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ORIGINAL ARTICLE

Simplified Virtual Surgical Planning Method for Reconstruction of Secondary Maxilla and Mandibular Defects Using Free Bone Flap

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Abstract

Objective Free fibula flap is the commonly used microvascular free tissue transfer for maxillary and mandibular reconstruction to restore form and function after ablative procedures. Bony reconstruction is an important aspect of reconstruction. This paper describes our technique in using virtual surgical planning for secondary reconstruction of the maxilla and mandible using only stereolithographic models.
Discussion In the recent past, virtual surgical planning has become a game changer in planning complex reconstruction of maxilla and mandible. This becomes even more important in the cases of secondary reconstruction. Virtual surgical planning requires close interaction between the surgeon and the design and manufacturing team. The latter is often done remotely making the process cumbersome and less user friendly. We have been using a simplified version of the virtual surgical planning at a low cost set up with effective outcomes. This report consists of 22 cases in which secondary reconstruction using osteo-cutaneous free fibula flap was carried out using virtual surgical planning. Mock surgery was performed on stereolithographic (STL) models (face and fibula), pre-bending of plates and fabrication of occlusal splints helped in precise translation of the treatment plan to the operating room which in turn helped in reducing the surgical time and attaining more predictable results.
Conclusion Secondary reconstruction of maxilla and mandible is complex and requires meticulous planning to achieve optimal and predictable results which directly improves the quality of life of the patients.

Keywords Secondary reconstruction · Virtual surgical planning · Maxillomandibular reconstruction · Inverse planning

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Introduction

Head and neck cancer and its treatment can cause significant disfigurement and difficulties in orofacial function with an impairing of quality of life. Immediate reconstruction with pedicled or free flaps is the treatment of choice in these patients. However, a small proportion of these patients present sometime after primary ablative surgery desirous of bone reconstruction to improve cosmesis and function. Secondary reconstruction of the maxilla and mandible is technically challenging as the normal landmarks (teeth, bony prominences) are absent and distorted by scarring. The aim of reconstruction in these patients is to improve form by recreating the bony contour, provide a stable platform for dental rehabilitation, restore occlusion and provide oronasal separation in cases of maxillary defects. Stereolithographic models are used in planning for primary bone reconstruction. They assist in contouring of the plate and for planning the fibula osteotomy and segments. Planning software allows virtual creation of the defect, virtual modeling of the fibula including the number of segments required and providing cutting guides for the osteotomies. While this technique allows for easy and precise reconstruction, it is expensive and requires long hours of coordinated work with engineers, often outside the institution. There are several studies examining the efficacy of 3D model-based planning for primary reconstruction. However, there is only sparse literature on the use of this technique in patients who present secondarily for reconstruction. The purpose of this paper is to share our technique in using virtual surgical planning for secondary reconstruction of the maxilla and mandible aided by only stereolithographic models.

Materials and Methods

This is a retrospective series of patients with secondary mandibular and maxillary defects treated in a tertiary care institute between 2014 and 2022. All the patients presented to us with ablative surgery done elsewhere and at varying points of time following their primary surgery. Institutional ethics approval was obtained for this study. Patient demographics, indication for surgery, type of flap, patient's requirement, reconstructive technique, complications, intra-operative findings and postoperative rehabilitation were collectively analyzed and described.

All patients for bone reconstruction had planning based on creation of a 3D model that facilitated plate bending and planning of the osteotomies in the bone flap. High-resolution (1 mm cuts) non-contrast CT scan of the facial bones and the fibula were obtained. The CT data are used for virtual creation of the model using open-source software (Meshmixer 3.2 California, USA). Virtual recreation of the defect in 3D and mirroring of the normal mandible or maxilla to reconstruct this defect was done. It was then sent for the construction of a 3D model of the facial bones and the fibula (Figs. 1 and 2). The 3D model was then used for surgical planning and the mock surgery which was performed to enable the fabrication of the cutting guide (for fibula osteotomy) and plate contouring. Occlusal wafer was also made which also helps in correct alignment of the mandibular segments. The 3D model, prebent plates and the occlusal wafer are kept sterilized to be used in the operating room.

Details of two representative cases is given below.

