

ORIGINAL ARTICLE



Digitally planned root end surgery with static guide and custom trephine burs: A case report

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Abstract

Introduction: Apicoectomy is an endodontic surgical intervention that requires high precision. The computer-assisted static guided approach has proven to increase the precision of dental implantation in a significant manner. The authors sought to transfer this precision to root-end resection with the use of custom designed trephine burs manufactured specifically for use in targeted endodontic microsurgery.

Methods: A set of custom bone trephines were designed and manufactured, then their digital models were integrated into an already existing implant surgical planning software, in cooperation with the software developer. Apicoectomy was performed in an actual case with the help of the new system.

Results: It has become possible to plan root end removal in the virtual space and to manufacture 3D printed static surgical guides to help the execution of the surgery. A patient with persistent periapical lesion was successfully treated without complication. The 6-month follow-up found uneventful healing.

Conclusion: The presented system is a step toward a standardized digital system and workflow dedicated to guided endodontic surgery.

KEYWORDS

3D printing, apicoectomy, targeted endodontic microsurgery, static surgical guide

1 | INTRODUCTION

Apicoectomy is a routine endodontic surgical intervention, the aim of which is to surgically maintain a tooth that primarily has an endodontic lesion that cannot be resolved by conventional endodontic (re-) treatment. It is widely accepted that 3 mm of the root tip has to be removed to eliminate >90% of the ramifications and lateral canals,^{1,2} in which case the chance of recurrence is minimal. In an optimal case, the cut is performed perpendicularly to the root axis. Apical and coronal deviations can both lead to suboptimal results, complications, and further recurrence. Precise targeting, therefore, is crucial. The conventional approach to such endodontic cases uses drills and relies entirely on mental navigation based on a cone-beam computer tomography

(CBCT) image. While a CBCT image means considerable help, it is still very difficult to determine the exact entry point on the surface of the bone without further aids, and navigation within the bone presupposes an excellent ability to transfer a mental image into the actual patient anatomy. A general drawback of this approach, thus, is that the outcome is highly operator dependent. Complications and undesirable outcomes include missing or simply perforating the apex and/or damaging nearby anatomical structures. Minimal invasiveness is similarly important: the smaller the osteotomy, the faster the healing.^{3,4}

Precision is a similarly important objective in dental implantology, given the complications associated with misplaced implants. 3D printed surgical templates to guide drills and other instruments, and

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even to insert implants have been used for some time in dental implantology, with considerable success. According to systematic reviews on this topic, surgical guides do contribute to the reduction of the inherent positional uncertainty of freehand surgery.^{5,6} Such guides are classified into two main categories: dynamic and static.

Dynamic systems offer real-time visualization during surgery, but their accuracy is lower than that of static systems.⁷ Furthermore, they are expensive, occupy considerable space,⁸ and their use is not always straightforward.⁹

Static systems are template-based, and their accuracy is acceptable in most clinical situations.⁵ Such templates are mostly fabricated via stereolithography based on digital images (CBCT/intraoral scanner), and the resulting template is either bone-, mucosa-, or tooth-supported.¹⁰⁻¹³ Of note, tooth-supported templates are reported to yield the best results.¹⁴⁻¹⁶

Gambarini et al used a dynamic navigation system to demonstrate the use of guided approach in endodontic microsurgery and reported good results.¹⁷ In this technical note and case study, we present a solution that allows digital planning and static guided execution of root-end resection with a custom bone trephine. Our approach is not entirely unprecedented: in 2018, Giacomino et al used trephine burs with static guides for targeted endodontic surgery in three anatomically challenging cases.¹⁸ However, they used conventional bone

trephines. Recently, our research group has published an article where a case series was presented with the same method. There we raised the potential issues associated with the use of conventional bone trephines for endodontic purposes, including overpenetration.¹⁹ The real novelty of our report is that for the presented case, we used a set of trephines designed by ourselves, especially for the purposes of guided endodontic surgery. A further refinement is that instead of using a model cylinder, we used the exact virtual replica of the trephine for planning.

Conventional bone trephines are not uniform in diameter along their entire length, instead, the cutting end is somewhat wider (Figure 1a). This is unfavorable for guided use as if the guiding sleeve of the template is wide enough to let the wider working end pass, the shaft of the trephine is not guided. Furthermore, regular trephines do not have a stop, which carries the risk of overpenetration. To address these problems, we designed a set of uniform diameter endotrephines (Figure 1b,c). The trephines are made of sulfur-alloyed martensitic stainless steel with 13% chromium content and high corrosion resistance (W.nr. 1.4197) and have a stop to prevent overpenetration. The set contains trephines of two different diameters: 3.46 and 4.46 mm, and of three different lengths: 10, 15 and 20 mm (Figure 1b). The set was manufactured by a local company specializing in medical device manufacturing (Lajos Döme EV, Szeged, Hungary).

