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Targeted Endodontic Microsurgery of a Mandibular First Molar with a Separated Instrument Using the 3D-printed Guide and Trephine Bur: A Case Report with a 2-year Follow-up

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ABSTRACT

Endodontic microsurgery (EMS) is a specific treatment modality that targets the root apex of infected teeth that have not been healed by traditional root canal treatments. Recently, the use of advanced three-dimensional (3D) reconstruction technology, such as cone beam computed tomography (CBCT), has improved diagnosis and treatment in dentistry. However, locating the root apex accurately using this technology can be challenging. Also, traditional surgical methods often require significant bone removal which usually results in prolonged surgery and increased risk of trauma and infection. This article introduces the concept of targeted EMS using the 3D-printed surgical guide and a trephine bur to perform single-step osteotomy and root-end resection in complex cases. The surgical guide was designed using a computer-aided planning software to ensure precise angulations and depths of preparation while avoiding critical anatomy regions. The use of the trephine bur enabled efficient and accurate targeted osteotomy regarding the site, angulation, and depth of preparation. This case report describes the use of the 3D-printed guide and the trephine bur to accurately perform EMS of a mandibular first molar with a separated instrument and periapical lesions.

Keywords: 3D-printed guide, apicoectomy, cone-beam computed tomography, micro-surgery, trephine bur

HIGHLIGHTS

- The 3D-printed guide in EMS offers a conservative technique for cases unresponsive to conventional root canal therapy.
- The surgical guide plays a crucial role in ensuring predictability in the osteotomy site's angulation site, diameter, and depth.
- Targeted EMS is a viable option for complicated cases like such as those with separated instruments management when EMS is indicated.

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INTRODUCTION

Endodontic microsurgery (EMS) is a treatment modality for infected teeth that have not responded to conventional root canal treatments (RCTs). The procedure often involves removal of bone to locate the root apex of the infected tooth and to remove any pathological tissues. This is followed by root-end resection, retrograde cavity preparation and root-end filling materials application, then the surgical site is closed with sutures. A minimum depth of 3 mm of root-end preparation is necessary to effectively seal any accessory canals that may present (1).

Over the past two decades, there have been significant developments in EMS, leading to its widespread use, increased efficiency, and improved outcomes (2). EMS achieves these favourable results through improved visualization, magnification, illumination, specialized microsurgical instruments, ultrasonic root-end preparations, and the use of biocompatible materials, especially those induce bone healing (3). Success rates of endodontic surgery, particularly root-end resection, have been found to vary widely in the literature, ranging from 17% to 96% (4). Reports indicate a 35% increase in success rates with EMS compared to traditional techniques (5). This variability is likely due to the sensitivity of these procedures. However, a meta-analysis has suggested that the use of high-powered magnification alone can significantly increase the success rate of EMS to as high as 94% (4).

Localization of the root apex and assessment of the access site for treatment have previously been limited to the use of two-dimensional (2D) radiography such as periapical or panoramic radiographs, unless there was a presence of fistula which allows tracking the origin of the apical pathology. However, the advancement of three-dimensional (3D) imaging, especially using cone beam computed tomography (CBCT), has significantly enhanced the accuracy of diagnosis and treatment planning (6). CBCT imaging has improved visualization of various structures such as root-canals morphologies, tooth abnormality, roots' resorptions, and surrounding anatomic structures (7, 8).

Despite this significant improvement in 3D imaging, locating the root apex is still challenging and usually requires removal of a significant amount of bone during the surgery. Additionally, this often requires gingival flap and alveolar bone fenestration, leading to prolonged surgery and increases the risk of trauma and infection (9). CBCT is commonly used in modern implant dentistry for 3D planning and creating surgical guides, especially with advancements in computer-aided design (CAD) and computer-aided manufacturing (CAM) software, as well as the use of intra oral scanners and 3D printers.

Using 3D software for pre-surgical implant planning reduces damages to surrounding roots or important structures and enables more accurate placement of the implant based on the available bone volume. Studies have shown that guided implantation is more precise than traditional freehand insertion (10, 11). The 3D software used for pre-surgical implant planning can also be applied in EMS procedures, as it allows less damage to the surrounding structure and accurately determining the location of the affected area. Therefore, it can provide better control and more accurate drilling position and depths, hence, to avoid critical anatomy structures (12, 13).

