

Targeted Endodontic Microsurgery: A Novel Approach to Anatomically Challenging Scenarios Using 3-dimensional–printed Guides and Trephine Burs—A Report of 3 Cases

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Abstract

Endodontic microsurgery (EMS) techniques have increased success rates over traditional approaches. Despite surgical advances, anatomically challenging scenarios can preclude EMS in certain cases. The aim of this article was to introduce targeted EMS, which uses 3-dimensional–printed surgical guides (3DSGs) and trephine burs to achieve single-step osteotomy, root-end resection, and biopsy in complex cases. In each of 3 cases, a 3DSG with a trephine port was printed using computer-aided design/computer-aided manufacturing implant planning software. The osteotomy site, angulation, and depth of preparation were defined preoperatively to avoid sensitive anatomic structures. The 3DSG was inserted at the target site to achieve precise osteotomy and root-end resection during surgery. A hollow trephine rotated within the 3DSG port produced single-step osteotomy, root-end resection, and biopsy. Root-end preparation and fill were accomplished, and tissues were sutured in place. Targeted EMS potentiated successful surgical treatment in 3 anatomically challenging scenarios: (1) a palatal approach to the palatal root of a maxillary second molar, (2) a facial approach to a fused distofacial-palatal root of a maxillary first molar, and (3) a mandibular second premolar in close proximity to the mental foramen. Trephine burs guided by 3DSGs produce efficient targeted osteotomies with a predictable site, angulation, and depth of preparation. Apical surgery in challenging anatomic cases such as the palatal root of the maxillary second molar, fused molar roots, and root ends in approximation to the mental nerve are possible with targeted EMS. (*J Endod* 2018; ■:1–7)

Key Words

3-dimensional printing, apical surgery, endodontic microsurgery, palatal root, surgical guide, trephine stent

Advances in endodontic microsurgery (EMS) have steadily accumulated over the past 20 years resulting in its widespread use, greater efficiency, and improved outcomes

(1). Nonsurgical root canal treatment and EMS provide viable options for dealing with irreversible pulpitis, pulp necrosis, and apical periodontitis in a majority of cases (2). EMS achieves desirable outcomes through enhanced visualization, magnification, and illumination; microsurgical instruments; ultrasonic root-end preparations; and the use of biocompatible materials (2). For EMS, a 35% increase in weighted, pooled success over antiquated techniques has been reported (1, 3).

Cone-beam computed tomographic (CBCT) imaging provides increased visualization of canal morphology, periodontal ligament and bone aberration, root resorption, and appreciation of surrounding anatomic structures (4, 5). CBCT Digital Imaging and Communications in Medicine (DICOM) files converted into stereolithography files have been used in the production of 3-dimensional–printed surgical guides (3DSGs) for implant placement (6, 7). A limited number of articles document the applications of 3-dimensional (3D) printing in endodontics for use as presurgical planning models, endodontic access guides, surgical soft tissue retraction, and localization of the osteotomy perforation site (8–12). The precision and usefulness inherent in preoperatively designed 3DSGs has yet to be fully developed and implemented in EMS.

Trephine burs have been used for the removal of failed implants and autogenous bone graft harvesting but have not previously been described in EMS (13–15). The second and third authors developed a technique (targeted EMS) that combines CBCT and computer-aided design/computer-aided manufacturing to generate 3DSGs for use with trephines. Targeted EMS produces a single-step osteotomy; root-end resection; and biopsy with a defined perforation site, angulation, depth, and diameter. Previous reports have used 3DSGs to locate an ideal bone perforation site, but none have used trephine burs within a stent to define all parameters of osteotomy and root-end resection (12, 16).

Targeted EMS Technique Overview

An 80 × 80 mm preoperative CBCT scan was required (3-D Accutomo 170; J Morita USA, Inc, Irvine, CA) and a polyvinyl siloxane (PVS) impression (Aquasil Ultra; Dentsply Caulk, Milford, DE) was made and poured. To overcome restoration-

Significance

Targeted EMS is useful for osteotomy and root-end resection when exacting control of depth, diameter, and angulation of osteotomy and root-end resection is necessary.

