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Reconstructive

Novel Plate Design to Improve Mandibular and Maxillary Reconstruction with the Osteocutaneous Fibula Flap

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Summary: Virtual surgical planning (VSP) has improved the accuracy and efficiency of craniofacial reconstruction using the osteocutaneous free fibula flap. Despite this, challenges remain in translating the VSP to a real-world construct due to small changes that can occur after osteotomies of the mandible or maxilla. Poor execution of the VSP can lead to malocclusion, undesirable aesthetics, or poor bony contact at the sites of osteosynthesis. We describe a novel technique using Selective LASER Melted plates to achieve maximum control and accuracy of complex, virtually planned reconstructions of the mandible and maxilla. *(Plast Reconstr Surg Glob Open 2019;7:e2094; doi: 10.1097/GOX.0000000000002094; Published online 4 January 2019.)*

The osteocutaneous free fibula flap is the ideal solution for complex reconstruction of the mandible and maxilla. Virtual surgical planning (VSP) can be used to optimize osteotomies and fibula position to achieve goals of bone union, dental rehabilitation, and facial aesthetics.[1,2] Furthermore, VSP reduces operative times[1,3] and cost.[4] Prefabricated, patient-specific, cutting guides allow accurate osteotomies of both the facial skeleton and the fibula according to the virtual plan. Still, perfect positioning of the bony elements (fibula and mandible or maxilla) have distinct challenges. For the lower jaw, maintaining correct alignment of the remaining segments of the mandible to avoid temporomandibular joint misarticulation is paramount. This is difficult to achieve once the mandible has lost continuity. Accurate placement of the fibula in maxillary reconstruction is difficult because there is limited space in the midface. The fibula must be placed precisely to ensure proper dental implant positioning while avoiding intrusion by the fibula into the nasal vestibule. In addition, if the fibula is positioned too anteriorly it will deform the alar bases, affecting the aesthetic result.

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The strategies traditionally used to prevent mandibular malposition all have limitations. First, a reconstruction plate can be placed on the lower border of the mandible before the resection.[5] The fibula is inset along this inferior mandibular border to fit the plate. However, with the introduction of VSP, the fibula position is planned preoperatively to ensure it meets the requirements for dental implant placement while optimizing aesthetics. If the fibula is not intended to be inset along the lower border, all landmarks for positioning are lost. The position of the fibula must be estimated and the fit to the plate can be poor. Second, external fixation or intermaxillary fixation may be used to maintain the temporomandibular joint (TMJ) position correct after the bone resection. Not only are external fixators cumbersome, but they may interfere with the resection and add time to the operation. Without patient-specific landmarks, insetting the fibula according to the VSP still requires estimation and good bone–bone or bone–plate contact is not guaranteed.

For maxillary reconstruction, intraoperative surgical navigation systems can assist in determining fibula location. This strategy is limited by the time required for registration of the device and the accuracy of the technology. Navigation systems have an SD of about 1 mm, which is difficult to tolerate in this location.[6]

Although VSP can delineate an ideal plan, improvements to the execution of the plan were needed to position and secure the native bone and fibula exactly as planned. This report serves to alert surgeons to the

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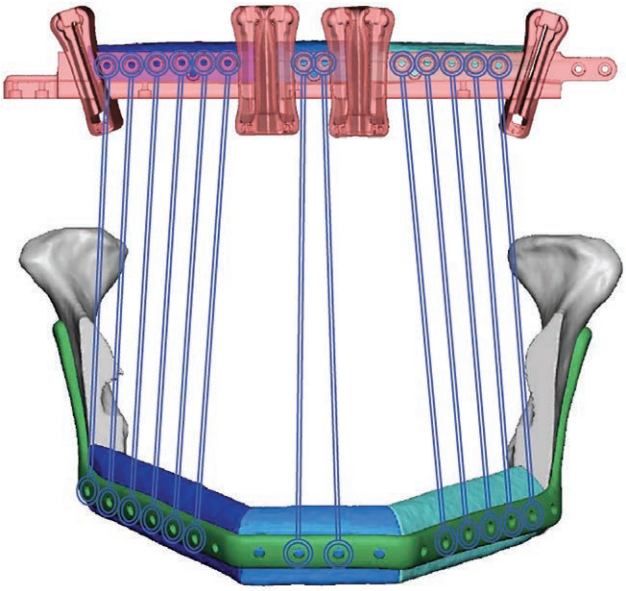