Recent case reports have revealed that employing guide templates in EMS is a valuable approach for treating obstructed canals which were inaccessible with conventional RCTs. This method becomes particularly beneficial in cases where tracking the position of root apices is challenging due to the absence of a fistula. The precise placement of the guide allows clinicians to execute a targeted surgical incision, promoting smoother healing and reducing overall procedure time (12, 13). In this case report, the use of the 3D-printed guide and trephine burs in EMS to precisely locate the root-ends of a mandibular first molar with a separated instrument in the mesial root and periapical lesion have been described.

CASE PRESENTATION

Diagnosis

A 43-year-old female patient had been complaining of pain on chewing in her mandibular left first molar (tooth No.36) indicating a symptomatic apical periodontitis. The diagnostic periapical radiograph revealed that the tooth had a defective RCT, a cast post, a porcelain fused metal crown and a separated instrument with periapical lesions (Fig. 1a). Taking into consideration these points, which will be discussed in details later, the non-surgical and surgical treatment options (EMS and reimplantation) were discussed with the patient, and the EMS was agreed on. A CBCT scan was taken by the PaX-i3D Green system (Vatech, South Korea) (FOV Size: 12×9 cm, Voxel Size: 0.3 mm, Tube Voltage/Current: 50–90 kVp/ 4–10 mA) which revealed apical radiolucency around the mesial and distal roots without buccal bone damage (Fig. 1b-d). Since traditional root-end resection would involve significant removal of the surrounding bone, an alternative approach of minimally invasive targeted EMS using the 3D-printed guide was suggested and agreed on.

Planning Procedures

An impression for the patient's mandibular teeth using the vinyl polysiloxane material (VPM) (additional silicone) was taken. The cast was scanned into a digital format using a desktop 3D scanner (Medit, Seoul, Korea) which was exported to stereolithography (STL) files. Both the digital data and the CBCT images were imported into the implant planning software Blue Sky Plan (Blue Sky Bio, Langenhagen, Germany) to produce a virtual 3D model of the surgical guide (Fig. 2a). The surgical guide was designed in such a way that allows a special trephine bur (cylindrical shape and a sharp cutting edge with a 5mm diameter) (Komet Dental, Germany) to reach the apex of the mesial and the distal roots taking into consideration the lesion dimensions. The position and direction of the trephine bur were determined to accurately reach and remove the roots apices with minimum depths (4 mm) and diameters (5 mm) of the bone penetration (Fig. 2b, c). The final virtual design was checked to ensure that the drill would accurately reach the target without damaging the surrounding structures (Fig. 2d). An STL file was produced and was exported to the Peopoly Moai Laser SLA 3D printer (Peopoly, Los Angeles, CA, USA) to create the surgical guide using a poly lactic acid material.

Surgical Procedures

The patient had been instructed to take Ibuprofen (400 mg) one hour before the surgery. Prior to initiating the surgery, the surgical guide was placed on the mandibular posterior region to verify its proper fit and to insure its good adaptation. All the surgical procedures were performed under the magnification of Zumax OMS2350 dental operating microscope (Zumax Medical Co, Ltd, Jiangsu, China). After local anaesthetic administration (2% lidocaine with epinephrine 1:80,000; Huons, Seongnam, Korea), the surgical site was punched with a probe to mark the surgical incision line (Fig. 3a). The Luebke-Oschenbein flap was performed for minimal invasive EMS (Fig. 3b). The surgical guide was placed back in direct contact with the bone to confirm its correct position and stability (Fig. 3c). An osteotomy of 4

