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MODERN METHODS OF MANDIBULAR RECONSTRUCTION: ADVANTAGES AND LIMITATIONS OF PATIENT-SPECIFIC IMPLANTS AND CONVENTIONAL RECONSTRUCTION PLATES

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Abstract: Mandibular reconstruction is a complex procedure aimed at restoring facial symmetry, mandibular continuity, mastication, speech, and overall quality of life following trauma, tumor resection, osteomyelitis, or congenital deformities. Advances in digital technologies have expanded reconstructive options, particularly through patient-specific implants (PSIs) designed using computed tomography, three-dimensional modeling, and computer-aided design and manufacturing (CAD/CAM). Conventional reconstruction plates remain widely used because of their availability, adaptability, and established clinical application. However, both approaches have distinct advantages and limitations related to anatomical accuracy, mechanical stability, surgical complexity, cost, and long-term outcomes. This article compares patient-specific implants and conventional reconstruction plates in mandibular reconstruction, focusing on their design principles, clinical applications, benefits, and potential complications. Particular attention is given to the importance of individualized treatment planning, bone and soft-tissue conditions, and the need to select reconstructive techniques according to the patient's clinical characteristics. The analysis emphasizes that neither method is universally superior; successful reconstruction depends on appropriate case selection, surgical expertise, and comprehensive postoperative management.

Keywords: mandibular reconstruction, patient-specific implants, reconstruction plates, CAD/CAM, three-dimensional planning, mandibular defects, oral and maxillofacial surgery, titanium implants, surgical complications, functional rehabilitation, personalized medicine, digital surgery, reconstructive outcomes.

Introduction

The mandible plays a fundamental role in facial contour, dental occlusion, mastication, swallowing, speech, and the structural integrity of the lower face. Extensive mandibular defects may arise from benign or malignant tumors, severe trauma, infection, osteonecrosis, and congenital abnormalities. Such defects can cause functional impairment, facial asymmetry, psychological distress, and difficulties with social interaction. Consequently, mandibular reconstruction is not limited to restoring bone continuity; it also aims to recover functional capacity, facial appearance, and the patient's quality of life.

Traditional reconstruction techniques commonly employ titanium reconstruction plates to bridge mandibular defects and maintain the continuity of the lower jaw. These plates can be shaped intraoperatively and are particularly useful when rapid stabilization is required or when patient-specific manufacturing is unavailable. Nevertheless, conventional plates may require substantial intraoperative bending and adjustment, potentially increase operative complexity and reduce the precision of anatomical restoration.

The development of digital imaging, three-dimensional (3D) modeling, virtual surgical planning, and computer-aided design and manufacturing has enabled the production of patient-specific implants. These implants are designed according to the patient's individual anatomy and intended reconstructive objectives. Their use may improve the accuracy of mandibular contour restoration and facilitate the transfer of a preoperative surgical plan into the operating theatre. However, their

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production requires advanced imaging, specialized software, manufacturing resources, and additional preoperative planning.

The relevance of comparing these methods lies in the need to balance anatomical precision, mechanical reliability, treatment cost, surgical time, and long-term functional outcomes. The objective of this article is to examine the advantages and limitations of patient-specific implants and conventional reconstruction plates and to identify the clinical factors that should guide the selection of an appropriate reconstructive method.

This article is based on a narrative review and comparative analysis of published scientific literature on mandibular reconstruction. Relevant studies were identified through PubMed and accessible peer-reviewed publications addressing patient-specific implants, conventional reconstruction plates, computer-assisted surgery, CAD/CAM technology, and postoperative complications. Priority was given to clinical comparative studies, systematic or narrative reviews, and publications discussing reconstructive planning and implant safety.

The analysis focused on five principal dimensions: anatomical accuracy, mechanical stability, surgical workflow, complications, and economic accessibility. The available evidence was interpreted comparatively, with attention to differences in patient populations, defect characteristics, reconstructive procedures, and follow-up periods. No new patient data were collected for this article. The numerical findings presented below are taken from published studies and should not be interpreted as results of an independent clinical trial.