Fig. 1. VSP and SLM plate design for a representative mandibular reconstruction. Anterior view of the mandible reconstructed with a 3-segment fibula flap. The fibula cutting guide (top) shows the predictive ◎ fixation holes to match SLM plate fixation holes on the reconstructed mandible.

benefits of Selective LASER Melted (SLM) plates designed with flanges or tabs. This combination has allowed a paradigm shift in the execution of VSP for mandibular and maxillary reconstruction in our center. SLM plates are now our choice for patient-specific implants to reduce the margin of error from the VSP.

SLM is a type of 3D printing. This technique uses a high power-density LASER to melt metallic powder into a solid 3-dimensional structure. Titanium particles are fused together in layers to generate a patient-specific plate based on computed tomography (CT) scans and the virtually planned reconstruction. Plate design is flexible allowing the surgical team to cover almost any part of the reconstruction necessary for stability and contour. SLM plates are dense, strong, and contour precisely to the reconstruction and native bone. In contradistinction to pre-bent plates, which are shaped by hand, the SLM is computer manufactured and therefore exact.

We have introduced a tab feature that wraps around the native bone segments to increase control (Figs. 1, 2). This novel plate design allows the surgical plan to be carried out precisely without the need for estimation. The tabs allow for precise registration of the plate to the remaining native segments of the mandible/maxilla. The flexibility in SLM plate design also permits the addition of predictive screw holes in the cutting guides that match the plate to increase the points of registration (Figs. 1–3). The accuracy of these plates makes them a positioning device. We feel the tabs have made the plate an ideal way to transfer the virtual plan to the surgical plan because the position of the remaining mandibular segments and the fibula are accurately controlled by the plates inherent design [Figs. 1–4; **see figure, Supplemental Digital Content 1**, which displays the VSP and SLM plate design for a representative mandibular reconstruction. **A.** Planned fibula reconstruction for left lateral mandibulectomy. Fibula is positioned to facilitate dental rehabilitation. **B.** Mandibular cutting guides with predictive ◎ fixation holes that match the SLM plate (**D**). **C.** Fibula cutting guide with predictive ◎ fixation holes that match the fibular portion of the SLM

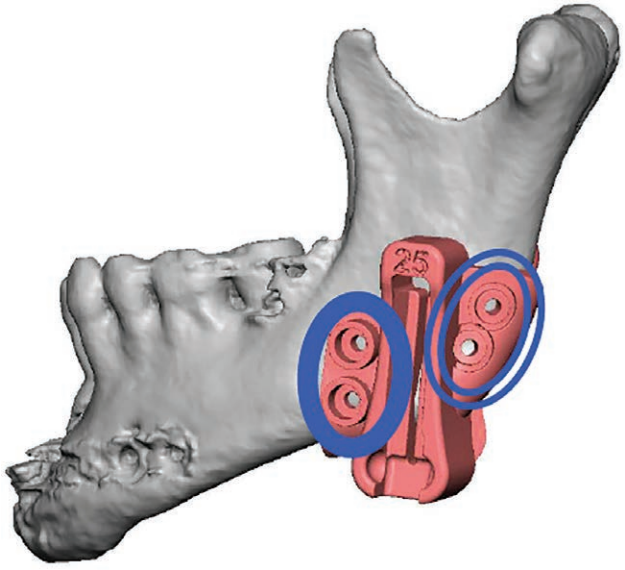


Fig. 2. VSP for the mandibular osteotomies of the reconstruction seen in Figure 1. Lateral view showing the left mandibular cutting guide. Predictive ◎ fixation holes and nonpredictive ○ holes are indicated. Predictive fixation holes on the cutting guide match fixation holes on the SLM plate for extra points of registration.

