Computer-designed surgical templates improve the extraction of impacted supernumerary teeth in the hard palate

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Objectives: *The surgical procedure of bony impacted supernumerary teeth (SNT) in hard palate is commonly done with poor visualization and uncomfortable posture. This study aims to introduce our primary practice of presurgical evaluation and guiding exodontia of bony impacted supernumerary teeth (SNT) in the hard palate to reduce surgical trauma, duration and uncertainty.* ***Study design:*** *Twelve patients with impacted supernumerary teeth in hard palate were included. Intraoral scan and the three-dimensional (3D) reconstruction of the cone beam computed tomography (CBCT) file was superimposed, and virtual simulation of flap elevation and osteotomy was conducted on the rebuilt 3D model. A couple of surgical templates were designed with surgical planning software Mimics, fabricated by a 3D printer and were used to guide the extraction of the impacted SNT.* ***Results:*** *The surgical templates fitted well to the teeth and operation site. All the impacted SNTs were accurately located and extracted without damaging the adjacent vital anatomical structures. All patients had an uneventful postoperative recovery without infection or sensory disturbance.* ***Conclusions:*** *The application of 3D printed surgical templates reduced trauma and increased the accuracy and predictability of surgical extraction of bony impacted SNT in hard palate. The results of this study increased the accuracy and predictability of surgical extraction of bony impacted SNT in hard palate, and reduced the surgeon's embarrassment and surgical trauma because of location difficulty.*

Keywords: *3D printing, Surgical template, Impacted supernumerary teeth, Hard palate*

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INTRODUCTION

Supernumerary teeth (SNT) may cause retarded eruption, malposition or incomplete impaction of permanent teeth, follicular cysts and commonly should be extracted[1,2]. Accurate location of the impacted SNT is a challenge even to an experienced oral maxillofacial surgeon and is critical during extraction[3]. Cone beam computed tomographic (CBCT) and intraoral scanner provide the clinicians with digital anatomical information of the SNT and the adjacent structures. With computer-aided design and computer-aided manufacturing (CAD/CAM) the digital information can be transferred accurately into actual surgery procedure[4]. Few scattered cases have been reported to combine these emerging technologies for impacted SNT extraction[5,6]. While in this study, we shared our experience of designing a couple of surgical templates for extraction of palatal bony impacted SNT in consecutive cases, making the surgical procedure more predictable and less invasive.

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MATERIAL AND METHOD

Study population

This study included 12 consecutive patients (7 females and 5 males) with impacted SNT, who underwent surgical extraction between October 2019 and February 2021 in our department (Department of Oral and Maxillofacial Surgery, School/Hospital of Stomatology, Zhejiang Chinese Medical University) for orthodontic treatment reasons. The age of the patients ranged from 8 to 16 years (mean age 11.08 years). The inclusion criteria were, (1) SNT impacted in hard palate, (2) covered by cortex bone, (3) have indication for extraction, (4) the patients and their guardian agreed with the procedure, (5) no contraindication for extraction.

Digital anatomical information acquisition

CBCT examination was performed for each patient, digital anatomical information of maxillary teeth and bone was acquired and stored in DICOM (Digital Imaging and Communications in Medicine) format. The maxillary teeth and hard palate mucosa were scanned by an intraoral scanner (3shape, Copenhagen, Denmark) (Fig. 1a) and data was stored in STL (stereolithography or surface tessellation) format.

Data processing and surgical guides fabrication

The DICOM file was uploaded to the computer-aided design software Mimics (Materialise, Belgium). With the segmentation function, the maxilla was separated from the skull and mandible and 3D modeling was performed (Fig. 1b). Next, the STL file acquired from oral scanning was imported into Mimics and superimposition of the DICOM and STL file was done using three dental cusps as reference points (Fig. 1c). On the new 3D model, which included both soft and hard tissue, thickness of mucoperiosteal flap and radius of curvature of palatal vault were measured. Then the SNT was projected to the surface of the mucosa (Fig. 1d).

According to the projection of the SNT, an incision template was designed. The template had three components: retainer, which was supported by teeth, connector and locating guide, which was supported by mucosa (Fig. 2a). Then virtual simulation of mucoperiosteal flap elevation was done and a fenestration template was designed. The fenestration template also had three components: retainer, which was supported by teeth, connector and osteotomy guide, which was supported by cortical bone (Fig. 2b). The designed digital templates and a 3D maxilla model were stored as STL files, which were then exported and send to a 3D printer. After the 3D maxilla model and surgical templates were fabricated, a final try-in was performed before sterilizing the templates.