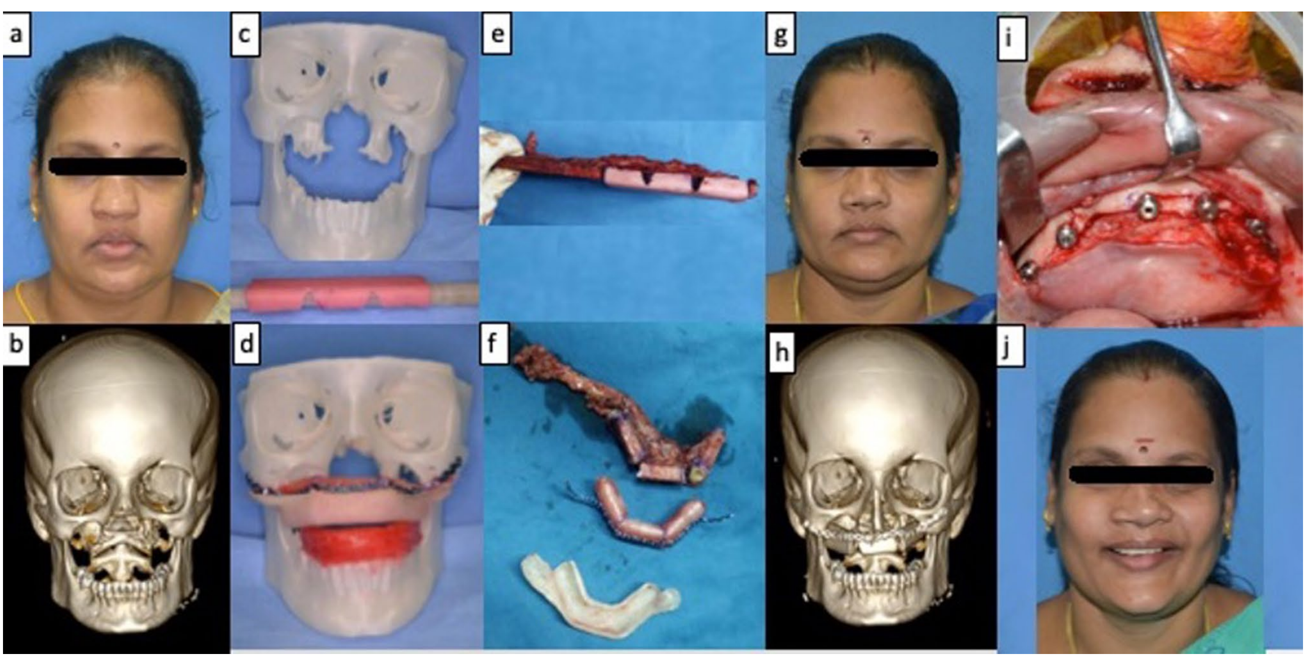

Fig. 1 Secondary maxillary reconstruction, Pre-operative (**a**, **b**), Pre-operative STL model of skull and fibula (**c**), Model surgery performed on STL (**d**), PMMA fibula cutting guide (**e**), Osteotomized fibula with PMMA carrying tray (**f**), Post-reconstruction (**g**, **h**), Dental implant placement in fibula (**i**), Post-dental rehabilitation (**j**)

