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DENTAL TECHNIQUE

Fully digital workflow for the design and manufacture of prostheses for maxillectomy defects

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ABSTRACT

A fully digital workflow for the design and manufacture of prostheses for maxillectomy defects was described. Three-dimensional images from spiral computed tomography and intraoral scanning were used to generate a three-dimensional digital cast of a maxillectomy defect. The obturator prosthesis was then designed on the digital cast by combining dental computer-aided design and reverse engineering software programs. The prosthesis was subsequently milled from polyetheretherketone or three-dimensional–printed from polylactic acid. (J Prosthet Dent 2021;126:257-61)

While surgical reconstruction is the preferred treatment for maxillectomy defects,[1] many patients continue to receive obturator prostheses for a variety of reasons, including specific anatomic features, tumor recurrences, and financial limitations.[2] Along with the development of digital technology in dentistry, digital procedures have gradually been introduced into the procedures for fabricating maxillofacial prostheses and have performed well in facial prostheses.[3] Although digital techniques have superseded some traditional processes of fabricating obturator prostheses,[4-8] reports of a fully digital workflow for fabricating obturator prostheses are lacking. A report described the production of 3D digital casts of maxillectomy defects by multisource data registration and mergence techniques and found their precision to be satisfactory for clinical application.[7] In addition, 1-piece removable partial dentures have been designed and manufactured with a fully digital workflow from polyetheretherketone (PEEK) and have been reported by in vitro studies to have good intaglio surface fit.[9,10] Other reports have described the use of PEEK to fabricate obturators and frameworks for

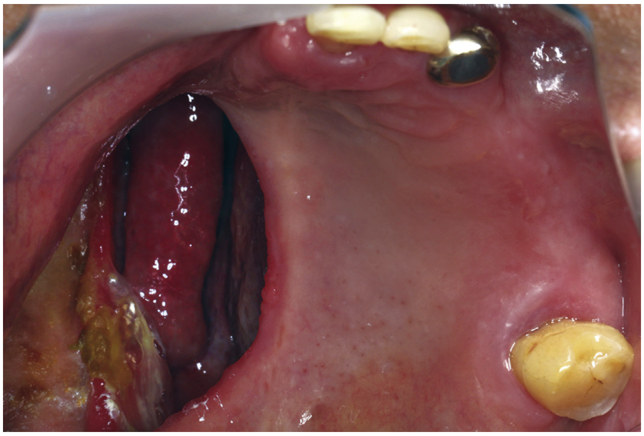

Figure 1. Occlusal view of right maxillectomy defect.

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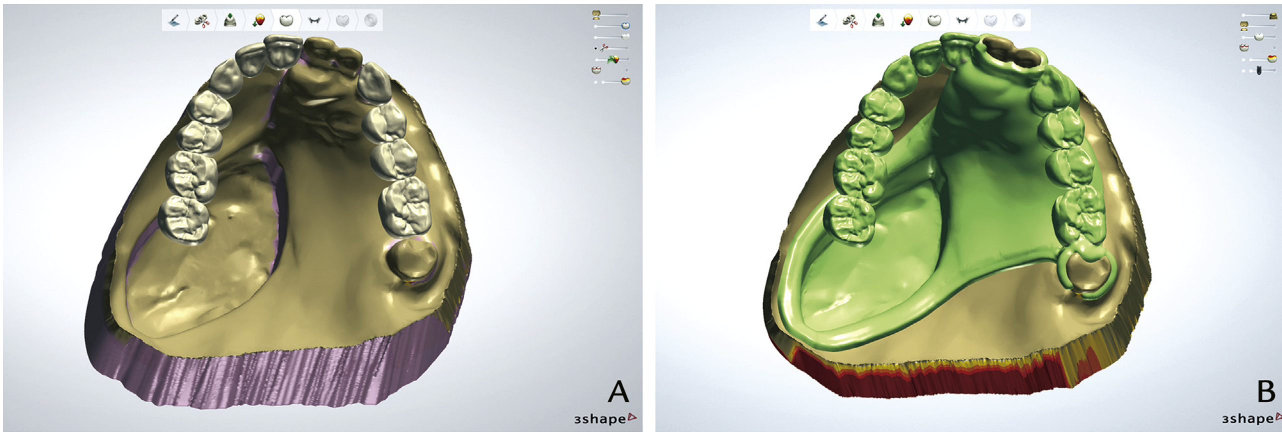

Figure 2. A, Placement of artificial teeth in appropriate position. B, Designing major and minor connectors and retainers.

removable partial dentures.[10,11] Based on the generation of 3D digital casts for maxillectomy defects, a technique was developed by combining dental computer-aided design (CAD) and reverse engineering software programs in a fully digital workflow for the design and manufacturing of prostheses for maxillectomy defects.

