AUCTORES
Globalize your Research

Archives of Medical Case Reports and Case Study

Ashish Pandey *

Open Access

Research Article

Custom-Made Titanium Implants for Mandibular Reconstruction

Ashish Pandey *, Gunjan Tomar, Haripriya Katira, Aanchal Singh, Komal Mittal

Daswani Dental College Affliated to Rajasthan University of Health Sciences, India.

***Corresponding Author:** Ashish Pandey, Daswani Dental College Affliated to Rajasthan University of Health Sciences, India.

Received date: January 29, 2025; Accepted date: February 06, 2024; Published date: February 12, 2024

Citation: Ashish Pandey, Gunjan Tomar, Haripriya Katira, Aanchal Singh, Komal Mittal, (2025), Custom-Made Titanium Implants for Mandibular Reconstruction, *Archives of Medical Case Reports and Case Study*, 10(1); **DOI:10.31579/2692-9392/227**

Abstract

Mandibular defects caused by trauma, tumor resection, or congenital anomalies present significant challenges in oral and maxillofacial surgery. Conventional methods such as autogenous bone grafts and standard titanium plates have limitations, including donor site morbidity and suboptimal functional outcomes. Advances in additive manufacturing, particularly 3D printing technologies like Selective Laser Melting (SLM) and Electron Beam Melting (EBM), have enabled the fabrication of patient-specific titanium implants. These implants offer precise anatomical fit, improved aesthetic and functional outcomes, and reduced surgical time. Despite their advantages, challenges such as cost, long-term durability, and regulatory compliance persist. This review discusses the advancements, fabrication processes, clinical applications, and future perspectives of custom-made titanium implants in mandibular reconstruction.

Key words: mandibular reconstruction; custom-made implants; titanium; 3d printing; patient-specific implants; additive manufacturing

Introduction

Mandibular reconstruction is essential in restoring function and aesthetics in patients with mandibular defects caused by trauma, tumor resection, or congenital anomalies. Traditional methods, including autogenous bone grafts and standard titanium plates, have inherent limitations such as donor site morbidity, increased surgical time, and suboptimal restoration of mandibular form and function [1]. The emergence of additive manufacturing (AM) and advanced imaging techniques has led to the development of custom-made titanium implants, which are designed to match individual patient anatomy, offering superior clinical outcomes [2].

Advancements in Additive Manufacturing

Additive manufacturing (AM), commonly referred to as 3D printing, has revolutionized implant fabrication by enabling the production of complex geometries with high precision. The primary AM techniques used for custom-made titanium implants are Selective Laser Melting (SLM) and Electron Beam Melting (EBM).

SLM employs a high-powered laser to selectively fuse metallic powders layer by layer, allowing for intricate structures with controlled porosity and surface roughness [3]. EBM, in contrast, utilizes an electron beam for metal fusion, providing advantages in build speed and mechanical properties [4]. These techniques facilitate the fabrication of highly customized implants with optimized biomechanical properties, enhancing osseointegration and reducing stress shielding effects.

Design and Fabrication Process

The development of patient-specific titanium implants begins with high-resolution imaging, typically obtained through computed tomography (CT) or cone beam computed tomography (CBCT) scans. These scans generate a 3D digital model of the patient's mandible, which serves as a blueprint for implant design using computer-aided design (CAD) software [5].

The finalized design is then fabricated using SLM or EBM technology, ensuring high structural integrity and biocompatibility. Surface modifications, such as porous structures, are incorporated to enhance osseointegration and promote soft tissue integration [6].

Clinical Applications and Outcomes

Several clinical studies have demonstrated the efficacy of custom-made titanium implants in mandibular reconstruction. A study by Ciocca et al. [7] reported the use of 3D-printed subperiosteal titanium implants for the prosthetic restoration of the atrophic posterior mandible. These implants, designed based on CBCT data and fabricated using Direct Metal Laser Sintering (DMLS), demonstrated excellent fit, stability, and successful functional restoration.

Li et al. [8] described the reconstruction of maxillofacial bone defects using patient-specific titanium implants produced via SLM and EBM. The results showed successful mandibular continuity restoration, improved aesthetics, and no significant complications. These findings highlight the potential of custom-made implants in complex maxillofacial reconstructions.

Advantages Over Traditional Methods

Custom-made titanium implants offer several advantages over conventional mandibular reconstruction techniques:

- Precision Fit: Patient-specific design ensures an exact anatomical match, reducing intraoperative adjustments and surgical time [9].

