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Bone Reconstruction In Oral And Maxillofacial Surgery: Innovations In Techniques And Biomaterials For Mandibular Defect Rehabilitation

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Abstract:
Introduction: *Treating cleft abnormalities, infections, and tumors are only a few of the problems that need maxillofacial repair. Effective rehabilitation approaches are necessary because mandibular anomalies, whether they are the result of trauma, tumors, or other circumstances, have a substantial influence on face appearance and oral function. Recent developments in bone repair methods and biomaterials for mandibular defect rehabilitation in oral and maxillofacial surgery are examined in this review.*
Methodology: *ScienceDirect, Google Scholar, PubMed, and other databases were used to do a thorough search. Recent English-language research on cutting-edge methods and biomaterials in bone healing for mandibular abnormalities was the primary focus of the inclusion criteria. For analysis, 58 relevant publications in total were chosen.*
Results: *Studies examined several bone-repairing materials, such as xenografts and allografts, and emphasized the benefits and drawbacks of each. Although they provide health issues, metal compounds like titanium alloys have exceptional mechanical strength. Magnesium alloys are one example of a biodegradable metal that shows promise but needs further investigation. Scaffold building involves the use of many materials such as bioinks, polymers, bioceramics, and composites, each having specific uses and characteristics. Digital navigation technology, distraction osteogenesis, and microvascular restoration are some of the techniques that improve surgical results.*
Conclusion: *In conclusion, the development of biomaterials and procedures provides a potential route for the rehabilitation of mandibular defects. Upcoming studies in oral and maxillofacial surgery have to concentrate on enhancing material qualities, perfecting surgical methods, and enhancing patient results.*
Key Word: *Bone Reconstruction, Maxillofacial Surgery; Biomaterials; Mandibular defect.*

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I. Introduction.

Among other ailments, maxillofacial restoration is essential in the treatment of cleft malformations, infections, and head and neck tumors. When it comes to tumors, maxillofacial reconstruction seeks to return the shape and functionality of the facial tissues damaged after tumor removal, giving patients their lives back and their self-worth back (1). Surgeons may improve speech, mastication, and facial aesthetics by reconstructing abnormalities and optimizing functional results via the use of many procedures, including bone grafting, tissue flaps, and implantology. Similarly, maxillofacial reconstruction is necessary to rectify orofacial clefts, allowing the afflicted tissues to grow and develop normally and enhancing their look and function (2). When dealing with infections, maxillofacial reconstruction plays a critical role in maintaining the integrity of the injured tissues, promoting the best possible recovery, and lowering the possibility of functional and aesthetic problems (3). All things considered, maxillofacial reconstruction is essential for tackling the intricate problems brought on by a variety of diseases, providing patients with better functional results, superior aesthetics, and an improved quality of life overall.

The mandible, which makes up the bottom third of the face, is a scaffold made of bones. It has a direct bearing on the patient's ability to eat, articulate, and speak in addition to maintaining the patient's face form and contour. Loss of bone tissue in the oral cavity can be caused by injury, tumor, infection, congenital disease, periodontitis, and iatrogenic injuries (e.g., excessive osteotomy in the mandible hypertrophy plastic surgery), which can have varying effects on the patient's facial appearance and oral function (4). Patients will unavoidably experience trauma and a great psychological load from these; many may exhibit symptoms of pain, inferiority, eccentricity, etc. Most of these individuals have heightened sensitivity to strong, delicate emotions of beauty, which may even manifest as suicidal thoughts in dejection. Reconstruction of the mandible flaws has long been a worry, and the study aim has always been how to repair the defects better (5)(6). Associated fields have been working on finding the best way to fix bone defects for a long time. The gold standard for bone grafting is the conventional autologous bone transplant (7). Nevertheless, their use is restricted, and they run the risk of subsequent bone resorption due to a lack of sources and donor problems (such hypofunction and persistent pain) (8).

Allograft and xenogeneic procedures are now often used in clinical settings. Allogeneic bone is often frozen, freeze-dried, decalcified, or treated with various chemicals to lessen the induction of severe immunological rejection in the host; as a result, many of its cell components are necrotic. As a result, there are several ways in which allogeneic differs from autograft in terms of osteogenesis, healing process manifestation, and immune response (9). Osteoconductive, osteoinductive, biocompatible, bioresorbable, physically comparable to bone, simple to use, and reasonably priced would be the characteristics of an ideal bone-graft alternative. Simultaneously, it may develop early into a bone bonding interface with bone tissue, break down over time, and ultimately be totally replaced by autologous bone tissue (10).

Scholars have been increasingly interested with the study of bone replacement biomaterials used to mandibular abnormalities in recent years due to the fast development of biological materials and the necessity for contemporary regenerative medicine. Biomaterials possess strong biocompatibility in addition to carrying out certain biological activities. Nonetheless, a wide range of biomaterials with customizable qualities are used to treat mandibular abnormalities. With an emphasis on mandibular defect rehabilitation, this narrative review examines current advancements in bone repair for oral and maxillofacial surgery. We explore novel approaches to surgery as well as developments in biomaterials, including polymers, bioceramics, etc. This study offers useful ideas for physicians to maximize patient care and achieve good outcomes in difficult settings by thoroughly analyzing the literature and clinical data.