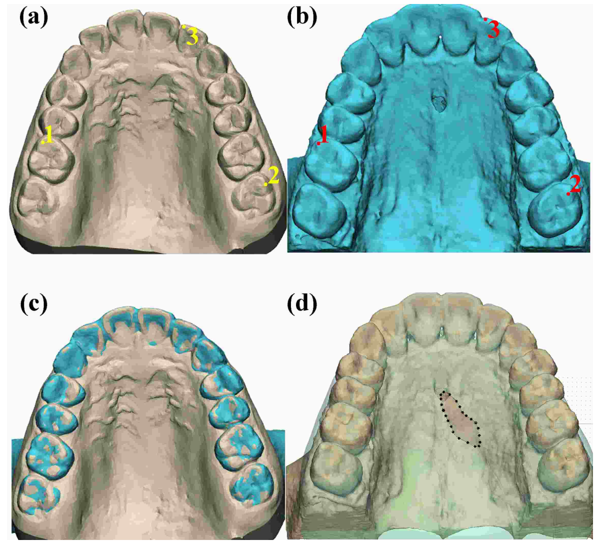

Figure 1: Data processing. a: Intraoral scan of upper teeth and palatal mucosa; b: 3D modeling of maxilla with CBCT data; c: Superimposition of the 3D model and intraoral scan; d: SNT was projected to the surface of palatal mucosa.

Surgical implementation

All the surgeries were executed under general anesthesia by the same senior surgeon. After disinfection, incision template was placed in right position and a semi-lunar mucosal incision was designed (Fig. 3a). Local anesthesia was obtained with 4% articaine and 1:100000 epinephrine. Subsequently, the incision template was detached, mucoperiosteal flap was elevated, and fenestration template was attached to the teeth (Fig. 3b). An electric surgical handpiece was used to perform the osteotomy under a permanent cooling with normal saline, until the crown of SNT was exposed. Then, the fenestration template was removed and the bone fenestration was father widened, the SNT was extracted by conventional method and the dental follicle was removed with curette. A primary wound closure was performed with 4-0 or 5-0 absorbable suture (Fig. 3c).

RESULTS

Anatomic parameters related to surgical difficulty, including thickness of mucoperiosteal flap, radius of curvature of palatal vault, and curvature of palatal vault of all patients were sum up (Table 1). A total of 13 teeth were extracted without injury to the adjacent teeth, nerves, and other structures. The surgical templates fitted well to the teeth and operation site. There was one patient suffered from postoperative bleeding on the day after operation because of one stich falling off, and was stitched up again with 3-0 silk suture. All the patients had an uneventful postoperative healing without infection and sensory disturbance. Except for present case (patient 2), with the guiding of surgical templates, the SNTs could be found quickly after osteotomy.

CASE PRESENTATION

A 10-year-old boy was referred by his orthodontist to our department for removing an impacted SNT. The patient's personal medical history was unremarkable, and the results of all laboratory analyses were within normal limits. CBCT visualized an impacted SNT on the palatal side of the dentition, with conic crown in proximity to right maxillary canine, and root in the vicinity of right maxillary lateral incisor root apex, right

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Table 1: Information and anatomic parameters of all patients included in study.

Patient	Sex	Age	N	Thickness (mm)	Radius (cm)	Curvature
1	F	16	1	1.63	4.73	0.21
2	M	10	1	5.11	2.36	0.42
3	F	12	1	2.44	3.79	0.26
4	F	10	1	2.15	2.90	0.34
5	M	8	1	2.61	3.50	0.29
6	M	13	1	1.68	4.12	0.24
7	M	11	1	2.72	3.13	0.32
8	F	12	1	2.36	3.21	0.31
9	F	9	2	2.21	4.07	0.25
10	M	10	1	2.16	3.65	0.27
11	F	10	1	1.93	4.38	0.23
12	F	12	1	2.52	3.47	0.29
Mean		11.08		2.46	3.61	0.29

F, female; M, male; N, number of SNT; Thickness, thickness of mucoperiosteal flap; Radius, radius of curvature of palatal vault; Curvature, curvature of palatal vault.

