3D Apicoectomy Guidance: Optimizing Access for Apicoectomies

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When conventional endodontic treatment resources are depleted, endodontic surgery becomes an alternative treatment for apical periodontitis to remove unreachable infected areas and seal the root canal. Digital workflows have been used more frequently in many dental applications in recent years. In endodontics, virtual 3-dimensional (3D) planning and endodontic guidance are new aspects important for the treatment of complex cases. This report aimed to present 3D Apicoectomy Guidance, a novel method of performing guided ultraconservative endodontic surgery with conventional implant-guided drills, and to describe its application in a case with a complex anatomic scenario and intimate contact with the maxillary sinus. Implantology computer software, as well as cone-beam computed tomography images and a digital scanning 3D impression, enabled virtual planning of the surgical procedure. Subsequently, a 3D template was produced to guide the instruments used in the osteotomy and root resection. The patient was completely asymptomatic at the 1-week follow-up visit. Cone-beam computed tomography scans were performed at 1 and 6 months after surgery and showed that resection of the apex of the root was performed accurately and that a thin dentin slice remained distally, preventing the rupture of the sinus membrane. The patient remained asymptomatic, and the tissue healed normally. The method used was shown to be very straightforward and reliable. This method allowed the patient to be treated expeditiously with very precise tissue removal.

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The goal of endodontic treatment is to prevent or resolve root canal infections.[1,2] However, treatments can fail owing to anatomic difficulties, iatrogenesis, and a lack of bacterial removal. Bacterial biofilm present in inaccessible areas such as isthmuses, lateral canals, deep dentinal tubules, or even the cementum may not be reached by a chemomechanical preparation.[3,4] When conventional endodontic techniques are exhausted, endodontic surgery becomes an alternative treatment for apical periodontitis to remove un-

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reachable infected areas and seal the root canal, allowing the restoration of healthy periapical tissue.[5-7]

In the past 20 years, modern endodontic microsurgery protocols have improved the prognosis in these cases.[8] The implementation of visual magnification with loupes or operating microscopes and the use of ultrasonic inserts and more biocompatible materials have led to smaller osteotomies and better outcomes than those of the conventional methods used previously.[5-8]

Digital workflows have been used more frequently in many dental applications in recent years.[9] In endodontics, virtual 3-dimensional (3D) planning and endodontic guidance are new aspects important for the treatment of complex cases. Implantology software, as well as cone-beam computed tomography (CBCT) images and a digital scanning 3D impression, enables virtual planning of a procedure. Guided endodontic procedures have been used for accessing canals and localizing calcified teeth,[10-13] removing adhesive fiberglass posts,[14] and performing apical surgical procedures.[15-17] However, more reproducible approaches are still needed for treatments in which apicoectomy surgery is involved.

Implant-guided instruments are intended for treatments planned preoperatively with 3D planning software. The instruments are designed to prepare the implant sites using surgical templates and permit reliable and precise surgical approaches.[18] This report presents the use of 3D apicoectomy guidance, a novel method of performing ultraconservative guided apicoectomy surgery with conventional implant drills, in a challenging premolar case presenting a complex anatomic scenario and intimate contact with the maxillary sinus.

Case Report

A 33-year-old female patient with a history of pain in the right maxillary second premolar was referred to a private clinic. Satisfactory endodontic treatment of the tooth had been performed 2 years earlier, and the presence of apical periodontitis was observed. The clinical symptoms included tenderness to percussion and palpation. On the CBCT images, the proximity of the root and apical periodontitis associated with the maxillary sinus was notable both distally and apically (Fig 1). After a discussion with the patient, 3D apicoectomy