1. Patient-specific implants: design principles and clinical advantages. Patient-specific implants are designed to match the anatomical characteristics and reconstructive requirements of an individual patient. The workflow usually begins with computed tomography (CT) imaging, which provides the anatomical data required to create a three-dimensional digital model of the mandible. Surgeons and biomedical engineers can then plan the intended resection, determine the desired mandibular contour, and design an implant or fixation plate that corresponds to the planned reconstruction.

CAD/CAM technology enables the digital design to be converted into a physical implant through computer-controlled milling or additive manufacturing, commonly known as three-dimensional printing. In selected cases, patient-specific cutting guides and drilling guides are produced alongside the implant to help transfer the virtual surgical plan into the operating theatre. These technologies can improve the reproducibility of the planned reconstruction and reduce the need for extensive intraoperative plate bending (Wilde et al., 2015).

One important advantage of patient-specific implants is their potential to restore mandibular anatomy more accurately. This is particularly relevant in defects involving the mandibular angle, body, symphysis, or multiple segments, where small discrepancies may affect facial symmetry and occlusal relationships. A preplanned implant may also simplify positioning and fixation by providing a design tailored to the intended reconstruction.

A retrospective comparative study involving 94 patients evaluated conventional reconstruction plates in 48 patients and patient-specific implants in 46 patients. The researchers found differences in postoperative anatomical measurements between the groups, but the findings did not establish universal superiority of either method across all measured parameters. The authors emphasized the importance of case selection, surgical experience, and familiarity with computer-assisted planning (Karnatz et al., 2021).

Another clinical study of 30 patients reported generally favorable handling and fit of patient-specific CAD/CAM reconstruction plates and surgical guides. However, the operative plan required adaptation in six cases, demonstrating that even carefully designed implants must remain compatible with intraoperative findings and changing clinical circumstances (Wilde et al., 2015).

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The potential benefits of patient-specific reconstruction can be summarized as follows:

- Anatomical customization: implant geometry can be designed according to the patient's mandibular anatomy and planned reconstruction.
- Preoperative planning: the surgical team can determine the intended implant position, screw locations, and reconstruction contour before surgery.
- Potential reduction in intraoperative adjustments: customized components may reduce the need for repeated bending and reshaping.
- Reproducibility: surgical guides and a predefined digital plan may help the team reproduce the intended result.
- Support for complex reconstruction: customized designs can be particularly useful when defects are extensive or the remaining anatomy is irregular.

These advantages should nevertheless be interpreted cautiously. Improved geometric fit does not automatically guarantee successful bone healing, infection prevention, stable soft-tissue coverage, or long-term implant survival. Clinical outcomes also depend on defect size, tissue vascularity, fixation quality, oral hygiene, systemic health, and the reconstructive technique used.

2. Conventional reconstruction plates: advantages and limitations. Conventional reconstruction plates remain an important option in oral and maxillofacial surgery. They are manufactured in standardized configurations and can be adapted to the patient's anatomy during the operation. Depending on the clinical situation, they may be used to bridge a mandibular defect, stabilize bone segments, or secure a bone graft or vascularized free flap.

Their principal advantage is practical accessibility. Standard plates are generally available through established surgical supply systems and do not necessarily require a separate patient-specific manufacturing process. They can be useful in urgent procedures, when the final extent of a defect is uncertain, or when the clinical team must adapt the reconstruction according to intraoperative findings.

The ability to reshape a conventional plate also offers flexibility. In some cases, this allows the surgeon to respond immediately to unexpected anatomical conditions without waiting for a new customized component. Furthermore, standardized systems are familiar to many surgical teams and may be more feasible in hospitals where advanced digital planning infrastructure is limited.

