Guided Modern Endodontic Surgery: A Novel Approach for Guided Osteotomy and Root Resection

Georg D. Strbac, DDS, PhD, * *Albrecht Schnappauf, DI,* † *Katharina Giannis, DMD,* ‡ *Andreas Moritz, MD, DMD, PhD,* § *and Christian Ulm, MD, DDS, PhD* *

Abstract

Introduction: Continuous improvements in techniques, instruments, and materials have established modern endodontic microsurgery as a state-of-the-art treatment method. The purpose of this approach was to introduce a new surgical endodontic technique by using a three-dimensional printed template for guided osteotomy and root resection. **Methods:** A 38-year-old patient was diagnosed with periapical lesions of teeth #3 and #4 and extruded gutta-percha material. Three-dimensional radiographic and optical scan files were imported into surgical planning software designed for guided implant surgery. Within the adapted software program the periapical lesions and the extruded gutta-percha were visualized and marked. With the aid of virtually positioned surgical pins and piezoelectric instruments, the osteotomy size, the apical resection level, and the bevel angle were defined before treatment. Three-dimensional surgical templates for each tooth were designed within the software program for a guided treatment approach. **Results:** This approach comprised the treatment of periapical lesions of teeth #3 and #4 with root-end fillings and the detection and complete removal of the extruded gutta-percha material without perforation of sinus membrane. There were no postoperative complications, and clinical and radiologic assessments verified complete healing of the teeth. **Conclusions:** The guided microsurgical endodontic treatment presented appears to be a viable technique that allows for predefined osteotomies and root resections. *(J Endod 2017;43:496–501)*

Key Words

Guided endodontic surgery, guided osteotomy, guided root resection, modern endodontic microsurgery, surgical template, 3D printed template

Significance

This case report describes a novel surgical endodontic approach using 3D printed surgical templates for osteotomies and root resections with appropriate consideration of the recommended guidelines for modern surgical endodontic treatments.

Endodontic microsurgery was introduced in the 1990s and has been continuously developing over the years. Improvements in endodontic equipment, instruments, and materials have established this procedure as a state-of-the-art surgical endodontic technique with a predictable outcome (1, 2). One of the main benefits of this modern surgical technique is the use of magnification devices such as dental operating microscopes. Surgical microscopes allow for microsurgical interventions with easier identification of the root apices resulting in smaller osteotomies and shallower resection angles, thus ensuring the maintenance of surrounding bone and the preservation of root length and dental structures. Furthermore, these modern magnification and illumination devices enable the identification of anatomic details such as isthmi, lateral canals, canal fins, and microfractures of the resected root before precision root-end preparation with microsurgical tips and root-end fillings (1, 3). The advances of modern microsurgical endodontic treatments provide for success rates of up to 89%, resulting in fewer failures and retreatment needs as compared with traditional approaches (1, 2).

These superior outcomes can also be credited to modern diagnostic techniques such as three-dimensional (3D) imaging, eg, multi-slice tomography (MSCT) and cone-beam computed tomography (CBCT), used in the diagnosis, pretreatment planning, post-treatment assessment, and follow-up evaluation of modern endodontics (4–6). Three-dimensional imaging devices used in oral and maxillofacial surgery for the visualization of anatomic structures not only allow accurate diagnosis but also precise planning of surgical treatments, as in guided implant surgery, by using templates for implant site preparation and insertion (7, 8). Templates such as this were also recently introduced in endodontic therapy for orthograde guide access cavity preparation and root canal location (9, 10).

These innovative treatment methods using templates could also be implemented in future surgical endodontic treatments, enabling pre-planning and guided surgical interventions.

From the *Division of Oral Surgery, School of Dentistry, Medical University of Vienna, Vienna, Austria; †Software Research, Dental Wings, Chemnitz, Germany; ‡Unit - Division of Dental Student Training and Patient Care, School of Dentistry, Medical University of Vienna, Vienna, Austria; and §Conservative Dentistry and Periodontology, Unit - Division of Dental Student Training and Patient Care, School of Dentistry, Medical University of Vienna, Vienna, Austria.

Address requests for reprints to Prof PD Dr Georg D. Strbac, Division of Oral Surgery, School of Dentistry, Medical University of Vienna, Sensengasse 2a, A-1090 Vienna, Austria. E-mail address: georg.strbac@meduniwien.ac.at

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The aim of this article was to introduce a novel surgical endodontic technique using a surgical template for guided osteotomy and root resection.

