognosis of complex cases and iatrogenic root perforation (29).

CONCLUSION AND CLINICAL IMPLICATIONS

The use of guided endodontics is claimed to be safe, straightforward, timesaving, and can be performed without the aid of an operating microscope and by less experienced operators; however, it still presents limitations. The present case report describes the limitations, possible causes and management of an unsuccessful case of severe obliteration where guided endodontic was employed. Endodontic microsurgery effectively resolved this case and should be considered the treatment of choice when guided endodontics cannot be employed safely or fails.

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REFERENCES

1. McCabe PS, Dummer PM. Pulp canal obliteration: An endodontic diagnosis and treatment challenge. *Int Endod J*. 2012;45:177–97.
2. Agamy HA, Bakry NS, Mounir MM, et al. Comparison of mineral trioxide aggregate and formocresol as pulp-capping agents in pulpotomized primary teeth. *Pediatr Dent*. 2004;26:302–9.
3. Fleig S, Attin T, Jungbluth H. Narrowing of the radicular pulp space in coronally restored teeth. *Clin Oral Investig*. 2017;21:1251–7.
4. Johnstone M, Parashos P. Endodontics and the ageing patient. *Aust Dent J*. 2015;60:20–7.
5. Kiefner P, Connert T, ElAyouti A, et al. Treatment of calcified root canals in elderly people: A clinical study about the accessibility, the time needed and the outcome with a three-year follow-up. *Gerodontology*. 2017;34:164–70.
6. Tavares WL, Lopes RC, Menezes GB, et al. Non-surgical Treatment of pulp canal obliteration using contemporary endodontic techniques: Case series. *Dental Press Endod*. 2012;2:52–8.
7. Tavares WL. Management of clinical complications following pulp canal obliteration: A report of two cases. *Dental Press Endod*. 2016;6:54–62.
8. Siqueira JF Jr, Rôças IN. Clinical implications and microbiology of bacterial persistence after treatment procedures. *J Endod*. 2008;34:1291–301.
9. Endodontics Colleagues for Excellence. Endodontic case difficulty assessment and referral. 2005. Available at: <https://www.aae.org/specialty/wp-content/uploads/sites/2/2017/07/ss05ecfe.pdf>. Accessed March 3, 2021.
10. Reis LC, Nascimento VD, Lenzi AR. Operative microscopy-indispensable resource for the Treatment of pulp canal obliteration-a case report. *Braz J Dent Traumatol*. 2009;1:3–6.
11. Plotino G, Pameijer CH, Grande NM, et al. Ultrasonics in endodontics: A review of the literature. *J Endod*. 2007;33:81–9.
12. Wanzeler AMV, Montagner F, Vieira HT, et al. Can cone-beam computed tomography change endodontists' level of confidence in diagnosis and treatment planning? A before and after study. *J Endod*. 2020;46: 283–88.

13. Tavares WL, Viana ACD, Machado VC, et al. Guided endodontic access of calcified anterior teeth. *J Endod.* 2018;7:1195–9.
14. Pujol ML, Vidal C, Mercade M, et al. Guided endodontics for managing severely calcified canals. *J Endod.* 2021;47:315–21.
15. Krastl G, Zehnder MS, Connert T, et al. Guided endodontics: A novel treatment approach for teeth with pulp canal calcification and apical pathology. *Dent Traumatol.* 2016;32:240–6.
16. Connert T, Zehnder MS, Amato M, et al. Microguided endodontics: A method to achieve minimally invasive access cavity preparation and root canal location in mandibular incisors using a novel computer-guided technique. *Int Endod J.* 2018;51:247–55.
17. Zehnder MS, Connert T, Weiger R, et al. Guided endodontics: Accuracy of a novel method for guided access cavity preparation and root canal location. *Int Endod J.* 2016;49:966–72.
18. Signoretti FG, Endo MS, Gomes BP, et al. Persistent extraradicular infection in root-filled asymptomatic human tooth: Scanning electron microscopic analysis and microbial investigation after apical microsurgery. *J Endod.* 2011;12:1696–700.
19. Rubenstein T, Torabinejad M. Contemporary endodontic surgery. *J Calif Dent Assoc.* 2004;6:485–92.
20. Van der Meer WJ, Vissink A, Ng YL, et al. 3D computer aided treatment planning in endodontics. *J Dent.* 2016;45:67–72.
21. Connert T, Krug R, Eggmann F, et al. Guided endodontics versus conventional access cavity preparation: A comparative study on substance loss using 3-dimensional-printed teeth. *J Endod.* 2019;45:327–31.
22. Moreno-Rabié C, Torres A, Lambrechts P, et al. Clinical applications, accuracy and limitations of guided endodontics: A systematic review. *Int Endod J.* 2020;53:214–31.
23. Tavares WL, Machado VC, Fonseca FO, et al. Guided endodontics in complex scenarios of calcified molars. *Iran Endod J.* 2020;1:50–6.
24. Tavares WLF, Ferreira MVL, de Carvalho Machado V, et al. Antimicrobial photodynamic therapy and guided endodontics: A case report. *Photodiagnosis Photodyn Ther.* 2020;31:101935.