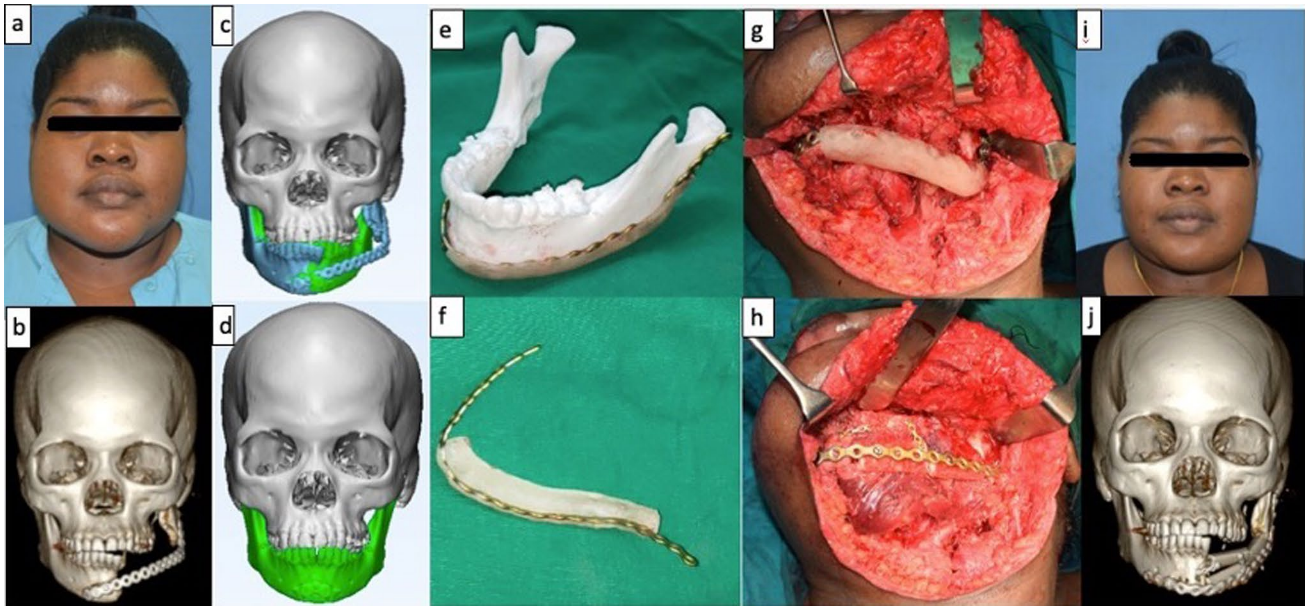

Fig. 2 Secondary mandibular reconstruction, Pre-operative (**a**, **b**), Mirrored mandible with existing malaligned proximal segment (**c**), Mirrored mandible (**d**), Prebent mandibular reconstruction plate with PMMA stent (**e**), PMMA stent with reconstruction plate in the groove (**f**), PMMA stent and the mandibular reconstruction plate fixed to the native mandible (**g**), Free fibula flap (double barrel) spanning the defect (**h**), Post-reconstruction (**i**, **j**)

Maxillary Reconstruction (Fig. 1)

Forty-five-year old lady reported with a complaint of missing upper jaw and alveolus following infrastructure maxillectomy for invasive aspergillosis 2 years back (Fig. 1a, b). The defect in the palate was initially reconstructed with an ALT flap. CT scan of the face and legs were captured, and STL models of the same were printed (Fig. 1c). The height and position of the dentition in maxilla were replicated by inverse planning using modeling wax patterned on the occlusal surface of the mandibular teeth (Fig. 1d). This enabled us to determine the position at which the osteotomized fibula needs to placed. In the fibula model, segments were created to fit into the defect by drilling away the edges in a trial and error method. Once found fitting well, they were straightened and placed in the polymethylmetharcylate (PMMA) trough and the wedge excisions marked accordingly. The necessary amount of PMMA is removed from the cutting guide thus mimicking the wedge osteotomy. This guide was used to mark the osteotomy on the fibula (Fig. 1e). This patient needed two osteotomies providing one central and two lateral segments. A carrying tray is made along the lower border of the osteotomized fibula so that the segments can be carried to the surgical site as one single unit (Fig. 1d). 1.5-mm mini plate is bent, adapted on the model and used for fixation of the bone to the zygoma on either side.

Mandibular Reconstruction (Fig. 2)

Thirty-five-year old female reported to the department with a history of Ameloblastoma of the left side of the mandible and underwent segmental resection with reconstruction using metal plate alone 2 years back. She presented with deranged occlusion and facial asymmetry (Fig. 2a, b). The proximal segment on the left was upturned due to the muscular pull. Bony reconstruction was planned to correct the malocclusion. CT data were uploaded to a planning software. The existing mandible was mirrored keeping the midline as the plane. The mandibular condyle on the left side was placed into the glenoid fossa also ensuring the dental occlusion is maintained (Fig. 2c). The two mandibular segments (normal and reconstructed) are fused at the midline. The STL file of the mandible was exported and was printed. Mandibular reconstruction plate (1.5-mm profile thickness) plate was adapted on the model. The major concern intraoperatively is the controlling and positioning of the proximal segment. To tackle this issue, an acrylic stent was prepared in the following way. The plate was fixed to the STL model. The PMMA stent was fabricated along the lower border of the mandible extending from the existing dentate mandible, spanning the defect to the proximal segment in its corrected position with the plate in situ. The open screw holes in the plate were filled with modeling wax while fabricating the stent. The plate created a groove in the inner aspect of the PMMA stent allowing its placement in the same position within the stent during the surgery (Fig. 2d, e). Maxillary and mandibular impressions were made preoperatively. The dental casts were articulated with the best possible occlusion replicating the virtual planning, and an acrylic dental splint was fabricated. Intra-operatively, after sufficient surgical exposure was achieved, the acrylic dental splint was placed between the maxilla, and dentate mandible was put into maxilla-mandibular fixation using arch bars. Temporalis was released from the left proximal segment. The PMMA stent with the plate was placed on the mandible, and the proximal segment was brought into position into the acrylic stent (Fig. 2g). Once the position was confirmed, the reconstruction plate was fixed to the dentate mandible and the proximal segment drilling the holes through the stent. The PMMA stent was then removed, and osteotomized fibula was placed into the plate spanning the defect (Fig. 2h). To compensate for the mandibular height, double-barrel segments of fibula were used (Fig. 2j). Postoperatively, she was put on guiding elastics to train her into the new occlusion. Subsequently, she was rehabilitated with dental implants.

Results

The total number of 22 patients were included in the study. There were 13 males and nine females included in the study. The mean age of the patients was 39 (range 12–60 years).

Maxillary Reconstruction

A total number of eight patients underwent maxillary reconstruction for secondary defects. The defects were classified as central alveolar defects, lateral alveolar defects, palatal defects, alveolar defects combined with orbital floor defects and combined defects.