Case Report

A 38-year-old female patient was referred to the Division of Oral Surgery with sporadic discomfort, swelling, and tenderness to percussion in the right maxillary region of teeth #3 and #4. Two-dimensional digital panoramic and intraoral x-rays revealed radiolucent periapical lesions of tooth #3 and tooth #4. In addition, intraoral x-rays showed an overfilled tooth #3 and extruded gutta-percha (Fig. 1*A*). A 3D MSCT scan (Siemens Somatom Sensation 4; Siemens Healthcare GmbH, Erlangen, Germany; voxel size 0.18 × 0.18 × 0.5 mm, 120 kV, 512 matrix, bone window) was performed at the Division of Radiology to ensure an accurate radiologic diagnosis of the periapical lesions and the extruded gutta-percha (4, 5, 11). Periapical lesions on the buccal roots of tooth #3 and on the root of tooth #4 could be confirmed. In addition, the presence of the extruded gutta-percha could be located lying inferior and laterally to the sinus membrane

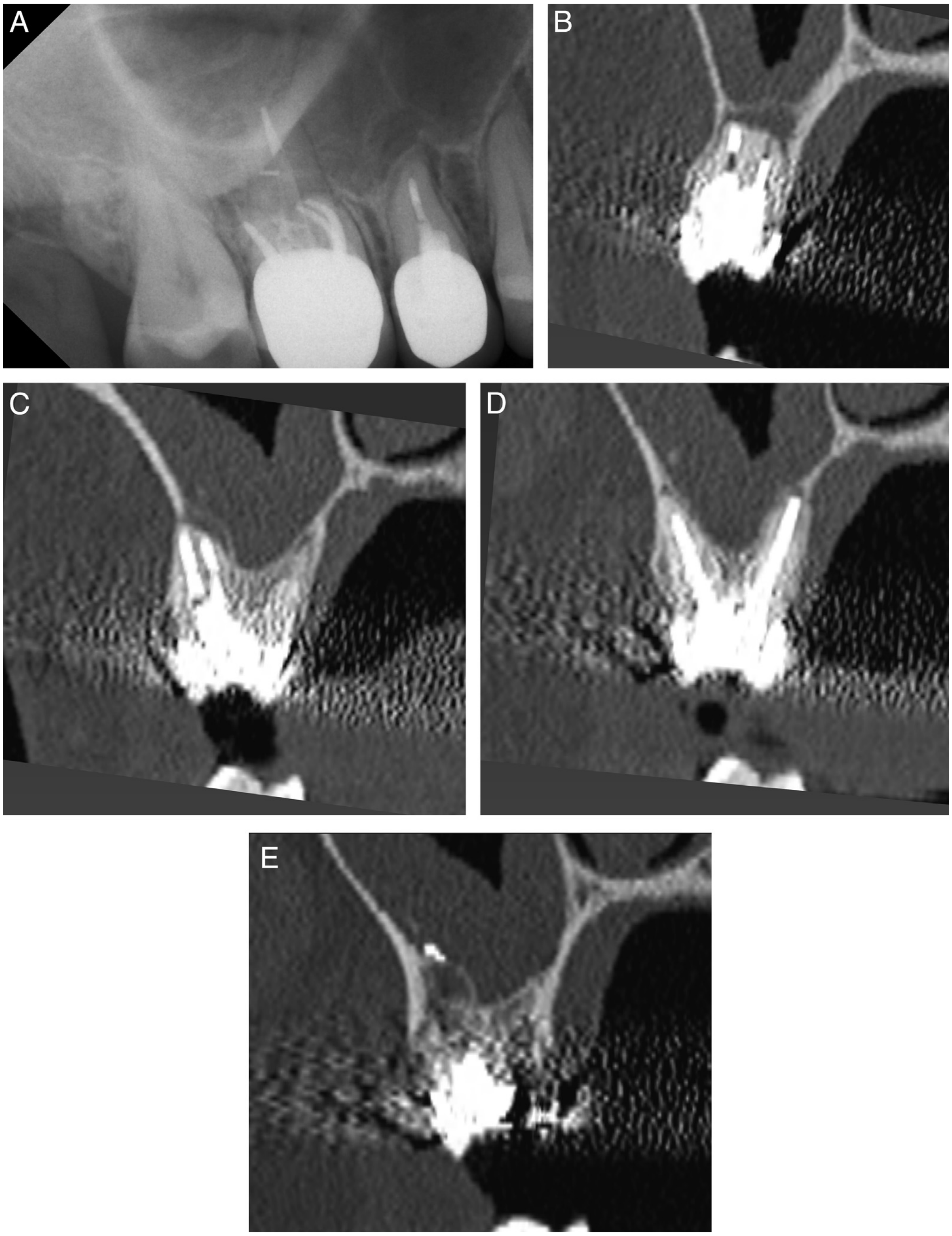

Figure 1. (*A*) Intraoral radiography showing periapical lesions and extruded gutta-percha material located at tooth #3. (*B*) Coronal slice of 3D radiographic examination presenting periapical lesion of tooth #4. (*C*) Mesiobuccal lesion of tooth #3 observed in 3D radiographic examination. (*D*) Coronal slice presenting distobuccal lesion of tooth #3. (*E*) 3D radiographic assessment showing location of extruded gutta-percha material lying inferior to the sinus membrane.

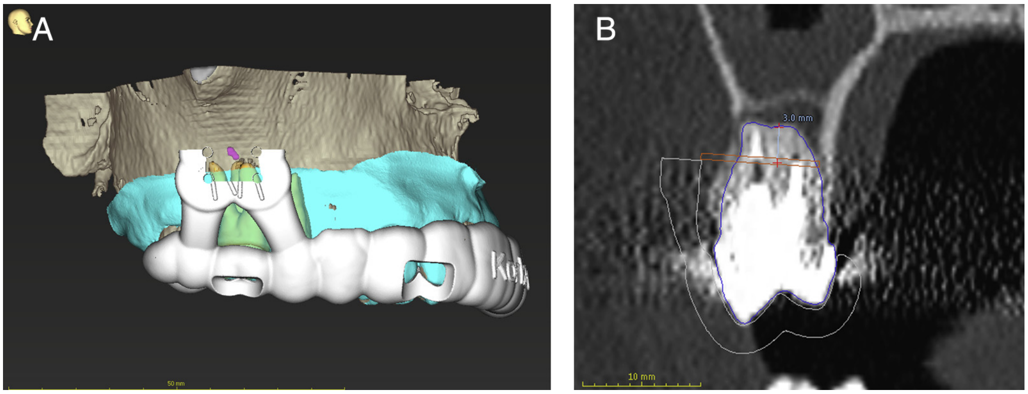

Figure 2. (*A*) Visualization of preoperative DICOM files with superimposed intraoral scan during pre-planning of osteotomy size for tooth #3 with the aid of virtually positioned surgical pins (1.5 mm in diameter); illustration showing surgical template of tooth #3 for guided surgical approach; vertical lines on 3D surgical template represent the root outline of each root for better visualization during resection of the roots with the piezoelectric instrument; object in pink color presenting the segmented extruded gutta-percha material for detection and removal during surgical intervention. (*B*) Coronal slice of tooth #4, visualized in surgical planning software, presenting pre-planned 3 mm apical resection level and bevel angle within the limitations of the surgical template.

(Fig. 1*B*–1*E*). The patient was advised of treatment options including microsurgical endodontic treatment of teeth #3 and #4 and surgical removal of the extruded endodontic material (1, 12).

