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Case Report

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A new minimally invasive guided endodontic microsurgery by cone beam computed tomography and 3-dimensional printing technology

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ABSTRACT

Endodontic microsurgery is defined as the treatment performed on the root apices of an infected tooth, which was unresolved with conventional root canal therapy. Recently, the advanced technology in 3-dimensional model reconstruction based on computed tomography such as cone beam computed tomography has opened a new avenue in application of personalized, accurate diagnosis and has been increasingly used in the field of dentistry. Nevertheless, direct intra-oral localization of root apex based on the 3-dimensional information is extremely difficult and significant amount of bone removal is inevitable when freehand surgical procedure was employed. Moreover, gingival flap and alveolar bone fenestration are usually required, which leads to prolonged time of surgery, thereby increasing the chance of trauma as well as the risk of infection. The purpose of this case report is to present endodontic microsurgery using the guide template that can accurately target the position of apex for the treatment of an anterior tooth with calcified canal which was untreatable with conventional root canal therapy and unable to track the position of the apex due to the absence of fistula.

Keywords: Apicoectomy; Cone-beam computed tomography; Endodontic surgery; Surgical guide; Three-dimensional printing

INTRODUCTION

Endodontic microsurgery is, in its broadest sense, defined as the treatment performed on the root apices of an infected tooth, which was unresolved with conventional root canal therapy. Generally, procedure for endodontic microsurgery encompasses the removal of the buccal bone in order to accurately locate the root apices of an infected tooth, which may include the removal of intact bone. Then, surgical debridement of pathological peri-radicular tissue is performed, followed by the removal of root-end resection. A minimum of 3 mm preparation depth is required to effectively seal the accessory canals that may be present. Finally, a root-end cavity is obturated with Mineral Trioxide Aggregate (MTA) and the surgical site is sutured [1].

Unless there is a presence of fistula, which allows tracking the origin of the apical pathology, initial root tip localization and assessment for access site have been limited

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to the use of traditional 2-dimensional radiography such as periapical or panoramic radiograph. More recently, the advanced technology in 3-dimensional (3D) model reconstruction based on computed tomography such as cone beam computed tomography (CBCT) has opened a new avenue in application of personalized, accurate diagnosis and has been increasingly used in the field of dentistry [2]. Nevertheless, direct intra-oral localization of root apex based on the 3D information is extremely difficult and significant amount of bone removal is inevitable when freehand surgical procedure was employed. Moreover, gingival flap and alveolar bone fenestration are usually required, which leads to prolonged time of surgery, thereby increasing the chance of trauma as well as the risk of infection [3].

Indeed, CBCT has been widely used in contemporary implant dentistry for 3D pre-surgical planning and fabrication of surgical guide. Consequently, the use of guide template has become an emerging gold standard [4,5] for it allows patient-specific treatment, which is still being developed by advancement and refinement of computer-aided design and computer-aided manufacturing (CAD/CAM) technology and auxiliary devices including intra oral scanner, CAD software and 3D printer. Pre-surgical implant planning using 3D software offers prevention of disrupting adjacent root or anatomically vital structures and precise implant placement in correct position and angulation depending on the residual bone volume. It was also reported that the use of guided implantation is more accurate than freehand insertion [6].

The 3D software used for pre-surgical implant planning can be utilized in root-end resection, for it allows to avoid damage of adjacent tooth and to accurately determine the position of the affected area. Since 3D software for pre-surgical implant planning has been used successfully, its accuracy can be equally adapted to root-end resection, giving significantly improved control over drilling position as well as the depth of drilling. In the field of endodontics, the use of surgical template that reproduced the root canal morphology was attempted for the treatment of challenging tooth anomaly, which was untreatable with conventional freehand procedure [7]. Previous *ex vivo* study conducted with extracted human teeth also indicated that 'guided endodontic technique' allowed an accurate access cavity preparation and showed negligible influence of the operator, reducing operator dependent 'technique sensitivity' [8]. It was also reported that guide template was successfully employed into root-end resections, showing improved accuracy and reduced patient discomfort and surgery time by 30% [3]. However, this study used the guide template made by reverse engineering software, which may be limited for utilizing in daily-based clinical settings.