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associated artifacts, a digital 3D scan of the poured model, or in 1 case with minimally restored dentition a CBCT scan of the PVS impression, was made and merged with the preoperative DICOM files. Care was taken to capture the alveolus at the surgical site during impression. The cast was imaged by a benchtop scanner (3Shape D1000; Whip Mix Corp, Louisville, KY). The digital impression file was merged with the CBCT DICOM file in implant planning software (Mimics [Materialise, Leuven, Belgium] or Blue Sky Plan 3 [Blue Sky Bio, LLC, Grayslake, IL]) for the design of the surgical guide. A guide port accommodating the trephine (BIOMET 3i, LLC, Palm Beach Gardens, FL) diameter and specifying the depth of penetration, angulation, and the site of root resection was designed (Fig. 1). Guide ports had a minimum depth of 7 mm to ensure trephine stabilization as determined during *in vitro* testing. The trephine diameter was selected based on root-end width, adjacent anatomic structures, and requirements for visualization. An irrigation window was created in the guide port allowing direct access for copious sterile saline for lubrication and cooling (Fig. 1). A stereolithography file was produced and exported to a 3D printer (Objet 260 Connex3; Stratasys Ltd, Austin, TX), a 3DSG was printed, and an intimate fit was verified on the poured cast.

After soft tissue reflection, the precise fit of the 3DSG was verified. Two retractors cleared soft tissue from the trephine site. The trephine bur port itself provided added protection of the soft tissue. A 5- or 6-mm outer-diameter hollow trephine was rotated at 1200 rpm with maximum torque in an electric handpiece (Anthogyr SAS, Sallanches, France) with sterile water irrigation, incrementally cutting through the bone, root end, and soft tissue with a light pecking motion over 1 to 2 minutes depending on the depth of insertion. For root-end resection of each case, respectively, adequate depth of penetration was designed and determined when the proximal extent of the trephine cylinder was flush with the orifice of the stent guide port (case 1); a depth-defining washer was designed, printed, and placed over the shaft of the bur such that the washer pressed against the guide port limiting penetration depth (case 2); and the handpiece head touched the guide port (case 3) (Fig. 1). Trephine burs with side

venting (Figs. 1 and 2), constant copious irrigation, and a gentle pecking motion allowed for osteotomy without excessive heat generation (17).

After cutting, the trephine was removed, and a cylindrical core of bone, root end, and soft tissue was removed. The core specimen was submitted for biopsy. For brevity, the preceding steps will be referred to as “targeted EMS” hereafter. Cases were completed under a surgical operating microscope (OPMI ProErgo; Zeiss Inc, Thornwood, NY) to include ultrasonic root-end preparation and root-end filling (cases 1 and 2) with Endosequence BC Root Repair Material (Brasseler USA, Savannah, GA) (2). Tissue was reapproximated and sutured.

Case 1: Maxillary Second Molar Palatal Root

A 66-year-old American Society of Anesthesiologists (ASA) class I woman taking no medications presented with biting pain in the posterior maxilla. Approximately 1 year before evaluation, tooth #1 was extracted, tooth #2 received nonsurgical root canal treatment, and tooth #3 received retreatment for a long-standing perforation and missed second mesiofacial canal. Tooth #3 had a 9-mm probing depth at the mesiolingual and a 6-mm probing depth at the distolingual. Tooth #2 probings were all 4 mm or less. A sinus tract was present at the base of the lingual papilla between teeth #2 and 3 and traced radiographically to the palatal root of tooth #3. A second sinus tract was present overlying alveolar bone 4 mm posterior to the distal marginal ridge of tooth #2 and traced to the palatal root of tooth #2. For tooth #2, CBCT imaging revealed a $7 \times 5 \times 5$ mm low-density area at the apex of the palatal root with osseous healing at the mesiofacial and distofacial root ends compared with images from 1 year earlier. For tooth #3, CBCT imaging revealed an $8 \times 8 \times 6$ mm low-density area at the apex of the palatal root extending into the furcation, indicating failure of an attempted perforation repair with a hopeless prognosis. Tooth #2 diagnosis was previously treated with a chronic apical abscess, and the patient elected to have palatal root-end surgery in conjunction with extraction and ridge preservation of tooth #3.