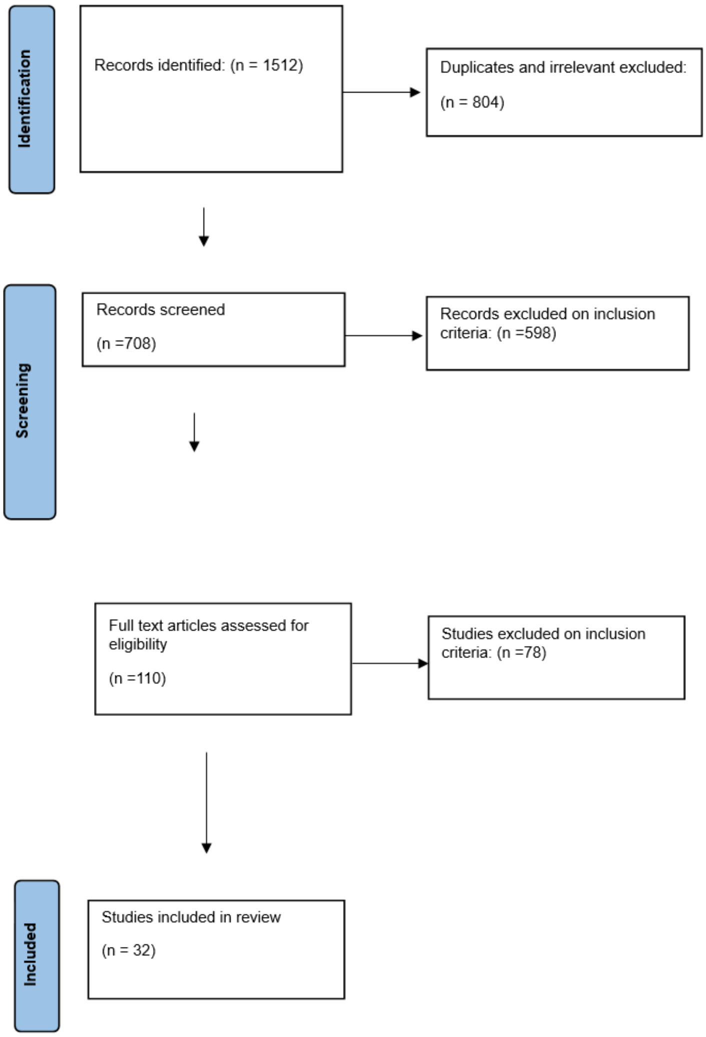
II. Material And Methods

Using an integrative approach, this review systematically gathers and examines pertinent material from reliable sources such as ScienceDirect, Google Scholar, and PubMed. Relevant literature was found by using search phrases like "biomaterials," "bone reconstruction techniques," and "mandibular defect rehabilitation." To improve search queries and concentrate on relevant material, Boolean operators (AND, OR) were used.

Inclusion and exclusion criteria:

The selection of high-quality research addressing current developments in bone repair methods and biomaterials for mandibular defect rehabilitation was ensured by the establishment of inclusion and exclusion criteria. The emphasis of the eligible research had to be on novel techniques in diagnosis and treatment, and they had to have been published in English over the previous five years (2018–2023). Research with non-English, unimportant results, or inadequate methodology were not included. Using exploratory searches, 1512 articles were found at first. A total of 110 articles were taken into consideration for full-text analysis after the inclusion and exclusion criteria were applied. Following a comprehensive evaluation process, 32 articles were chosen to be included in this narrative review.

The findings of the literature study on new developments in biomaterials and bone restoration methods for the rehabilitation of mandibular defects were categorized using a systematic methodology. To guarantee uniformity and clarity in the presentation of cutting-edge methods and technology, analytical categories were created. Microvascular reconstruction, tissue engineering, digital navigation technology, and 3D printing were among the advanced techniques. Biomaterials include polymers, artificial biomaterial, bioink material, bio ceramics, and composites employed in scaffold building were classified as innovative biomaterials. A thorough grasp of the many developments in bone repair methods and biomaterials in oral and maxillofacial surgery is made easier by this organized classification.



III. Results.

Materials from animal and human:

Allograft materials:

The term "allograft" describes the transplantation of tissue obtained from one member of a species into another. They also have potential antigenic reactions, poor osteogenic properties, unstable bone induction, limited supply, and their biological and mechanical properties can be altered by processing and preparation (11). An increasing number of surgical practitioners are becoming worried and using autologous bone grafts to simplify surgical procedures and prevent further procedures due to the treatment of mandibular abnormalities using allograft. In clinical practice, allograft is a kind of bone replacement material that is often used. Nevertheless, the impact of its individual use is still far from therapeutic standards because of its gradual "creeping substitution" approach (12). Currently, autologous stem cells, bone morphogenetic protein (BMP), and allogeneic bone composite immunosuppressants are thought to lower the risk of post-transplant problems; however, the exact cellular and molecular processes behind these effects remain unknown.

Materials for xenogeneic bones:

A xenograft is an animal transplant that uses tissues from one species to another. Examples of these tissues include ostrich, bovine, and pig bone, which may be freeze-dried, demineralized, deproteinized, or decellularized before being utilized to treat bone abnormalities (13). Even though xenografts are readily available, have good physical qualities, and are inexpensive, they also carry the risk of spreading zoonotic diseases like PERV (porcine endogenous retrovirus) and BSE (bovine spongiform encephalopathy), and their rejection response is stronger than that of allografts. Furthermore, some experts hypothesize that after months of implanting frozen allografts, a component known as proteoglycans degrades greatly, slowing the regeneration of the vasculature and the formation of new bone, which may even become loose. Other researchers, however, contend that the osteogenesis impact is significantly increased upon transplantation and that the drawbacks of xenograft may be addressed by combining allograft and autologous bone marrow. They even go so far as to say that spongiform xenograft could provide an appropriate culture medium for bone marrow cell osteogenesis (12).

Artificial biomaterials

Metal materials

Because of their remarkable mechanical strength and biological healing ability, metallic materials such titanium alloys, cobalt-based alloys, and stainless steel are often employed for mandibular defect implantation surgical procedures (12). However, since they produce toxic metal ions, they increase the risk of cancer, allergic reactions, and inflammation. The danger of fracture and the difficulty to build suitable three-dimensional porous structures are challenges. Future studies seek to create low-cost metal materials with advantageous properties such as bioactivity, tissue compatibility, stability, and simplicity of use (12).

Materials made of indegradable metal

Currently, titanium and its alloy—which are often used in clinics—are the non-biodegradable metal materials for mandibular defects. Because of its low toxicity, high strength-to-weight ratio, good corrosion resistance, and small weight, titanium is one of the few materials that can naturally be used for human implantation (12). Three-dimensional (3D) technology advancements have made it possible to use selective-laser sintered titanium implants to synchronize mandibular reconstruction with computer-aided design/computer-aided manufacturing (CAD/CAM) bimaxillary orthognathic surgery. For example, Sang-Woon Lee et al. manufactured customized implants for rabbit mandibular defects using CAD/CAM technology. The implants were made from titanium powder. The rabbits in the experimental group recovered their daily food intake more quickly and had less screw looseness than those in the 5-hole micro-plate without bone graft (14). A personalized 3D titanium implant was created using the computer-aided simulation approach in successful instances to address defects after mandibular tumor removal (15).