In this case report, we present endodontic microsurgery using the guide template that can accurately target the position of apex for the treatment of an anterior tooth with calcified canal which was untreatable with conventional root canal therapy and unable to track the position of the apex due to the absence of fistula.

CASE REPORT

A male patient, 25 years old, attended Yonsei University College of Dental Hospital complaining of pain in the maxillary right central incisor (tooth #21), which presented a history of trauma on tooth #21. After clinical and radiological examination, calcified canal was observed to be significant. Under a surgical microscope, localization of root canals was attempted twice but failed as patient continued to show clinical symptoms. Therefore, endodontic microsurgery was suggested, and patient consent was obtained. A CBCT scan was taken and apical radiolucency and completely blocked root canal with intact buccal bone were identified. Alginate impression was taken and poured up in yellow stone to obtain study cast. With conventional root-end resection, vast amount of buccal bone removal was inevitable and therefore, the use of minimally invasive guided endodontic microsurgery by using surgical template, cone-beam computed tomography and 3D printing technology was suggested as an alternative.

Planning procedure

The study cast made by alginate impression was scanned and transformed to the digital data using tabletop scanner (Identica Blue; Medit Co., Seoul, Korea). Both CBCT data and digital data obtained from patient's study cast were imported to implant planning software (In2Guide; Cybermed Co., Seoul, Korea). Two sets of data were merged for the tooth image, so the surgical template was designed accordingly.

The guide template was designed to cover 5 teeth with maxillary left central incisor placed in the middle. Among various guide drills with different diameter contained within In2Guid Universal implant kit (Cybermed Co.), which is compatible with the guide template, anchor pin drill with 1.5 mm in diameter was selected for targeting root apex and sleeves to accommodate anchor pin drill was designed inside the template. The position and direction of sleeve were determined in consideration of approachable drill angulation as well as accessibility for minimum of 3 mm preparation depth. Finally, it was once more confirmed if the drill accurately aims for target root without damaging the adjacent root or surrounding vital structures. (**Figure 1**) Designed guide template was exported in forms of STereoLithography (STL) file and printed with 3D printer (Objet 260; Stratasys Co., MN, USA).

Surgical procedure

Like conventional oral surgery, patient was prescribed amoxicillin (250 mg) and Ibuprofen (400 mg) 1 hour before surgery. Before starting microsurgery, surgical guide was applied

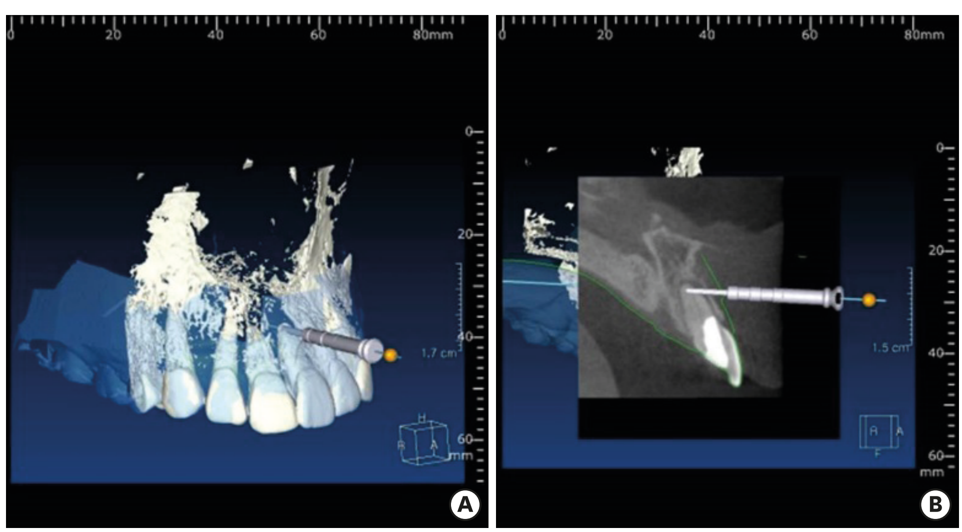

Figure 1. This figure demonstrates cone beam computed tomography (CBCT) data merged with STereoLithography (STL) data obtained from scanning dental cast on implant planning software. (A) Merging of CBCT (white) and STL (blue transparency) data with the area of targeting indicated. (B) Cross-sectional view of CBCT. Depth and angulation of drill can be determined.

