CASE REPORT

A novel method for soft tissue retraction during periapical surgery using 3D technology: a case report

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Abstract


Aim This case report describes a new approach to isolation and soft tissue retraction during endodontic surgery using cone-beam computed tomography (CBCT), computer-aided design (CAD) and three-dimensional (3D) printing.

Summary A 53-year-old patient presented for endodontic treatment of her maxillary left central incisor. It was decided to treat this tooth with a microsurgical approach. The data from the diagnostic CBCT scan were also used to make a physical model of the operative site, and CAD software was used to design a soft tissue retractor to be used during the patient’s surgery. A custom retractor was then fabricated using a 3D printer. The custom-made retractor enhanced visualization and soft tissue handling during the patient’s surgery. The patient was asymptomatic at a 1-year review. No abnormalities were detected during her clinical examination, and radiographic examination revealed complete healing of the surgical site.

Key learning points

• The significance of proper soft tissue retraction in periapical microsurgery is underemphasized.
• Geometric data from CBCT scans may be harvested for a variety of uses, adding value to the examination.
• 3D printing is a promising technology that may potentially have many uses in endodontic surgery.

Keywords: 3D printing, apical periodontitis, cone-beam computed tomography, endodontic microsurgery.

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Introduction

The principle objective of endodontic therapy is to treat apical periodontitis caused by infection of the root canal system (Ørstavik & Pitt Ford 2008). However, apical periodontitis can still persist after primary and even secondary root canal treatment, which may then require surgical intervention (Barone et al. 2010).

Bacteria may remain in the apical ramifications inside and outside of a root canal making them inaccessible to conventional root canal treatment (Siqueira 2001). In addition, periapical pathosis may also be sustained by a periapical foreign body (Nair 2006). Endodontic surgery can treat persistent apical periodontitis by removing the infected site, thus enhancing the chances of healing (Bakland et al. 2008).

Endodontic surgery is now considered a microsurgical specialty with state-of-the-art instruments (Kim & Kratchman 2006). A microsurgical approach permits clinicians to undertake endodontic surgery with more conservative osteotomies, shallower bevels, preparation of accessory canals, retropreparations in alignment with root canals and more accurate placement of biocompatible root-end filling materials (Kim & Kratchman 2006, Saunders 2008, Setzer et al. 2010). Outcomes of endodontic microsurgery have shown success rates ranging from 91.5% to 96.8% (Rubinstein & Kim 1999, 2002).

Cone-beam computed tomography (CBCT) is a promising tool to the endodontist’s armamentarium, especially when performing surgical procedures (Patel et al. 2015). CBCT is a three-dimensional imaging technique that appears to overcome some of the limitations of conventional radiography, such as their two-dimensional nature (Huominen & Ørstavik 2002), associated anatomical noise (Bender & Seltzer 1961) and geometric distortion (Forsberg & Halse 1994).

Use of CBCT prior to endodontic microsurgery may allow the endodontist to identify accessory anatomy, untreated root canals, visualize the true extent of a periradicular lesion and prevent damage to vital anatomical structures (Low et al. 2008, Bornstein et al. 2011). The European Society of Endodontology’s (ESE) CBCT position statement indicates that CBCT should be considered in preoperative assessment and management of complex periradicular surgery (European Society of Endodontology 2014).

Three-dimensional printing uses computer-aided design (CAD) technology to create physical models from geometric data (Dawood et al. 2015). Three-dimensional printing has found various uses in aerospace, defence, arts, sciences, engineering, medicine and dentistry. Use of 3D printing in dentistry includes the fabrication of implants (Xiong et al. 2012) and their surgical guides (Flügge et al. 2013), the fabrication of physical dental models (Liu et al. 2006), and the assembly of copings and frameworks for implants and dental restorations (Miyazaki & Hotta 2011).

In endodontics, 3D printing may become of increasing significance when combined with CBCT. Byun et al. (2015) described a novel method of root canal treatment of an anomalous maxillary central incisor with the aid of CBCT and 3D printing. A translucent physical tooth model with complex internal root canal anatomy was constructed, and a custom-made guide was used to aid access cavity preparation. The tooth was subsequently treated successfully. In their case report, numerous anatomical intricacies and previous iatrogenic errors would have made the tooth difficult to treat via conventional endodontic techniques. Their custom-made jig allowed them safe and accurate access to the root canal and ensured restorability of the tooth.

