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Reconstructive

Computer-aided Design and Syringe-aided Manufacturing for Mandibular Reconstruction Using a Vascularized Fibula Flap

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Summary: Thanks to the introduction of virtual surgical planning (VSP), mandibular reconstruction using a fibula flap has become simplified, and patient-specific reconstruction is now possible. With a VSP software, surgical "cutting guides" and custom-made titanium plates can be designed to help surgeons. However, they are expensive and require extended periods of time either for prototyping or to acquire the advanced knowledge necessary for operating the VSP software. The aim of this article is to introduce a new easy and low-cost method of surgical planning for mandible reconstruction using a computer-aided design and the syringe-aided manufacturing technique. Simulations of fibula osteotomy are performed using regular and commercially available 10-ml syringes. The syringes are cut into separate segments to fit the defect of the 3-dimensional mandible model and to match the prebent titanium plate. The syringe segments are then connected together 3-dimensionally to confirm that the shape matched both the contour of the defect and the angles of the mandible. The simulated syringe segments are used as cutting guides. Then osteotomies are performed according to the cutting guide to obtain the exact lengths and angles required to achieve precise bony reconstruction. The mandibular reconstruction procedures are successful, with a good match between the preoperative planned syringe models and the final results of the surgery. Although further clinical investigation will be required to confirm its efficacy, the computer-aided design and the syringe-aided manufacturing method has the potential to be a useful technique for mandible reconstruction using a vascularized fibula flap. *(Plast Reconstr Surg Glob Open 2020;8:e2819; doi: 10.1097/GOX.0000000000002819; Published online 21 May 2020.)*

INTRODUCTION

In mandibular reconstruction after tumor resection, it is still challenging for reconstructive surgeons to achieve functionally and esthetically good results. Since the introduction of virtual surgical planning (VSP), mandibular reconstruction has become simplified, and patient-specific reconstruction is now possible.[1–3] In 2009, Hirsch et al[4] reported that with computer-aided designs and computer-aided manufacturing (CAD-CAM), esthetically and functionally ideal surgical outcomes could be achieved. Introduction of so-called "cutting guides" enables exactitude in both the osteotomy of the mandible and the end and closing wedge osteotomies of the fibula bone.[4–7] With the VSP software, surgical "cutting guides" and custom-made titanium plates can be designed to help surgeons.[8,9] Although these methods have radically changed mandibular reconstructive surgery, they are expensive and require extended periods of time either for prototyping or to acquire the advanced knowledge necessary for operating the VSP software.

The aim of this article is to introduce a new easy and low-cost method of surgical planning for mandible reconstruction using computer-aided design and the syringe-aided manufacturing (CAD-SAM) technique.

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METHODS

A 66-year-old woman with a mandible gingival mass was diagnosed with squamous cell carcinoma and underwent hemimandibulectomy and left functional neck dissection. Reconstruction with a fibula osteocutaneous flap using the CAD-SAM technique as discussed below was performed.

CAD-SAM TECHNIQUE

1. Digital Imaging and Communications in Medicine (DICOM) data to create a 3-dimensional (3D) model: Planning began with a high-resolution axial computed tomography scan of the mandible. The data are saved in DICOM format and forwarded to the modeling company (Ahead Laboratories, Tokyo, Japan). These DICOM data are then converted to a 3D physical model of the mandible (Fig. 1).
2. Planning of mandible osteotomy and titanium reconstruction plate bending: A preoperative simulation of mandibular resection using a 3D physical model was performed. A titanium reconstruction plate or miniplates were then prebent to match the contours of the mandible shape, considering good occlusion on the 3D physical model (Fig. 1).
3. Preoperative simulations of the fibula osteotomy and manufacturing surgical guides with normal syringes: Simulations of the fibula osteotomy were performed using normal and commercially available 10-ml syringes. The syringes were cut into separate segments to fit the defect of the 3D mandible model and to match the prebent titanium plate. The syringe segments were then connected together 3D to confirm that the shape matched both the contour of the defect and the angles of the mandible (Fig. 1). Then, these simulated syringe segments were sterilized and used as cutting guides for fibula bone osteotomy after flap elevation.