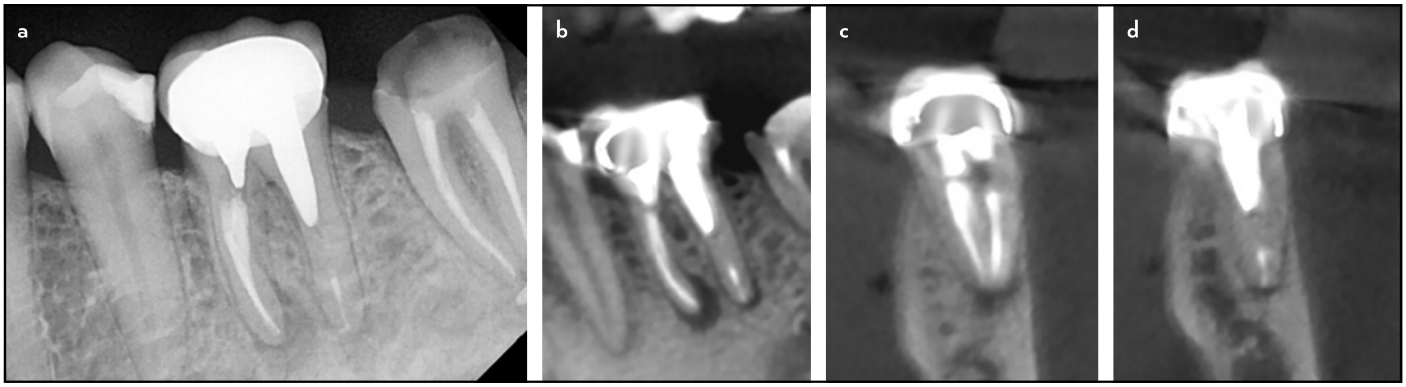

Figure 1. (a) Pre-surgical periapical radiograph. (b) Sagittal view of the pre-operative CBCT scan. (c, d) Coronal views of the pre-surgical CBCT scan of the mesial and the distal roots, respectively