TECHNIQUE

1. Scan the maxillofacial region of a patient with a maxillectomy defect (Fig. 1) to include the whole defect cavity, the maxilla, and the maxillary dentition with spiral computed tomography (CT) (Optima CT520Pro; GE Healthcare). Import the CT images into a software program (Mimics Research 22.0; Materialise). Then reconstruct and extract the 3D images of the defect cavity and maxillary dentition respectively. Scan the maxillary dentition and palate, the mandible dentition, and the occlusal relationship with an intraoral scanner (TRIOS 3; 3Shape A/S). Register and merge the 3D images from the CT and intraoral scanner in a reverse engineering software program (Geomagic studio 2012; 3D Systems) to form a 3D digital cast of the maxillectomy defect containing the anatomic structures needed for the obturator prosthesis.[7] Another way to obtain a 3D digital cast of the maxillectomy defect is by scanning a gypsum cast formed from a silicone impression.
2. Set up a removable partial denture framework order in the dental CAD software program (Dental System 19; 3Shape A/S). Choose the missing teeth to set up a pontic order. Then import the 3D digital cast of the maxillectomy defect into the dental CAD software program.
3. Survey the 3D digital cast of the maxillectomy defect and virtually block out the undesirable undercuts of the teeth and the cavity of the defect. Trim the clasp shoulders where the clasps engage and locate the tips of the clasps in a 0.5-mm undercut. Trim the virtual wax in the undercut of the cavity of the defect depending on the design and material of the obturator prosthesis.

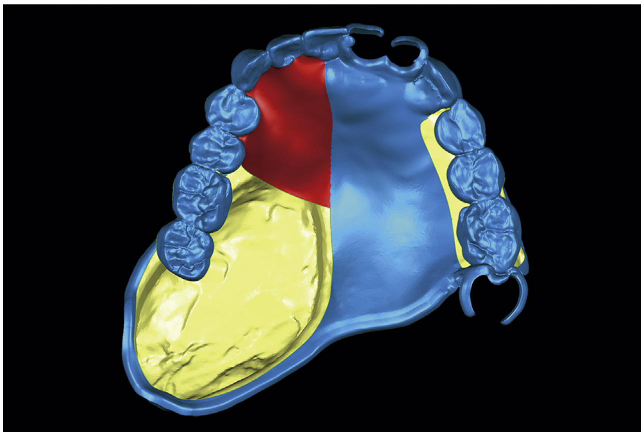

Figure 3. Denture bases designed in reverse engineering software.

4. Place the artificial teeth in the correct position according to the maxillary arch and mandible dentition (Fig. 2A). Ensure infraocclusion of the artificial teeth on the surgical side with the defect.
5. Design the retainers and connectors of the obturator prosthesis by carrying out the following points (Fig. 2B). First, the tips of the clasps are located in an undercut of 0.5 mm, the width and thickness of the clasps are 1.5 to 2.5 mm and 1.3 to 1.8 mm respectively. Second, the major connector extends to the border of the obturator prosthesis with the thickness of 2 to 2.5 mm. Then export the designed 3D image as a standard tessellation language file.
6. Import the designed 3D image into the Geomagic Studio software program. Create closed boundaries along the edge of the defect cavity, the