Zehnder et al. (2015) used CBCT and intra-oral optical scans to produce 3D-printed templates to gain guided access to root canals. In their ex vivo study, templates allowed precise access cavity preparation and root canal negotiation of the apical third of extracted teeth. Using similar techniques, Krastl et al. (2015) successfully treated a maxillary central incisor with pulp canal obliteration.
In medicine, 3D-printing technology has been used in the fabrication of custom-made surgical instruments (Malik et al. 2015). Birnbaum et al. (2001) produced custom poly-carbonate templates using CAD and 3D printing to aid placement of pedicle screws in spinal surgery. The templates conformed to bone allowing drilling to a prearranged point marked on 3D images processed preoperatively. They found that this technique improved accuracy and significantly decreased operative time.

In endodontic treatment, the routine use of rubber dam is standard, yet when working in the periapical region, moisture control is much more difficult, and moisture contamination could affect the sealing ability of retrograde root filling materials (Scarano et al. 2012). In addition, soft tissue retraction has been traditionally viewed as the surgical assistant’s responsibility (Kim & Kratchman 2006). Efficient and atraumatic soft tissue retraction is essential regardless of whether apical surgery is being carried out on anterior or posterior teeth. Inadvertent soft tissue damage suffered by inappropriate tissue elevation and reflection may delay healing (Harrison & Jurosky 1991).

This article describes a novel surgical retractor, which takes advantage of 3D technology that is becoming increasingly accessible in dentistry.

Case report

A 53-year-old female patient was referred by her general dental practitioner (GDP) for root canal treatment of her maxillary left central incisor (tooth 21). The patient presented to her GDP with an abscess on the attached gingiva labial to tooth 21.

On presentation, the patient reported that tooth 21 was tender on biting. Medically, she was fit and healthy. She was a regular dental attender.

She recalled that the tooth had root canal treatment over 20 years ago; her GDP confirmed this stating that the tooth was treated by an endodontic specialist and a rubber dam was used.

Clinical examination revealed a moderately restored dentition with good levels of oral hygiene. Tooth 21 was restored with a well-adapted palatal direct composite resin restoration. Periodontal probing depths were not greater than 2 mm. The tooth was tender to percussion and to labial palpation. The remaining maxillary anterior teeth responded positively to thermal and electric pulp testing.

A periapical radiograph using a beam-aiming device and a digital charge-coupled device (Schick Technologies, New York, NY, USA) revealed that the tooth had been

![Figure 1](a) Preoperative radiograph of tooth 21 revealed a periapical radiolucency associated with this tooth. (b) Preoperative coronal and (c) sagittal reconstructed cone-beam computed tomography (CBCT) images showed that the periapical lesion was approximately 5 mm in diameter with no perforation of the palatal cortical plate and that the incisive foramen was not in close proximity.
previously root filled, had a periapical radiolucency 3 mm in diameter and had a shortened root end (Fig. 1a).

With the consent of the patient, a small volume CBCT scan (3D Accuitomo 80; J Morita Manufacturing, Kyoto, Japan) with exposure parameters 80 kV, 3.0 mA and 17.5 s was taken of the area of interest. The reconstructed images from the CBCT scan revealed that periapical radiolucency was 5 mm in diameter and had not perforated the palatal cortical plate and that the incisive foramen was not in close proximity (Fig. 1b, c).

A diagnosis of chronic periapical periodontitis associated with an existing root filling and external inflammatory resorption was reached for tooth 21. After discussing the various treatment options with the patient, it was decided to treat the tooth with a microsurgical approach.

The volumetric data from the CBCT scan were exported as a Digital Imaging and Communications in Medicine (DICOM) file. As a starting point in the retractor design process, the DICOM file was converted into a stereolithography (STL) file using CAD software (Mimics, Materialise, Leuven, Belgium). The STL file was then uploaded to an industrial design and 3D-printing studio (www.digits2widgets.com), and a resin 3D-printed model of the surgical site ordered (Fig. 2a). To convey the intended design of

