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Reconstructive

Multiple Buttresses Reconstruction of Maxilla with Fibular Flap Using Computer-aided Design/Computer-aided Manufacturing after Maxillectomy

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Background: The maxilla comprises horizontal and vertical buttresses, each with specific functions, supporting various organs, such as the eyes, nose, and oral cavity. Notably, they combine to form a three-dimensional structure, which enables the buttresses to provide their inherent support strength. However, reconstructing the maxilla after maxillectomy by assembling new buttresses is challenging. We successfully reconstructed all the buttresses crucial for facial appearance and dental rehabilitation using a vascularized fibular flap.

Methods: Four patients underwent maxillary buttress reconstruction with a fibular flap after total or subtotal maxillectomy. We used computer-aided design/computer-aided manufacturing digital technology to osteotomize the fibula into multiple segments and assemble them to reconstruct the maxillary buttresses. Each buttress was assembled based on a preoperative simulation.

Results: All patients underwent immediate one-stage maxillary reconstruction. They had good maxillary buttress alignment and acquired good facial appearance, eye position, nasal airway, and prosthetically suitable maxillary alveolus ridge.

Conclusions: The combination of computer-aided design/computer-aided manufacturing digital technology and surgical techniques has enabled novel maxillary reconstruction, providing great hope to patients experiencing facial disfigurement and loss of function after maxillectomy. *(Plast Reconstr Surg Glob Open 2024; 12:e5914; doi: 10.1097/GOX.0000000000005914; Published online 18 June 2024.)*

INTRODUCTION

Yamamoto et al[1] first reported the role of buttresses in maxillary reconstruction 25 years ago. Since then, the importance of buttress reconstruction has become widely known, and various methods have been reported.[2–7] However, reconstructing all buttresses with a vascularized bone flap is difficult and has not been reported in the literature.

The maxilla comprises horizontal and vertical buttresses that combine to form a three-dimensional (3D) structure that absorbs and disperses strong masticatory forces. The infraorbital rim, an upper horizontal buttress, maintains the ocular and lower eyelid positions; meanwhile, the maxillary alveolus, a lower horizontal buttress, forms the denture ridge. The nasomaxillary buttress (NMB), a vertical buttress, provides anterior support for the maxillary alveolus against masticatory forces and provides a foundation for maintaining the height of the nasal alar base from the columella base, thereby ensuring good nasal airflow. The zygomaticomaxillary buttress (ZMB), another vertical buttress, supports the maxillary alveolus of the molars posteriorly for masticatory forces and forms the zygomatic prominence, an important element of facial appearance. To achieve all these functions, reconstructing a 3D structure with four buttresses is imperative.

We have successfully used computer-aided design/computer-aided manufacturing (CAD/CAM) to create a 3D structure that precisely combines four buttresses. This is the first reconstruction report of four buttresses with a vascularized bone flap.

Disclosure statements are at the end of this article, following the correspondence information.

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PATIENTS AND METHODS

Four patients underwent maxillary buttress reconstruction with a fibular flap after total or subtotal maxillectomy between 2019 and 2023. All patients underwent immediate one-stage maxillary reconstruction.

Surgical Design

Osteotomy and assembly diagrams were used to reconstruct a new maxilla consisting of the four buttresses with a fibular flap (Fig. 1). The details for generating a 3D virtual model are described later. The infraorbital rim consisted of the fibula segments placed along the orbital floor. Additionally, the maxillary alveolus consisted of the fibula segments placed from the incisor to the canine and from the first premolar to the first molar. The longitudinal centerline of the fibula comprising the alveolus was the denture attachment line, and to ensure nasal ventilation, the fibula segment compromising the

Takeaways

Question: Is it possible to apply a virtual surgical planning technology to maxillary reconstruction?

Findings: We successfully reconstructed all the buttresses consisting of fibular segments to resemble the maxilla.

Meaning: The combination of digital technology and surgical techniques has enabled novel maxillary reconstruction, providing a good facial appearance and multifunctionality post maxillectomy.