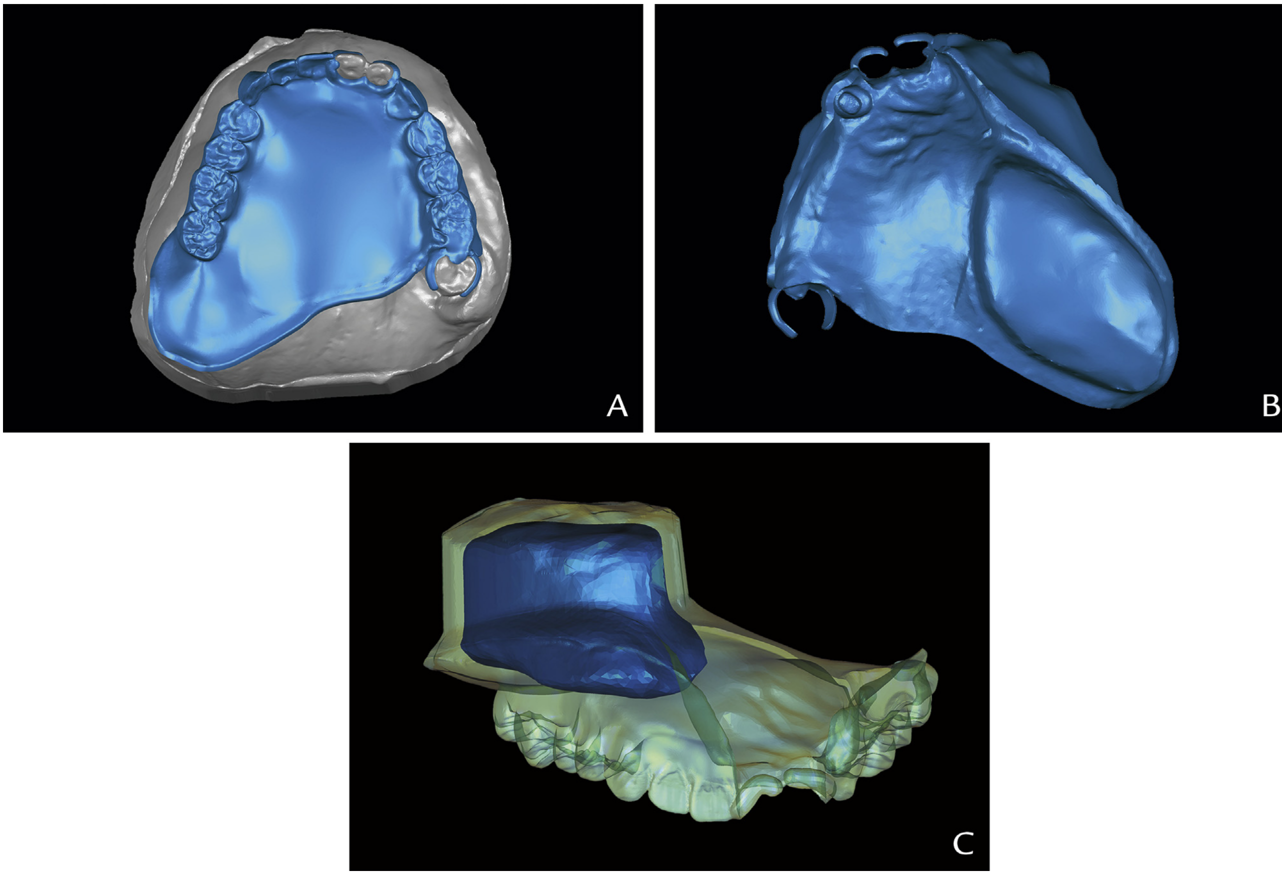

Figure 4. A, One-piece obturator prosthesis on digital cast. B, Intaglio surface of 1-piece obturator prosthesis. C, One-piece hollow obturator prosthesis.