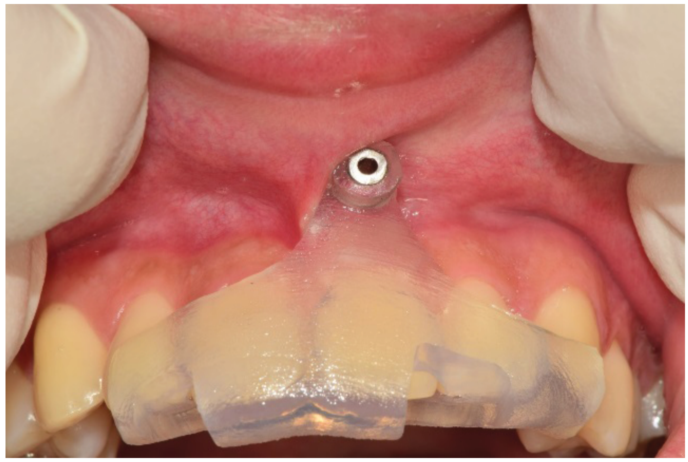

Figure 2. Clinical photograph showing intraoral guide template *in situ*. Windows made on the guide template indicates the fitness of the guide template.

to upper anterior area for checking its adaptation. Incisal opening of guide was helpful for fully adaptation between tooth and guide (**Figure 2**). The Leubke-Oschenbein flap design was applied after 1 ample local anesthesia (2% lidocaine with epinephrine 1:80,000; Huons, Seongnam, Korea) for minimal invasion. All surgical procedures were performed with an operating microscope (OPMI PICO; Carl Zeiss, Göttingen, Germany) (**Supplemental Video 1**).

Under the application of guide, surgical site was punched 3 mm depth with 2 mm straight rotary instrument (**Figure 3A and 3B**). After removing guide template, punched buccal bone was checked. Only apical buccal bone was prepared again with a No.6 round rotary straight instrument (No. 6; Prima Classic Prima Dental Group, Gloucester, UK) under distilled irrigation (**Figure 3C**). Exposed root tip was confirmed with methylene blue. And then root tip was finally prepared and removed with diamond high speed bur (**Figure 3D**). After removing of all inflammatory tissues, the resected root surfaces were then stained with methylene blue and inspected with micro-mirrors (Obtura Spartan, Fenton, MO, USA) under ×20 magnification to detect the canal space. The root-end preparation was made with KIS ultrasonic tips (Obtura Spartan). ProRoot MTA (Dentsply Tulsa Dental, Tulsa, OK, USA) used with the root-end filling material. ProRoot MTA was incrementally placed under the bleeding control, after that, the wound site was closed and sutured with 5 × 0 monofilament sutures. A post-operative radiograph was taken and compared with pre-operative radiograph (**Figure 4**). Only 30 minutes was taken for entire operation.

After 1 month follow up, clinical symptom was completely resolved. No other signs of adverse effects around surrounding soft tissues were identified.

DISCUSSION

Endodontic microsurgery using the guide template has demonstrated improved accuracy over a free hand operation. Moreover, the guide template itself may act as soft tissue retractor, helping to avoid iatrogenic soft tissue damage. It is generally accepted that it is more advantageous to use the guide template for the clinical cases in which there is an apical pathology with clinical symptom but untreatable with conventional root canal therapy due to canal calcification and absence of fistula, which otherwise helps to identify the position of root apex.