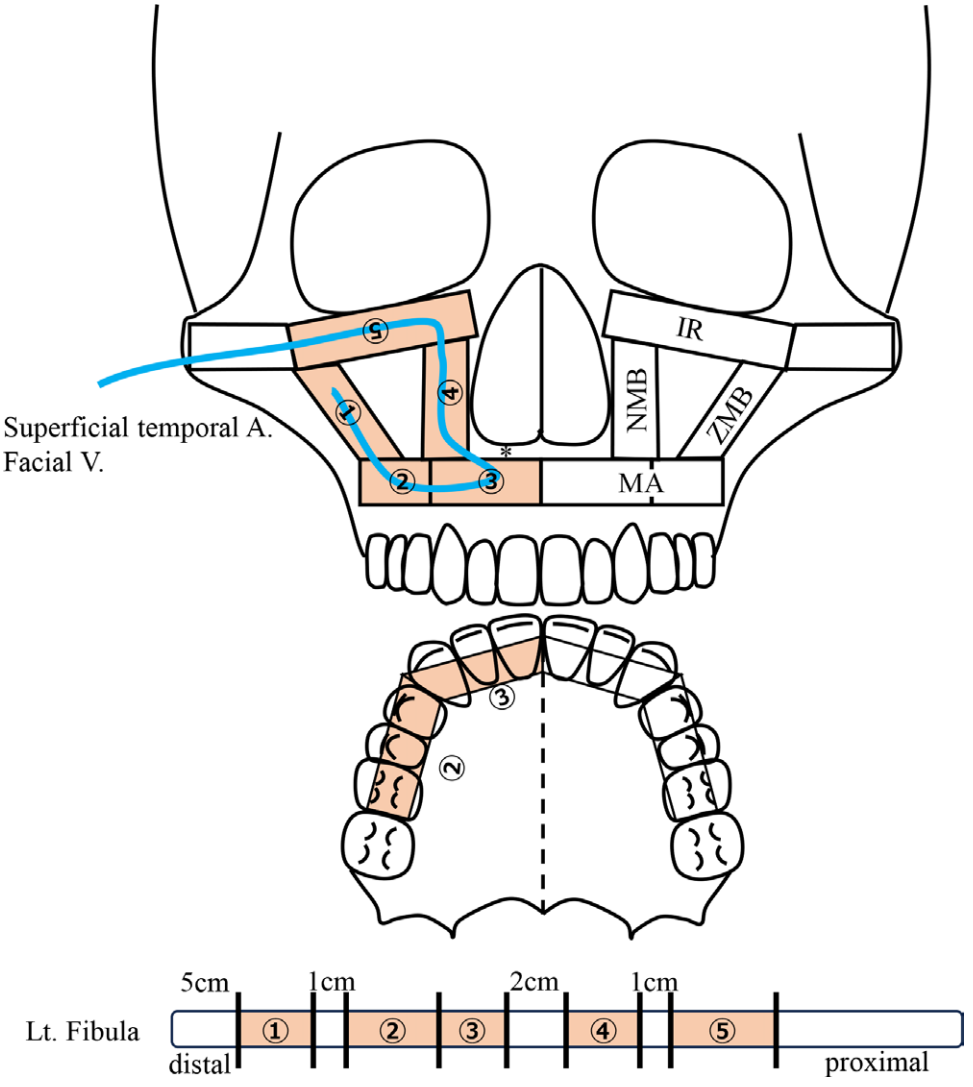

Fig. 1. Frontal assembly, palatal assembly, an osteotomy diagram of the fibula. IR: Placed along the orbital floor. MA: Placed from the incisor to the canine and from the first premolar to the first molar. The longitudinal centerline of the fibula in the palatal diagram was the denture attachment line. NMB: Placed over the canine to the medial end of the infraorbital rim. ZMB: Placed over the first molar to the lateral end of the infraorbital rim. *Lower 3 mm from the nasal floor to ensure nasal ventilation. IR, infraorbital rim; MA, maxillary alveolus; NMB, nasomaxillary buttress; ZMB, zygomaticomaxillary buttress.

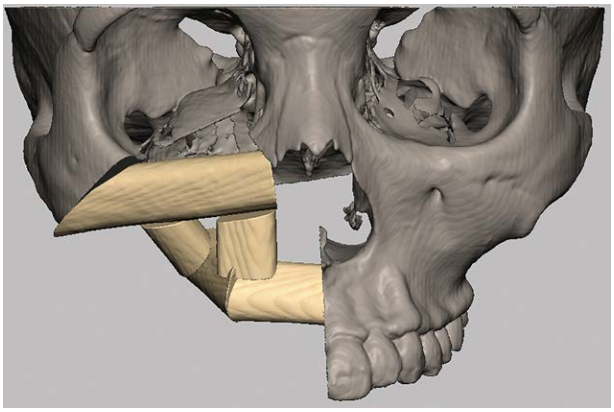

Fig. 2. 3D virtual model of the maxillofacial bones.