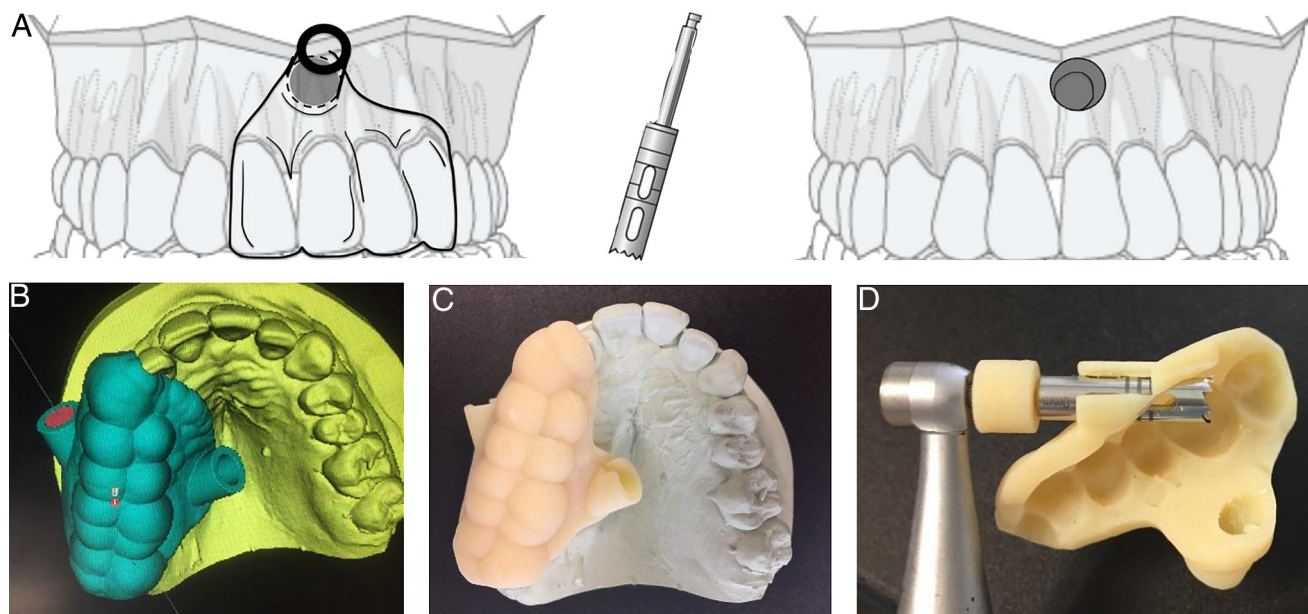


Figure 1. Targeted EMS Overview. (A) Illustration of trephine port, trephine, and resultant osteotomy. (B) 3DSG with palatal root port and facial port angulated for simultaneous resection of both MF and DF roots. (C) Printed 3DSG seated on stone model. (D) Trephine placed in port with 3D-printed washer for depth control. Depth control can also be achieved when the handpiece contacts the port or with demarcation lines on the trephine.