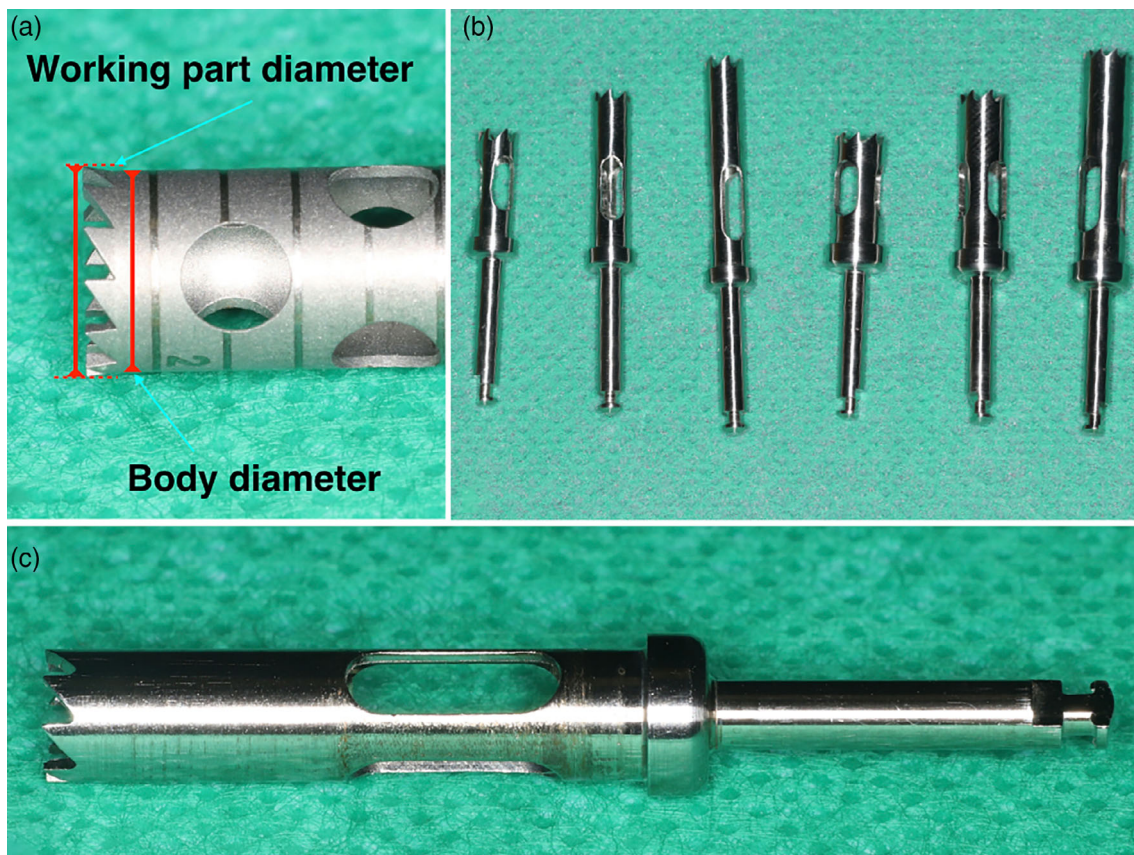


FIGURE 1 a, A conventional bone trephine. The diameter of the working end differs from that of the body. b, A set of trephines for endodontic surgical purposes (SmileDent, Hungary). c, A single trephine from the set. Note the stop and that the diameter is uniform along the entire working length



The diameters were designed to allow a gap of 0.04 mm between the guiding sleeve and the trephine to allow frictionless rotation (based on the technical documentation of the instruments of the SMART Guide implant surgical kit, with the kind permission of dicomLAB Dental). The digital models of the trephines were used for the next stage of development.