25. Andreasen FM, Zhijie Y, Thomsen BL, et al. Occurrence of pulp canal obliteration after luxation injuries in the permanent dentition. *Endod Dent Traumatol.* 1987;3:103–15.
26. Choi JY, Choi JH, Kim NK, et al. analysis of errors in medical rapid prototyping models. *Int J Oral Maxillofac Surg.* 2002;31:23–32.
27. Kim S, Kratchman S. Modern endodontic surgery concepts and practice: A review. *J Endod.* 2006;32:601.
28. Tavares WLF, Fonseca FO, Maia LM, et al. 3D apicoectomy guidance: Optimizing access for apicoectomies. *J Oral Maxillofac Surg.* 2020;78(3):357.e1–357.e8.
29. Evans MD. A contemporary treatment of an iatrogenic root perforation: A case report. *J Endod.* 2021;47:520–25.

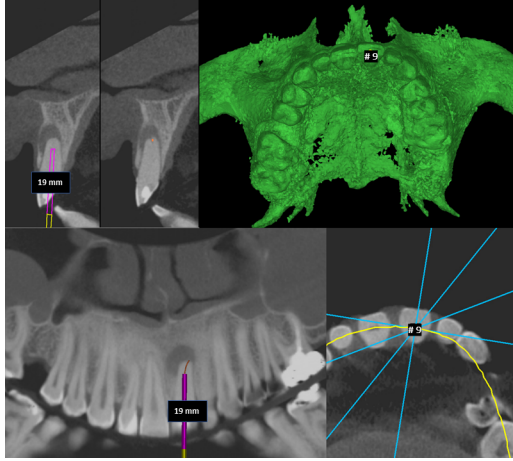
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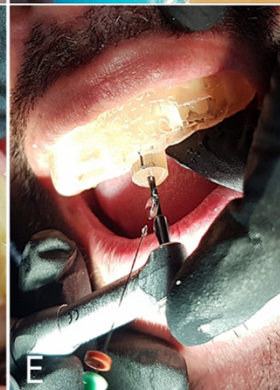
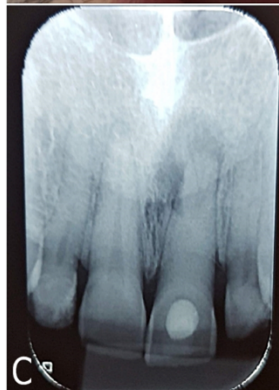
Figure 1: CBCT image of the upper left central incisor presenting severe pulp canal obliteration (PCO) associated with a periapical lesion. In the virtual planning of guided endodontics, the drill position was verified in virtually three dimensions in a depth of 19.00 mm until the apparent image of root canal space could be reached.

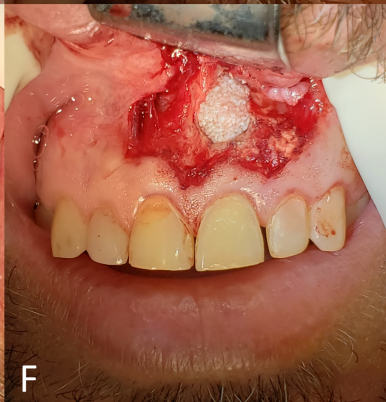
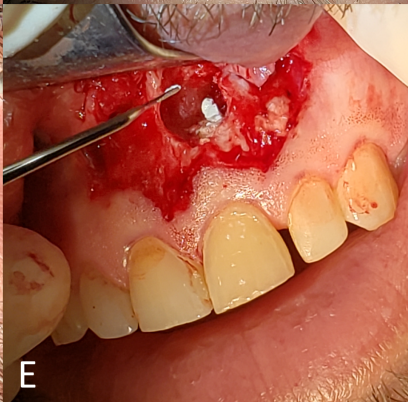
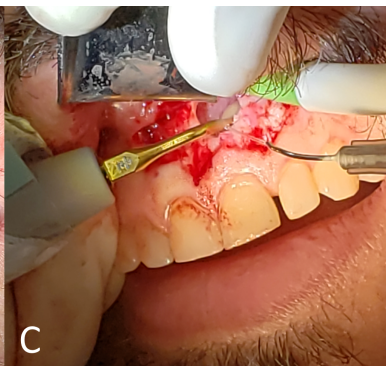
Figure 2: (A) Upper left central incisor with a yellowish appearance. (B) Palatal view of previous attempt to access the root canal. (C) Pre-operative radiograph of tooth 9 showing pulp canal obliteration (PCO). (D) Palatal view. Note the crown inclination towards the buccal surface. (E) Guided endodontics being performed. (F) Post-operative radiograph showing root canal deviation and failure of guided endodontic therapy.