Fig. 3. Maxillary reconstruction model and fibula cutting guides.

anterior alveolus should be 3 mm lower than the nasal floor. The NMB comprised the fibula segment placed over the canine to the medial end of the infraorbital rim, whereas the ZMB comprised the fibula segment placed over the first molar to the lateral end of the infraorbital rim. The choice of the harvested fibular flap side was patient-dependent. The anterior wall of the maxilla was reconstructed on the lateral flat surface of the fibula, and the peroneal artery and vein and a flexor hallucis longus (FHL) muscle were placed posteriorly on the maxilla. As a result, it was possible to avoid traction and kinking of vessels, and to reconstruct the palate and to seal the nasal cavity by adjusting the volume of the FHL. The surgical procedure with CAD/CAM support is presented later.[8] The craniofacial bones and fibula were scanned by computed tomography, and the resulting STL files were imported into CAD software (Dental modeling software; Toyotsu Machinery, Nagoya, Japan) to create 3D virtual models of the maxillofacial bones (Fig. 2). Next, a maxillary reconstruction model and fibula cutting guides were created based on virtual simulations (Fig. 3).

Surgical Techniques

The fibular flap was harvested with a combination of the skin paddle. Osteotomy and fibula assembly were performed at the donor site where the pedicle was connected. The horizontal and vertical buttresses were spaced 2–3 cm apart to avoid traction on the vessels during assembling. This spacing was created through osteotomies and extension by cutting the periosteum, interosseous membrane, and fascia, which were continuous between the segments. Miniplates (Matrix MIDFACE System; DePuy Synthes, N.J., or 1.7 mm mid-face mini fixation plate and 1.2 mm upper-face fixation Orbital plate; Stryker, Mich.) were used for segment fixation, bent to fit the prepared 3D model; using the miniplates for fixation between the fibula segments, the fibula was assembled as per the 3D model. The new maxilla consisting of fibula segments was applied to the defect and fixed to the surrounding bone using miniplates. If the flap vessel pedicle length was insufficient, the small saphenous vein was harvested and used as an interposition graft. The skin paddle flap of the fibular flap served solely for palatal reconstruction. If placement of skin paddle on the palate was not feasible, it was excised, and the palate was closed with an FHL muscle. The nasal cavity was sealed with the FHL and NMB of the fibula segment without skin paddles.

RESULTS

All patients had good maxillary buttress alignment and acquired good facial appearance, eye position, nasal airway, and prosthetically suitable maxillary alveolus ridge (Table 1). Patients 1 and 3, over 1 year postsurgery, were attached to a maxillary denture on the reconstructed site and could consume a regular diet using the denture for chewing. In these patients, bony union was observed between each segment and between the segment and maxilla. In case 4, the palate was reconstructed using the FHL instead of the skin paddle. We usually harvested an osteocutaneous flap; however, in case 4, we harvested a fibular flap without a skin paddle because the perforator to the skin paddle was not branching from the peroneal artery and vein.

Case 1

A 25-year-old woman diagnosed with right maxillary odontogenic myxoma was scheduled for total maxillectomy (Brown classification IIId) and maxillary reconstruction (Figs. 1–3). The patient underwent a total maxillectomy. The left fibular flap was harvested, the fibula was osteotomized into five segments using a CAD/CAM cutting guide, and these segments were assembled. This new maxilla comprising fibula segments was applied to the defect and fixed to the surrounding bones using miniplates (Fig. 4). The peroneal artery was anastomosed to the right superficial temporal artery. The peroneal vein was anastomosed to the right facial vein (with an interposition graft of the small saphenous vein). The frontal part of the nasal septum was resected, and a cantilever made of a nonvascularized fibula was inserted into the nasal dorsum