The digital models of the trephines were integrated into SMART Guide 1.26 (dicomLAB Dental, Szeged, Hungary). SMART Guide is part of a comprehensive digital planning and 3D printed template manufacturing workflow. This software allows the surgeon to plan the three-dimensional position of implants in a digital model of any given patient generated from CBCT images, and then the manufacturing of 3D printed surgical guides based on the resulting plan. In the upgraded version of the software, the user can select the custom trephine as if selecting an implant or fixation pin and use it for the planning of the endodontic surgical intervention (Figure 2). While the upgraded software contains only our pre-defined trephine sizes at the moment, other sizes can be added at any time. With the help of the integrated measurement tools of the software, it is possible to plan a cut as close to 3 mm and 90° as the patient's anatomy allows (the main limiting factor is the depth of the vestibule). From the plan, a surgical guide is printed, with a guiding sleeve in the vestibular area, through which the trephine is applied after flap elevation. The template is placed like any tooth-supported template. The trephine is applied through the guiding sleeve and used for the osteotomy and the resection of the apex tip. The subsequent steps of the surgery are periapical curettage, retrograde preparation, retrograde filling, and wound closure. These are best done as recommended by Kim et al.⁴

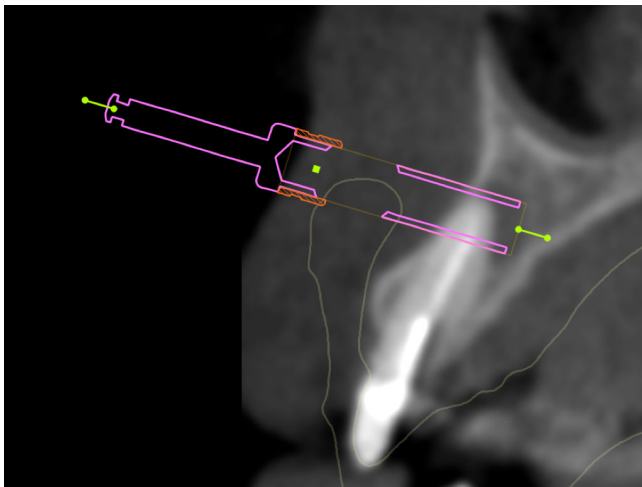


FIGURE 2 Planning the surgery in the software with the model of the trephine. The position of the guiding sleeve is also displayed, which allows planning in such a manner that the operator will have to push the trephine exactly till stop to reach the optimal end result. Distances and lengths are measured with the built-in measurement tool of the software. The figure shows the planning of the reported case

2 | CASE REPORT

The 43-year-old male patient presented with a persistent periapical lesion around the apex of tooth 12 after root canal treatment (Figure 3). The subjective symptoms were recurrent sensitivity and mild pain. As the patient had a metal post in the affected tooth, which was not possible to remove without risking damage to the tooth, antegrade revision of the root canal was ruled out. The new procedure was explained to the patient in both oral and written forms, and he gave his informed consent to the surgery. The clinical testing of the method was approved by the Medical Devices Department of the Hungarian National Institute of Pharmacy and Nutrition (Approval No. OGYÉI/43796/2018).

A vestibularly extended C-silicone impression (Zetaplus, Zhermack, Italy) was taken of the patient's upper dentition in a plastic tray (Hi-Tray, Zhermack, Italy), then two CBCT scans were taken: one of the patient and one of the impression (iCAT Next Generation, iCAT, USA; 120 kV, 5 mA, 9 seconds, voxel size: 250 μ m, FOV: 110 mm, for both the patient and the impression. (Please note that in the literature it is often recommended that the exposure settings for the scan should be lower than for the patient). Both scans were sent to dicomLAB Dental for digital image registration. With the help of these images, dicomLAB Dental generated a model of the anatomy of the patient and sent this image back to the surgical team. For the planning, the unreleased upgrade of SMART Guide 1.26 was used, with