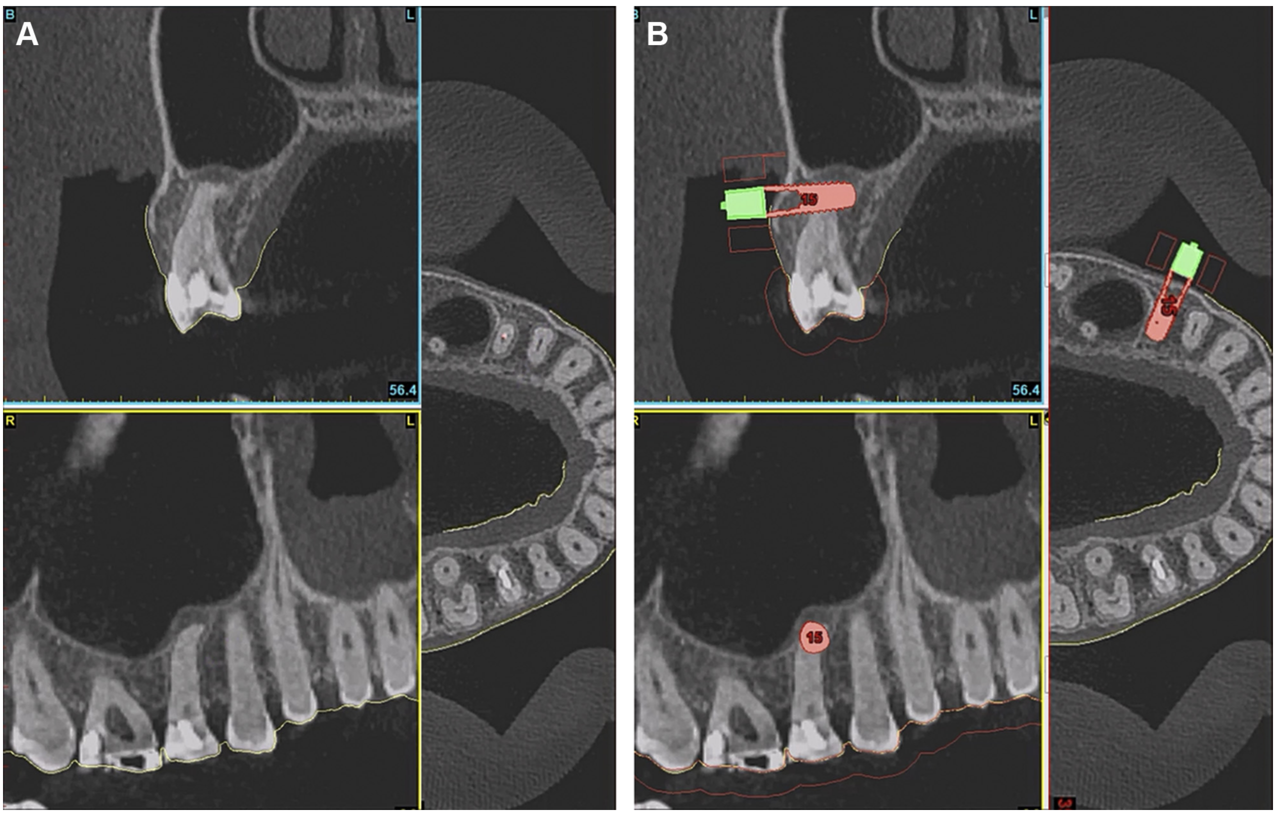

FIGURE 1. *A*, Cone-beam computed tomography image of right maxillary second premolar with unsatisfactory root canal treatment and apical periodontitis. The proximity to the maxillary sinus is evident. *B*, Virtual planning of guided surgery avoiding any damage to sinus bone wall.

Tavares et al. Apicoectomy Surgery. J Oral Maxillofac Surg 2020.