CBCT: Cone beam computed tomography

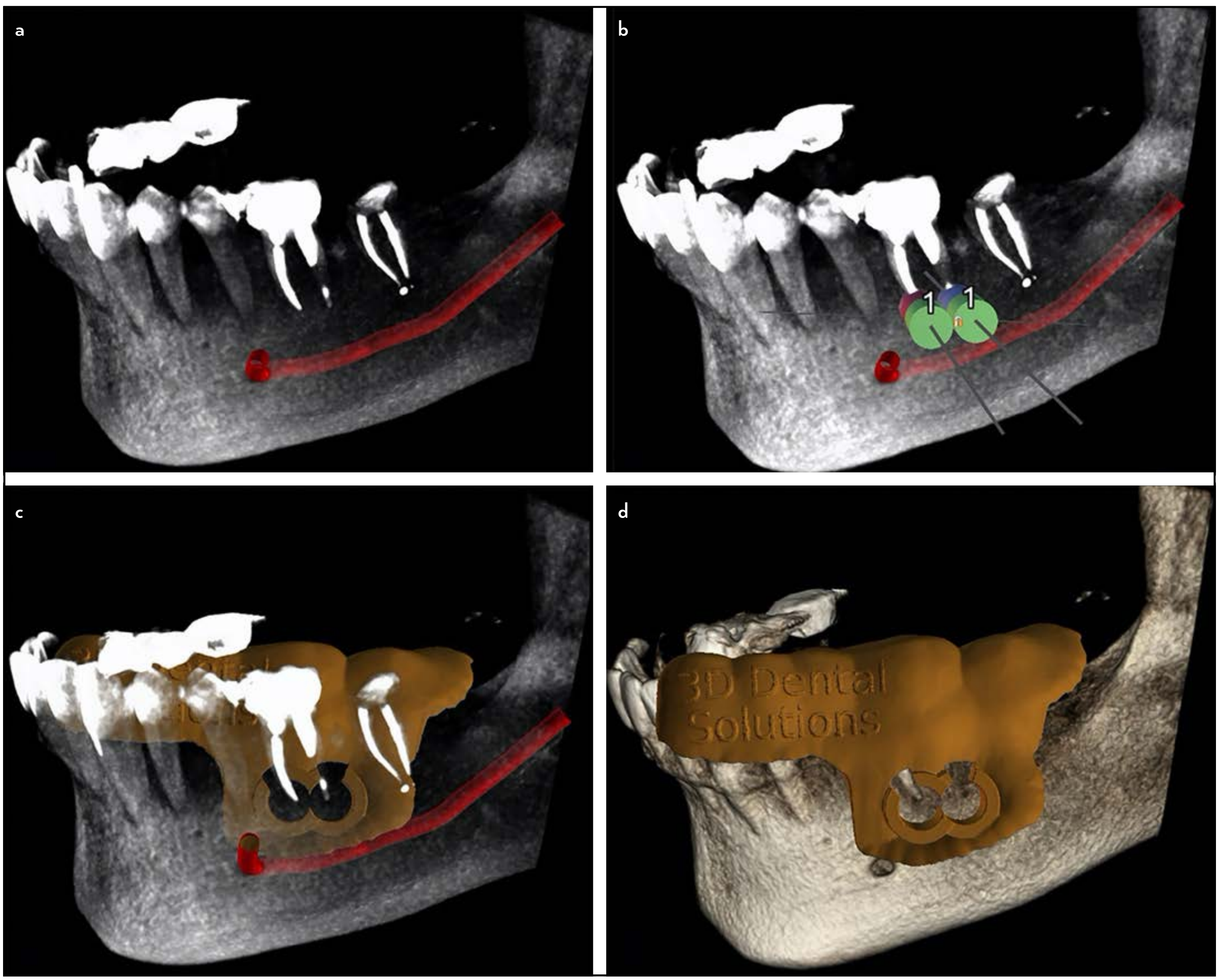

Figure 2. (a) The 3D planning view in Blue Sky Bio software. (b, c) The position and direction of the trephine bur were determined to accurately reach the root apex with a depth (4 mm) and a diameter (5 mm) of the bone. (d) The pre-printed final design was checked to ensure that the drill would accurately reach the target without damaging the adjacent structures

mm depth was performed on the mesial and distal roots using the 5 mm diameter trephine bur (Komet Dental, Germany), utilizing the Surgic Pro surgical motor (NSK, Tokyo, Japan) rotating at 1000rpm with copious saline irrigation (Fig. 3d, e). During the osteotomy, the apical part of the separated instrument in the mesial root was removed (Fig. 3f). The remnants of the peri-