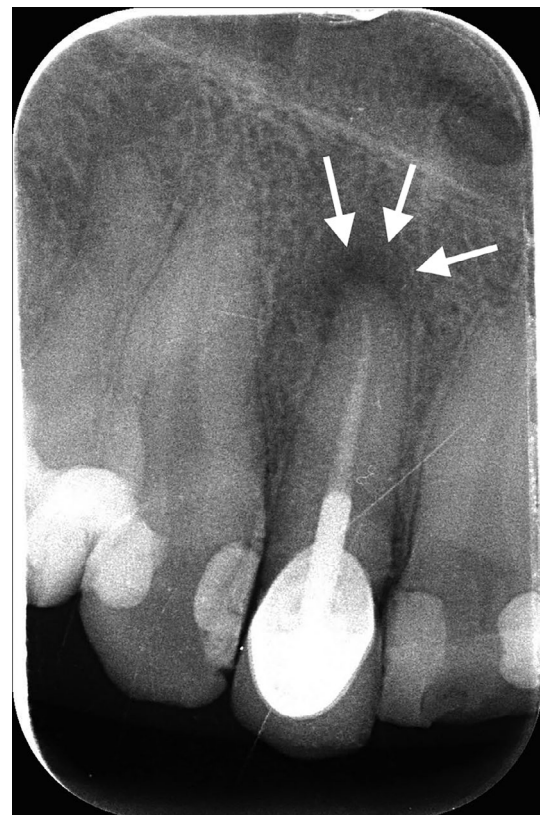


FIGURE 3 Periapical x-ray of the initial status. The white arrows point at the periapical lesion

the integrated model of the bone trephine to be used. Screenshots of the final plan are shown in Figure 4.

The plans were sent to dicomLAB Dental for 3D printing. When the final product (the tooth-supported surgical guide) had been delivered, the first step was to check the fit of the trephine in the guiding sleeve (Figure 5), and then a fit check was performed in the patient's mouth as well (Figure 6).

Once we had made sure that the fit of the trephine was suitable for the surgery and that the template sat firmly on the patient's dentition, the surgery began. To induce anesthesia, subperiosteal infiltration with 3×2 mL Ubistein Forte (articaine-hydrochloride and epinephrine 1:100 000, 3M, Germany) was utilized. Anesthetic was administered to the root of the treated tooth, and 2 cm both mesially and distally from the root, to ensure the block of sensation in the entire surgical site. Flap was prepared with a submarginal incision and with one vertical releasing incision. The guide was placed in a way that it also retracted the soft tissues, but a Freer elevator was also used to prevent the flap from sliding back underneath the guide. The trephine was inserted into the guiding sleeve and drilling was performed until the stop prevented the instrument from being inserted any further (Figure 7). Constant external irrigation was provided through a standard cannula (W&H, Austria) attached to the surgical unit and the hand piece. The irrigation fluid was saline at room temperature. The guide was stabilized manually at three points.

The surgical access is shown in Figure 8. When the trephine was removed, we noticed that it had not only resected the apex, but also removed it (Figure 9). The trephine prepared a symmetrical round access, through which retrograde preparation and filling could be performed. For a better view, epinephrine-containing solution was applied

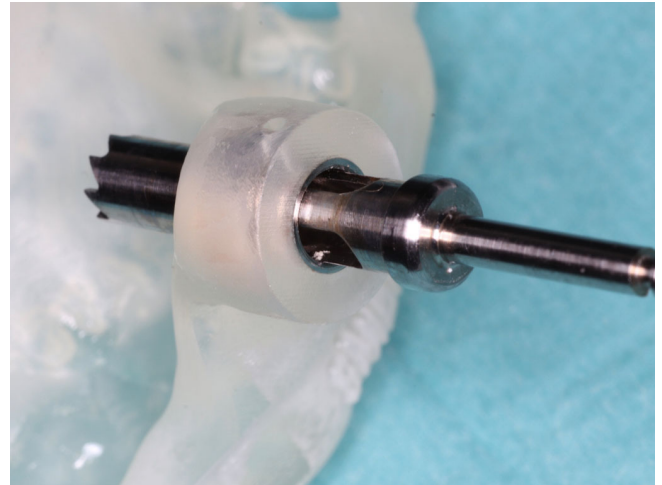


FIGURE 5 Trephine fit check outside the patient's mouth. Note the stop that mechanically prevents overpenetration