Titanium meshes and 3-D scaffolds are still the gold standard for load-bearing defect locations in mandible restoration. Although employing titanium meshes or titanium 3-D scaffolds to insert dental implants during mandible repair is challenging (12). Thus, the following should be the focus of future research on titanium and its alloys: (1) avoid using toxic elements like vanadium in alloys; (2) investigate titanium alloys with higher fatigue strength and lower elastic modulus to reduce the stress shielding effect and encourage fracture healing; and (3) further design modification would be necessary for the installation of the customized 3D titanium implant in dental implants.

Biodegradable Metal Substances:

Magnesium and its alloys are utilized as implants in the mandible because they can deteriorate and prevent the need for removal of the implants after a second operation, in addition to having the mechanical strength of metal materials. However, since magnesium is very soluble, there is a danger of overdose poisoning because of the significant release of magnesium ions in magnesium and its alloy materials (12). Furthermore, the current research focuses on the mechanical stability and deterioration of the magnesium (Mg) alloy. To verify if magnesium and its alloy may aid in the mandible defect area's restoration, When Guo et al. used magnesium and calcium alloy to repair the dog's jaw, they discovered that although the alloy could retain a sizable osteogenic space and accelerate the creation of new bone, it was unable to produce the necessary quantity of bone to repair the defect region (16). Furthermore, Wang et al. discovered that mg-sr alloy has strong osteogenesis and biocompatibility, both of which may aid in the healing of dogs' mandibular abnormalities (17). The exceptional all-around mechanical qualities, high biocompatibility with the human body, and biodegradable absorbability of magnesium alloys are their defining characteristics. Magnesium alloys have the potential to produce new medical tools with a wide market reach. From the development of products to the management of the corrosion degradation rate of magnesium and its alloys, mechanical property degradation, and the creation of biocompatibility evaluation criteria for degradable metals, there are still a lot of issues that need to be resolved.

Bioink material:

Materials that exhibit bioinert behavior and biocompatibility—that is, that do not cause an immunological response or rejection—are among the first generation of bioinks. Conversely, the body reacts by generating a dense fibrous capsule; hence, the scaffold—which consists of metals like titanium and stainless steel and polymers like silicone and polymethylmethacrylate—remains implanted without deteriorating (18). The materials that exhibit both biocompatibility and bioactivity are the second generation of bioinks. They enable the production of mineralization, or hydroxyapatite, and they may be biodegradable so that repairing cells can take the place of the scaffold (19). Bio responsive materials, which include growth factors and stimulatory chemicals like fibroblast growth factors (FGF) and bone morphogenetic proteins (BMP) that promote osteoblast development, are the third generation of bioinks (20). In the modern era, a multicomponent bioink is used since it integrates the mechanical and functional qualities to satisfy the intricate requirements inside the substituted tissue (21).

Biomaterials used in the building of scaffolds:

Polymers:

Polymers are organic materials constituted mostly of carbon atoms that are linked together by covalent connections between repeating subunits known as monomers (22). They are a flexible material that can modify its mechanical characteristics by changing its chemical structure. Research has demonstrated that they are both biocompatible and biodegradable. Like hydrogel polymer, it may be very fluid, or like polycaprolactone (PCL), it can be stiffer to provide a stronger scaffold. However, the kind of 3D printing used and the tissue that the polymer is replacing determine its mechanical qualities (23). Stiff bioink has the potential to block the printer's nozzle during the ink deposit process when utilized with inkjet printing. One way to deal with this would be to apply unpolymerized ink that solidifies and forms crosslinks upon deposition.

Materials made of polymers may be synthetic or natural. Natural polymers include polysaccharides (like alginate, agarose, and chitosan) and proteins (like silk, gelatin, and collagen). In comparison to protein polymers, polysaccharide polymers are less antigenic and have worse mechanical characters (24). Conversely, synthetic polymers such polyglycolic acid (PGA), polylactic acid (PLA), and polylactic-glycolic acid (PLGA) are examples of polyhydroxy acids (25). Although they are effective in creating a porous scaffold, they biodegrade to create carbon dioxide and lactic acid after being implanted. Although these byproducts are readily expelled from the body, they also create an acidic environment that promotes inflammation rather than healing (26). Unlike polyhydroxy acid polymers, polycaprolactone (PCL) is a synthetic polymer that is proven to biodegrade safely via hydrolysis degradation, hence not adversely influencing the tissue environment. Additionally, because of its low melting point, living cells may be encapsulated in it during deposit without losing any of their vitality.

Bio ceramics:

Ceramics are inorganic materials that have been created for use in dentistry and medicine as a substitute for bone, such as bioactive glass (BG), metal oxides, or bioactive ceramics (27). Calcium oxide, phosphorus, sodium dioxide, and silicon dioxide, or silicate, make up BGs (28). After coming into touch with biological fluid, they stimulate the synthesis of hydroxyapatite (Hap), which promotes osteogenesis and bone repair (29). Conversely, bioactive glass ceramics (such tricalcium phosphate and Hap) make a direct connection with bone without the need for the development of an intermediary fibrous connective tissue layer (30). Because of their brittleness, limited mechanical strength, and low fracture toughness, bioceramic materials cannot be employed exclusively to build scaffolds.

Composites:

A composite material is made up of two or more separate materials mixed with the goal of using the original components' qualities to influence the final material's mechanical properties (31). Polymer mixes or polymer-ceramic mixtures are used to make the composite. For instance, adding PCL to Hap increases the latter's brittleness and reduces the former's hydrophobicity, which promotes cell adhesion and penetration into the scaffold (32).