Figure 2  (a) A surface model of the area of interest was fabricated from CBCT DICOM data. The location of the lesion was marked in red wax as a reference point for the retractor’s design. (b) A ‘mock-up’ retractor was made in dental wax on the anatomical model to convey the intended design to the technician prior to 3D printing. (c, d) The preliminary design was reinterpreted and modified by an industrial designer at a 3D-printing studio against the 3D model using CAD software. (e) The retractor was tried in on the model to check fit and access. (f) The custom retractor improved soft tissue management and access during the patient’s periapical microsurgery.
the retraction device to the designer, a ‘mock-up’ of the device was formed in dental wax on the resin model of the surgical site (Fig. 2b). This sketch design was then reinterpreted by the industrial designer at the 3D-printing studio against the 3D model in a software environment using CAD software (SpaceClaim, Concord, MA, USA; Fig. 2c, d). A variety of screenshots of the device were then sent for approval, and minor adjustments made. At the end of this collaborative iterative design process, the STL file of the device was printed in an autoclavable nylon material, and its fit confirmed against the anatomical model (Fig. 2e).

On the day of surgery, local anaesthetic was administered via labial and palatal infiltration. A full thickness mucoperiosteal flap with distal releasing incisions was raised from tooth 12 to tooth 22. The autoclaved custom retractor clipped onto the incisal edges of the teeth and was used to hold the flap in place and keep it away from the operating area (Fig. 2f).

Treatment was carried out with the aid of a dental operating microscope (3-step entree; Global, St Louis, MO, USA). An osteotomy was created with a long tapered diamond bur in a surgical high-speed handpiece (TwinPower 47, J Morita), after which all visible granulation tissues were removed. Due to the already short nature of the root, a 2-mm apical root resection with a shallow bevel was carried out on tooth 21. There were no signs of root fracture on the resected root surface. A 3-mm root-end cavity was prepared on the tooth with an ultrasonic tip (KiS ID, Obtura Spartan, IL, USA) and was sealed with IRM (Dentsply DeTrey GmbH, Konstanz, Germany) (Fig. 3a). The flap was repositioned and sutured (5/0 Ethilon, Ethicon Inc, Somerville, NJ, USA). Verbal and written postoperative instructions were given to the patient following the procedure. The patient was reviewed 3 days later. The surgical site was healing well; the patient did not report any postoperative pain or discomfort and the sutures were removed.

At a 1-year review, the patient was asymptomatic. Clinical examination was unremarkable. Radiographic examination revealed completed healing of the surgical site (Fig. 3b).
Discussion

Persistent apical periodontitis is preferably treated by root canal retreatment (Barone et al. 2010). However, post-treatment failure can still occur when treatment has been performed to a good standard (Siqueira 2001). Apical periodontitis may persist because of extraradicular infections, and/or due to intraradicular infection (Nair 2006). The infected site(s) may not be accessible by conventional therapy and therefore may require surgical intervention. Patient preference and benefit-risk analysis may also favour management of persistent apical periodontitis by periapical surgery instead of root canal retreatment (Friedman 2002). In this case, the tooth was previously treated by an endodontic specialist under aseptic conditions.

The patient consented to have endodontic microsurgery performed after being informed of the risks and benefits of all treatment options, which included conventional root canal retreatment. The healing observed in this case demonstrates the effectiveness of microsurgical techniques, especially when compared with traditional methods (Setzer et al. 2010). As the patient initially had the root canal treatment carried out under rubber dam by an endodontist, it was felt that her choice of treatment was justifiable.

This case report presents a novel technique for soft tissue retraction during periapical surgery. The relevance of adequate and atraumatic soft tissue retraction in periapical microsurgery is often underemphasized. Improved access and soft tissue handling will ultimately improve the efficiency of treatment as well as the predictability of soft tissue healing (Cortellini & Tonetti 2001). Microsurgery alone will not enhance epithelial healing rates, but optimal tissue adaptation of wound edges can create smaller distances for epithelial migration during the healing process; more rapid soft tissue healing is a result of decreased tissue trauma and improved wound closure during microsurgical procedures (Velvart & Peters 2005). Frequent slippage of a retractor during surgery is one of the major causes of postoperative tissue swelling and can trigger transient paraesthesia in the mandibular molar/premolar region (Kim & Kratchman 2006). The 3D-printed retractor used in this case provided stable soft tissue retraction and was easily sterilized beforehand to reduce contamination of the surgical field.