Mandibular Reconstruction

A total number of 14 patients underwent mandibular reconstruction for secondary defects of the mandible. The most common defect was the lateral mandibular defect (LM). The commonest flap used in the patient was the free fibula flap. In one patient, DCIA was used after the loss of the fibula flap, and one patient underwent free scapula flap. One of the patients with free fibula flap reconstruction for mandible underwent re-exploration in the immediate postoperative period for flap congestion. On re-exploring, a thrombus in the draining superior thyroid vein was evacuated, and the flap was salvaged successfully. Two patients developed postoperative infection that was managed with daily dressings and antibiotics. Flap success rate was 97%.

Discussion

Maxillary and mandibular reconstruction pose a major challenge for head and neck reconstructive surgeons. Bony reconstruction is currently integral part of the standard of care. A wide range of donor sites are available, namely the fibula, deep circumflex iliac artery-based iliac crest and scapula for bony reconstruction. Currently, the fibula flap is the preferred choice in most of the centers for maxillary and mandibular reconstruction due to its good bone stock, adequate pedicle length and the ability to perform osteotomies for good contour match. Routinely, the reconstructive surgery is done along with the ablative surgery. This has several advantages namely early return of form and function and better patient satisfaction [1].

The use of virtual planning and rapid prototyping is increasingly popular in reconstructive surgery, particularly in complex anatomical reconstruction [2]. Rapid prototyping facilitates the manufacture of 3D models and templates that allows the surgeon to plan the procedure before surgery, thereby closing the gap between preoperative planning and execution. There is also the benefit of reducing the operative and ischemia time during surgery [3]. Three-dimensional model-based reconstruction is particularly useful in secondary reconstruction where there is no landmark or bone to allow for pre-plating. The use of the normal side and mirroring allows for recreating the normal contour on the defect side and producing a complete 3D model of the skull. This allows for pre-bending the plate on the mandible of the STL model. Also in such cases, the occlusion can be corrected on the 3D model, and the bone flap segments can be planned with the right occlusion.

Patients desirous of secondary reconstruction pose a specific challenge to the reconstructive surgeon when they present years after the ablative surgery. In mandibulectomy defects, there is often loss of occlusion and malposition of the condyle in the glenoid fossa. Any attempt to reconstruct the defect will have to address the above-mentioned problems prior to flap inset. Our technique of mirroring the normal mandible and positioning it with the condyle in the fossa ensures good contour and occlusion. Scar tissue will hinder the placement of the fibula flap, and this needs to be released to make the soft tissue mobile. Once the fibula is in place, the occlusion is checked with the corresponding maxillary teeth. Patients are given an arch bar and guiding elastics for a few weeks to keep the occlusion in place. The availability of a remnant mobile condylar segment on the reconstructed side will make the decision for connecting it with the reconstructed segment easier. But when there is only a small condylar segment available, it will be difficult to mobilize and may not provide stable fixation. Hence in these cases, as well as where there is no condyle at all, the reconstructed ascending ramus is left with a gap arthroplasty. In these cases, it will be difficult to prevent drifting of mandible on chewing, but prolonged inter-maxillary elastics may help. However, in two of our patients, wherein there was no condyle, we had used a condylar prosthesis to bridge the defect between the flap and the glenoid fossa.

Maxillary defects have their own challenges. The essential aspect of reconstructing the maxilla is to place the fibula bone at the appropriate position to accommodate future dental rehabilitation. This is done by using modeling wax with the normal contralateral maxillary teeth as well as the mandibular teeth as a guide. The fibula placed is to be placed at a height above the modeling wax. The contour of the maxilla is usually modeled on the basis of the curvature of the mandible.

The literature is sparse with regard to the planning of secondary reconstruction. Futran published a series of midface reconstruction, wherein 11 patients had secondary reconstruction with good results [4]. Their series did not include the use of 3D models for reconstruction. Shen and colleagues reported their outcomes on 11 patients for maxillary reconstruction alone [5]. Their technique was similar to ours with one difference in that they used they used the contra lateral maxilla if available for mirroring into the defect. Yu [6] and colleagues described the use of navigational software, virtual planning and 3D model creation on a single patient with mandibular reconstruction, More recently, Kadam [7] published the results of a series of 21 patients of secondary mandible reconstruction; however, there was no use of a 3D-based planning in that series.

The technique described is a series of steps that are easy to learn and produce consistent results across all end points of bone reconstruction, i.e., ease of surgery, good bone position, acceptable aesthetics and platform for dental prosthesis. All of the model surgery was done in the inhouse laboratory. The construction of the 3D model was done with open-source software thereby keeping the cost down. The technique provided consistent results with regard to aesthetics and function without the need for complex software-based planning or the need for complex osteotomy guides.

Conclusion

Secondary maxillary and mandibular defects are challenging to reconstruct. The use of 3D models allows precise bony reconstruction, is easy to perform, reproducible and economically viable.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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