Stem cells and bioactive molecules:

For a biomaterial to qualify as a bioink, it must include stem cells that possess the ability to develop into several lineages and facilitate the process of bodily repair and regeneration (33). There are ethical issues associated with extracting stem cells from embryos if they are embryonic (ESC) in origin. As an alternative, adult stem cells may be discovered in certain adult body niches such the bone marrow, umbilical cord, dental pulp, amniotic tissue, and adipose tissue. Mesenchymal stem cells (MSCs) produced from the amniotic membrane and umbilical cord tissue had the best osteogenic potential when compared to other MSC-derived cells, according to a comparison of the osteogenic differentiation capacity of various MSC sources conducted by Shen et al. (34). The bioink contains bioactive molecules such as VEGF (vascular endothelial growth factor), BMP, FGF, and insulin-like growth factor-1 (IGF-1), which are growth factors that promote angiogenesis or may possibly boost osteogenic differentiation and bone production.

Techniques:

Tissue engineering for Bone Regeneration:

Significant defects in the maxilla and mandible that require surgery are caused by infections, surgical resection of benign or malignant tumors, congenital abnormalities, and unintentional traumatic injuries. The restoration of large bony defects resulting from trauma or post-resection presents the greatest challenge for the maxillofacial surgeon. Even though autologous grafting has numerous drawbacks, it remains the gold standard technique for the standard reconstruction of maxillofacial bone defects (35).

Despite several clinical attempts in recent years, the ideal method and material for bone reconstruction have not yet been identified. With sufficient vascularization, autologous bone grafts can be used to repair large-scale bone defects in the oral and maxillofacial region thanks to bone tissue engineering techniques. Wu et al.'s review of novel approaches to enhance the vascularization of engineered bone tissue included potential clinical uses for stem cells (SCs), primarily MSCs derived from bone marrow or adipose tissue as well as dental tissues (36). Because MSCs can mimic biological processes to induce bone regeneration, they are an important component in bone regeneration (37).

MSCs can be directed to differentiate into osteoblasts, which ultimately start the mineralization process, after being seeded into freshly regenerated tissue. MSCs' secretion of growth factors and cytokines can enhance bone regeneration in an indirect manner. There are two approaches: MSCs are isolated from the patient and expanded ex vivo, and they are seeded onto appropriate internal 3D scaffolds where they proliferate and pre-differentiate under controlled culture conditions (38). Alternatively, the MSCs are directly transplanted into the defect bone site and combined with an external scaffold. The most promising combination, as recently summarized by Chocholata et al., is cells with scaffolds made of various materials and technologies (39). Various MSC types combined with different scaffolds have been reported in several bone tissue engineering investigations as potentially suitable for regeneration for oral and maxillofacial surgical procedures.

Human GMSCs have recently been explored as a potential treatment option for trauma or unintentional surgical injuries, particularly involving the cranium. GMSC-complexed three-dimensional scaffolds may offer a novel therapeutic strategy for enhancing bone tissue regeneration (40).

Using bone-marrow-derived MSCs, Gjerde et al. performed regeneration of severe mandibular ridge resorption in a less invasive manner than traditional bone grafting (41). Human platelet lysate was used to expand the bone marrow and plastic adherent cells that were aspirated from the posterior iliac crest and placed in culture medium. Biphasic calcium phosphate granules were then added to the defect along with the cells. A sizeable amount of newly generated bone was created, suitable for the implantation of dental implants.

Microvascular reconstruction:

Large tissue defects may be repaired, transplanted bone and soft tissue get an instant blood supply, healing can occur quickly, and resistance to radiation and infection can be strengthened with the use of autologous vascularized tissue, especially microvascular grafts (42). These grafts are essential for severe deficits that arise after hemimaxillectomy or hemimandibulectomy. Larger bone deficiencies often need grafts from the scapula, iliac crest, or fibula, while augmentation procedures are mostly used to correct lesser faults in the mandible and maxilla (43).

Because of its considerable length, long and wide vascular pedicle, and adaptability for a two-team approach, the fibula flap is used for mandibular and maxillary reconstruction. With the least amount of donor site morbidity—typically, stiffness, ankle instability, and sensory abnormalities—it makes the placement of dental implants easier and results in occlusion, mastication, and speech (44). Nevertheless, these techniques come with a high equipment need and may result in significant flap problems and donor site morbidity.

Preoperative and postoperative CT scan reconstructions document the use of a fibula-free flap in mandibular reconstruction for a female patient who had medication-induced osteonecrosis of the jaws (45). While the fibula flap has benefits including the ability to remove soft tissue for repair and three-vessel leg flow, it also has drawbacks such a thin skin paddle. As an alternative, the iliac crest flap supplies enough bone for maxillary and mandibular restoration; nevertheless, it has a high donor site morbidity, with the maxilla being largely supported because of its ability to regenerate bone and separate oronasally. Another approach is the scapula free flap, which has a low morbidity and high amount of soft tissue but requires realigning the patient for flap harvesting, which presents some complications.

Conventional free-hand techniques are being replaced by virtual planning and computer-aided surgery using customized devices for microvascular repair of bone segments (46). The steps in this process are planning, modelling, surgery, and postoperative assessment. First, CT images are obtained for preoperative fabrication and planning using computer-aided design and manufacturing (44). This workflow allows for the preoperative determination of cutting routes and angles and the shaping of osteosynthesis material, which reduces operating times and improves precision. Nevertheless, it also entails substantial additional costs and might make intraoperative modifications to the surgical plan more difficult (47).

Large tissue defects may be repaired with autologous vascularized tissue, especially microvascular grafts, which can feed transplanted bone and soft tissue with blood right away, speed up the healing process, and increase resistance to radiation and infection (42). For severe deficits that occur after hemimaxillectomy or hemimandibulectomy, these grafts are essential. Smaller deficiencies in the mandible and maxilla are usually treated using augmentation procedures, however major bone defects sometimes need grafts from the scapula, iliac crest, or fibula (43).

Distraction:

Although technique was first utilized to treat mandibular deficits, distraction osteogenesis has also been employed to treat maxillary hypoplasia (44). Osteotomy, delay, distraction, and consolidation are its constituent steps. Between the two segments, new bone grows during distraction osteogenesis, which lasts until the callus tissue progressively distracts. Consequently, a new bone will grow parallel to the vectors of the distractions (44). The major purpose of distraction osteogenesis is to treat craniomaxillofacial abnormalities that are either congenital or acquired. Most of the literature on the reconstruction of jaw abnormalities consists of case studies, case series, and brief comparative analyses that report vertical gains of up to 15 mm along with a gradual extension of the surrounding soft tissues (48). Distraction osteogenesis is often a dependable method with positive clinical outcomes.