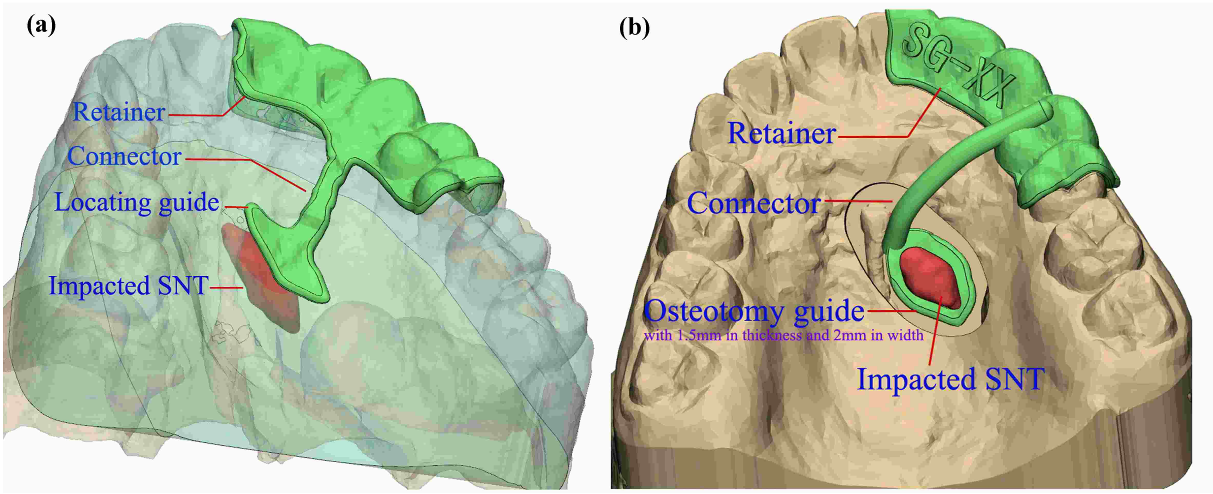

Figure 2: Templates design. a: Incision template was designed according to the projection of SNT, including 3 portions: retainer, connector, locating guide. The thickness was 1.5 mm; b: Fenestration template was designed. The diameter of connector was 3 mm. The osteotomy guide should cover the crown and cervix of the SNT, with 1.5 mm in thickness and 2 mm in width.

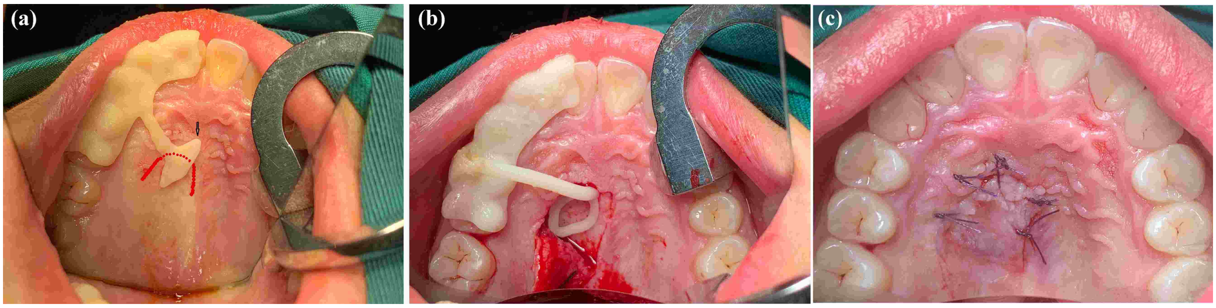

Figure 3: Intraoperative application. a: Arrow shows the locating guide, and red line shows the incision design; b: Mucoperiosteal flap was elevated and fenestration template was mounted; c: Primary wound closure with 4-0 absorbable suture.

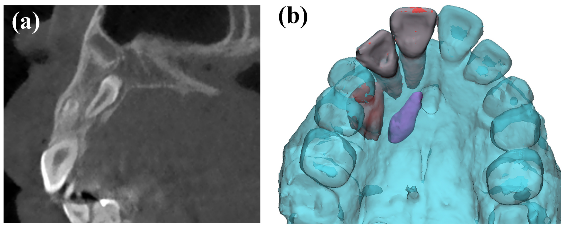

Figure 4: Anatomical location of the SNT. a: Sagittal view of the impacted SNT; b: Three dimensional relationship between the SNT and adjacent teeth and incisive foramina.