Table 1. Patient Demographics

Case	Age, y	Sex	Pathology	Excision of Maxilla (Brown Classification)	Flap	No. Segments	Length of Harvested Fibular Flap (Final Used Fibula Bone)	Average Length of Segments (Min–Max)	Defects of Buttress	Anastomosis Vessels	Palatal Reconstruction	Additional Information	Total Operating Time (Ischemia Time)	Adjuvant Radiotherapy	Complications	Follow-up Period	Figures
1	25	Female	Odontogenic myxoma	Rt. Total maxillectomy (IIId)	Lt. fibula	5	225 mm (134 mm)	26.8 mm (14–53 mm)	Infraorbital rim, ZMB, NMB, maxillary alveolus	Rt. superficial temporal A. and facial V. Interposition graft of a small saphenous vein added for vein anastomosis	Skin paddle	Cantilever into the nose No diplopia postoperatively	14 h 37 min (2 h 36 min)	No	Palatal fistula Vein thrombosis (salvaged by reanastomosis)	1 y 9 mo	Figures 1–7
2	57	Male	Squamous cell carcinoma	Rt. Total maxillectomy (IIId)	Rt. fibula	7	275 mm (217 mm)	31.0 mm (10–45 mm)	Infraorbital rim, ZMB, NMB, maxillary alveolus	Rt. facial A. V. Interposition grafts of small saphenous veins were added for A. V. anastomosis	Skin paddle	Titanium mesh for the orbital floor Cantilever into the nose History of lt. zygomatic bone fracture and blindness of the lt. eye	12 h 31 min (1 h 56 min)	No	No	4 mo	Figures 8–10
3	64	Male	Adenoid cystic carcinoma	Rt. Subtotal maxillectomy (IId)	Lt. fibula	4	250 mm (118 mm)	29.5 mm (25–36 mm)	ZMB, NMB, maxillary alveolus	Rt. facial A. V. No vein grafts	Skin paddle		12 h 30 min (3 h 15 min)	No	No	5 y	Figure 11
4	62	Male	Squamous cell carcinoma	Lt. Subtotal maxillectomy (IId)	Rt. fibula	4	250 mm (90 mm)	22.5 mm (17–30 mm)	ZMB, NMB, maxillary alveolus	Rt. facial A. V. No vein grafts	FHL	ZMB reconstructed with free bone Cantilever into the nose Complicated excision of lt. cheek skin	10 h 9 min (1 h 30 min)	Yes	No	5 mo	Figure 12

FHL, flexor hallucis longus; NMB, nasomaxillary buttress; ZMB, zygomaticomaxillary buttress.

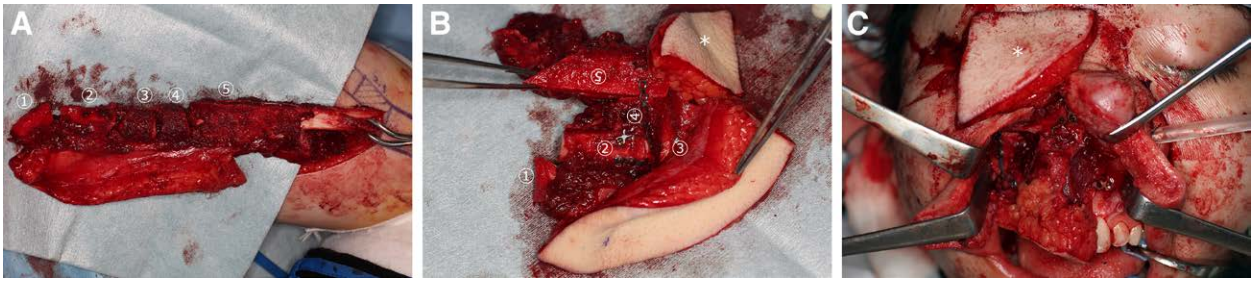

Fig. 4. Process of maxillary reconstruction. A, Postosteotomy of the fibula. B, Assembled fibula segments. C, Fixation of the new maxilla. Segment ① was fixed after the fibula frame was transplanted to the maxilla. The skin paddle (*) on the nasal side was resected to prevent it from obstructing the nasal cavity. The nasal cavity was sealed with the FHL and NMB of the fibula segment.