Nevertheless, several disadvantages must be considered, such as distraction osteogenesis. The size of the osteotomies and the distraction devices may restrict the use of distraction osteogenesis, and it may not be possible to concurrently address vertical and horizontal defects with it. In addition, broken devices and issues with the intended vectors might happen (44).

Digital navigation technology

The fast advancement of computer technology and imaging in recent years has led to a widespread use of computer aided navigation system (CANS) technology in hard tissue repair surgery. The combination of customized titanium stent insertion, bone transplantation, and computer-aided design and manufacture (CAD/CAM) technologies has become more advanced and produced excellent outcomes. Its benefits include the ability to simulate different surgical plans prior to surgery, design digital guides, reconstruct titanium plates, and determine the optimal location for titanium screw fixation, optimize prosthesis biomechanics (protecting ligaments and muscle attachments to maintain chewing function and encourage bone healing), streamline the surgical procedure, and reduce operating time (12). During the follow-up two years (and in most cases less than six months) after titanium plate reconstruction surgery, Gutwald R et al. found that the incidence rate of titanium plate nail loosening and fracture caused by excessive stress (either by strength or fatigue) in the reconstruction area was 2.9%–10.7% (12).

To address the issues, Hoefert et al. simulated the changes in stress following the reconstruction of the mandible defect in the titanium plate and assessed the biological performance of the plate using computerized three-dimensional finite element analysis software. To lower the risk of both the titanium plate and nail breaking, additional titanium plate fixation was used to lessen the tension in the stressed region. Nevertheless, the existing body of research is theoretical in nature, and further evidence is required for the practical use (49).

The technique of 3D printing:

One kind of CAD/CAM fast prototyping technology is 3D printing. Extrusion-based, inkjet, laser-assisted, and stereolithography (SLA) bioprinting are the major bioprinting methods utilized for the deposition and patterning of biological materials employing various bioink designs (50). Laser printing technology led to the development of two more conventional 3D printing techniques. Using the first approach, layers of substrate are extruded onto the build platform, often with additional energy applied to promote melting, fusion, or polymerization. The second technique uses a powdered substrate that is layered, then energy is added to trigger polymerization or other chemical processes including melting, selective laser sintering, or crystallization to the required shape. With the use of a computer, layer-by-layer stacking creates three-dimensional things based on the discrete stacking principle. Prior to surgery, Julius et al. performed a CT scan of the heads of cats that had mandible osteosarcoma (12). They then used CAD/CAM processing technology to 3D print a customized titanium plate for reconstruction. Mandible periodic resection was then performed, and the defect was then intraoperatively repaired using the specially made titanium plate. Aside from pulp damage in the lesion region, no indications of feeding difficulties were discovered during the postoperative follow-up. Fourteen months after surgery, the cat remained healthy and living (12). Moiduddin et al. created a matching titanium plate model for the restoration of mandibular deformities using computerized three-dimensional finite element analysis and additive manufacturing (51). Shao et al. created CSi-Mg10 bioceramics scaffolds using 3D printing technology. These scaffolds have good mechanical strength, outstanding biological activity, and the right capacity to biodegrade (52). They can exactly fit the model of a rabbit mandibular defect in both macro and micro dimensions. Without the aid of any osteogenic agents, they could readily promote bone repair. Additionally, a unique 3D-printed bioactive ceramic scaffold with osteoconductive capabilities was suggested by Christopher et al. to treat segmental mandibular abnormalities in a rabbit model (53). Su et al. evaluated the effectiveness of alveolar bone defect regeneration in beagle dogs by customizing a 3D polycaprolactone (3D PCL) scaffold and implanting tricalcium phosphate powder in it. This was done using 3D printing technology. They discovered that 3D-printed porous PCL scaffolds may encourage the regeneration of alveolar bone to aid in the repair of dental defects (54).

IV. Discussion

With an emphasis on mandibular defect rehabilitation, the narrative review delves deeply into developments in bone repair methods and biomaterials for oral and maxillofacial surgery.

For the rehabilitation of mandibular defects, many surgical approaches are emphasized, such as microvascular repair (42), distraction osteogenesis (44), and digital navigation technology (12). Large tissue defects may be restored, and recovery can be accelerated by microvascular restoration, particularly when autologous vascularized tissue like the fibula flap is used (42). By promoting the formation of new bone, distraction osteogenesis offers a useful treatment for congenital or acquired craniomaxillofacial defects (44). By combining digital navigation technology with CAD/CAM and customized titanium stent insertion, surgical planning, implant placement accuracy, and biomechanical optimization are improved, which in turn improves patient outcomes (12).

Various materials utilized in scaffold building, such as polymers, bioceramics, composites, and bioink materials, are explored in biomaterials. Because polymers are biocompatible and biodegradable, they may be used to adjust mechanical characteristics with flexibility, which makes them appropriate for scaffold construction (38). Bioceramics, like bioactive glass and ceramics, encourage osteogenesis and bone mending, but there are drawbacks, including their brittleness and low mechanical strength (16). Composites improve scaffold characteristics including cell adherence and penetration by fusing the best features of many materials (32). Stem cells and bioactive compounds found in bioink materials promote tissue regeneration and repair, opening exciting new research directions (58).

Despite tremendous progress, mandibular deformity rehabilitation still faces difficulties. To further enhance surgical outcomes, concerns including immunological responses, donor site morbidity, and scaffold mechanical characteristics need to be addressed (177–179). The development of novel biomaterials with improved mechanical strength, bioactivity, and biocompatibility should be the main goal of future research (58). Furthermore, developments in bioprinting and tissue engineering technologies provide hope for customized and regenerative methods of mandibular defect repair (58).

V. Conclusion

This narrative review concludes by highlighting the noteworthy developments in biomaterials and bone rebuilding methods for the treatment of mandibular defects in oral and maxillofacial surgery. Novel techniques including microvascular reconstruction, CAD/CAM technology, and the utilization of polymers and bioceramics have been clarified by a methodical examination of recent research. These developments provide exciting new opportunities to improve surgical results, patient care, and the quality of life for those with mandibular abnormalities.