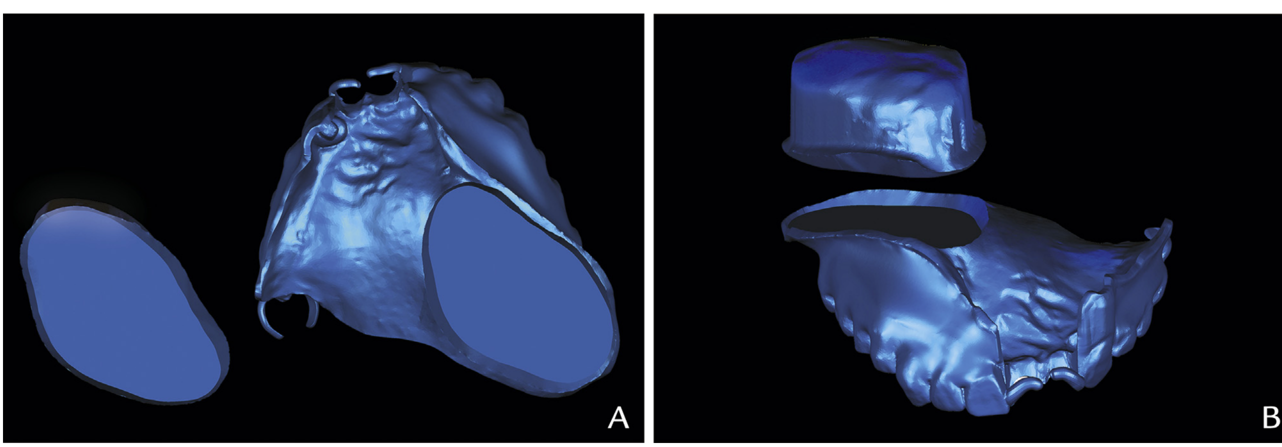

Figure 5. Design of 2-piece obturator prosthesis. A, Intaglio view. B, Frontal view.

corresponding alveolar ridge below the artificial teeth and the gingival curves of the artificial teeth. Delete the undesirable part within the boundaries; refill the gaps between the boundary of the defect cavity or the alveolar ridge and the boundary of the gingival curves by using the "Filling holes" function to form the bases of the obturator prosthesis (Fig. 3). Sculpt and smooth the cameo surface, if necessary, to complete the design of a 1-piece obturator prosthesis (Fig. 4A, B). Design the hollow structure by using the "Offset" function to obtain a 1-piece hollow obturator prosthesis if necessary (Fig. 4C).

7. Design the 2-piece obturator prosthesis (containing a bulb and a removable denture). Create a closed boundary on the intaglio surface of the 1-piece obturator prosthesis 3 mm away from the perforated hole on the oral side as the boundary between

Figure 6. Two-piece polyetheretherketone obturator prosthesis. A, Intaglio view. B, Frontal view.

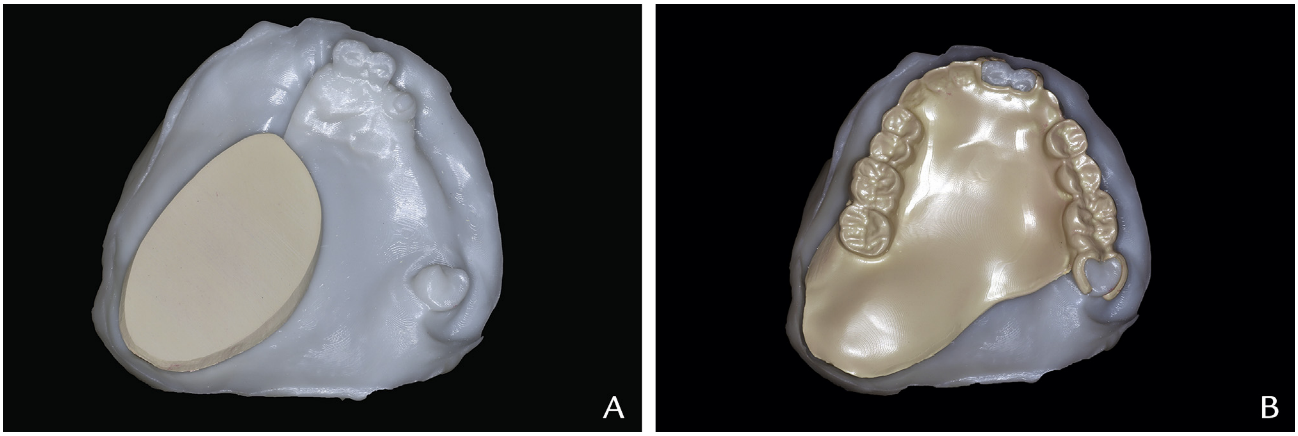

Figure 7. A, Bulb of 2-piece obturator prosthesis seated on resin cast. B, Obturator prosthesis seated on resin cast.