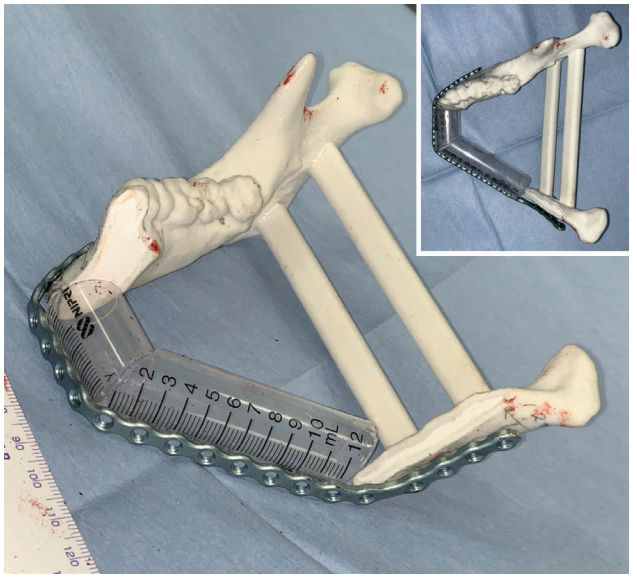

Fig. 1. The syringes were cut into separate segments to fit the defect of the 3D mandible model and to match the prebent titanium plate. The syringe segments were then connected together 3-dimensionally to confirm that the shape matched both the contour of the defect and the angles of the mandible.

Performing the Surgery

The simulated syringe segments were cut in half to use as cutting guides (Fig. 2). After the fibula flap was elevated, the cutting guides were temporarily attached to the fibula bone. Then, osteotomies were performed according to the cutting guide to obtain the exact lengths and angles required to achieve precise bony reconstruction. (**See Video 1 [online],** which shows that after the fibula flap was elevated, the cutting guides were temporarily attached to the fibula bone. Then osteotomies were performed according to the cutting guide to obtain the exact lengths and angles required to achieve precise bony reconstruction.) After insetting the osteotomized segments of the fibula bone to the defect with the prebent titanium reconstruction plate, microvascular anastomoses were performed (Fig. 3). A skin paddle was used to cover mucosal defect.

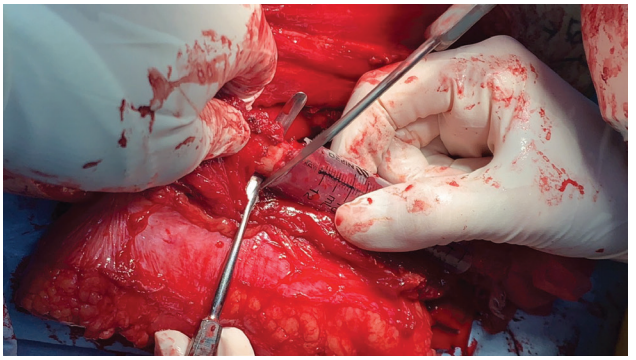

Fig. 2. After the fibula flap was elevated, the cutting guides were temporarily attached to the fibula bone. Then, osteotomies were performed according to the cutting guide to obtain the exact lengths and angles required to achieve precise bony reconstruction in accordance with preoperative planning.

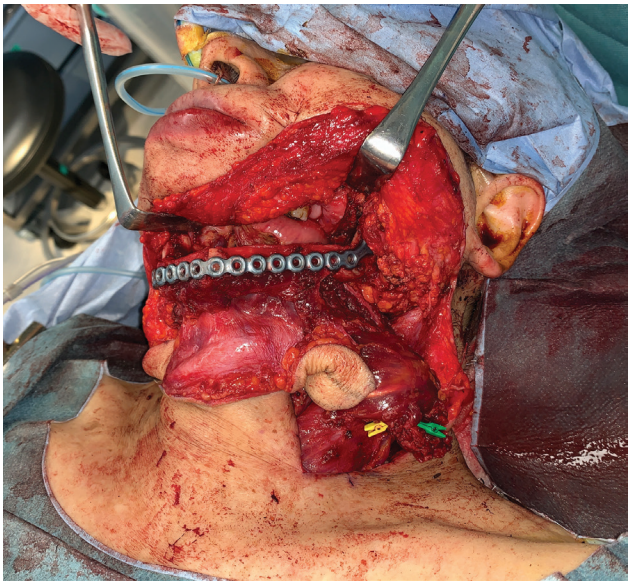

Fig. 3. Intraoperative view after the inset of the fibula bone.