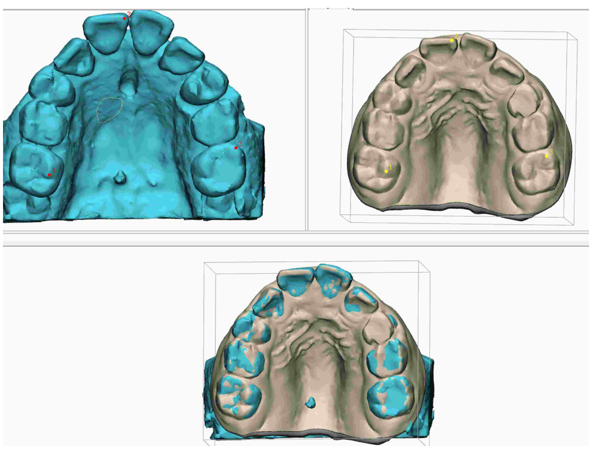

Figure 5: Data fusion. Superimposition of the CBCT image and intraoral scan.

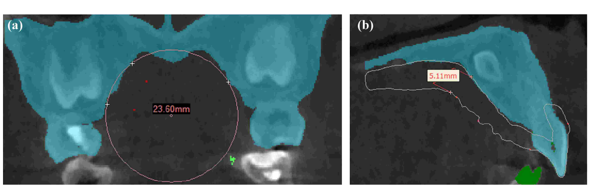

Figure 6: Anatomical features of the palate. a: Radius of curvature of palatal vault was 2.36 cm; b: Thickness of mucoperiosteal flap was 5.11 mm.

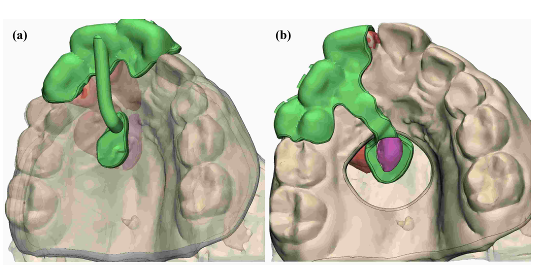

Figure 7: Templates design. a: Incision template was designed based on the projection of SNT; b: Virtual simulation of mucoperiosteal flap elevation was done and fenestration template was designed.

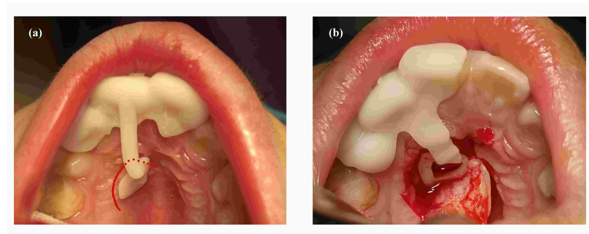

Figure 8: Intraoperative application. a: Semi-lunar mucosal incision (red line) was designed with the indication of locating guide; b: Mucoperiosteal flap was elevated, and large amount of submucosal tissue was noticed.

Figure 9: The SNT was successfully extracted.

maxillary central incisor root, and incisive foramina (Fig. 4a–b). Intraoral surface scan was performed and the STL file was superimposed with DICOM file acquired from CBCT (Fig. 5). With this digital information, the radius of curvature of palatal vault was metered as 2.36 cm (Fig. 6a), and the corresponding curvature was 0.42, which is larger than the average number 0.29 (Table 1). The thickness of mucoperiosteal flap was 5.11 mm (Fig. 6b), much thicker than the average thickness of the other 11 patients. A couple of surgical templates were designed, and fabricated by 3D printer (Fig. 7). During operation, a minimal, semi-lunar mucosal incision was designed around the crown, avoid stretching across the incisive foramina (Fig. 8a). Subsequently, the mucoperiosteal flap was elevated, and large amount of submucosal tissues was noticed (Fig. 8b). Large curvature of palatal vault and abnormal thickened mucoperiosteum led to poor visualization and difficult surgical access. Osteotomy was poorly able done with straight electric handpiece. The SNT was extracted as a whole after more invasive osteotomy (Fig. 9). After irrigation, a primary wound closure was performed with 5-0 absorbable suture. There was no bleeding, infection or sensory disturbance in the following 3 months.