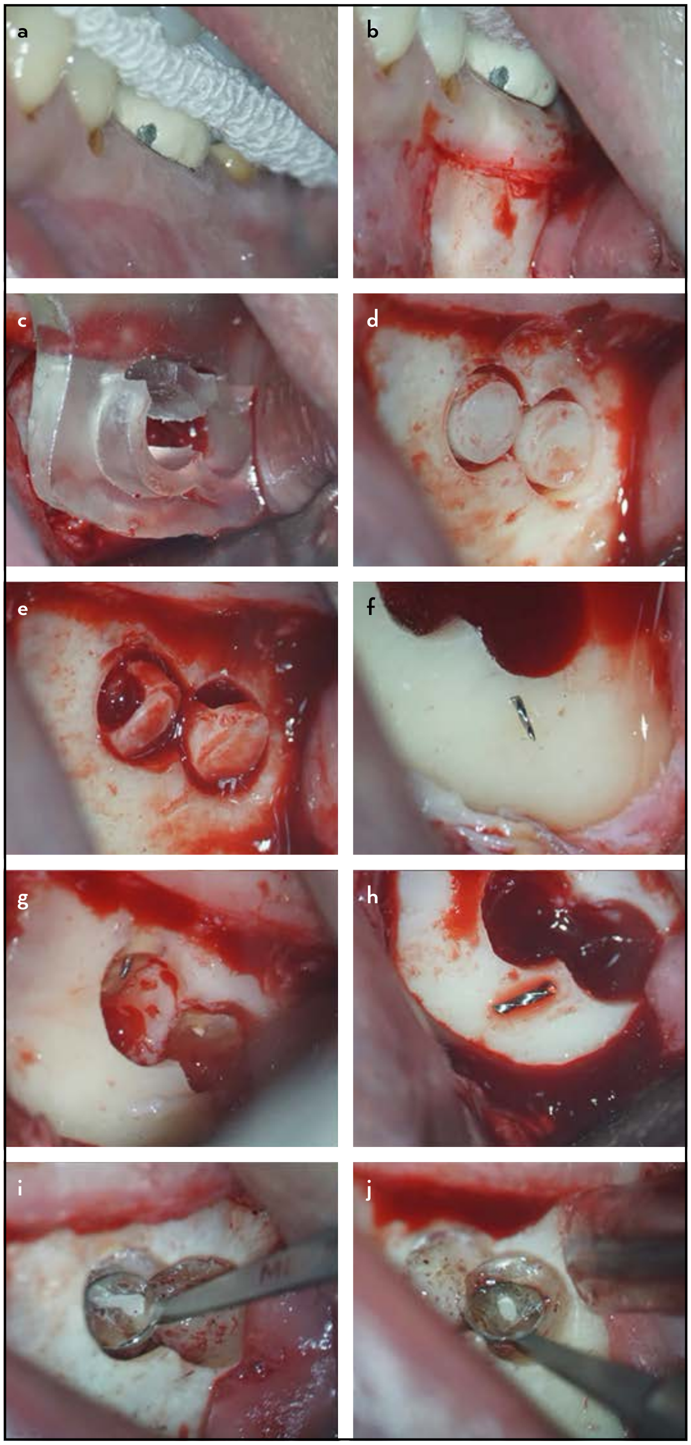

Figure 3. Surgical procedures: (a) Clinical view after local anaesthesia. (b) A Luebke-Oschenbein flap for minimal invasive EMS. (c) The surgical guide in direct contact with the bone to confirm its fitting and stability. (d, e) The osteotomy was performed with a 5 mm of diameter trephine bur. (f) The apical part of the separated instrument was removed. (g) The apical part of the roots was resected with a high-speed diamond bur. (h) The remaining separated instrument in the mesial root was removed by the ET25 ultrasonic endodontic tip. (i, j) Bioceramic Root Repair Material Putty was used as a root-end filling material

apical lesions were removed and the roots-ends of the mesial and distal roots were resected with a high-speed diamond bur using the Ti-Max X450 highspeed surgical handpiece (NSK, Tokyo, Japan) (Fig. 3g). The remaining separated instrument in the mesial root was removed by the ultrasonic vibration technique using the ET25 ultrasonic tip (Satelec, Merignac, France) which was activated at power-settings of 8 (out of 20) with irrigation by the P5 Booster Neutron ultrasonic unit (Satelec, Merignac, France) (3 seconds per an activation stroke) (Fig. 3h).

After removing all inflammatory tissues, the resected roots surfaces were stained with methylene blue and were inspected carefully with micro-mirrors under ×20 magnification to detect the canals' spaces, isthmus and cracks, if any. The root-end cavities were prepared using a diamond surgical ultrasonic tip (ProUltra; Dentsply Tulsa Dental, Tulsa, OK, USA) which was activated at medium power-settings (10 out of 20) with irrigation and for 5 seconds per an activation stroke. The Bioceramic Root Repair Material Putty (EndoSequence, Brasseler, USA) was used as a root-end filling material (Fig. 3i, j). Following a post-operative periapical radiograph, the wound site was sutured with a 4–0 monofilament nylon suture. The entire surgery took around 45 minutes. An antibiotic was prescribed for 5 days (Amoxicillin with clavulanic acid 1000 mg 500 mg q8h) as part of the clinic protocol in such cases and according to the European Society of Endodontology guidelines (14).

The surgical sutures were removed after 10 days, and the clinical symptom disappeared after 3 weeks. Periapical radiographs and CBCT scans were taken for periodical follow-ups (Fig. 4a-d), as the patient had routine visits scheduled every six months to follow-up the healing progress. The two-year radiographic and clinical follow-ups showed healing of the periapical lesion and the tooth was asymptomatic on percussion as well as on palpation (Fig. 4e-h), (Fig. 5a- c).