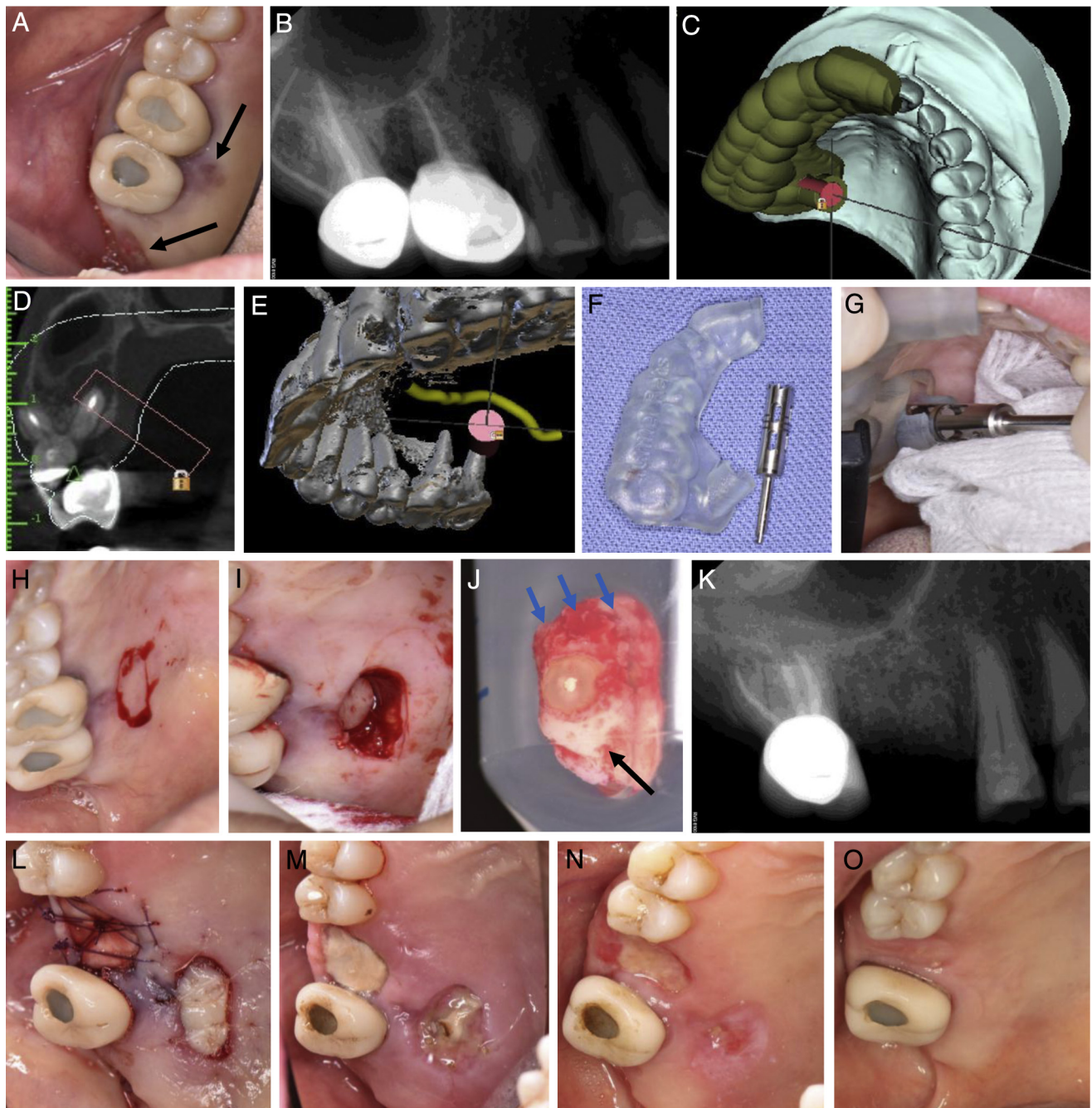


Figure 2. Tooth #2 palatal root. (A) Preoperative image with 2 sinus tracts (*black arrows*). (B) Pre-operative radiograph with gutta-percha tracing the distal sinus tract to palatal root of tooth #2. (C) 3DSG fabricated on the digital cast with trephine port designed for contralateral occlusal clearance. (D) CBCT coronal view of planned trephine path. (E) 3D view of trephine path avoiding the GPA traced in yellow from the greater palatine foramen running anteriorly (18). (F) 3DSG with custom fit trephine. (G) 3DSG with trephine inserted in port for production of bleeding points. (H) Bleeding points and subsequent incision for mucosal window. (I) Mucosal window after trephine osteotomy with core in place. (J) Core specimen with palatal cortical bone (*black arrow*), resected root end, and soft tissue (*blue arrows*). (K) Immediate postoperative radiograph. (L) Immediate postoperative image with replanted palatal mucosa. (M) One week postoperative. (N) Four weeks postoperative. (O) Three months postoperative with healed palatal tissue and sinus tracts.

A 3DSG was designed to accommodate a 6-mm outer-diameter trephine oriented to accommodate a palatal approach with clearance of the occlusal table on the contralateral side. The 3DSG prescription preserved the greater palatine artery and ensured complete resection of the palatal root, avoiding perforation of a pneumatized maxillary sinus between the facial and palatal roots.