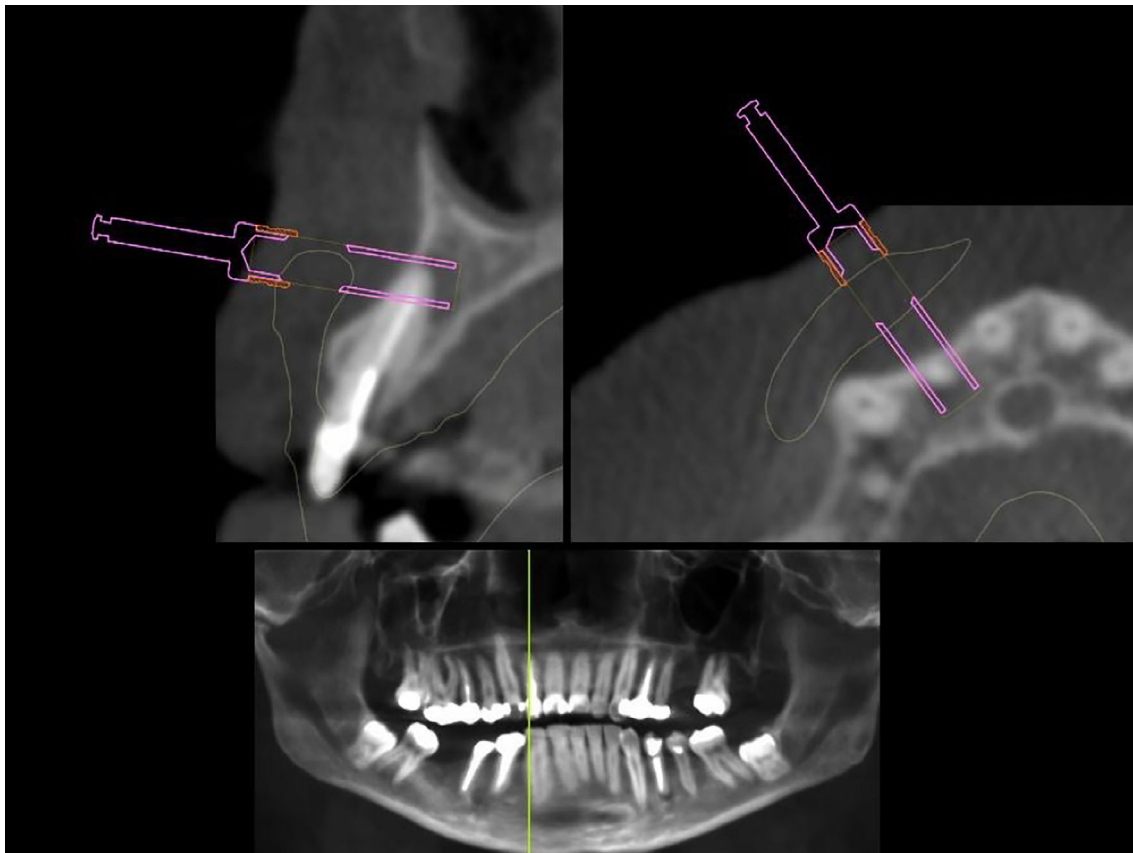


FIGURE 4 Screenshots of the surgical plan exported from SMART Guide

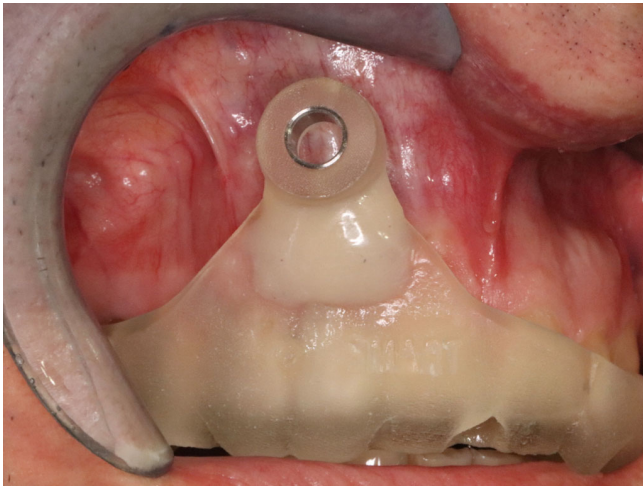


FIGURE 6 Template fit check in the patient's mouth

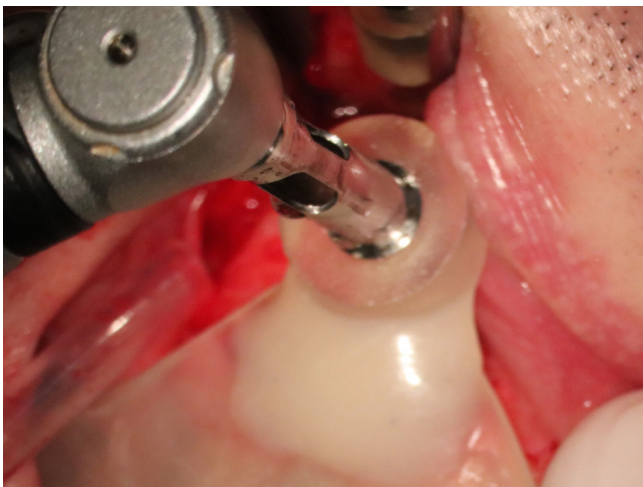


FIGURE 7 Application of the trephine through the guide. Note that the guide also functions as tissue retractor

both inside and outside the bony housing. Inspection of the site and root canal location were done under surgical microscope (OPMI Pico, Zeiss, Germany). For the visualization of the root canal, methylene blue was used. Retrograde preparation was carried out with Piezomed (WH, Bürmoos Austria), with the R3D tip, to a depth of approximately 2.5 mm. The cavity was dried and bioceramic filling was applied (TotalFill Fast Set Putty, FKG, La Chaux-de-Fonds, Switzerland). The wound was closed with 5-0 Moplyen (Resorba, Nürnberg, Germany).