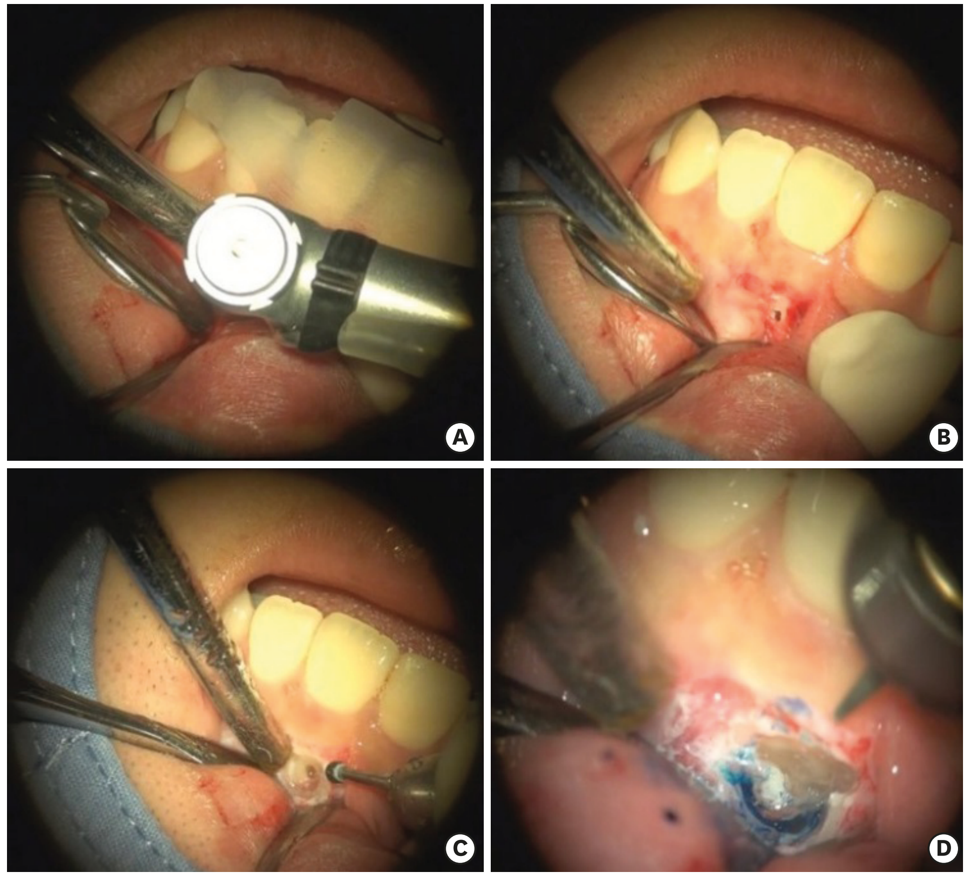

Figure 3. (A) Drilling with guide template placed. (B) After initial drilling, the position of targeting area can be identified. (C) Removal of adjacent labial bone using tooth #6 round bur after initial drilling. (D) Root resection as indicated by guide drilling after confirming the contour of root apex using methylene blue dye.

