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Patient-specific three-dimensional (3D) printed titanium prosthesis in mandibular reconstruction- Literature Review

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Abstract

The gold standard for benign lesions is microvascular free tissue transfer in mandibular reconstruction. Fibula and Iliac crest have been most commonly used for this purpose as they provide acceptable aesthetics, but related complications include ischemia and graft rejection, which have serious consequences. In addition, contraindication to microvascular surgery requires an alternative treatment option for extensive bone reconstruction. Advances in technology in craniomaxillofacial surgery have provided surgeons with the potential to customise surgical procedures and offer stable aesthetics and function to the patient. The use of virtual surgical planning and additive manufacturing has led to the successful planning and fabrication of three-dimensional printed patient-specific titanium prostheses. Reduced operating time, acceptable aesthetic and functional outcomes have been reported in the literature. These novel designs combined with functionality allow for a better surgical outcome, ultimately leading to improved quality of life. Patient-specific prostheses have a future possibility of becoming the gold standard in post-resection rehabilitation, thus replacing the conventional methods of reconstruction in benign lesions.

Keywords: Patient-specific, virtual surgical planning, 3D printing, mandibular reconstruction.

Introduction

Mandibular reconstruction following resection secondary to benign or malignant disease and trauma is essential to provide a patient with an acceptable quality of life in terms of form and function. Many reconstruction methods include non-customized pre-bent reconstruction plates, non-vascularized autografts, allografts and xenografts, and more popular vascularised bone flaps like free Fibula and Iliac.[1] Continuity defects are complex to reconstruct concerning the type of reconstruction, timing, and surgical skill set of the operator and, more importantly, the patient's health. With the advent of advanced imaging systems and additive manufacturing of 3-dimensional (3D) printed models, mandibular reconstruction has progressed and

undergone various modifications. At first, 3D printed models were used for treatment planning of complex cases and patient education, following which it was used in conjunction with microvascular free flaps to use cutting guides.[2,3] It was also used to pre-bend reconstruction plates prior to the operation, thus saving valuable intraoperative time.[4] In the last decade, patient-specific implants (PSI) have made their way to replace autogenous grafts and free flaps in regions of cranial bone, orbital floor and, more recently, mandibular reconstruction.[5,6,7] 3D printing of implants has brought about a paradigm shift in the techniques of mandibular reconstruction. These implants provide more than adequate contour, decreased donor site morbidity, decreased intra-operative time, leading to an immediate improvement in the patient's facial symmetry and quicker rehabilitation. The implants also have been teamed up with autogenous or allogenous bone grafts. Disadvantages include infection of the plate, dehiscence, and time taken for its fabrication and majorly its cost. With better reconstruction efficiency, PSIs are bound to be a surgical success, provided the costs are negated by their universal use. With very few studies that have been conducted to evaluate the efficacy of these implants in mandibular reconstruction, it is imperative to conduct randomised clinical trials. Here, we present the current literature regarding patient-specific implants in mandibular reconstruction.

Discussion

The invention of virtual surgical planning and additive manufacturing has expanded surgical planning, particularly in craniomaxillofacial trauma, orthognathic surgery, and reconstructive maxillofacial surgery.[5,6,7] The development of patient-specific mandibular reconstruction plates, particularly when paired with cutting and drill guides, has opened up a range of diverse possibilities for mandibular reconstruction planning and implementation.[8] This applies not only to reconstruction with bone grafts or bone flaps but also to stand-alone alloplastic reconstructions. There is limited literature for the clinical application of a 3D printed mandibular prosthesis or implant fabricated by selective laser sintering (SLS) of titanium. The length and contour of the plate and the number and angulation of the screw holes may all be arranged in addition to virtually mirror-imaging the normal side of the mandible to the defect side. The contour of the 3D printed prosthesis is accurate because it is a replica of the opposite side mandible. Contouring is required for free bone flaps and can be done using 3D printed cutting guides.[9,10,11] This would increase the intra-operative time, and the contour may not be as precise as the opposite side mandible. The findings of a study conducted by Wilde et al. suggested that complicated maxillary and mandibular defects could be reconstructed with printed individualised titanium meshes, resulting in the reconstruction procedure's structural, esthetic, and functional goals.

With the use of 3D printed titanium prosthesis, the requirement of a second surgical site and donor site morbidity is eliminated. With free flaps and grafts, the presence of a secondary surgical site increases the risk of complications and thus the patient's overall recovery. The complications range from free flap loss to significant donor site morbidity.[1] Due to the porous nature of the titanium prosthesis, it can be combined with autogenous or alloplastic grafts. The time taken for the fixation of the prosthesis is less than the use of a free flap and similar to that of a conventional reconstruction plate. This includes reducing the operating time required for harvesting a free flap or bending traditional plates. Also, this allows for a more conservative incision or approach.

The major disadvantage of 3D printed implants is similar to that of conventional implants; infection is the single major disadvantage that would require implant removal. Reconstruction using 3D printed implants is limited to benign lesions due to their alloplastic nature. The effects of radiotherapy, delayed reconstruction and vascularity in malignant diseases need to be studied. In addition, the response of the prosthesis under functional loading may vary between patients. Andrew et al., in their case study, rehabilitated an edentulous mandible. At the same time, Qassaymer et al. concluded that more time is needed for the prosthesis to undergo osseointegration and rehabilitation.[12,13] Lastly, 3D printed implants require extensive pre-procedural planning and fabrication time, and more cost is involved. It is not yet foreseeable whether patient-specific implants will become a routine clinical practice for mandibular reconstruction or will be confined to selected isolated cases.

Conclusion

With the three-dimensional printed patient-specific implants being in their early stages of validation, there is very little literature that reports its efficacy over the other reconstruction methods, in terms of anatomic symmetry, healing, ease of prosthetic rehabilitation and complications like plate fracture or screw loosening. With PSI being an option for immediate mandibular reconstruction, the success rates for this kind of reconstruction will prove to be predictable and viable for delayed reconstruction. Clinical trials are required to determine whether these promising results can be translated into successful practice and further developments.

Abbreviations

1. 3D -Three dimensional
2. VSP-Virtual surgical planning
3. PSP-Patient-specific implant
4. SLS-Selective laser sintering

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