An envelope flap with vertical release was not used in order to avoid damage to the greater palatine artery. Rather, the trephine within the

3DSG was pressed against the mucosa to create bleeding points defining the borders of a full-thickness mucosal “window” excision at the site of osteotomy. A full-thickness 8×6 mm window of palatal tissue was excised and placed in Hank’s Balanced Salt Solution (Lonza, Walkersville, MD). Targeted EMS was performed (Fig. 2). Root-end preparation and fill were accomplished as previously described. Bio-Oss (Geistlich Biomaterials, Princeton, NJ) was placed in the osteotomy for tooth #2, and the palatal tissue was replaced and secured with 6-0 Monocryl

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Plus (Ethicon US LLC, Cornelia, GA). A freeze-dried bone allograft (Stryker, Kalamazoo, MI) with an Osseoguard membrane (BIOMET 3i) was placed and secured with 4-0 Monocryl sutures (Ethicon US LLC) at the extraction socket of tooth #3. At 2 weeks, all sutures were removed. The excised palatal tissue was replaced by new mucosa at 6 weeks. A biopsy report for tooth #2 described a periapical cyst. The patient remained asymptomatic throughout a 12-week follow-up period.

Case 2: Maxillary First Molar Fused DF-palatal Root

A 39-year-old ASA 1 woman taking no medications presented with left maxillary posterior biting pain of several months duration. Teeth #14 and 15 received root canal treatment several years prior. Clinical examination revealed probings all 4 mm or less for teeth #11 to 15. Teeth #12 and 13 had short cold responses, no percussion or palpation tenderness, and physiologic mobility. Teeth #14 and 15 had no cold

response, no percussion or palpation tenderness, and physiologic mobility. Tooth #15 had biting pain with Tooth Slooth (Patterson Dental Supply, Inc, St. Paul, MN) over all cusps reproducing the patient's chief complaint. CBCT imaging and radiographic examination revealed root canal treatment of tooth #14 with 3 canals obturated with a 1-mm palatal root overfill and a $7 \times 2 \times 1$ mm low-density area associated with the apex of a fused DF and palatal root. Tooth #15 had little coronal tooth structure remaining with prior mesial perforation of the MF root and an $8 \times 8 \times 6$ mm low-density area or "halo" radiolucency extending coronally on the mesial to a site of previous perforation near the osseous crest. Diagnosis for tooth #14 was previously treated with asymptomatic apical periodontitis, and after discussion of treatment alternatives, the patient elected to have apical surgery addressing the fused DF and palatal root. Diagnosis for tooth #15 was previously treated with symptomatic apical periodontitis, likely vertical root fracture, with a hopeless long-term prognosis, and the patient elected to receive extraction.