DISCUSSION

Research related to EMS indicates that contemporary microsurgical approaches have considerably higher success rates compared to traditional methods (2, 15). Studies have shown that targeted EMS is effective and more precise than freehand surgery regarding roots ends localization and resection (16, 17). Locating the root apex accurately offers several advantages. It reduces the need for unnecessary surgical exploration and minimizes the risk of iatrogenic damage to adjacent roots and critical anatomical structures (the mental nerve, the inferior alveolar nerve, and the maxillary sinus) (16). In addition, more cortical bone is preserved leading to a shorter surgical time. Hence, adoption of the guided surgery to minimize the osteotomy size has the potential to enhance the healing process (17).

However, there are limited research and case reports in this respect, particularly regarding complex cases involved with separated instruments. Bordone et al. (18) described a customed guide in separated instrument management through access cavity. The 3D-printed guide was designed with a tube to guide a trephine for achieving a straight-line access towards the broken instrument. Following the drilling process, the instrument was extracted using the Zumax removal kit (Zumax Medical Co. Ltd., Suzhou, China), then a conventional RCT was done. Sudha et al. (19) and Langaliya et al. (20) reported the use of a customized 3D-printed guide for management of over-extruded sep-

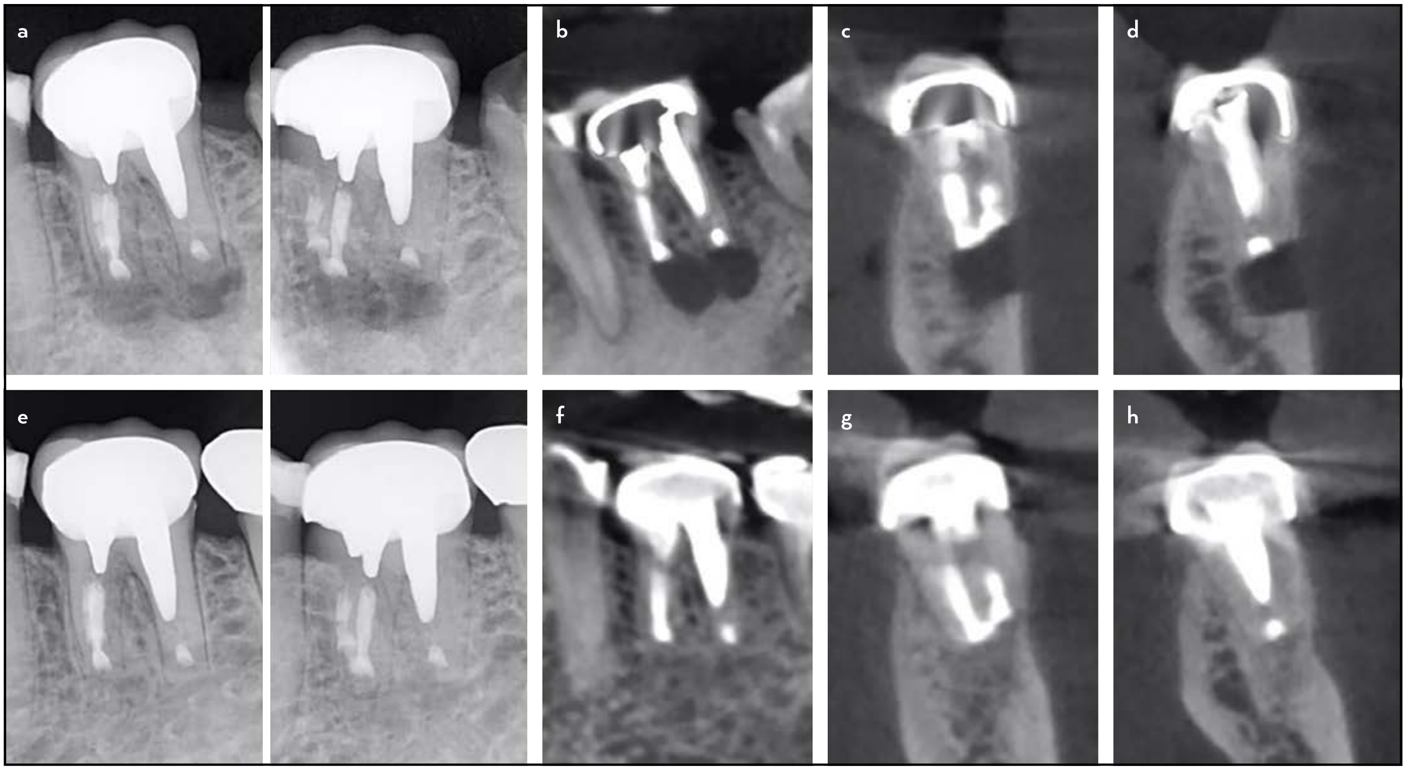

Figure 4. (a) Post-surgical periapical radiographs. (b) Sagittal view of the post-surgical CBCT scan. (c, d) Coronal views of the post-surgical CBCT scan of the mesial and the distal root, respectively. (e) Periapical radiographs upon the 2-year follow-up. (f) Sagittal view of CBCT scan upon the 2-year follow-up. (g, h) Coronal views of CBCT scan upon the 2-year follow-up of the mesial and the distal roots, respectively