DISCUSSION

SNTs are common developmental abnormalities, with a prevalence varies between 0.15% and 3.9% in the general pop-

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ulation [7–9], and have the most frequent location in the anterior maxilla [10].

Three-dimensional imaging examination is commonly needed to provide anatomical information for locating the impacted SNTs [11]. With the impression of the CT image, the oral maxillofacial surgeons locate the SNTs by 3D spatial imagination and use adjacent erupted teeth as reference substance. If SNT is adjacent to dentition and covered by very thin cortex bone, the locating process is relatively not complex. As the distance from the dentition and the depth of the SNT increase, the surgeon's spatial perception decrease. Surgical extraction of SNT could be complicated and challenging, if it is deeply impacted inside the bone. Furthermore, during a palatal approach surgery, our line of sight is not perpendicular to the surface of bone and the osteotomy may deviate from vertical direction, which will lead to more trauma to the bone and mental and physical exhaustion to the surgeons. Therefore, an auxiliary locating appliance is necessary.

CBCT is characterized by high spatial resolution and provides detailed digital anatomical information of teeth and bone [12]. Intraoral scan acquires accurate topographic information of teeth and mucosa, compensating for the unclear occlusal surface of CBCT data [11]. With superimposition of CBCT scan and intraoral scan, we acquire relatively intact anatomical information of both soft and hard tissue [13]. According to the statistical description (Table 1), the palatal vault commonly curves gently with an average curvature of 0.3, and the mean thickness of mucoperiosteum was 2.48 mm. Surgeons are used to focus their attentions on the CBCT image about the thickness of bone covering the SNT in presurgical evaluation. Considering the poor visualization and uncomfortable posture of palatable approach, we emphasize the importance of preoperative evaluation of mucoperiosteum thickness, which also decides the depth of SNT, and palatal anatomical morphology, which significantly affects the visualization. In present case, abnormal thickened mucoperiosteum was noticed in virtual surgery and was verified with abundant submucosal tissue in actual surgery. In this situation, a larger flap should be elevated and more invasive osteotomy should be done to get better visualization, and angled handpiece works much better than straight one.

In present study, a couple of templates were designed for auxiliary localization of impacted SNT, reducing trauma caused by flap elevating and osteotomy, by transferring the virtual surgical simulation to the actual surgical procedure. When the SNT was already exposed, conventional method was used to extract it. The incision template was designed to display the mucosa surface projection of SNT and guide the incision design. Semi-lunar flap was commonly designed and elevated toward the opposite side of template retainer to avoid surgical access inconvenience of fenestration template. Besides, the size of osteotomy guide should be as small as possible on condition that by guiding osteotomy the crown of SNT should be exposed.

As it is known to all, any workflow has systematic error. Surgical templates fabricated by CAD/CAM (Computer-Aided Design and Manufacturing) based on superimposition data from CBCT and oral scan have been widely used in dental implant [14], which require higher accuracy. According to present study, as long as the fabrication was done step-by-step and no mistake was made, the 3D printed templates showed high satisfaction in surgical procedure. Indeed, there were some disadvantages including intensive labor, time consuming and extra cost to the patients. While, as the rapid development of 3D printing technology, a number of medical technology services companies have sprung up. They provide highly efficient service in no more than one day and reasonable price at about $140 for one set of templates.

There were some limitations to present study. First, randomized controlled trial was not performed to evaluate the advantages of present method compared to conventional method. Secondly, the fenestration template indicated the initial site of osteotomy, but couldn't make sure the osteotomy done minimally invasive. Modification should be performed to the surgical templates design to gain better outcome in further study. Thirdly, according to our experience, thickness of mucoperiosteal flap was correlated with curvature of palatal vault, but this need more samples and rigorous statistical analysis.

In conclusion, 3D printed surgical templates increased the accuracy and predictability of surgical extraction of bony impacted SNT in hard palate, and reduced the surgeon's embarrassment and surgical trauma because of location difficulty.

FUNDING

Research Project of Zhejiang Chinese Medical University (Number: 2021ZY13).

ETHICAL APPROVAL

The study protocol was approved by the Ethics Committee of School/Hospital of Stomatology, Zhejiang Chinese Medical University (judgement reference number ZYYKQ2019012).

COMPETING INTERESTS

We declare no conflict of interest.

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