Preoperative Digital Imaging and Communications in Medicine (DICOM) files acquired from the 3D radiologic assessment were imported into surgical planning software designed for guided implant surgery (coDiagnostiX Version 9.6; Dental Wings Inc, Montreal, Canada). The periapical lesions of teeth #3 and #4 and the location of the extruded gutta-percha were identified and marked within the planning software. In accordance with the guidelines of modern endodontic microsurgery, the appropriate osteotomy size, the bevel angle degree, and the recommended 3 mm apical resection level of the root ends for reducing the apical ramifications were virtually pre-planned (1, 13). The osteotomy dimensions of teeth #3 and #4 were determined with virtually positioned surgical pins that were 1.5 mm in diameter. The lower margin of the osteotomy for each root defined the cutting plane, consistent to the recommended 3 mm apical resection level and the bevel angle degree. The upper margin of the osteotomy was planned with a vertical distance of 4 mm to the lower margin, according to the dimensions of the diamond-coated retrotips of the microsurgical instruments. These predefined margins could be implemented in the software with the aid of these individually positioned surgical pins (Fig. 2). For achieving these specifications with a guided preparation procedure, technical stereolithography (STL) files of corresponding piezoelectric instruments (Piezomed Instruments, Piezomed, W&H Dentalwerk GmbH, Buermoos, Austria) were imported and virtually used within the planning software. After the pre-planning of the endodontic microsurgery, the location of the extruded gutta-percha material was marked with a virtual surgical pin and was visualized in total by the segmentation method within the software. For the final production of the 3D printed templates, a surface scan of the upper jaw was performed with an intraoral scanner (iTero; Align Technology Inc, San Jose, CA), and the data were transferred to the planning software. The intraoral scan of the maxilla was matched with the 3D radiographic data by the alignment of corresponding dental structures. Two surgical templates (one for tooth #3 and one for tooth #4) were designed in the coDiagnostiX software by using the digital guide designer. For better visualization during the intervention, the upper and lower margins of the osteotomies, the exact position of the roots, and the location of the extruded gutta-percha material were defined and marked on the surgical templates within the software program. The virtually designed templates were exported as STL files and sent to a 3D printer for production (Objet350 Connex 3, Material MED610; Stratasys Ltd, Minneapolis, MN) (Fig. 3).