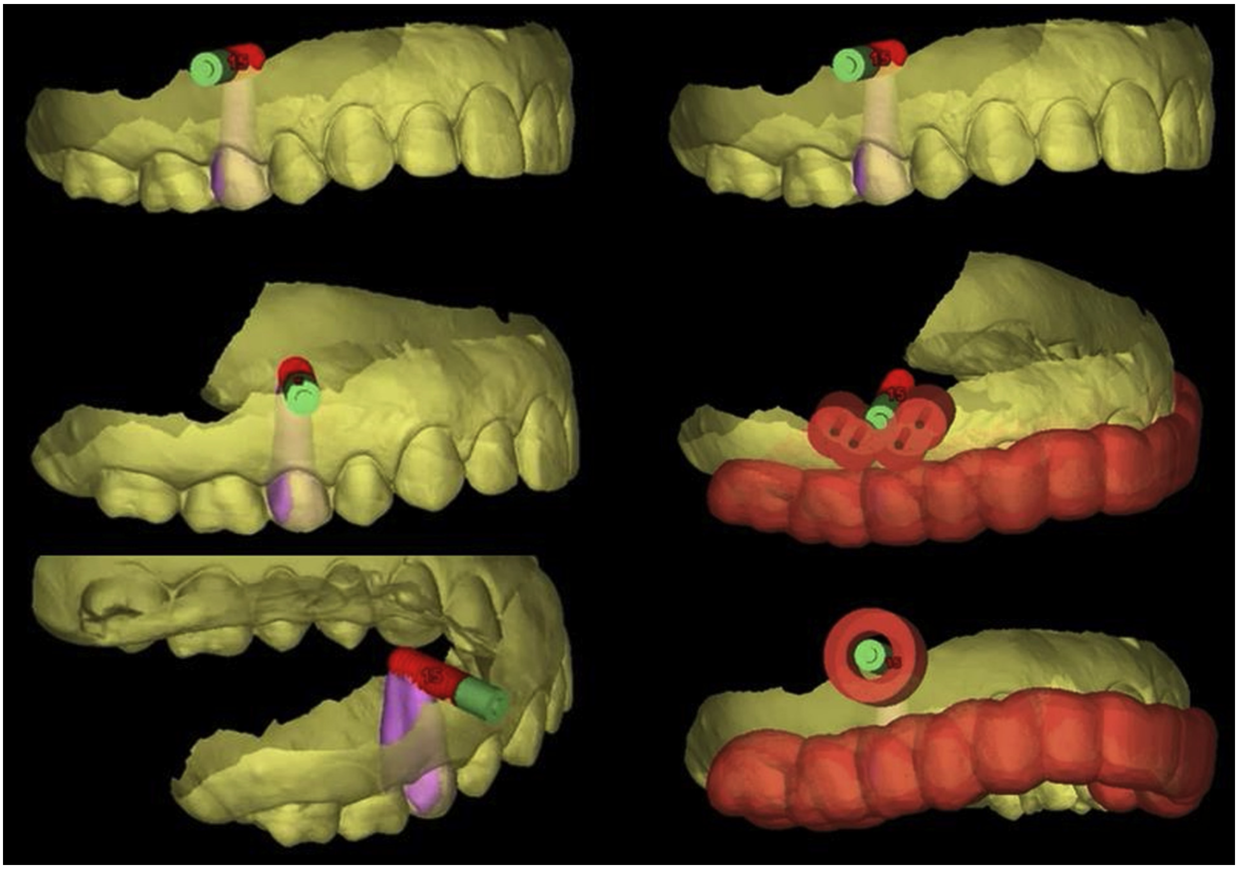

FIGURE 2. Virtual copy of drill aligned to virtual 3-dimensional template to be used in guided incision, osteotomy, and root resection.

Tavares et al. Apicoectomy Surgery. J Oral Maxillofac Surg 2020.

guidance was chosen as the most appropriate treatment option.

The whole maxillary arch was scanned (3Shape Trios 3 color intraoral scanner; Holmes Kanal, Copenhagen, Denmark). High-resolution CBCT images were taken 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). A plastic lip retractor for soft tissue CBCT images was used, as previously described,[19] to obtain a more detailed view of the dentogingival unit. Afterward, the CBCT and tooth scans were aligned and processed with the planning software (CoDiagnostiX; Dental Wings, Basel, Switzerland) complementing the Straumann guided instruments (Straumann, Basel, Switzerland).