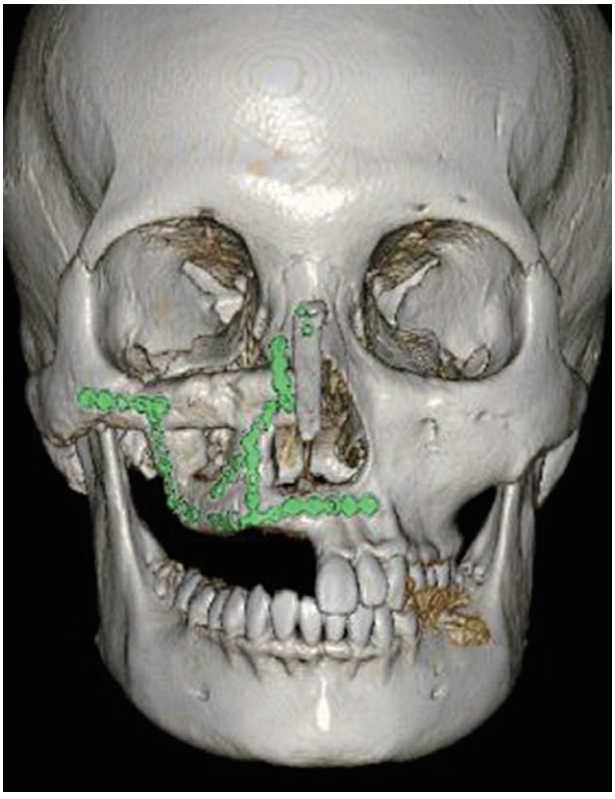

Fig. 5. 3D computed tomography at 1 year postoperative.

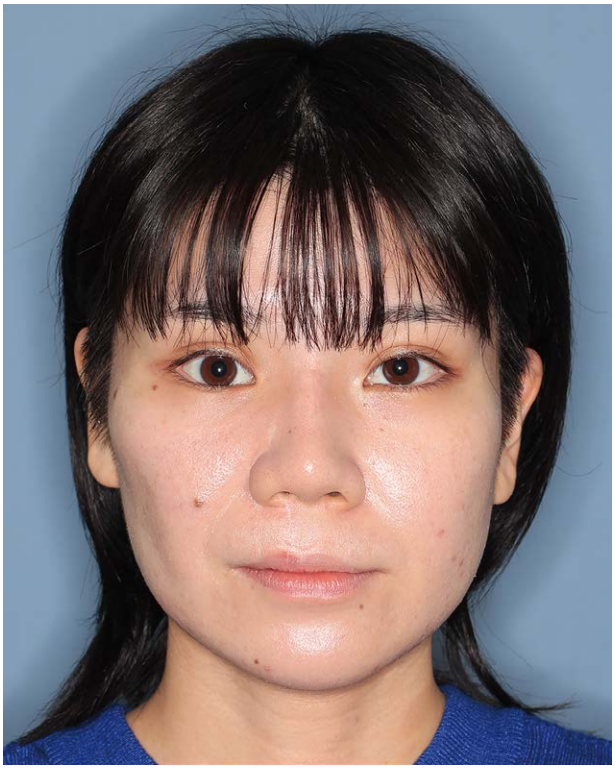

Fig. 6. Facial appearance at 1 year postoperative.

instead of the septal support. One year postoperatively, the morphology of the reconstructed maxilla and the bony union between segments were good, and her facial appearance was excellent (Figs. 5 and 6). The morphology of the maxillary alveolus ridge was suitable for denture placement, and the patient could chew and consume regular food on the reconstructed side using a maxillary denture (Fig. 7). Dental implant treatment is currently being prepared.

Case 2

A 57-year-old man diagnosed with right maxillary sinus cancer was scheduled for total maxillectomy (Brown classification IIId) and maxillary reconstruction (Fig. 8). The patient underwent a total maxillectomy. The right fibular flap was harvested, and the fibula was osteotomized into seven segments (Fig. 9A). The new maxilla was assembled with fibula segments, and interposition grafts of the small saphenous veins were added for anastomosis (Fig. 9B). The new maxilla was placed in the defect and fixed to the surrounding bones using miniplates (Fig. 9C). The nasal septum was resected, and a cantilever made of a nonvascularized fibula was inserted into the nasal dorsum instead of the septal support. One month postoperatively, the morphology of the reconstructed maxilla was good (Fig. 10).