However, conventional plates have important limitations. Manual bending may be time-consuming and can introduce deviations from the intended mandibular contour. Repeated adjustment may also make it more difficult to reproduce a preoperative plan consistently. Depending on the defect and loading conditions, plate-related complications may include screw loosening, plate fracture, infection, wound dehiscence, mucosal or skin perforation, and plate exposure. These complications are influenced by several clinical and technical factors and cannot be attributed to plate design alone (Karnatz et al., 2021; Bone reconstruction using CAD/CAM technology in head and neck surgical oncology, 2024).

3. Comparative assessment of patient-specific implants and conventional plates. Table 1 presents a qualitative comparison of the two approaches. The assessment reflects their general technical characteristics rather than a claim that one method is superior in every clinical situation.

Table 1. Comparative characteristics of patient-specific implants and conventional reconstruction plates

Evaluation criterion	Patient-specific implants	Conventional reconstruction plates
Anatomical adaptation	Designed for the patient's anatomy and planned reconstruction	Adapted manually during surgery
Preoperative	Usually involves CT-based digital	May be used with or without advanced

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planning	modeling and CAD/CAM planning	digital planning
Intraoperative adjustment	Often reduced, but modifications may still be necessary	Bending and adjustment are commonly required
Manufacturing	Requires individualized design and production	Standardized components are generally available
Surgical flexibility	May be limited when unexpected changes require redesign	Can be reshaped or adapted during surgery
Technical requirements	Requires digital planning, manufacturing expertise, and quality control	Requires appropriate plate selection and surgical expertise
Cost and accessibility	Usually involves additional planning and customization costs	Often more accessible where standard systems are available
Potential complications	Infection, exposure, fixation failure, and other implant-related complications remain possible	Infection, exposure, screw loosening, plate fracture, and fixation failure remain possible
Best-suited situations	Selected complex defects where precise preoperative reconstruction is valuable	Situations requiring readily available, adaptable fixation or where customization is not feasible

Source: Compiled by the author based on Wilde et al. (2015), Karnatz et al. (2021), and published reviews of CAD/CAM-assisted mandibular reconstruction.

The comparison indicates that patient-specific implants offer advantages in planned anatomical reconstruction, whereas conventional plates provide practical flexibility and may be more readily accessible. Neither approach eliminates the risks associated with mandibular reconstruction. The selection of a technique should therefore be based on the patient's anatomical defect, the need for bone reconstruction, soft-tissue conditions, the expected functional load, available resources, and the surgical team's experience.

Further research should compare these methods using consistent outcome measures, including operative time, reconstruction accuracy, implant exposure, infection, revision surgery, functional recovery, patient-reported quality of life, and total treatment cost. Prospective multicenter studies with adequate follow-up would help clarify which patient groups benefit most from customized reconstruction and whether its initial cost is offset by improvements in subsequent treatment.

Conclusion

Modern mandibular reconstruction involves a range of techniques designed to restore facial anatomy, mandibular continuity, and functional capacity. Patient-specific implants offer an individualized approach based on CT imaging, three-dimensional modeling, and CAD/CAM manufacturing. Their principal advantages include customized anatomical adaptation, detailed preoperative planning, and the potential to reduce intraoperative adjustments. These characteristics can be particularly valuable in complex defects where precise restoration of mandibular contour is important.

Conventional reconstruction plates remain clinically relevant because they are adaptable, generally accessible, and familiar to surgical teams. Their limitations include the need for intraoperative shaping and the possibility of deviations from the intended anatomical contour. Nevertheless, available comparative evidence does not establish universal superiority of patient-specific implants in terms of complications or long-term clinical outcomes.

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The most appropriate reconstruction method should therefore be selected according to defect characteristics, biological requirements, soft-tissue conditions, functional objectives, and institutional resources. Patient-specific implants should be considered a valuable addition to reconstructive practice rather than a universal replacement for conventional plates. Ultimately, successful mandibular reconstruction depends on sound clinical judgment, careful surgical planning, appropriate fixation, effective postoperative management, and long-term functional evaluation.

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