The drill handles of the system (Straumann guided surgery) included direct milling cutters and guided drills based on the sleeve-in-sleeve concept. The cylinder of the drill handle is inserted into the sleeve (diameter, 5 mm) fixed to the surgical template. An ergonomic drill handle is available for each instrument diameter: 2.2 mm, 2.8 mm, 3.5 mm, and 4.2 mm. Every drill handle features 1 cylinder with an additional height of +1 mm at 1 end and a second cylinder with an extra cylinder height of +3 mm at the other end. In this study, a 3.5-mm-diameter instrument with a +3-mm extra cylinder was used.

The position of the drill was verified to precisely cut the portion of the root affected by apical periodontitis. Care was taken to avoid contacting the maxillary sinus. To that end, a selective resection of the apical root was planned, leaving a thin slice of dentin distally (Fig 1). The incision was planned virtually, and a specific 3D guide was built for this purpose. Subsequently, the 3D templates to be used in the incision, osteotomy, and root resection were exported as stereolithography files and sent to a 3D printer (Form 2; Formlabs, Somerville, MA) (Fig 2).

The printed 3D templates were positioned in the mouth, and the fit was verified (Fig 3). The patient was anesthetized with 2% lidocaine with epinephrine (1:100,000), the incision was performed with the guidance of the incision template, and a full-thickness flap reflection was performed using a curette. Then, the 3D template designed for the drilling procedure was positioned for the initial osteotomy. The first milling cutter, a 3.5-mm-diameter drill, was inserted into the guide with the aid of the drill handle, and the osteotomy was performed at 980 rpm under copious irrigation