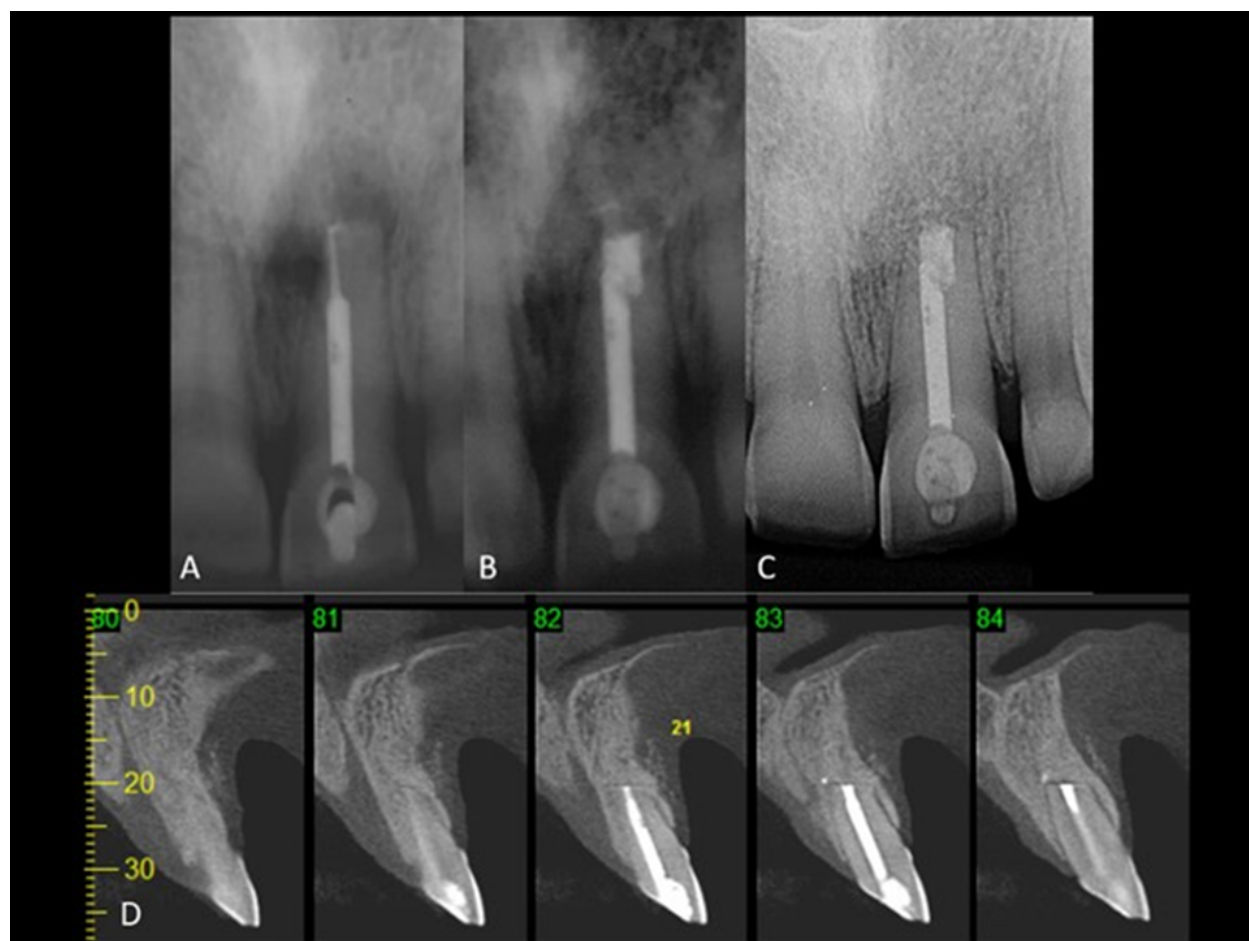
Figure 3: (A) Horizontal submarginal incision with the maintenance of the attached gingiva with two vertical reliefs. (B) Clinical view after osteotomy and enucleation of the periapical lesion. (C) Root end resection using an ultrasonic tip under copious saline solution irrigation. (D) Retro-preparation performed with an ultrasonic tip under copious saline solution irrigation. (E) Retro-filling was performed with bioceramic cement PBS. (F) Surgical cavity filled with heterologous bone graft with the lyophilized bovine bone.

Figure 4: (A) Radiography after guided endodontics. (B) Post-operative radiography after endodontic microsurgery. (C) 6-month follow-up. (D) CBCT: 2-year follow-up.









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