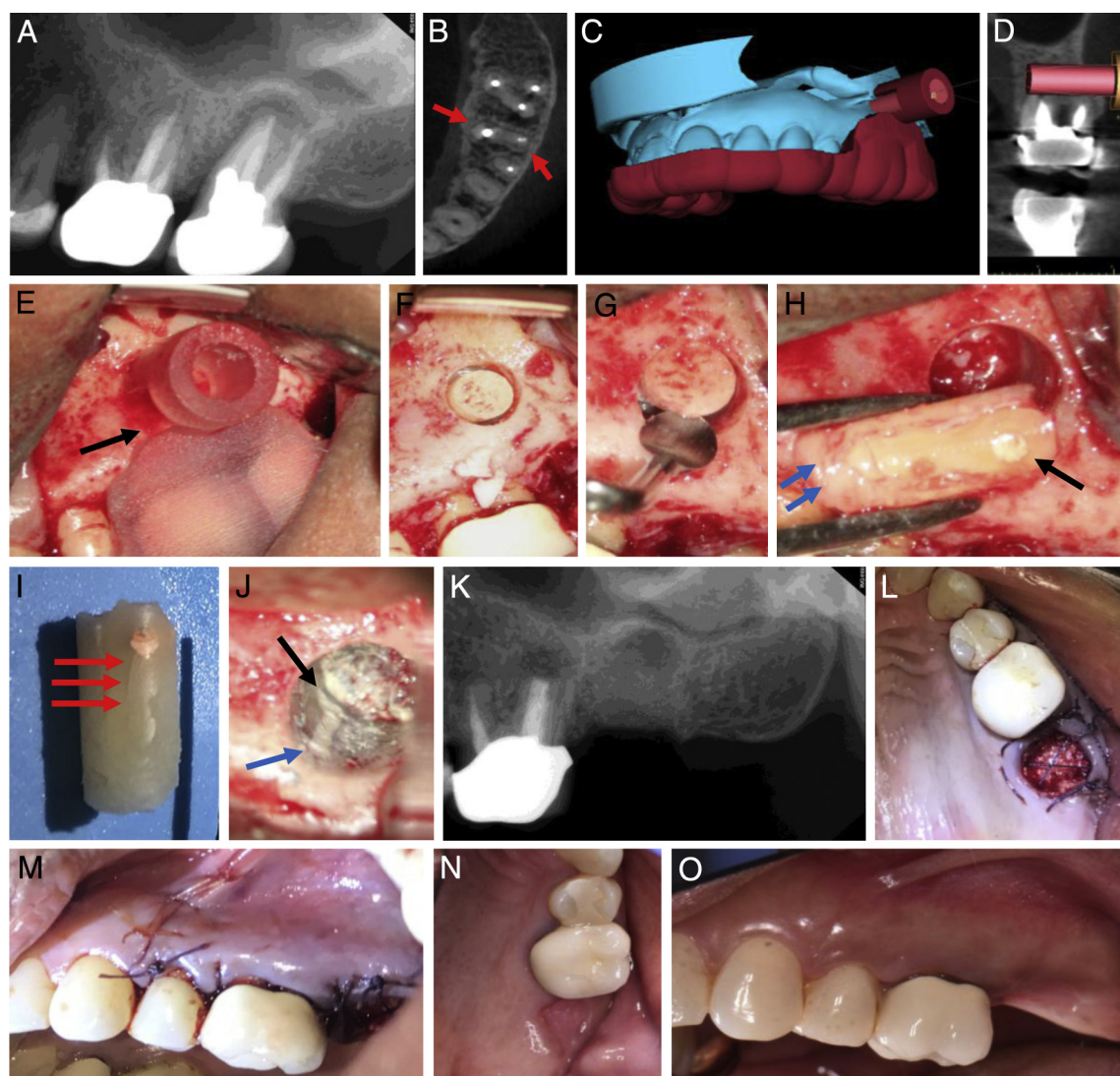


Figure 3. Tooth #14 fused DF-palatal root. (A) Preoperative radiograph. (B) CBCT axial view with fused DF/palatal root and isthmus tooth #14. (C) 3DSG fabricated on digital cast. (D) CBCT coronal view with planned trephine path. (E) Inserted 3DSG after full-thickness flap with trephine port defining osteotomy and irrigation window (*black arrow*). (F) Core prior to elevation. (G) Core elevation. (H) Core removed, revealing facial cortical bone (*blue arrows*), fused DF-palatal root end with palatal canal GP (*black arrow*). (I) Core specimen with undebrided DF canal and isthmus (*red arrows*) (J) Fill of DF canal (*blue arrow*), palatal canal (*black arrow*) and isthmus. (K) Immediate postoperative radiograph. (L) Immediate postoperative occlusal view. (M) Immediate postoperative facial view. (N, O) One month postoperative images.

A PVS impression of the maxillary arch was made. A 3DSG was designed to accommodate a 5-mm outer-diameter trephine at the angulation required to remove the fused DF-palatal root end with an insertion depth of 11 mm from the facial cortical plate. The surgery was performed under intravenous sedation. A full-thickness mucoperiosteal flap was elevated, and the surgical guide was inserted. Targeted EMS was performed (Fig. 3). Retrograde fill of 1 canal and a previously undebried 6-mm isthmus was accomplished as previously described. Tooth #15 was extracted, and Bio-Oss Collagen (Geistlich Biomaterials, Princeton, NJ) was placed within the socket and the osteotomy before suturing with 4-0 Vicryl (Ethicon US LLC) and 4-0 Chromic Gut sutures (Ethicon US LLC). A biopsy report described a periapical cyst. The patient was asymptomatic at 1 week and 1 -month.