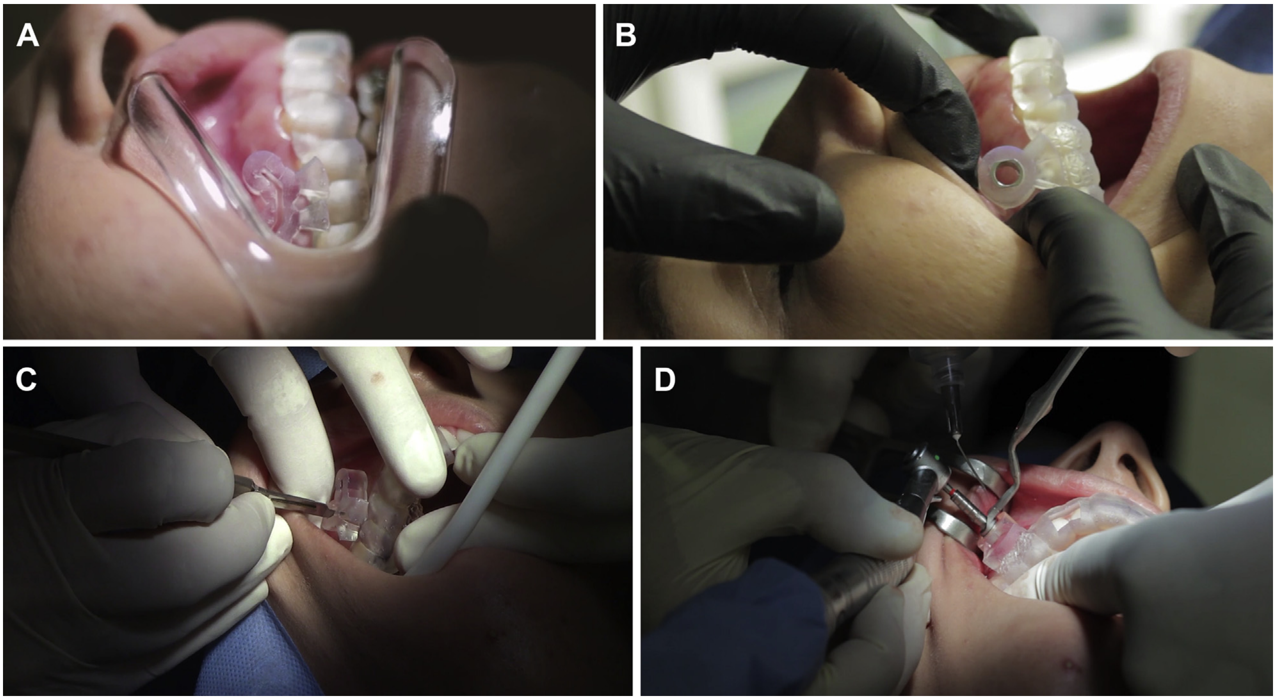

FIGURE 3. *A*, Checking of template used to guide incision. *B*, Checking of template used to guide osteotomy and root resection. *C*, Conservative incision being performed with aid of guide. *D*, Osteotomy and root resection being performed with aid of guide.

Tavares et al. Apicoectomy Surgery. J Oral Maxillofac Surg 2020.

with saline solution. A second drill, a Twist Drill PRO (Straumann) with a diameter of 3.5 mm, was used at the same speed and under irrigation until it reached the bed of the drill handle and ensured apical resection as planned. The apical lesion was removed with a curette, and the surgical site was cleaned with saline solution irrigation.

Localization of the root canal was confirmed with the aid of a micromirror under an operating microscope at a magnification of 20×. Root-end retro-preparation was performed with an ultrasonic diamond-tip instrument with a diameter of 3 mm under copious irrigation with saline solution. The prepared root-end cavity was dried and sealed with a putty bioceramic sealer (Bio-C Repair; Angelus, Londrina, Brazil). The bone crypt was cleaned and assessed for the presence of any excess material and was then filled with bone graft cement (4Matrix MIS; Augma Biomaterials, Caesarea, Israel). The flap was repositioned, and the incision was closed with No. 5-0 Monocryl (Ethicon, Somerville, NJ) (Fig 4). A postoperative radiographic examination showed the absence of any foreign material and the correct position of the retro-filled material. The patient was prescribed ibuprofen (600 mg every 8 hs) for 3 days postoperatively.

The patient was completely asymptomatic at the 1-week follow-up visit. CBCT scans were performed at 1 month (Fig 5) and 6 months (Fig 6) after surgery and showed that resection of the apex of the root was performed accurately and that a thin dentin slice remained distally, preventing the rupture of the sinus membrane. The patient remained asymptomatic, and the tissue healed normally.

Discussion

There are many challenges related to endodontic surgery in anatomically complex areas.[20,21] Freehand execution of the procedure may be risky, considering the presence of vital structures, such as the inferior alveolar nerve in the mandibular teeth or the maxillary sinus, for cases such as that presented in this study of a maxillary tooth. The advent of guided surgery has drastically reduced the chances of iatrogenesis for these types of cases. The precision of the 3D oral scans aligned with the CBCT scans and the software used in the construction of the 3D template provide us with a very reliable tool to achieve the goals of endodontic surgery.[17,18] In the case presented, the proximity of the tooth to the maxillary sinus and the presence of thick buccal bone may be limitations in the execution of apical surgery without digital guidance.

The application of guided endodontic surgery had been described in previous studies with different instruments.[16,17] In this report, we propose a new technique that is available to any clinician because