It is important, therefore, to recognize the limits of the existing corpus of study. The review may have excluded pertinent research outside of these limitations since it mainly focuses on published material that falls within a certain period and language. Furthermore, even if the procedures and biomaterials that have been found have potential, further research and clinical validation are necessary to ensure their broad acceptance and long-term effectiveness.

Future studies should focus on overcoming these constraints and investigating novel technologies and biomaterials for the rehabilitation of mandibular defects. To evaluate these advances' efficacy, safety, and longevity in a range of patient groups, long-term clinical trials are required. Furthermore, the advancement of oral and maxillofacial surgery will depend heavily on multidisciplinary cooperation between surgeons, engineers, and biomaterial scientists, opening the door to more individualized treatment plans and better patient results.

References

[1]. John J, Jeroen Vdb, Sander L. Oral And Maxillofacial Bone Reconstruction. Front Bioeng Biotechnol. 2016;4.
[2]. Sethi A, Kaus T, Cawood Ji, Plaha H, Boscoe M, Sochor P. Onlay Bone Grafts From Iliac Crest: A Retrospective Analysis. Int J Oral Maxillofac Surg. 2020 Feb 1;49(2):264–71.
[3]. Salyer Ke, Taylor Dp. Bone Grafts In Craniofacial Surgery. Craniomaxillofac Trauma Reconstr. 2009;2(3):125–34.
[4]. Bauermeister Aj, Zuriarrain A, Newman Mi. Three-Dimensional Printing In Plastic And Reconstructive Surgery A Systematic Review. Ann Plast Surg. 2016 Nov 1;77(5):569–76.
[5]. Ishida S, Shibuya Y, Kobayashi M, Komori T. Assessing Stomatognathic Performance After Mandibulectomy According To The Method Of Mandibular Reconstruction. Int J Oral Maxillofac Surg. 2015 Aug 1;44(8):948–55.
[6]. Johnson J, Jundt J, Hanna I, Shum Jw, Badger G, Melville Jc. Resection Of An Ameloblastoma In A Pediatric Patient And Immediate Reconstruction Using A Combination Of Tissue Engineering And Costochondral Rib Graft: A Case Report. J Am Dent Assoc. 2017 Jan 1;148(1):40–3.
[7]. Sarkar Sk, Lee Bt. Hard Tissue Regeneration Using Bone Substitutes: An Update On Innovations In Materials. Korean J Intern Med [Internet]. 2015 [Cited 2024 Feb 7];30(3):279. Available From: /Pmc/Articles/Pmc4438282/