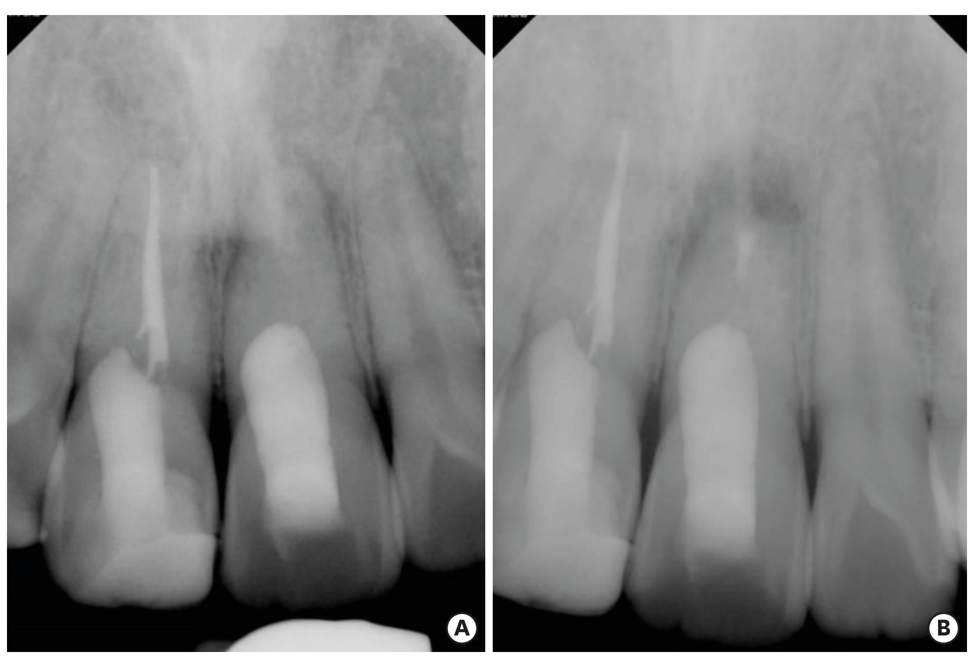

Figure 4. (A) Pre- and (B) post-operative periapical radiograph showing root-end fillings with Mineral Trioxide Aggregate (MTA).

Compared to the conventional approach, endodontic microsurgery using the guide template has many advantages: 1) root apex can be more accurately located through the provision of drilling hole, which will result in the minimal invasive preparation, 2) Surgical time and the volume of bone preparation can be significantly reduced, 3) Post-operative healing is more favorable and reduced risk of infection leads to better prognosis [9], and 4) more predictable and less-technique sensitive results can be expected regardless of clinician's experience. Therefore, it can also be used for educational purpose.

One of the most critical disadvantages of conventional root-end resection include the damage to anatomically vital structures such as inferior dental nerve, mental nerve, adjacent root and maxillary sinus. In contrast, endodontic microsurgery using the guide template significantly reduces these damages [10,11]. Pinsky *et al.* [2] confirmed in their *in vitro* study that the greater accuracy and consistency was achieved during endodontic surgery with surgical guidance without damaging vital structures. An error greater than 3 mm occurred over 22% of the time with freehand whereas none of errors occurred with surgical guidance [2].

Despite the aforementioned advantages, the limitations of guided endodontic microsurgery still do exist. Scattering artifact of CBCT caused by metal prosthesis may negatively affect the accuracy of diagnosis as accuracy of template is largely dependent on the process of merging CBCT data (DICOM) with digitalized intra oral data (STL). When there is much scattering artifact, the merging process cannot be accurately performed, leading to reduced accuracy of the template. Also, when the template is *in situ*, surgical access and vision may be disturbed by lips and cheeks for anterior and posterior region, respectively. Technically, the guide template and associated surgical kit were designed for implant placement not for the root-end resection and therefore, may have inappropriate length of metal sleeve or drills, which may restrict the use of surgical template for root-end resection.

In addition, accuracy of impression process may have a significant effect on the accuracy of guide template. Bubbles formed on impression material or gypsum model may reduce the accuracy. Consequently, *in situ* intraoral fitting of the guide template will be of great importance in determining the reliability and accuracy of root-end resection. Such was likewise this case in which guide template has to play both roles in accurately targeting the area 3 mm above the root apex as well as removal of such amount. In this sense, therefore, high-precision impression material such as rubber impression materials may better help to improve the accuracy of the guide template rather than using alginate impression.

Further clinical study may be required regarding surgical procedure for endodontic microsurgery using the guide template to improve the accuracy or to reduce the surgical time. Evaluation of accuracy depending on surgical site (anterior or posterior) may also be utilized to construct new treatment modality for the root-end resection. For easy application, it is also worth considering constructing guide template in 'modeless' manner using intraoral scanner.

CONCLUSIONS

Endodontic microsurgery using the guide template could be useful method in calcified canal which was untreatable with conventional root canal therapy and unable to track the position of the apex due to the absence of fistula.

SUPPLEMENTARY MATERIAL

Supplemental Video 1

Surgical procedures.

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