CBCT: Cone beam computed tomography

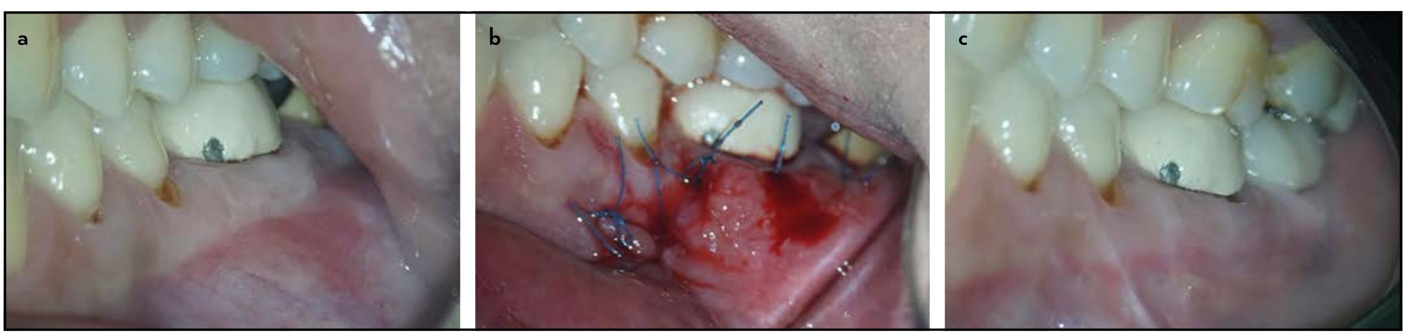

Figure 5. (a) Pre-surgical intra-oral view. (b) Post-surgical intra-oral view (c) A 2-year follow-up intra-oral view shows normal oral mucosa

arated instruments. The guide was placed intraorally to assist locating the precise osteotomy site for instruments retrieval surgically, followed by a conventional RCT without performing apicoectomy or root-end filling. In these two reports, there were no coronal obstructions preventing access to the separated instrument site. Hence, attempts to manage separated instruments, especially removal, using traditional orthograde approaches such as endodontic ultrasonic vibration techniques, loop techniques and extractors under microscopic magnification were feasible. It could be also argued that exposing the teeth to surgery that could be treated non-surgically is usually neither indicated nor necessary. More importantly, both reports were about management of separated instruments that were only extruded beyond the apex without performing root ends resection. Consequently, this approach, particularly with the fact that neither retrograde cavity was prepared nor apical seal with a filling material inducing healing was inserted, could have jeopardized the cases outcome (21). This is especially true in cases associated with periapical lesions.

To our knowledge, the current case report is the first report that describes the removal of separated instruments by endodontic microsurgery, including apicoectomy, using the 3D-printed guide and trephine burs. This innovative approach allows a single-step process that includes osteotomy, root-end resection and separated instrument retrieval with precise control over the perforation site, angulation, depth, and diameter of preparation.