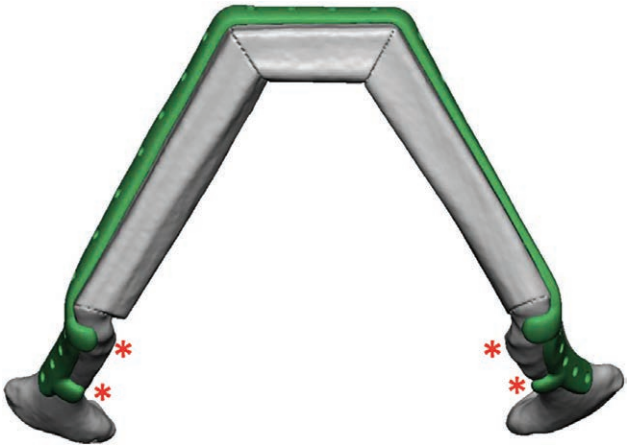
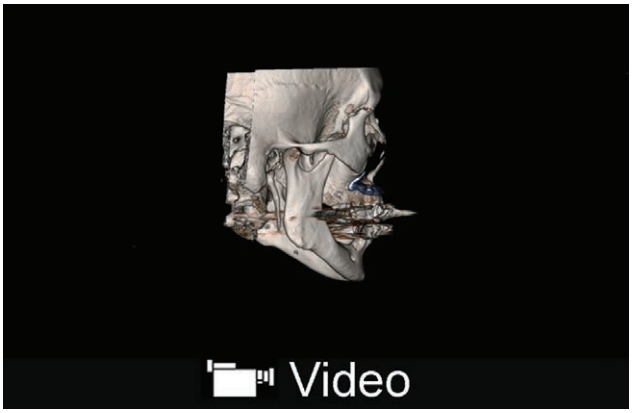


Fig. 3. VSP and SLM plate design for the mandibular reconstruction seen in Figure 1. Worms-eye view of the reconstructive mandible with SLM plate in place. Novel positioning tabs (*) are used to register precisely with the native mandible.



Video Graphic 1. See video, Supplemental Digital Content 5, which displays the postoperative CT scan of the maxillary reconstruction illustrated in **Supplemental Digital Content 2**. Three-dimensional reformatting demonstrates the fibula free flap and SLM plate in the configuration of the virtual surgical plan. This video is available in the "Related Videos" section of the Full-Text article on PRSGlobalOpen.com or at ***http://links.lww.com/PRSGO/A972***.