Many endodontic surgical failures have been attributed to poor visibility and ability to treat the microscopic causes of apical disease (Setzer et al. 2010). The retractor described in this case report was designed in such a way to provide a clear ‘window’ to perform an osteotomy and root-end surgery. This allowed the operator to ensure that the osteotomy site was kept as small as practically possible, and in this case, both the operator and patient benefited from improved visualization, soft tissue handling and moisture control. Rubinstein & Kim (1999) demonstrated that there was a correlation between the size of the osteotomy and the time of healing. They showed that smaller osteotomies tended to heal faster using radiographic changes as evidence.

Regardless of whether endodontic surgery is being planned on anterior or posterior teeth, atraumatic handling of soft tissues is essential to increase the likelihood of successful healing and plays a significant role in the aesthetic outcome of endodontic surgery (Velvart & Peters 2005). Therefore, the use of a custom-made retractor was felt to be justified in this case.

Fabrication of a retractor using CBCT and 3D printing may ultimately be used to improve the microsurgical management of posterior teeth. Mandibular molars, in particular, are more difficult to treat with a microsurgical approach (Bornstein et al. 2011). Periapical surgery in mandibular molars is associated with complications such as challenging access to the roots as a product of the posterior location, depth of the buccal cortical plate (Rud et al. 2001), and closeness of the roots or pathologic processes....
to the mandibular canal (Littner et al. 1986). In a prospective study involving two district general hospitals, 20%–21% of patients experienced sensory disorders of the lower lip after periradicular surgery on mandibular molars (Wesson & Gale 2003). Fabrication of a custom-made retractor may provide surgeons better vision and more stable soft tissue retraction during surgical treatment of mandibular premolars and molars. This may help prevent soft tissue trauma and damage to adjacent sensory nerves.

Prospective clinical trials have demonstrated that there was no significant difference between MTA and IRM as root-end filling materials in the outcome of endodontic surgery when modern microsurgical techniques were used (Chong et al. 2003, Lindeboom et al. 2005). Zuolo et al. (2000) reported a success rate of 91.2% using contemporary surgical techniques and IRM as a root-end material in their prospective clinical study. IRM was used in this case due to its ease of handling.

The use of CAD CAM technology has become commonplace in the dental laboratory, and many now have their own scanners and milling units (Van Noort 2012). In the dental surgery, intra-oral and CBCT scanners are becoming more mainstream, and dental professionals are becoming well acquainted and adept at working with large volumes of digital data (Dawood et al. 2015).

3D printing offers another form of output for dental CAD software, making it possible to develop complex components and objects in an array of different materials (Liu et al. 2006). Three-dimensional-printing technologies have been readily available for more than a decade (Petzold et al. 1999). However, developments and access to scanner technology and CAD software have made this technology easier to use (Malik et al. 2015, van der Meer et al. 2016). In addition, commercial and public interest has made 3D printing more affordable, raised awareness and improved access to resources (Cohen et al. 2009, Condino et al. 2011, Duan et al. 2013).

In this case, sintered nylon was selected as the material of choice, as it is robust, flexible and autoclavable, but other options might include titanium, stainless steel and other plastic materials (Dawood et al. 2015). Three-dimensional-printed retractors may be customized to suit the nature of their intended purpose.

The use of CBCT in this case significantly enhanced the management of this surgical case, allowing the determination of bone thickness, the nature of the periapical lesion and the inclination of the root, which are all pertinent factors in preoperative assessment for endodontic surgery (Patel et al. 2015). The fabrication of the 3D-printed model and the custom retractor show how patient management may be further improved from an existing CBCT scan.

It is essential that the radiation dose is optimized and kept As Low as Reasonably Achievable (ALARA) when exposing patients to ionizing radiation (Farman 2005). Use of CBCT must be justified and only be utilized when it enhances the management of a case (European Society of Endodontology 2014). The smallest field of view suitable for the clinical situation should be used to decrease radiation doses (Patel et al. 2015). This is even more relevant for younger patients, who are more sensitive to the stochastic effects of radiation (Verdun et al. 2008). The effective dose of the CBCT scanner (3D Accuitomo; J Morita Mfg. Corp) used in this case was approximately 13 μSv (Loubele et al. 2009), which is in the same magnitude of 2–3 standard periapical exposures (Arai et al. 2001, Mah et al. 2003).

Conclusion

The use of CBCT in this case not only assisted in the diagnostic process but also enabled the production of a custom 3D-printed soft tissue retractor, which improved access to the surgical site, whilst also improving treatment efficiency and minimizing soft tissue damage.
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Conflict of interest
The authors have stated explicitly that there are no conflicts of interest in connection with this article.

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