Case 3: Mandibular Second Premolar

A 23-year-old ASA I man taking no medications presented with pain upon biting in the mandibular left posterior. Eleven years prior, tooth #20 received immediate apexification treating pulp necrosis associated with dens evaginatus. Teeth #18 to 21 all had probings less than 3 mm. Teeth #18, 19, and 21 were unrestored and had short cold responses, no percussion or palpation tenderness, and physiologic mobility. Tooth #20 had a porcelain crown with adequate margins, no cold response, moderate percussion tenderness, no palpation tenderness, and physiologic mobility. Radiographic and CBCT imaging revealed a $2 \times 2 \times 2$ mm low-density area at the apex of tooth #20, which was 2.0 mm superior to the mental foramen. Diagnosis for tooth

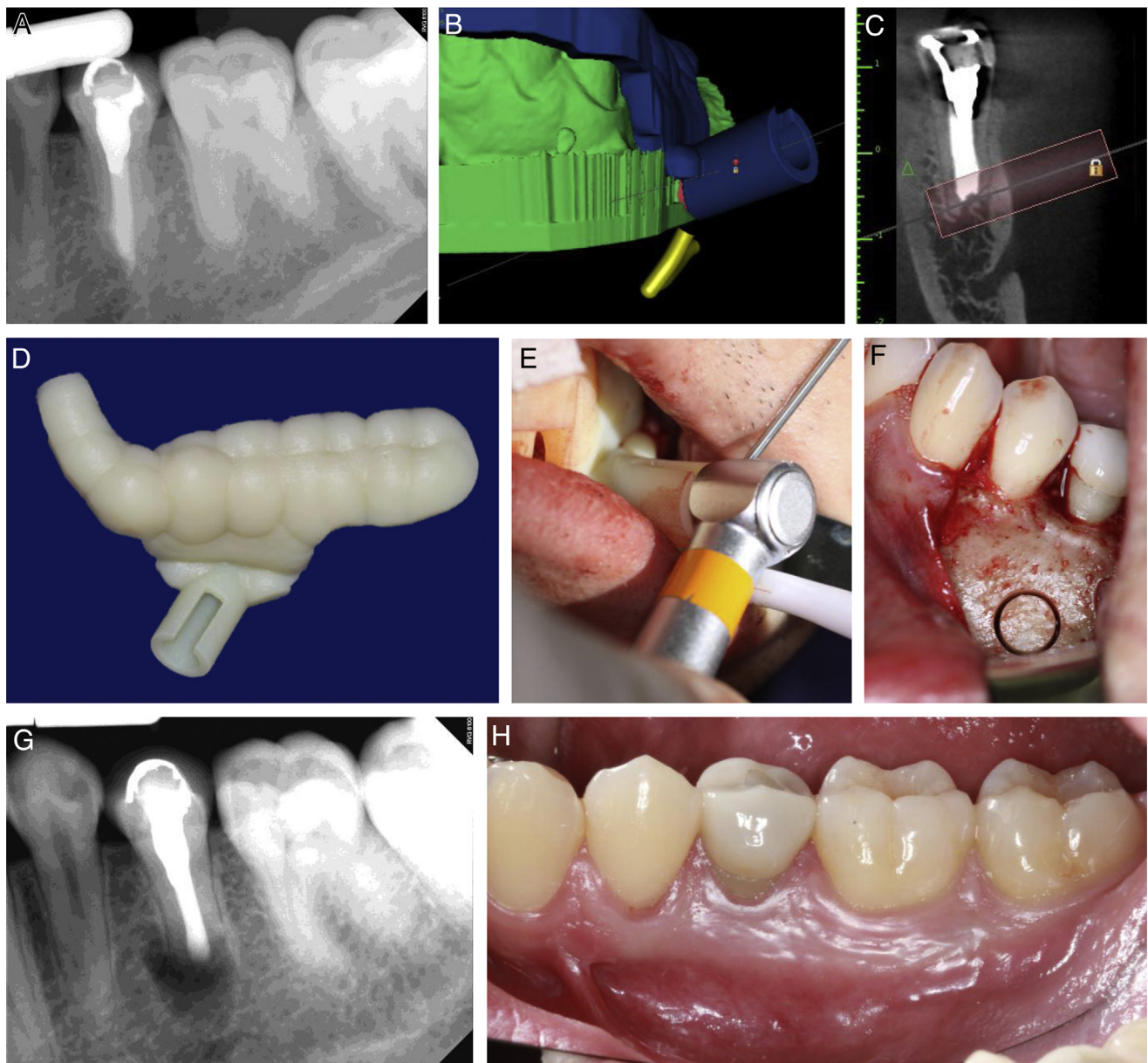


Figure 4. Tooth #20 (A) Preoperative radiograph. (B) 3DSG fabricated on the digital cast with trephine port designed to avoid the mental nerve traced in yellow. (C) CBCT coronal view with trephine path 1.5 mm from mental nerve exit. (D) 3DSG with guide port irrigation window. (E) Inserted 3DSG providing lip retraction. Osteotomy termination was reached when the handpiece touched the guide port. (F) Bone, root end, and soft tissue core prior to elevation. (G) Immediate postoperative radiograph. (H) 2-month postoperative image.