plate in (**D**). **D.** Oblique and worms eye view of VSP with mandible, fibula and SLM plate in positions. Predictive ◎ fixation holes on the native mandible and fibula ensure precise positioning of all element of the reconstruction. Tabs (*) are designed to wrap around the lateral mandibular segment for addition points of registration. Intraoperative view of completed reconstruction with positioning tab (*), ***http://links.lww.com/PRSGO/A968***; **see figure, Supplemental Digital Content 2**, which displays the VSP and SLM plate design for a representative maxillary reconstruction. **A.** Preoperative imaging of maxillectomy defect after previously resection. The patient's goals were to eliminate the need for an obturator, have dental rehabilitation and improve the appearance of the ipsilateral alar base. **B.** VSP of fibula reconstruction to achieve the stated goals. **C.** SLM plate designed to position and stabilize the construct. **D.** Worms eye views of reconstruction demonstrating the positioning tab on the SLM plate (*). **E.** Left lateral view of reconstruction demonstrating the positioning tab on the SLM plate (*) as well as the predictive fixation holes ◎ matched to those on the fibula cutting guide (**F.**). Free style SLM plate design, registration tab and predictive fixation holes facilitate rapid and accurate positioning of a complex maxillary reconstruction, ***http://links.lww.com/PRSGO/A969***; **see figure, Supplemental Digital Content 3**, which displays the VSP and SLM plate design for a representative mandibular reconstruction. **A.** Anterior view of Virtual Surgical Plan for 3 segment fibula reconstruction. **B.** Lateral mandibular view showing the left mandibular cutting guide. Predictive ◎ fixation holes and nonpredictive ○ holes are indicated. Predictive fixation holes on the cutting guide match fixation holes on the SLM plate for extra points of registration. **C.** Anterior and worms-eye view of the reconstructive mandible. The fibula cutting guide shows the predictive ◎ fixation holes to match SLM plate fixation holes and the novel positioning tabs (*) are used to register precisely with the native mandible, ***http://links.lww.com/PRSGO/A970***; **see figure, Supplemental Digital Content 4**, which displays the intraoperative images for the VSP represented in Fig. 3. **A.** SLM plate with tabs (*) for control of lateral segment visualized. **B.** Inferior view of completed reconstruction demonstrating excellent bone to bone and bone to SLM plate contact, ***http://links.lww.com/PRSGO/A971***; **see video, Supplemental Digital Content 5**, which displays the postoperative CT scan of the maxillary reconstruction illustrated in supplementary Figure 6. Three-dimensional reformatting demonstrates the fibula free flap and SLM plate in the configuration of the virtual surgical plan. This video is available in the "Related Videos" section of the Full-Text article on PRSGlobalOpen.com or at ***http://links.lww.com/PRSGO/A972***].

The SLM with tab format eliminates the need for external fixators, 3D positioning devices or guesswork. We hypothesize this modification will reduce operative times. Also, the excellent bone to bone and bone to plate contact

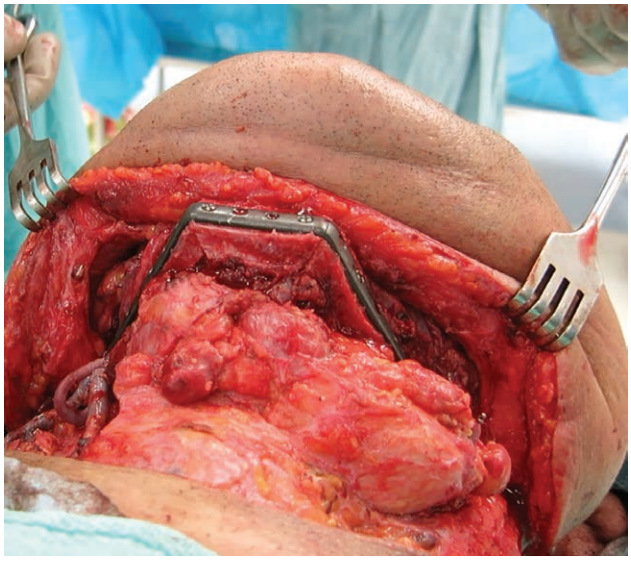


Fig. 4. Intraoperative image for the VSP represented in Figure 1. Inferior view of completed reconstruction demonstrating excellent bone to bone and bone to SLM plate contact.

achieved with this reconstructive protocol could speed osteosynthesis rates and therefore improve patient outcomes (Fig. 4). Potential disadvantages of this technique include the additional cost of the plate (approximately $1,546), increased volume of foreign material in potentially radiated field and increased planning time required before surgery that could delay a patient's surgical day.

Between April 2015 and June 2018, 49 fibula flaps for reconstruction of the mandible or maxilla were completed using VSP. Sixteen of these patients were completed using the SLM plating technique described. An outcome study is being conducted to compare these techniques including alignment of key anatomic landmarks on preoperative and postoperative CT scans. There have been no hardware or flap failures with the SLM plates after an average follow-up of 20.5 months. We look forward to reporting the final results from this study.

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