3 | RESULTS

No intraoperative complications occurred related to the applied technique or otherwise. The pre- and postoperative status can be compared in Figure 10. The immediate postoperative periapical radiograph showed good clinical results. To check positional accuracy,

three-dimensional analysis was performed in Amira 5.4.0 (ThermoFisher Scientific, Waltham, Massachusetts, USA), with dedicated algorithms. The planned position of the trephine bur was extracted from the digital surgical plan and compared with the actual position determined with the segmentation of the burhole (Figure 11). The following parameters were analyzed: deviation of the distal endpoint (DD, mm), deviation of the proximal midpoint (PD, mm), and angular deviation (ie, the deviation of the principal axes, ANG, degrees). Proximal and distal refer to the ends of the trephine bur. PD and DD were broken down to x,y,z vectors, where x: horizontal, y: depth (mesio-distal) and z: vertical (cranio-caudal). The results were as follows: PD: $-0.006, 0.08, 1.18$ mm; DD: $-0.25, -0.097, 0.014$ mm; ANG: 3.5° . At the 6-month follow-up it was found that periapical inflammation had not recurred, the healing had been uneventful, and no complications were observed. The observation of the patient continues until complete healing.

4 | DISCUSSION

The approach demonstrated here has been developed to reduce user error and thus make root end surgery safer and more accurate by applying custom-made trephines with a stopper feature in combination with digital planning and static guidance. Based on our initial results, our approach appears to be fit for that purpose. Of the elements of the system, the custom-made endo-trephines mean to be the real innovation. The necessity of a stop to prevent over-penetration does not require further explanation, but we think that it is important to briefly discuss the diameters and the shape and design of these instruments.

As for the diameters, our goal was to define diameters that could be used in most of the patients we see without risking damage to neighboring anatomical structures (the roots of neighboring teeth, the alveolar nerve or the sinuses). As the aim is to cut a 3 mm piece of the apex, the starting point was that the diameter should be larger than 3 mm. Initially, we planned 3.5- and 4.5-mm trephines, but we reduced these values to 3.46 and 4.46 mm to allow for the 0.4 mm distance from the sleeve and the horizontal motion of the pieces. 5.0 mm we considered as the upper limit, as with such a large diameter it would be difficult to keep the 3 mm rule, and we could have ended up eliminating the accuracy benefit of the guidance and minimal invasiveness as well. Working with smaller diameters also leaves room for further extension if need be, while repairing damage done by a larger-diameter instrument is not always possible - if at all.

As for the shape and design, it was established before that we sought to create a guided trephine that could be inserted into the guiding sleeve from the front side. We approached this problem in the most straightforward fashion, by designing a trephine without the usual slight widening at the working end. While the exact function of that design element is not clear, (we have found nothing about it in the literature whatsoever), it is reasonable to assume that it is related to cutting efficiency or heat dissipation. In our experience, this modification has not decreased the cutting efficiency of the instrument. We have no data regarding heat generation and heat dissipation, but it is