Case 3

A 64-year-old man with right hard palate cancer underwent subtotal maxillectomy (Brown classification IId). The maxilla was reconstructed by assembling a four-segment left fibula. Four years postoperatively, his facial appearance

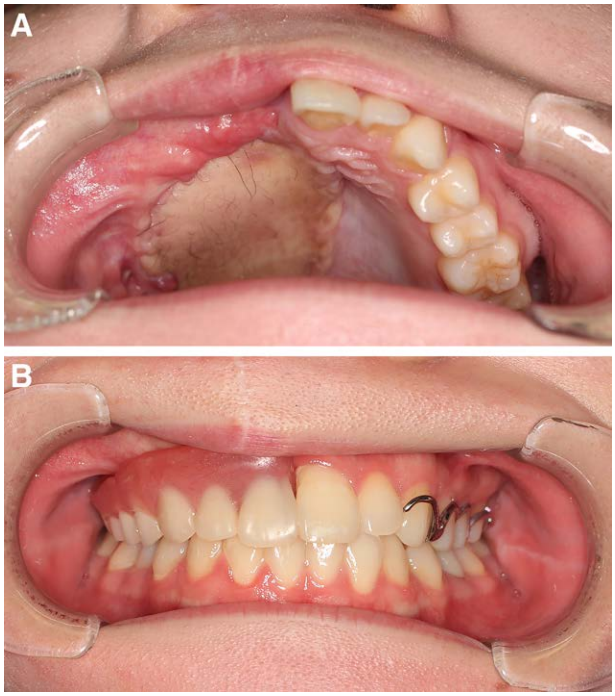

Fig. 7. The morphology of the maxillary alveolus ridge was suitable for denture placement. A, Reconstructed maxillary alveolus ridge. B, After denture placement.

was excellent, and the morphology of the reconstructed maxilla and the bony union between segments were good (Fig. 11). The morphology of the maxillary alveolus ridge was suitable for denture placement, and the patient could chew and consume regular food on the reconstructed side using a maxillary denture.

Case 4

A 62-year-old man with maxillary gingival cancer underwent subtotal maxillectomy and facial skin excision (Brown classification IId). The maxilla was reconstructed by assembling a four-segment right fibula and a nonvascularized fibula bone graft. The nasal septum was resected, and a cantilever made of a nonvascularized fibula was inserted into the nasal dorsum instead of the septal support. Facial appearance and the morphology of the maxilla at 2 months postoperatively were good (Fig. 12).

DISCUSSION

Maxillary defects resulting from tumor resection are aesthetically unpleasing and cause reduced function for speech, mastication, swallowing, and breathing. Therefore, advancements in reconstructive techniques are necessary to restore postoperative quality of life. For the maxilla, buttress reconstruction has been performed in various ways, using flaps appropriate for each reconstructive goal.[6,7,9–11] The reconstruction of multiple maxillary buttresses is challenging and requires complex reconstruction using multiple reconstructive materials.[2,12–15] However, our method uses only the fibular flap, and the alignment principle for fibula segments is straightforward without any undue torsion of the vessel pedicle.

Many reports on CAD/CAM in mandibular reconstruction prove that accurate reconstruction and dental rehabilitation are possible.[16,17] As virtual surgical planning technology evolves, it is increasingly applied to maxillary reconstruction using free tissue osseous transfer.[18] We believe that the true value of CAD/CAM is fully achieved in maxillary reconstruction, which requires accurate multiple osteotomies and assembly. Our method is strongly oriented toward dental rehabilitation. The fibula segments were placed according to the preoperative simulation, which included an implant-supported prosthesis. Thus, postoperative dental rehabilitations were facilitated and functioned well. The combination of CAD/CAM digital technology and surgical techniques has enabled novel maxillary reconstruction, providing a good facial appearance and multifunctionality post maxillectomy.