Surgery was carried out under local anesthesia (Ultracain D-S forte 1:100,000; Sanofi-Aventis GmbH, Frankfurt am Main, Germany) by using an operating microscope (OPMI pico; Carl Zeiss Meditec GmbH, Oberkochen, Germany) and was performed according to recommended guidelines for a modern endodontic surgical procedure (1). Initially the surgical templates of tooth #3 and tooth #4 were positioned on the maxillary teeth, and their precision was checked. The flap design was conceived according to the templates and under consideration of the potential perforation of the sinus membrane during the removal of the foreign material. A sulcular full-thickness flap with vertical releasing incisions was raised from tooth #2 to tooth #5. The surgical template of tooth #4 was placed on the maxillary teeth, followed by the guided preparation of the upper and lower margins for the osteotomy and the guided apical resection by using a particularly thin piezoelectric saw (B7; Piezomed Instrument) (Supplemental Figure 1 is available online at www.jendodon.com). Elevation of the cortical plate was performed with a periosteal elevator, and final removal of the previously resected root was performed with the tip of the piezoelectric instrument (Supplemental Figure 2 is available online at www.jendodon.com). The entire root surface was inspected at high magnification with the operating microscope after methylene blue

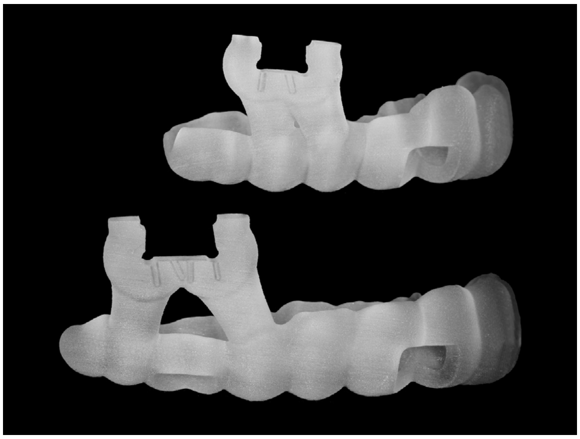

Figure 3. 3D printed surgical templates of teeth #3 and #4 for guided surgical intervention.

staining. No fractures, perforations, or other signs of damage to the roots could be detected. Root-end preparation of buccal and palatal canals of tooth #4 was performed at least 3 mm into the root dentin to create a cavity for the retrograde fillings by using the diamond-coated piezoelectric microsurgical retrotips (R3D, R4RD; Piezomed Instruments). After sufficient drying (paper points; Dentsply DeTrey GmbH, Konstanz, Germany) and disinfection (24% EDTA, PrefGel; Strauman AG, Basel, Switzerland), root-end fillings of the buccal and palatal canals were performed (IRM Caps; Dentsply DeTrey GmbH), and residual periapical tissue was removed after final inspection of the root-end seals. The second surgical template of tooth #3 was positioned on the maxillary teeth, and the guided osteotomies and resections of mesiobuccal and distobuccal roots were performed by using the virtually implemented piezoelectric microsurgical instrument (B7; Piezomed Instruments) (Supplemental Figure 3 is available online at www.jendodon.com). After elevation and removal of the cortical plate and the resected roots, subsequent inspection and root-end preparation of both mesiobuccal and distobuccal canals were performed by using the diamond-coated piezoelectric retrotips (R3D, R4RD, R4LD; Piezomed Instruments) (Supplemental Figure 4 is available online at www.jendodon.com). After the root-end fillings and inspection of the root-end seals, the location of the extruded gutta-percha material could successfully be detected with the help of the marks on the surgical template. The material was carefully dissected away from the surface and removed intact without causing any perforation of the sinus membrane during the intervention. A final inspection of the osteotomy sites and seals was performed, a resorbable matrix membrane (TachoSil; Takeda GmbH, Linz, Austria) was inserted to ensure stable conditions of the repositioned cortical plates of the osteotomies, and the full-thickness flap was repositioned and sutured. The postsurgical intraoral x-ray verified adequate root-end fillings of teeth #3 and #4 and confirmed the complete removal of the extruded endodontic material (Fig. 4*A*).