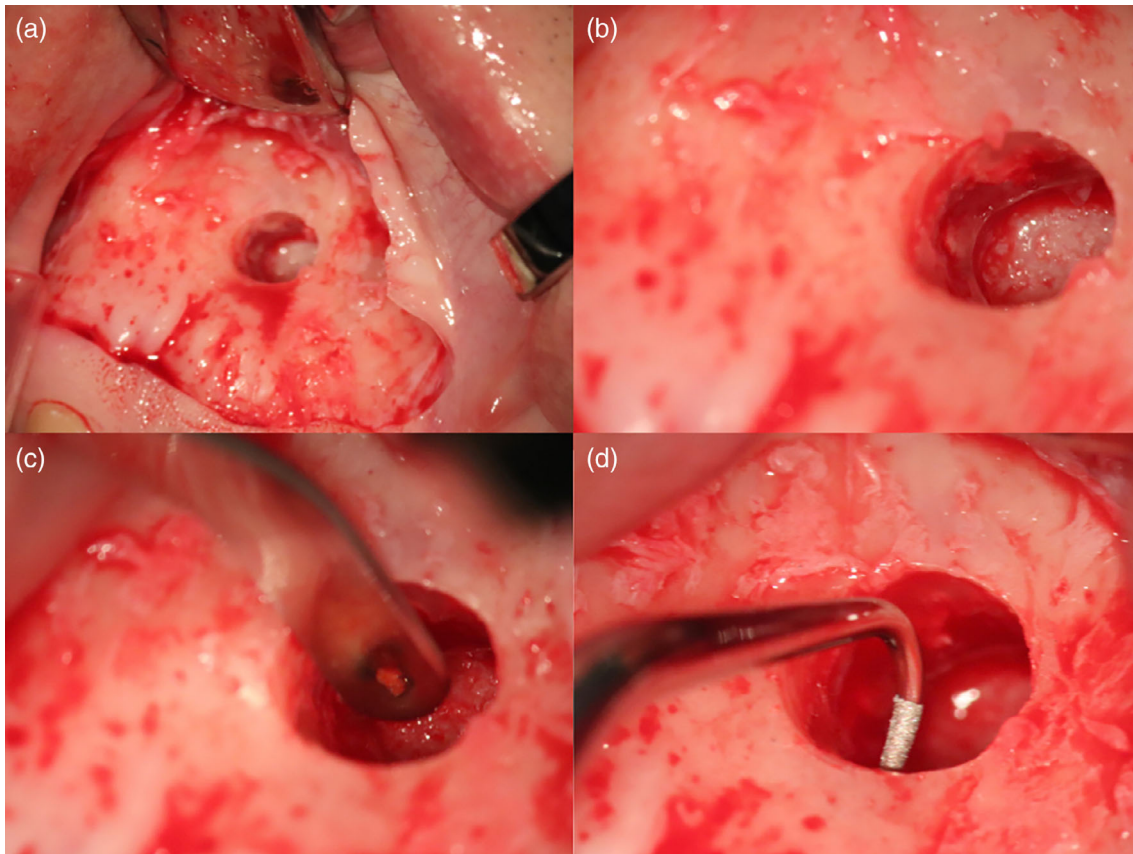


FIGURE 8 After the osteotomy. a, Surgical access with the soft tissue flap retracted. b, A close-up of the access. c, Localization of the root with a micro-mirror. d, Insertion of the piezo instrument. Retrograde preparation and filling and wound closure were performed as recommended by Kim et al⁴

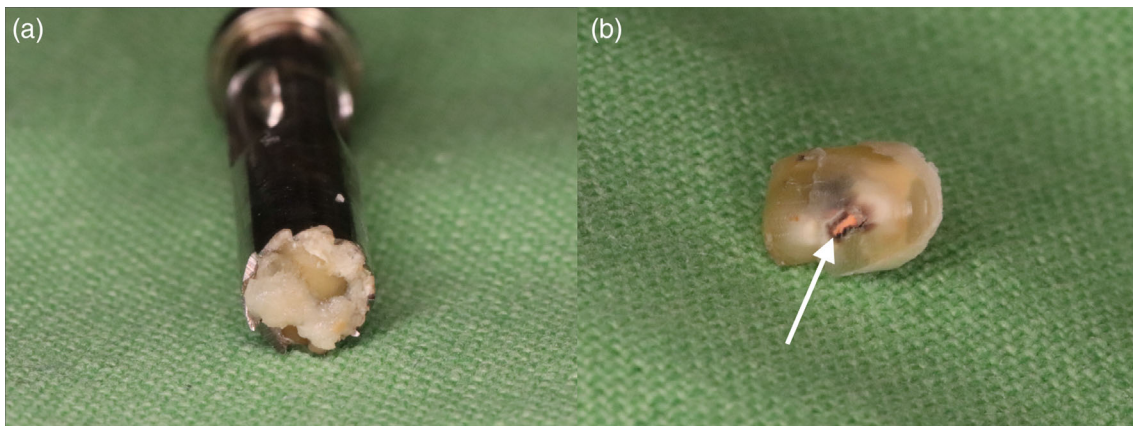


FIGURE 9 a, Core specimen in the trephine. b, The removed piece of apex. The arrow points to the gutta-percha in the root canal

safe to assume that with copious irrigation it should not be a problem.²⁰⁻²² However, this question definitely needs further exploration. The only difficulty we experienced with this design is that the cylindrical piece of tissue that was removed often stuck into the instrument and could be removed only with great difficulty. The problem of removal needs to be solved, possibly with some simple pushout mechanism. However, we do not wish to eliminate the excessive adherence

of the instrument to the removed tissue, as this is probably the very feature that makes it possible to resect and remove in one step. All in all, our overall (if limited) experience with the new design is positive.