[8]. Mcmahon Re, Wang L, Skoracki R, Mathur Ab. Development Of Nanomaterials For Bone Repair And Regeneration. J Biomed Mater Res Part B Appl Biomater [Internet]. 2013 Feb 1 [Cited 2024 Feb 7];101b (2):387–97. Available From: Https://Onlinelibrary.Wiley.Com/Doi/Full/10.1002/Jbm.B.32823
[9]. Nguyen H, Morgan Daf, Forwood Mr. Sterilization Of Allograft Bone: Effects Of Gamma Irradiation On Allograft Biology And Biomechanics. Cell Tissue Bank [Internet]. 2007 Jun 25 [Cited 2024 Feb 7];8(2):93–105. Available From: Https://Link.Springer.Com/Article/10.1007/S10561-006-9020-1
[10]. Gruene M, Deiwick A, Koch L, Schlie S, Unger C, Hofmann N, Et Al. Laser Printing Of Stem Cells For Biofabrication Of Scaffold-Free Autologous Grafts. Tissue Eng Part C Methods. 2011 Aug 10;17(1):79–87.
[11]. Gardin C, Ricci S, Ferroni L, Guazzo R, Sbricoli L, De Benedictis G, Et Al. Decellularization And Delipidation Protocols Of Bovine Bone And Pericardium For Bone Grafting And Guided Bone Regeneration Procedures. Plos One [Internet]. 2015 Jul 20 [Cited 2024 Feb 7];10(7): E0132344. Available From: Https://Journals.Plos.Org/Plosone/Article?Id=10.1371/Journal.Pone.0132344
[12]. Zhang Q, Wu W, Qian C, Xiao W, Zhu H, Guo J, Et Al. Advanced Biomaterials For Repairing And Reconstruction Of Mandibular Defects. Mater Sci Eng C. 2019 Oct 1; 103:109858.
[13]. Campana V, Milano G, Pagano E, Barba M, Cicione C, Salonna G, Et Al. Bone Substitutes In Orthopaedic Surgery: From Basic Science To Clinical Practice. J Mater Sci Mater Med. 2014 Sep 20;25(10):2445–61.
[14]. Lee Sw, Kim Hg, Ham Mj, Hong Dgk, Kim Sg, Rotaru H. Custom Implant For Reconstruction Of Mandibular Continuity Defect. J Oral Maxillofac Surg. 2018 Jun 1;76(6):1370–6.
[15]. Jo Yy, Kim Sg, Kim Mk, Shin Sh, Ahn J, Seok H. Mandibular Reconstruction Using A Customized Three-Dimensional Titanium Implant Applied On The Lingual Surface Of The Mandible. J Craniofac Surg [Internet]. 2018 Mar 1 [Cited 2024 Feb 7];29(2):415–9. Available From: Https://Journals.Lww.Com/Jcraniofacialsurgery/Fulltext/2018/03000/Mandibular_Reconstruction_Using_A_Customized.35.Aspx
[16]. Guo C-W, Yu Q, Sun B-Z, Wang C-Y, Yang J-X. Evaluation Of Alveolar Bone Repair With Mineralized Collagen Block Reinforced With Mg&#8211, Ca Alloy Rods. J Biomater Tissue Eng. 2018 Sep 28;8(1):1–10.
[17]. Wang C-Y, Kang C-Y, Zhang S-N, Yang J-X, Cheng G. Study On Repairing Canine Mandibular Defect With Mg–Sr Alloy. J Biomater Tissue Eng. 2018 Sep 28;8(1):11–9.
[18]. Mariani E, Lisignoli G, Borzì Rm, Pulsatelli L. Biomaterials: Foreign Bodies Or Tuners For The Immune Response? Int J Mol Sci. 2019 Feb 1;20(3):636.
[19]. Turnbull G, Clarke J, Picard F, Riches P, Jia L, Han F, Et Al. 3d Bioactive Composite Scaffolds For Bone Tissue Engineering. Bioact Mater. 2018 Sep 1;3(3):278–314.
[20]. Maisani M, Pezzoli D, Chassande O, Mantovani D. Cellularizing Hydrogel-Based Scaffolds To Repair Bone Tissue: How To Create A Physiologically Relevant Micro-Environment? J Tissue Eng. 2017 Jan 1; 8:2041731417712073.
[21]. Ashammakhi N, Ahadian S, Xu C, Montazerian H, Ko H, Nasiri R, Et Al. Bioinks And Bioprinting Technologies To Make Heterogeneous And Biomimetic Tissue Constructs. Mater Today Bio. 2019 Jan 1; 1:100008.
[22]. Padovani Gc, Feitosa Vp, Sauro S, Tay Fr, Durán G, Paula Aj, Et Al. Advances In Dental Materials Through Nanotechnology: Facts, Perspectives And Toxicological Aspects. Trends Biotechnol. 2015 Nov 1;33(11):621–36.
[23]. Dizon Jrc, Espera Ah, Chen Q, Advincula Rc. Mechanical Characterization Of 3d-Printed Polymers. Addit Manuf. 2018 Mar 1; 20:44–67.
[24]. Tiwari S, Patil R, Bahadur P. Polysaccharide Based Scaffolds For Soft Tissue Engineering Applications. Polym. 2018 Jan 1;11(1):1.
[25]. Grémare A, Guduric V, Bareille R, Heroguez V, Latour S, L'heureux N, Et Al. Characterization Of Printed Pla Scaffolds For Bone Tissue Engineering. J Biomed Mater Res - Part A. 2018 Apr 1;106(4):887–94.
[26]. Ginjupalli K, Shavi Gv, Averineni Rk, Bhat M, Udupa N, Nagaraja Upadhya P. Poly (A-Hydroxy Acid) Based Polymers: A Review On Material And Degradation Aspects. Polym Degrad Stab. 2017 Oct 1; 144:520–35.
[27]. Surya Raghavendra S, Jadhav Gr, Gathani Km, Kotadia P. Bioceramics In Endodontics – A Review. J Istanbul Univ Fac Dent. 2017 Nov 17;51(0).
[28]. Vugt T, Geurts J, Arts J, Lindfors N. 3 - Biomaterials In Treatment Of Orthopedic Infections. Woodhead Publishing; 2017. P. 41–68.
[29]. Fernandes Hr, Gaddam A, Rebelo A, Brazete D, Stan Ge, Ferreira Jmf. Bioactive Glasses And Glass-Ceramics For Healthcare Applications In Bone Regeneration And Tissue Engineering. Mater. 2018 Dec 12;11(12):2530.
[30]. Ishikawa K, Matsuya S, Miyamoto Y, Kawate K. 9.05 - Bioceramics. Compr Struct Integr Nine Vol Set. 2003 Jan 1;1–9:169–214.
[31]. Hölzl K, Lin S, Tytgat L, Van Vlierberghe S, Gu L, Ovsianikov A. Bioink Properties Before, During And After 3d Bioprinting. Biofabrication. 2016 Sep 23;8(3).
[32]. Rajzer I. Fabrication Of Bioactive Polycaprolactone/Hydroxyapatite Scaffolds With Final Bilayer Nano-/Micro-Fibrous Structures For Tissue Engineering Application. J Mater Sci. 2014;49(16):5799–807.
[33]. Groll J, Burdick Ja, Cho Dw, Derby B, Gelinsky M, Heilshorn Sc, Et Al. A Definition Of Bioinks And Their Distinction From Biomaterial Inks. Biofabrication. 2018 Jan 1;11(1).
[34]. Shen C, Yang C, Xu S, Zhao H. Comparison Of Osteogenic Differentiation Capacity In Mesenchymal Stem Cells Derived From Human Amniotic Membrane (Am), Umbilical Cord (Uc), Chorionic Membrane (Cm), And Decidua (Dc). Cell Biosci. 2019 Feb 11;9(1):17–17.
[35]. Matichescu A, Ardelean Lc, Rusu Lc, Craciun D, Bratu Ea, Babucea M, Et Al. Advanced Biomaterials And Techniques For Oral Tissue Engineering And Regeneration—A Review. Mater 2020, Vol 13, Page 5303 [Internet]. 2020 Nov 23 [Cited 2024 Feb 7];13(22):5303. Available From: Https://Www.Mdpi.Com/1996-1944/13/22/5303/Htm
[36]. Wu V, Helder Mn, Bravenboer N, Ten Bruggenkate Cm, Jin J, Klein-Nulend J, Et Al. Bone Tissue Regeneration In The Oral And Maxillofacial Region: A Review On The Application Of Stem Cells And New Strategies To Improve Vascularization. Stem Cells Int. 2019;2019.
[37]. Trubiani O, Marconi Gd, Pierdomenico Sd, Piattelli A, Diomede F, Pizzicannella J. Human Oral Stem Cells, Biomaterials And Extracellular Vesicles: A Promising Tool In Bone Tissue Repair. Int J Mol Sci 2019, Vol 20, Page 4987 [Internet]. 2019 Oct 9 [Cited 2024 Feb 7];20(20):4987. Available From: Https://Www.Mdpi.Com/1422-0067/20/20/4987/Htm
[38]. Iaquinta Mr, Mazzoni E, Bononi I, Rotondo Jc, Mazziotta C, Montesi M, Et Al. Adult Stem Cells For Bone Regeneration And Repair. Front Cell Dev Biol. 2019 Nov 12; 7:485383.
[39]. Chocholata P, Kulda V, Babuska V. Fabrication Of Scaffolds For Bone-Tissue Regeneration. Mater 2019, Vol 12, Page 568 [Internet]. 2019 Feb 14 [Cited 2024 Feb 7];12(4):568. Available From: Https://Www.Mdpi.Com/1996-1944/12/4/568/Htm
[40]. Diomede F, Gugliandolo A, Cardelli P, Merciaro I, Ettorre V, Traini T, Et Al. Three-Dimensional Printed Pla Scaffold And Human Gingival Stem Cell-Derived Extracellular Vesicles: A New Tool For Bone Defect Repair. Stem Cell Res Ther [Internet]. 2018 Apr 13 [Cited 2024 Feb 7];9(1):1–21. Available From: Https://Stemcellres.Biomedcentral.Com/Articles/10.1186/S13287-018-0850-0