Analgesics (400 mg dexibuprofen, 3 times per day), oral antibiotics (1 g amoxicillin and clavulanic acid, twice daily), nasal decongestant (0.05% oxymetazoline hydrochloride, 3 times per day), and rinsing with chlorhexidine (0.2%, 3 times per day) were prescribed for 5 days. The sutures (PGA Suture 5/0; Omnia Spa, Fidenza, Italy) were removed 7 days postoperatively. There were no postoperative complications, and the healing process was uneventful.

At the 6-month follow-up the patient was clinically asymptomatic with no sensitivity to percussion and no bleeding on probing, and probing depths at all sites of teeth #3 and #4 were <3 mm.

At the 12-month follow-up a CBCT scan (Morita Veraviewepocs 3D R100; J. Morita Mfg Corp, Kyoto, Japan; voxel size 0.17 × 0.17 × 0.32 mm, 90 kV, 512 matrix) was performed to verify complete healing of the periapical lesions of tooth #3 and tooth #4 (Fig. 4*B*–4*D*).

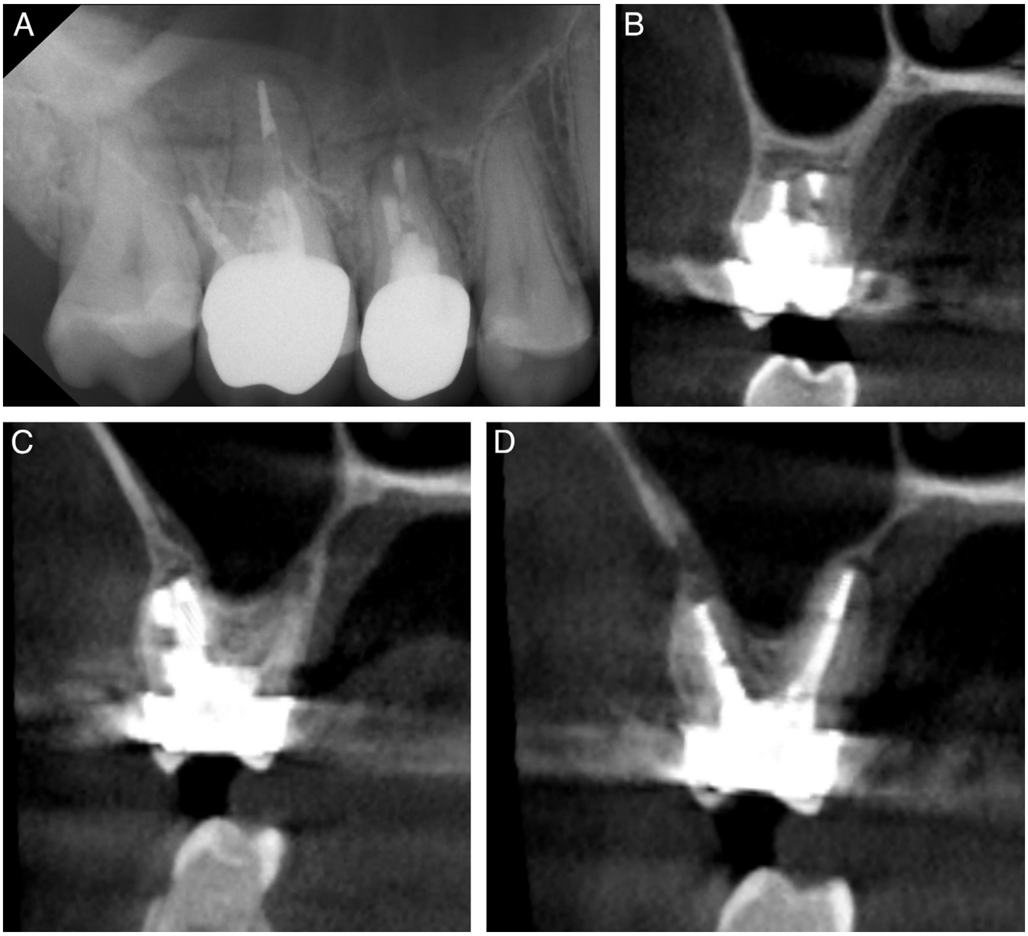

Figure 4. (*A*) Intraoral radiograph after surgical intervention presenting root-end fillings of teeth #3 and #4 and removal of extruded material. (*B*) Coronal slice of 3D radiographic assessment showing tooth #4 one year after surgical intervention. (*C*) 3D radiographic image presenting mesiobuccal root of tooth #3 one year after surgical intervention. (*D*) Coronal slice showing distobuccal root of tooth #3 one year after surgical intervention.

Discussion

Guided implant surgery using prefabricated 3D printed templates has become a common treatment option in dentistry because of its potential to reduce surgical intervention time and postoperative complications during treatment procedures (7, 8).

The currently available implant planning software programs can simplify the previously used template production techniques by shortening the fabrication process. This can be achieved directly after 3D radiographic assessment by merging the uploaded radiographic data with the 3D optical scans generated from intraoral scans or cast models. Thus, the previously required diagnostic radiographic templates that include the reference elements for the production process are no longer required for the transmission of the radiographic files for the final production of the surgical templates. This not only ensures the reduction of additional radiographic exposures for the patient but also the elimination of time-consuming steps such as the production and chairside fitting of the conventional radiographic templates (14).

The 3D planning for the production of the surgical templates is certainly costly and still time-consuming compared with conventional procedures. Because our guided endodontic surgical approach for osteotomy and root resection uses the modified software program of guided implant surgery, similar planning time and production costs compared with guided implant treatment can be expected. However, the preservation of the cortical bone and dental structures, as recommended in the guidelines for state-of-the-art endodontic surgery, could be credited as potential benefits and may justify additional planning time and costs (9, 10, 14).