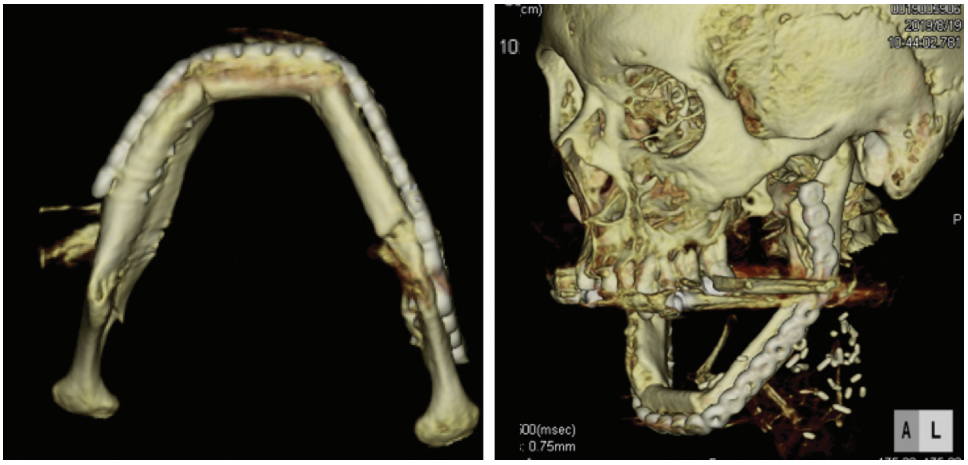

Fig. 4. The computed tomography images at 6 months after reconstruction of the mandible.

RESULTS

The CAD-SAM technique provided both low-cost fibula models and cutting guides for the fibula bone. This method shortened both the operation time and the ischemia time of vascularized fibula bone. The total time required to plan and fashion the plates was 30 minutes, and the operative time was 11.7 hours.

The mandibular reconstruction procedures were successful, with a good match between the preoperatively planned syringe models and the final results of the surgery (Fig. 4). The postoperative course was uneventful, and the transferred flap survived completely.

DISCUSSION

In recent years, several articles have recommended the use of VSP, computer-aided surgery, and CAD-CAM technology to guide mandibular segmental osteotomies for mandibular reconstruction using a fibula flap. Tarsitano et al[10] reported that the mean ischemic time of a fibula flap was 99 minutes using the CAD-CAM method, whereas 120–180 minutes was required if only hand shaping was used.[11] Hanasono and Skoracki[1] reported that reconstruction using virtual simulated methods was significantly more accurate than reconstruction using conventional methods. Ayoub et al[12] reported that deviation in the computer-assisted group was 1.5 mm, which was significantly smaller than that using conventional methods, where the deviation was 6 mm. Roser et al[5] achieved a mean deviation of 1.30 mm between VSP and the final results.

Apart from the advantages, the costs of CAD-CAM methods must be taken into account. Wilde et al[13] reported that it costs >6,000 US dollars for a fibula flap, including cutting guides. Orabona et al[14] reported on low-cost CAD-CAM methods using an algorithm based on free open-source software for digital planning and a 3D-layer plastic deposition printer to keep costs low. This method, however, needs advanced knowledge for operating the software, and there is also the initial investment cost. Thus, we introduced the easy and low-cost CAD-SAM technique.

The CAD-SAM technique is not as good as the CAD-CAM method, in terms of accuracy of reconstruction outcomes. The cutting guides manufactured from syringes only serve as cutting guides for a fibula bone. Aside from these drawbacks, the CAD-SAM technique confers several advantages. First, this technique is easy and low cost. The 10-ml syringes, which are used for the fibula model and cutting guides, are easy to obtain in any medical institution and cost only $0.12 per piece. A previous study in which the cost of CAD-CAM of mandibular reconstruction using a free fibula flap is analyzed reported that the cost of operative medical devices of CAD-CAM group is €3,876.4 higher than that of conventional method group.[15] The cost of the 3D physical model of the mandible, which is used in our article, is about ¥40,000 = €333. Therefore, our method is about €3,500 cheaper than that of VSP with cutting guides. As advanced knowledge for operating the software is not necessary, any surgeon can use this method. Second, using this method, it is easy to change the plan or cutting guide during the surgery. It is easy to change the shape of a plastic syringe using scissors. Therefore, it is easy to change the shape of the fibula models manufactured from syringes to match the defect, even if the plan for mandible resection has changed.

Although further clinical investigation will be required to confirm its efficacy, the CAD-SAM method has the potential to be a useful technique for mandible reconstruction using a vascularized fibula flap.

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PATIENT CONSENT STATEMENT

The patient provided written consent for the use of her image.

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