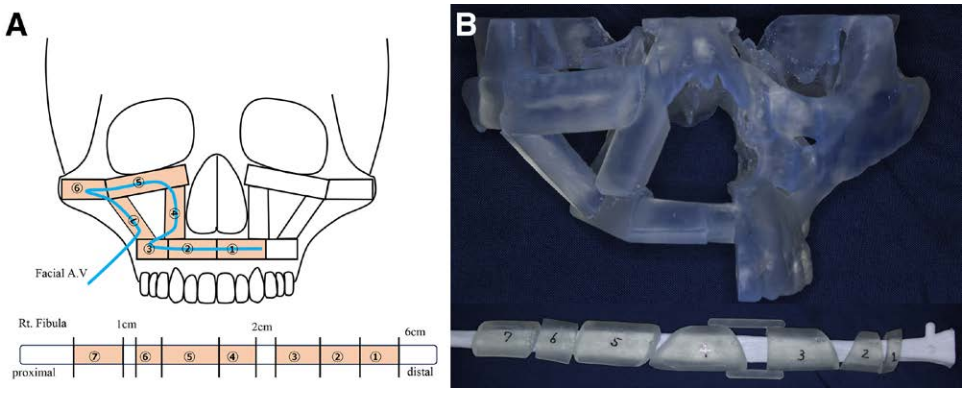

Fig. 8. Case 2. Maxillary reconstruction with a fibular flap was scheduled for a defect after total right maxillectomy (Brown classification IIId) in a 57-year-old man with right maxillary sinus cancer. A, Frontal assembly and osteotomy diagram of the fibula. B, Maxillary reconstruction model and fibula cutting guide.

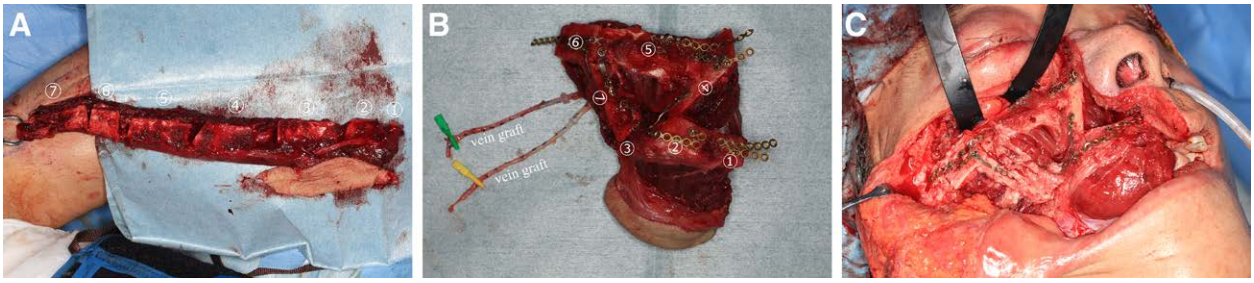

Fig. 9. Case 2. A, Right fibular flap was harvested, and the fibula was osteotomized into seven segments. B, New maxilla was assembled with fibula segments, and interposition grafts of the small saphenous veins were added for anastomosis. C, New maxilla was placed in the defect and fixed to the surrounding bones using miniplates.

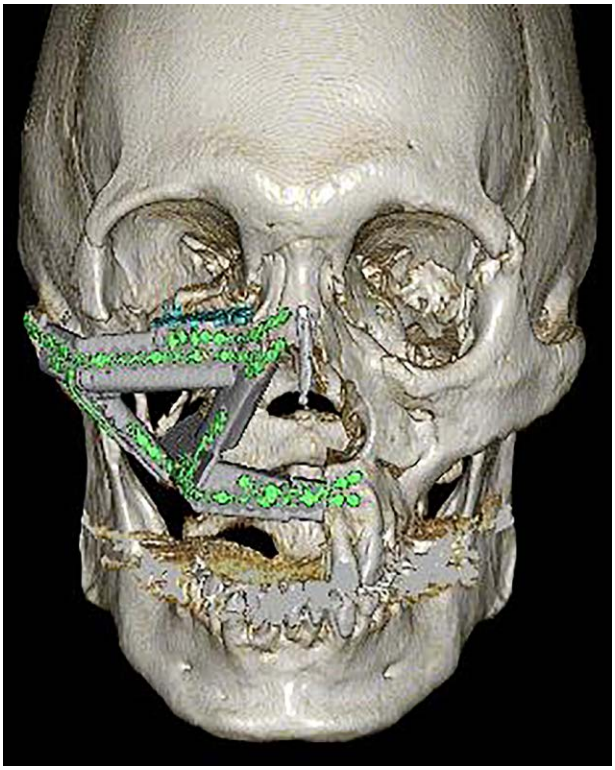

Fig. 10. Case 2, 3D computed tomography at 1 month postoperative. He had a history of left zygomatic bone fracture and was blind in his left eye.

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DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

PATIENT CONSENT

Patients provided written consent for the use of their images.