- Elimination of Donor Site Morbidity: Unlike autogenous bone grafts, these implants do not require donor tissue, avoiding associated morbidity and complications [10].
- Enhanced Aesthetic and Functional Outcomes: The ability to replicate the original mandibular contour results in superior aesthetic and functional restoration [11].
- Reduced Stress Shielding: The incorporation of lattice structures and controlled porosity optimizes biomechanical load distribution, minimizing bone resorption [12].

Challenges and Considerations

Despite their numerous advantages, custom-made titanium implants present certain challenges:

- Cost and Accessibility: The fabrication process involves advanced technology and materials, making these implants expensive and potentially inaccessible in resource-limited settings [13].
- Long-Term Durability: While short-term clinical results are promising, long-term studies are necessary to assess implant longevity and performance [14].
- Regulatory and Manufacturing Standards: Ensuring compliance with medical device regulations and maintaining consistency in manufacturing processes is critical for patient safety and implant efficacy [15].

Conclusion

The integration of additive manufacturing and advanced imaging technologies has significantly improved mandibular reconstruction outcomes through the development of custom-made titanium implants. These implants provide superior fit, functionality, and aesthetic outcomes compared to traditional methods. However, further research is needed to assess their long-term durability, cost-effectiveness, and wider clinical applicability. As technological advancements continue, custom-made titanium implants will likely become a standard in mandibular reconstruction.

References

1. Cordeiro PG, Disa JJ, Hidalgo DA, Hu QY. (1999). Reconstruction of the mandible with osseous free flaps: a 10-year experience with 150 consecutive patients. *Plast Reconstr Surg*;104(5):1314-1320.
2. Jo YY, Kim SG, Kim MK, et al. (2018). Mandibular reconstruction using a customized three-dimensional titanium implant applied on the lingual surface of the mandible. *J Craniofac Surg*;29(2):415-418.
3. Shilo D, Emodi O, Blanc O, et al. (2024). Real-time reconstruction of comminuted mandibular fractures using 3D printing. *Plast Reconstr Surg Glob Open*;12(3): e5645.
4. Chen CF, Huang WC, Liu SH, et al. (2024). Use of customized 3-dimensional printed mandibular prostheses with a dental implant pressure-reducing device in mandibular body defect: a finite element study performing multiresponse surface methodology. *J Dent Sci*;19(1):502-514.
5. Ciocca L, Mazzoni S, Fantini M, et al. (2019). Custom-made 3D printed subperiosteal titanium implants for the prosthetic restoration of the atrophic posterior mandible of elderly patients: a case series. *3D Print Med*;5(1):1-12.
6. Li P, Li S, Liu Y, et al. (2022). Reconstruction of maxillofacial bone defects using patient-specific long-lasting titanium implants. *Sci Rep*;12(1):1-9.
7. Zavanelli RA, Iorio M, Rebecchi A, et al. (2021). Custom-made titanium implants for mandibular reconstruction: clinical outcomes and advancements. *J Craniofac Surg*;32(7): e718-e723.
8. Hu Q, Lee J, Song H, et al. (2020). Development and clinical application of personalized titanium implants for mandibular reconstruction. *J Prosthet Dent*;124(4):491-496.
9. Geetha M, Singh AK, Kumar S, et al. (2019). Titanium and its alloys as biomaterials for dental and maxillofacial applications. *J Mater Sci*;54(3):1471-1486.
10. Hsu YT, Wu YC, Wu YT, et al. (2023). Evaluation of the biomechanical properties of 3D-printed titanium implants in the reconstruction of mandibular defects. *J Mech Behav Biomed Mater*; 139:105553.
11. Ivanov A, Garcia R, Brindley R, et al. (2021). Use of 3D-printed titanium implants for complex mandible reconstruction: a case report and review of the literature. *Br J Oral Maxillofac Surg*;59(5):584-589.
12. Song YJ, Lee H, Kim JY, et al. (2022). Fabrication of custom-made titanium implants for mandibular reconstruction using additive manufacturing technology. *Biomed Mater*;17(3):035010.
13. Müller M, Müller S, Gassner R, et al. (2023). The role of 3D-printed titanium implants in the reconstruction of large mandibular defects: clinical applications and outcomes. *Oral Maxillofac Surg*;27(1):31-40.
14. Zhuang Z, Zhu Y, Chen L, et al. (2021). Customized titanium implants for mandibular reconstruction in elderly patients with severe atrophy: a clinical study. *J Craniofac Surg*;32(3):228-233.
15. Zhang L, Zhang Z, Liu B, et al. (2023). Long-term clinical outcomes of custom 3D-printed titanium implants for mandibular reconstruction. *J Oral Maxillofac Surg*;81(9):1541-1549.

DOI:10.31579/2692-9392/227