The tooth in the presented case had been restored with a metal cast post and a porcelain fused to metal (PFM) crown. These obstacles made the conservative treatment approach complicated. Attempting to remove the metal post may compromise the structural integrity of the tooth, potentially leading to fracture or weakening of the remaining tooth structure (22). Moreover, the removal process itself may be challenging and retreatment procedures may necessitate multi-visits and can take longer time compared to the single visit surgery. In addition, the crown margins were well adapted. Although intentional reimplantation presents an alternative surgical solution, it may pose few drawbacks including potential damage to adjacent teeth, risk of infection, ankylosis and compromised long-term prognosis due to the trauma associated with tooth extraction and reinsertion (23). Hence, EMS intervention is advantageous for preserving the integrity of the tooth structure, particularly as guided EMS has been the preferred surgical approach. The Blue Sky Plan implant planning software has been primarily utilized in implant dentistry for 3D planning and designing surgical guides. However, its application has extended into EMS in the current report. The radiographic and optical scan files were combined to produce a virtual 3D model of the surgical guide (Fig. 2a). We also chose the concept of using the trephine bur in EMS which is a specialized rotary instrument with a cylindrical shape and a sharp cutting edge. The use of the trephine bur in conjunction with the 3D dental guides allows for a minimally invasive approach for bone removal, while still providing adequate access to the surgical site (12).

The targeted EMS offers several benefits over the conventional approach, such as precise location of the root apex with minimal invasive access, reduced surgery time and favourable postoperative healing (12). In addition, the targeted EMS is a predictable technique, hence the EMS is planned well before execution, which reduces the incidence of complications and saves operation time (3, 12, 24). By contrast, conventional root-end resection poses a significant risk on critical anatomical structures (the inferior alveolar nerve, the mental nerve, adjacent roots and the maxillary sinus). On the other hand, using the 3D-printed guide during EMS can significantly reduce these risks (25). Pinsky et al. (6) found that unlike the freehand surgery which had greater than 3 mm error rate in 22% of cases, surgical guides enabled greater accuracy without damaging adjacent structures. Moreover, studies have also demonstrated that the use of guide templates in endodontic procedures lead to improved accuracy, reduced patients' discomfort and saved surgeries time (24). Nevertheless, targeted EMS requires access to CBCT imaging, CAD and CAM software, and the 3D printing technology, which are considered as main limitations (26). Additional limitations could be summarized as: anatomical variability, limited operation access, the need for special training and good surgical skills, cost and laboratory errors (26). It is important to indicate that the accuracy of the 3D-printed guide usually can be affected by the accuracy of the radiographs, optical oral scanning and the impression process. For example, the presence of bubbles in the impression material can reduce the accuracy of the guide which may pose a high risk during surgical intervention, particularly in critical anatomical areas (25, 26). Good impression materials, such as silicone materials, can enhance the accuracy of the guide (26). Recently, intra-oral scanners offer many advantages over traditional impression techniques including increased accuracy, efficiency, patient comfort and reduced material waste. In addition, they create highly detailed digital impressions which can be easily shared with dental laboratories in digital format (27, 28). Therefore, implementing such advancements can improve the effectiveness of targeted EMS, and it will be interesting to investigate their impact on the long-term treatments' outcomes.

Utilizing the 3D-guided technology in medical and dental surgeries is promising and encourages its adoption in EMS, particularly in challenging anatomical areas (12). Despite the need for comprehensive preoperative planning, the actual surgical procedures are more precise and can be performed in a shorter time. Nevertheless, future research, especially large-scale randomized clinical trials, is paramount to evaluate the effectiveness and advantages of this approach compared to routine EMS.

CONCLUSION

The use of the 3D-printed guide in EMS is a valuable technique for cases that cannot be treated with conventional root canal therapy. In instances where the position of the apex is close to critical anatomy structures, the surgical guide serves to pilot the osteotomy site with a predictable angulation, diameter, and depth. In addition, the use of the surgical guide is considered a more conservative approach in cases in which root-end apices cannot be tracked by a fistula. This case report suggested the targeted EMS as a viable option for root-end resection in complicated cases such as separated instruments. However, future research about its impact on the long-term success is necessary.

Disclosures

Informed consent: Written informed consent was obtained from the patient for the publication of the case report and the accompanying images.

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