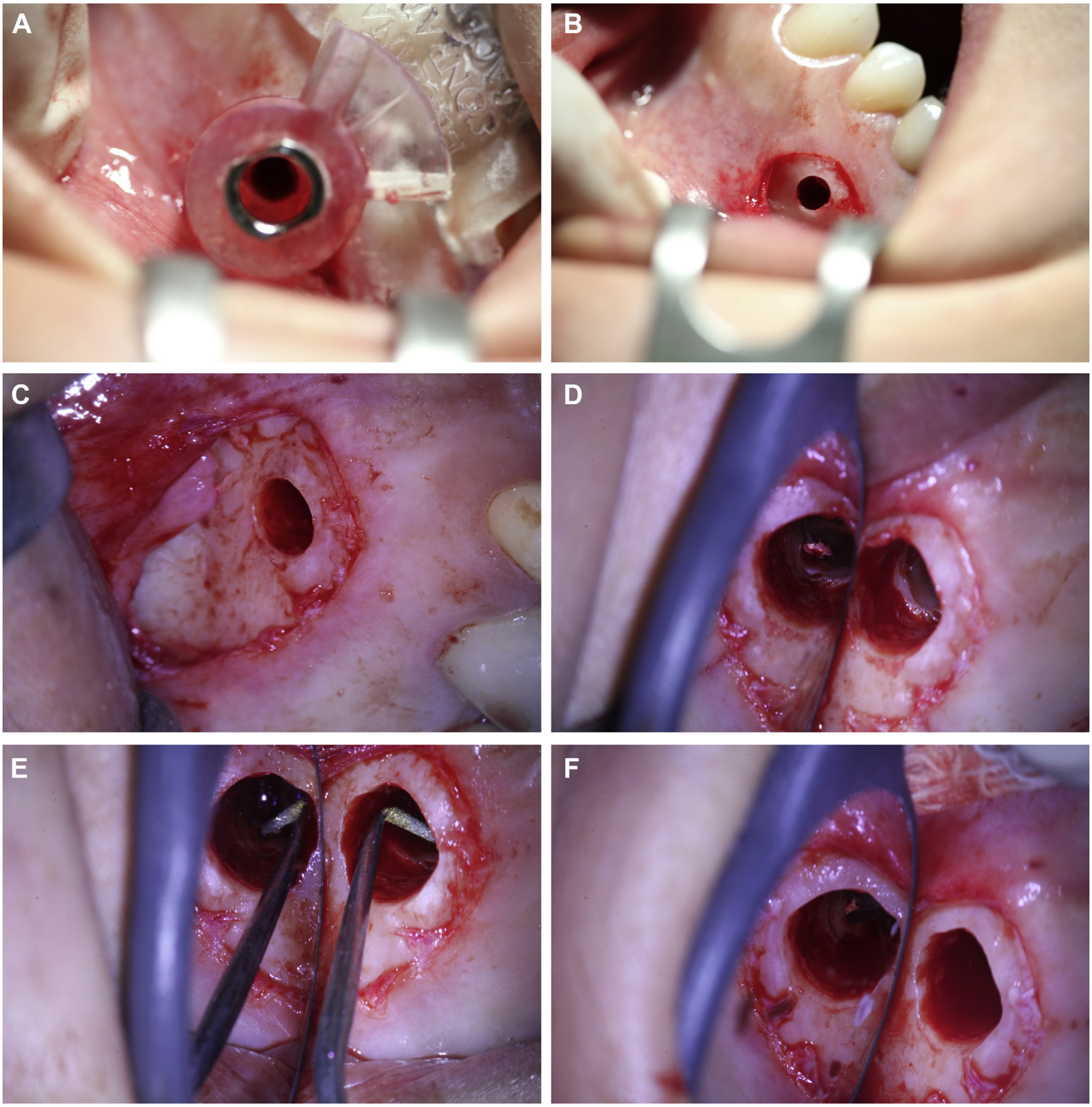

FIGURE 4. *A*, View of ultraconservative guided osteotomy. *B*, Clinical aspect after ultraconservative guided osteotomy and root resection. *C*, Closer view of clinical aspect after ultraconservative guided osteotomy and root resection. *D*, Root-end view after root resection. *E*, Root-end preparation with ultrasonic diamond-tip instrument. *F*, Clinical aspect after root-end preparation. **(Fig 4 continued on next page.)**

Tavares et al. Apicoectomy Surgery. J Oral Maxillofac Surg 2020.

the instruments required are routinely used in guided implant surgical procedures and can be purchased worldwide. Hence, owing to the reliability and straightforwardness of the technique, it can be readily reproduced by other professionals. The additional costs to the patient are related to the CBCT scans and intraoral scans associated with 3D printing, which can be performed in a radiologic center.