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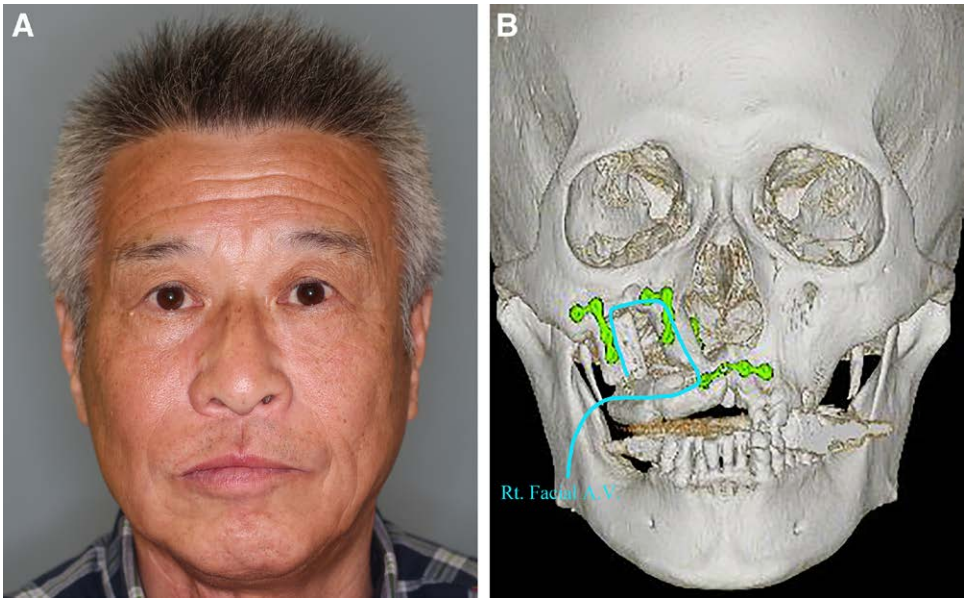

Fig. 11. Case 3. A 64-year-old man with right hard palate cancer underwent subtotal maxillectomy (Brown classification IId). The maxilla was reconstructed by assembling a four-segment left fibula. A, Facial appearance at 4 years postoperative. B, 3D computed tomography at 3 years postoperative. The blue line indicates the peroneal artery or vein.

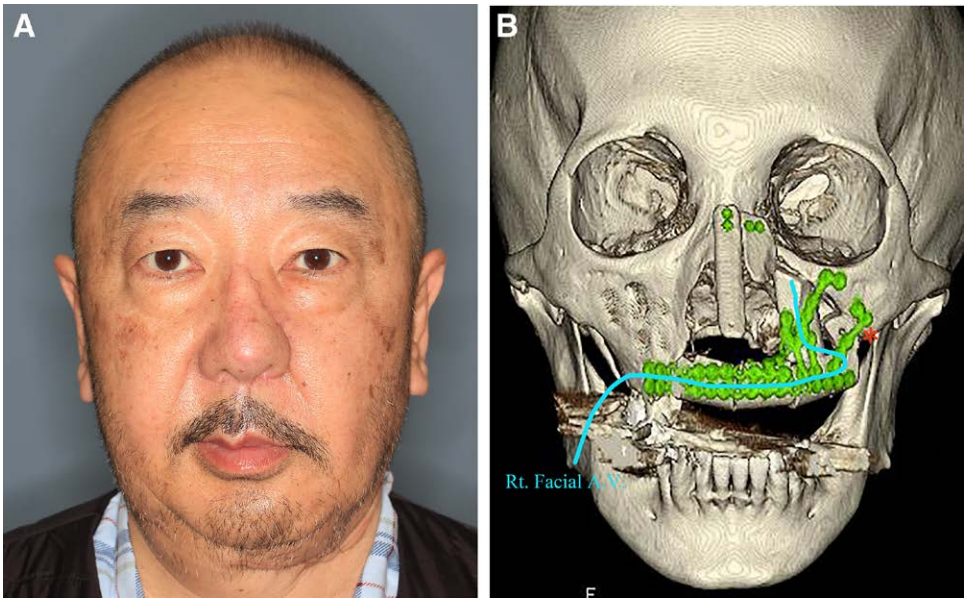

Fig. 12. Case 4. A 62-year-old man with maxillary gingival cancer underwent subtotal maxillectomy and facial skin excision (Brown classification IId). The maxilla was reconstructed by assembling a four-segment right fibula and a nonvascularized fibula bone graft. A, Facial appearance at 2 months postoperative. B, 3D computed tomography at 2 months postoperative. The zygomaticomaxillary buttress was reconstructed using a nonvascularized fibula bone graft (*). The blue line indicates the peroneal artery or vein.

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