[41]. Gjerde C, Mustafa K, Hellem S, Rojewski M, Gjengedal H, Yassin Ma, Et Al. Cell Therapy Induced Regeneration Of Severely Atrophied Mandibular Bone In A Clinical Trial. Stem Cell Res Ther [Internet]. 2018 Aug 9 [Cited 2024 Feb 7];9(1):1–15. Available From: Https://Link.Springer.Com/Articles/10.1186/S13287-018-0951-9

[42]. Becker P, Blatt S, Pabst A, Heimes D, Al-Nawas B, Kämmerer Pw, Et Al. Comparison Of Hyperspectral Imaging And Microvascular Doppler For Perfusion Monitoring Of Free Flaps In An In Vivo Rodent Model. J Clin Med [Internet]. 2022 Jul 1 [Cited 2024 Feb 7];11(14):4134. Available From: Https://Www.Mdpi.Com/2077-0383/11/14/4134/Htm

[43]. Goetze E, Kämmerer Pw, Al-Nawas B, Moergel M. Integration Of Perforator Vessels In Cad/Cam Free Fibula Graft Planning: A Clinical Feasibility Study. J Maxillofac Oral Surg [Internet]. 2020 Mar 1 [Cited 2024 Feb 7];19(1):61–6. Available From: Https://Link.Springer.Com/Article/10.1007/S12663-019-01215-Y

[44]. Kämmerer Pw, Al-Nawas B. Bone Reconstruction Of Extensive Maxillomandibular Defects In Adults. Periodontol 2000 [Internet]. 2023 Oct 1 [Cited 2024 Feb 7];93(1):340–57. Available From: Https://Onlinelibrary.Wiley.Com/Doi/Full/10.1111/Prd.12499

[45]. Hurley Cm, Mcconn Walsh R, Shine Np, O'neill Jp, Martin F, O'sullivan Jb. Current Trends In Craniofacial Reconstruction. Surg. 2023 Jun 1;21(3): E118–25.

[46]. Dowgierd K, Pokrowiecki R, Wolanski W, Kawlewska E, Kozakiewicz M, Wos J, Et Al. Analysis Of The Effects Of Mandibular Reconstruction Based On Microvascular Free Flaps After Oncological Resections In 21 Patients, Using 3d Planning, Surgical Templates And Individual Implants. Oral Oncol. 2022 Apr 1; 127:105800.

[47]. Goetze E, Moergel M, Gielisch M, Kämmerer Pw. Safety Of Resection Margins In Cad/Cam-Guided Primarily Reconstructed Oral Squamous Cell Carcinoma—A Retrospective Case Series. Oral Maxillofac Surg [Internet]. 2019 Dec 1 [Cited 2024 Feb 7];23(4):459–64. Available From: Https://Link.Springer.Com/Article/10.1007/S10006-019-00797-8

[48]. Jensen Ot. Le Fort I Distraction Osteogenesis Of Edentulous Maxillae Combined With Simultaneous Sinus Floor Grafting To Obtain Orthoalveolar Form For Emergence Profile Dental Implant Restorations: Report Of Three Patient Treatments Followed For 12 Years. Oral Maxillofac Surg Clin [Internet]. 2019 May 1 [Cited 2024 Feb 7];31(2):339–48. Available From: Http://Www.Oralmaxsurgery.Theclinics.Com/Article/S1042369918301092/Fulltext

[49]. Hoefert S, Taier R. Mechanical Stress In Plates For Bridging Reconstruction Mandibular Defects And Purposes Of Double Plate Reinforcement. J Cranio-Maxillofacial Surg. 2018 May 1;46(5):785–94.

[50]. Midha S, Dalela M, Sybil D, Patra P, Mohanty S. Advances In Three-Dimensional Bioprinting Of Bone: Progress And Challenges. J Tissue Eng Regen Med [Internet]. 2019 Jun 1 [Cited 2024 Feb 7];13(6):925–45. Available From: Https://Pubmed.Ncbi.Nlm.Nih.Gov/30812062/

[51]. Moiduddin K. Implementation Of Computer-Assisted Design, Analysis, And Additive Manufactured Customized Mandibular Implants. J Med Biol Eng [Internet]. 2018 Oct 1 [Cited 2024 Feb 7];38(5):744–56. Available From: Https://Link.Springer.Com/Article/10.1007/S40846-018-0370-5

[52]. Shao H, Sun M, Zhang F, Liu A, He Y, Fu J, Et Al. Custom Repair Of Mandibular Bone Defects With 3d Printed Bioceramic Scaffolds. Https://Doi.Org/101177/0022034517734846 [Internet]. 2017 Oct 11 [Cited 2024 Feb 7];97(1):68–76. Available From: Https://Journals.Sagepub.Com/Doi/Abs/10.1177/0022034517734846

[53]. Lopez Cd, Diaz-Siso Jr, Witek L, Bekisz Jm, Cronstein Bn, Torroni A, Et Al. Three Dimensionally Printed Bioactive Ceramic Scaffold Osseoconduction Across Critical-Sized Mandibular Defects. J Surg Res. 2018 Mar 1; 223:115–22.

[54]. Park Sa, Lee Hj, Kim Ks, Lee Sj, Lee Jt, Kim Sy, Et Al. In Vivo Evaluation Of 3d-Printed Polycaprolactone Scaffold Implantation Combined With Β-Tcp Powder For Alveolar Bone Augmentation In A Beagle Defect Model. Mater 2018, Vol 11, Page 238 [Internet]. 2018 Feb 4 [Cited 2024 Feb 7];11(2):238. Available From: Https://Www.Mdpi.Com/1996-1944/11/2/238/Htm