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#20 was previously treated with symptomatic apical periodontitis, and the patient elected to have targeted EMS.

A PVS impression was imaged with a CBCT system, and resultant files were merged with preoperative CBCT imaging. A 3DSG was designed with the trephine port in a posture that would avoid trauma to the mental nerve. The surgery was performed under oral sedation. A full-thickness mucoperiosteal flap was reflected without visualization of the mental nerve. Targeted EMS was performed (Fig. 4). Root-end inspection revealed serviceable white material consistent with tricalcium silicate cement, and no further root-end manipulation was conducted. The site was closed with 4-0 Vicryl and 5-0 Chromic Gut sutures. A biopsy report described a periapical granuloma. At 1 week, the otherwise asymptomatic patient reported dysesthesia of the lower left lip to the midline for which he received a Medrol Dosepak (Pfizer, New York, NY). At 1 month, the dysesthesia resolved, and the patient was asymptomatic.

Discussion

These cases illustrate the clinical simplicity and merit of targeted EMS in the treatment of anatomically complex scenarios involving the maxillary sinus, greater palatine artery, posterior dental arch location, mental nerve, and fused roots (18, 19). *In vitro*, freehand osteotomy produced 3-mm initial perforation deviations 22% of the time compared with more accurate 3DSG osteotomy (16). Case 1 used a flapless mucosal window and was closed with tissue replantation to optimize healing and patient comfort. The 3DSG ensured the greater palatine artery, which coursed near the surgical site, was preserved (18). The palatal tissue was replaced over the surgical site for patient comfort during anticipated healing by secondary intention. It is uncertain whether peripheral areas of the replanted tissue remained vital surrounding a central area of necrosis or if healing was completely by secondary intention. In case 2, the 3DSG enabled an accurate 11-mm osteotomy depth for resection of the fused DF-palatal root. For case 3, the 3DSG ensured preservation of the mental nerve, which exited 2 mm apical to the trephine path. Simplification of surgical steps through targeted EMS may increase the clinical prevalence of apical surgery overall. Minimally invasive surgical concepts with improved patient-centered outcomes may develop as 3DSG applications are refined. In the future, mandibular second molars that would benefit from EMS with thick facial bone and challenging surgical access may receive obturation with biologically optimal materials followed by targeted EMS. During targeted EMS, bone can be removed from the resected core and placed as an autogenous graft. A current research collaboration is investigating the nature and relationship of bone, root end, and soft tissue within targeted EMS core specimens.

Limiting factors must be overcome before specialty-wide use of targeted EMS, which requires CBCT imaging, computer-aided design/computer-aided manufacturing software, and 3D printing capability. Most endodontic practices currently have CBCT resources available (20). Surgical phase simplification is achieved and time is reduced, but preoperative preparation requires technical expertise, equipment, and software for merging files and designing and printing 3DSGs. Polymer-based computer-aided manufacturing applications are steadily increasing, and affordable benchtop printers are now available (21). Current research is underway testing the usefulness of affordable benchtop 3D printers that may be deployed in individual endodontic practices. Alternatively, commercial 3D printing laboratories with expertise in implant surgical guide fabrication may be leveraged to fabricate targeted EMS 3DSGs. Regardless of where a 3DSG is designed and printed, the clinician is ultimately responsible

for the prescription. Before undertaking targeted EMS, it is imperative that clinicians are cognizant of measures necessary to ensure proper fit and design of the 3DSG, prevent thermal injury to bone, and preserve surrounding soft tissues and sensitive anatomic structures. Long-term investigations of patient-centered outcomes of targeted EMS are warranted.

Conclusion

In these 3 cases, targeted EMS produced an osteotomy site with predictable angulation, diameter, and depth. Targeted EMS could prove to be an important breakthrough allowing precision-guided surgery in anatomically complex areas for teeth that may have otherwise required extraction. Investing time and resources developing technological and clinical expertise within the specialty will place clinical endodontics astride other dental specialties leveraging 3DSGs.

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