The technique permitted a very precise incision and a conservative osteotomy. The amount of tissue removed was limited to that strictly necessary to reach and resect the apical root and completely remove the periapical granuloma. This approach also may be very beneficial in cases in close proximity to the inferior alveolar nerve. The extension of the access did not limit the root-end preparation and backfill procedures. The duration of the procedure must be taken into consideration. All of the steps for the osteotomy and apical resection took fewer than 5 minutes. This technique led to very

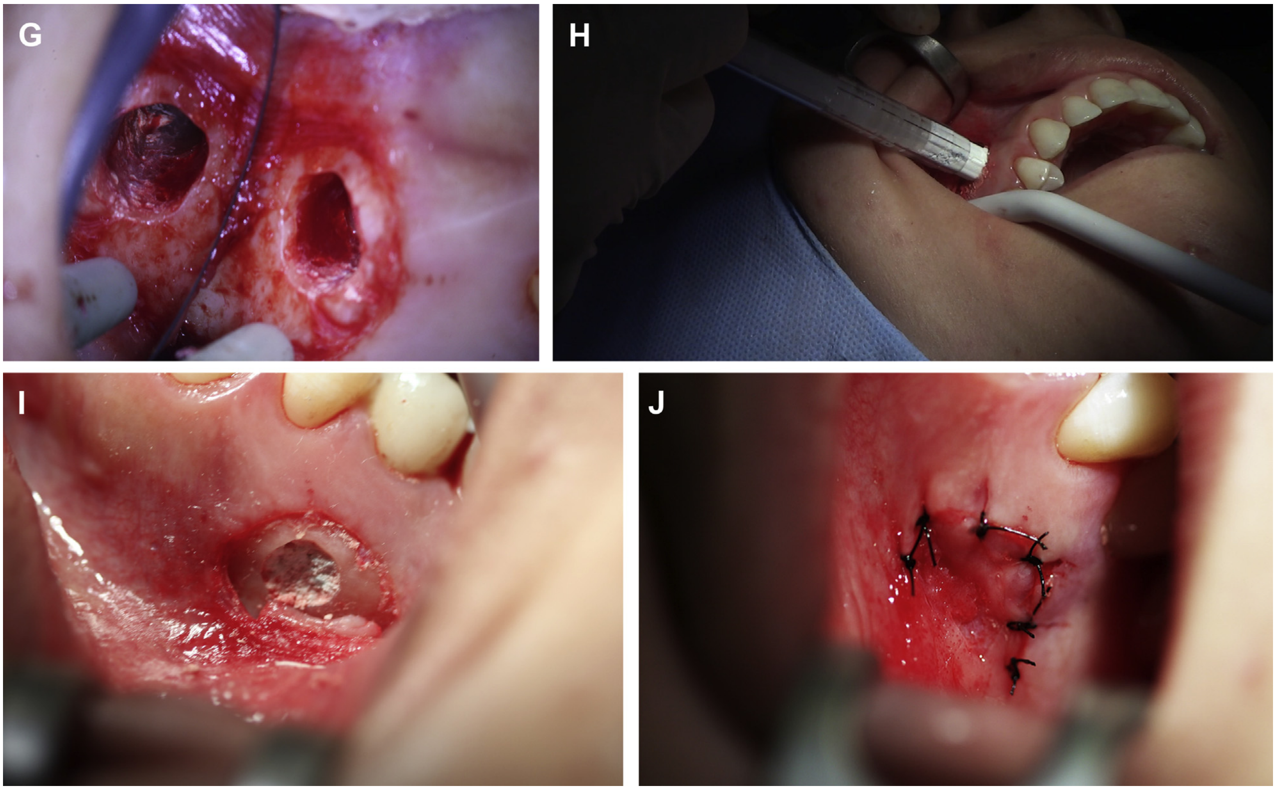

FIGURE 4 (cont'd). *G*, Root-end filling with bioceramic sealer. *H*, Exogenous bone grafting. *I*, Clinical aspect after exogenous bone grafting. *J*, Suture.