The primary indication of the presented intervention is the peri-apical surgery of single-rooted teeth. In the case of multi-rooted teeth, we recommend this technique only for the treatment of one root at a time, preferably a buccal root. The treatment of palatal roots is



FIGURE 10 Periapical radiographs. a, Before the surgery. b, Immediately after the surgery. c, Three months after the surgery. d, Six months after the surgery. Bisecting angle technique. The crown has also been replaced for esthetic reasons

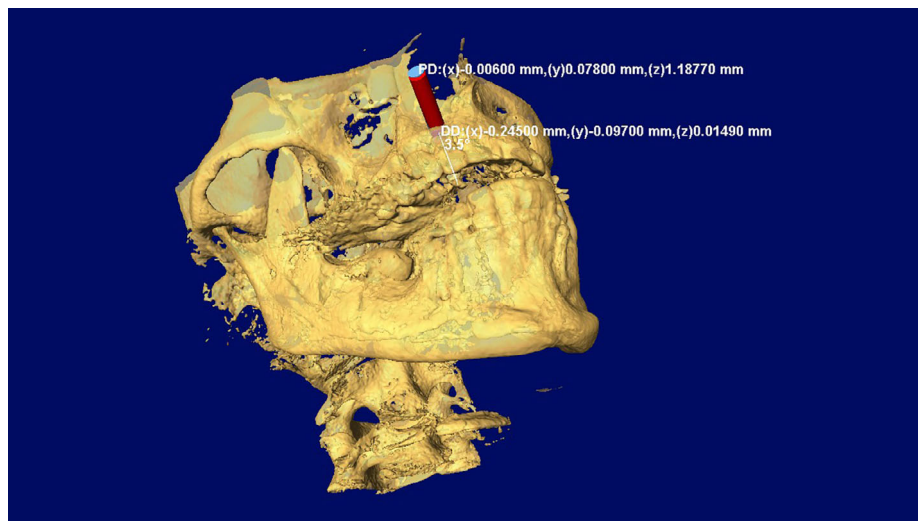


FIGURE 11 Accuracy analysis in Amira. ANG, angular deviation; DD, distal deviation; PD, proximal deviation. Coronal and apical deviations are broken down to x (horizontal), y (depth), z (vertical) vectors

theoretically not excluded (with buccal access preparation), but we have no experience with such cases. A foreseeable limitation is that in some cases access in the molar region will be limited (ie, the soft tissues of the face cannot be retracted enough to allow the insertion of the guide with the trephine and a hand piece). The problem may be addressed by using shorter trephines (readily handled by the software too), but this naturally limits the possible depth of penetration.

A technical issue to be mentioned is that we CBCT scanned the patient's impression, but this is only one of the possible protocols, which we followed because we have prior experience with it.^{19,23} Optical scanning of the impression or of a poured model, however, is just as possible, and may even allow more accurate 3D models, as the latest studies suggest.²⁴ Still, we would not recommend intraoral optical scanning, given the difficulties with soft tissue movement during scanning.

Our case corroborates the findings of Giacomino et al¹⁸ regarding guided endodontic surgery with a trephine. Digitally assisted, guided endodontic surgery with a trephine appears to be an easily performed,

safe, and complication-free method, which allows the resection and removal of the root tip in a single step. The approach itself is a step toward a standardized digital system and workflow dedicated to guided endodontic surgery.

The system is still under testing and not yet commercially available. Three-dimensional accuracy measurements (ie, comparison of the digital plans with the end results) are under way, but we do not have enough data at this point to draw firm conclusions. The available data indicate that surgical accuracy achievable this way is similar to that observed in connection with full guided implant placement. This suggests that the enhanced fit of the trephines also enhances accuracy, but this can be stated only when a statistically meaningful number of cases has been reached.

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commercial organization with direct financial interest in the subject or materials discussed in this manuscript, nor have any such arrangements existed in the past 3 years.

CONFLICT OF INTEREST

Other potential conflicts of interests are: L.S. is senior software developer at dicomLAB Dental, Ltd.; G.B. is chief researcher at dicomLAB Dental, Ltd.

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