As proposed in implant dentistry when selecting the approach for implementing 3D templates in complex cases, this approach could also be used in cases such as the one presented here to accomplish difficult microsurgical endodontic treatments by avoiding free hand procedures. The surgical guidance may allow for a consistently accurate and reliable access to the apex of a root by minimizing the risks of damaging vital structures (15).

The endodontic 3D template procedure has recently been introduced for orthograde access cavity preparation and root canal location with the restriction of using the technique only for anterior teeth; nevertheless, results are promising (9, 10). Our surgical approach could show that 3D printed templates can be used for the treatment of single or multiple roots with anterior or posterior location, because radiographic DICOM and optical scan files are merged to create an individual surgical template.

In contrast to the rather clumsy radiographic templates, the presented 3D printed surgical guides allow for the implementation of soft tissue in the planning, because flap design and soft tissue management can be customized to the individual patient. Depending on the required surgical location, the individually designed surgical guides can be supported by mucosa, teeth, bone, or with a combination technique (9, 10, 14). In the present case report, osteotomy and root resection were performed with the aid of bone and teeth supported surgical templates.

The method presented is based on planning software creating archives that are open architecture in format. This enabled the utilization of surgical instruments such as piezoelectric devices in our digital workflow by importing technical STL files, thus permitting their visualization within the software program for the guided surgical approach. Piezoelectric instruments were introduced in endodontic surgery to ensure integrity of root apices after root-end cavity preparation and resection (16, 17). They ensure a precise and safe approach by selective cutting of mineralized tissues such as bone and by preserving soft tissues such as blood vessels, nerves, and mucosa. Furthermore, the air-water cavitation effect provides better visibility by creating a clear and blood-free surgical field (17–19).

Within the limits of this technical report the outcome of this guided surgical approach appears to be promising; it was possible to perform guided osteotomy, apex localization, and root-end resection as planned and with adequate consideration of the recommended guidelines for modern surgical endodontic treatment. However, to confirm the reliability of this method in the future, clinical studies should be performed to prove and confirm its viability and accuracy.

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The authors deny any conflicts of interest related to this study.

Supplementary Material

Supplementary material associated with this article can be found in the online version at www.jendodon.com (http://dx.doi.org/10.1016/j.joen.2016.11.001).

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