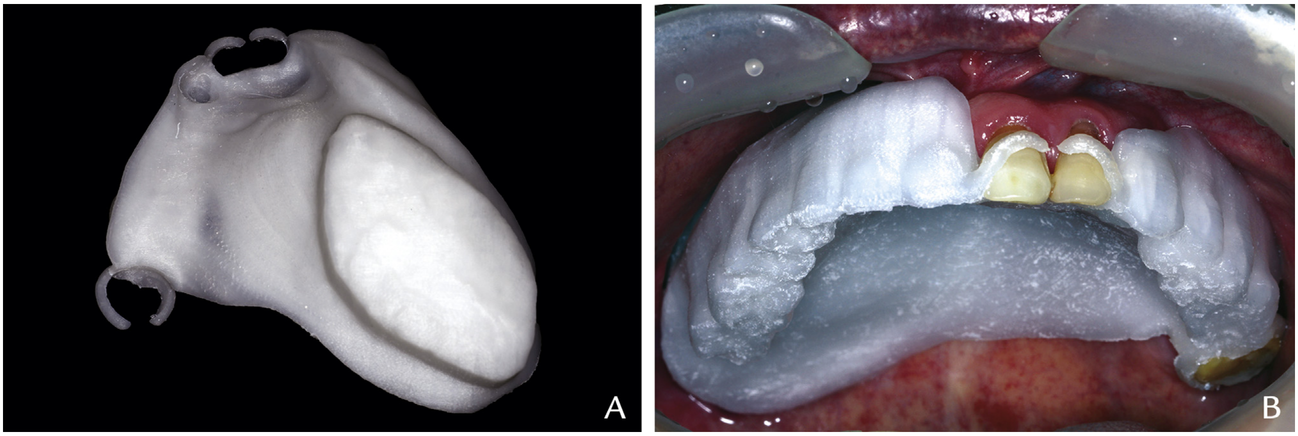

Figure 8. A, One-piece polylactic acid obturator prosthesis. B, Intraoral evaluation of 1-piece polylactic acid obturator prosthesis.

the bulb and the removable denture. Select and copy the 3D-image above the boundary as the bulb and design a chimeric structure attached to the removable denture. Subtract the bulb from the 1-piece obturator prosthesis with a Boolean operation to obtain the separated removable denture component of the obturator prosthesis (Fig. 5).

8. Digitally manufacture the obturator prosthesis. The first method is milling PEEK disks by using a 5-axis milling machine (Organical Multi; Organical CAD/CAM), which is suitable for a 2-piece obturator prosthesis and 1-piece obturator prosthesis of small height, as the height of any piece must be less than 28 mm (Figs. 6, 7). Connect the separated bulb and

removable denture with magnetic attachments inside or outside the oral cavity. The second method is 3D printing from a biosafe material such as polylactic acid (PLA) by using a fused deposition modeling 3D printer (Lingtong II; BeijingShino) with the high precision mode. The PLA obturator prosthesis can be used as an interim obturator prosthesis (Fig. 8).

DISCUSSION

The main innovation of this technique was the design and manufacture of 1-piece or 2-piece obturator prostheses by means of fully digital procedures. The technique allowed the undercuts of both the abutment teeth and the cavity of the defect to be accurately identified and trimmed. The chosen material, PEEK, has suitable strength, low density, good biocompatibility, and a similar elastic modulus to cortical bone, making it suitable for fabricating a reduced weight obturator prosthesis.[11] The retention force of PEEK clasps has been reported to ensure adequate retention of the obturator prosthesis.[10] The design and manufacture of hollow bulb obturators in the technique were more convenient than traditional methods. For the 2-piece PEEK obturator prosthesis, the space for magnetic attachments could be trimmed after fabrication of the PEEK prosthesis or directly designed, both of which were straightforward to perform. However, the esthetics of PEEK and PLA obturator prostheses are poor for anterior use but may be improved by facing a PEEK obturator prosthesis with resin or 3D printing a multicolored PLA obturator prosthesis. Another disadvantage of this technique was that a reverse engineering software program was needed in addition to the dental CAD software program, which will increase the learning time for a new designer. In the future, special software for designing obturator prostheses will be explored to improve the convenience and efficiency of the CAD procedures.

SUMMARY

This technique provided a fully digital workflow for the design and manufacture of prostheses for patients with maxillectomy defects.

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