Tavares et al. Apicoectomy Surgery. J Oral Maxillofac Surg 2020.

favorable postoperative follow-up results. The patient had no edema or pain after surgery, even without the prescription of a corticosteroid. Most experienced professionals spend more time performing these steps because osteotomies and apical resections are often time-consuming procedures.[7]

The surgical procedure in this case study was planned so that a thin slice of dentin remained distally to minimize potential damage to the bone based on its proximity to the maxillary sinus. In fact, this approach enabled the contaminated apical root involved in the periapical lesion to

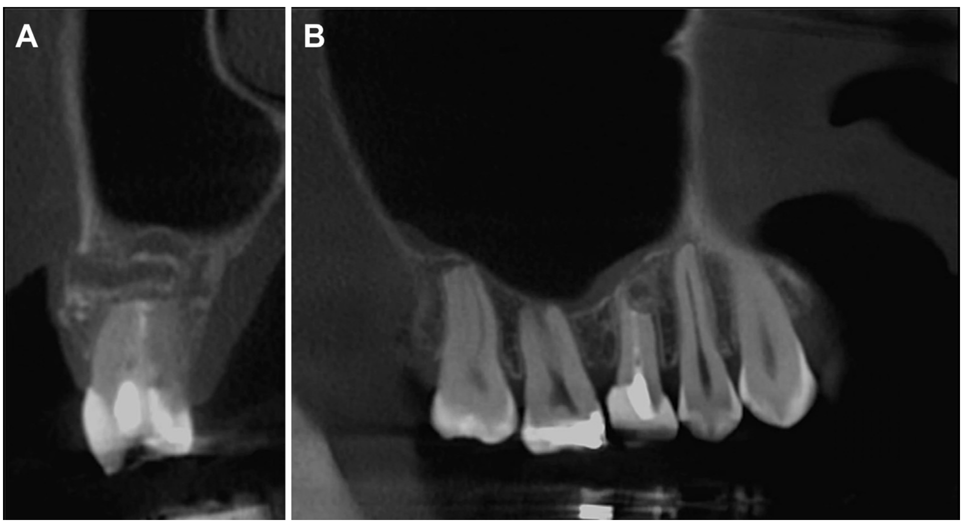

FIGURE 5. *A*, *B*, One-month follow-up cone-beam computed tomography images showing selective tissue removal and absence of any damage to sinus bone wall.

Tavares et al. Apicoectomy Surgery. J Oral Maxillofac Surg 2020.

FIGURE 6. *A*, Axial view of 6-month follow-up cone-beam computed tomography image. *B, C*, Six-month follow-up cone-beam computed tomography images showing complete bone and sinus membrane healing.

Tavares et al. Apicoectomy Surgery. J Oral Maxillofac Surg 2020.

be selectively removed and healthy tissue to be preserved.

The root-end preparation was performed as usual with the aid of an ultrasonic diamond-tip instrument followed by retro-filling with a bioceramic sealer. These steps were the only steps in which view magnification with the operating microscope was required. However, an improvement in the technique is being tested in vitro by our group to include this step in the planned and guided procedures.

The method presented was shown to be very straightforward, reproducible, and reliable. Its applicability can be extended to other anatomically complex scenarios and multiple endodontic surgery cases. The reproducibility of the technique enables teeth indicated for endodontic surgery to be preserved when the anatomy is a hindrance. This technique allowed our patient to be treated expeditiously and precisely. Although guided periapical surgery has the potential advantage of reducing the risk of iatrogenic injuries, additional research is needed to quantify the reduction in this risk with this method.

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