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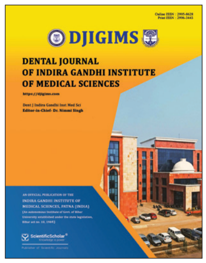

Review Article

Role of 3-Dimensional Printing in Oral and Maxillofacial Surgery

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ABSTRACT

Three-dimensional (3D) printing has been at the forefront of major innovations in medicine, dentistry, engineering, and education. It has also opened up access to surgical education, improved patient and physician relations, and improved surgical outcomes. In this review, we will look at the many applications of 3D printing in the fields of Maxillofacial Trauma and Reconstruction, Orthognathic Surgery, Maxillofacial Protoplast, Temporomandibular Joint (TMJ) Reconstruction, Dentistry, Bone Tissue Engineering for Maxillofacial Regeneration, Clinical Education, and Patient Communication. 3D printing was initially used to create custom prosthetic products and implants. Scientists were able to construct organs from patients' own cells supported by a 3D printed scaffold. In the last two decades, advances in technology have ushered in a new age of Oral and Maxillofacial Surgery.

Keywords: 3-D Printing, Advances in technology, Maxillofacial reconstruction, Maxillofacial Trauma, Oral surgery

INTRODUCTION

Three-dimensional (3D) printing has been at the forefront of major innovations in medicine, dentistry, engineering, and education. In the field of Oral and Maxillofacial Surgery (OMFS), it has been used to enhance surgical precision, enhance surgical predictability, and reduce operation times and overall costs. It has also opened up access to surgical education, improved patient and physician relations, and improved surgical outcomes. In this review, we will look at the many applications of 3D-printing in the fields of Maxillofacial Trauma and Reconstruction, Orthognathic Surgery, Maxillofacial Protoplast, Temporomandibular Joint (TMJ) Reconstruction, Dentistry, Bone Tissue Engineering for Maxillofacial Regeneration, Clinical Education, and Patient Communication. 3D printing was initially used to create custom prosthetic products and implants. Scientists were able to construct organs from patients' own cells supported by a 3D printed scaffold.Currently, they are aiming to grow fully functional organs that do not require scaffold support.[1]

In the last two decades, advances in technology have ushered in a new age of Oral and maxillofacial surgery (OMFS).[2] The theory behind 3D printing in the field of surgery is primarily the usage of MRI and CT scan data, for generating and storing it in Digital Imaging and Communications in Medicine (DICOM) format.[3] Computer-aided design (CAD) software is used to create a 3D printed virtual prototype. The main benefits of 3D printing are the ability to customize and personalize, creating highly precise and detailed devices/scaffolds, cost-effectiveness, and improved productivity. In addition, 3D printing technologies help surgeons prepare for complex procedures and improve patient results.[4,5]

DIFFERENT APPLICATIONS OF 3D PRINTING IN OMFS

1. Maxillofacial trauma and reconstruction:
   Maxillofacial Trauma and Reconstructions: 3D printed Models and Osteotomy Guides are very useful for treating trauma sequelae. These models can help plan osteotomies, reshape the bones, and create pre-bend orthodontic plates. Surgical simulation in these models increases accuracy and reduces the amount of time spent on the surgery. Cutting guides are recommended for mandibular reconstruction with fibula grafts to reduce the length of the surgery and improve the results.[6,7] For treating bone defects, you can mirror the good contralateral side to create a personalized device to restore anatomy along with pre-set screw depths. These devices are printed metal, are easy to adjust to the bone and restore symmetry.[8]
2. Dental implants:
   Dental implant insertion precision is improved when Virtual Surgical Planning (VSP), and 3D printed surgical guides are used, as they allow for minimal angular and linear errors.[9,10]
   Moreover, guided implants offer a benefit and exhibit survival that is comparable to or higher than before through flapless procedures, which cause patients to have less discomfort and fewer problems after surgery.[11]
3. TMJ reconstruction:
   With total joint replacement, precise condylectomy and prosthetic implantation can be carried out in one procedure with the use of 3D printed guides. In the event that the osteotomy guide is not used, the patient will undergo a second examination. Essentially a postoperative CT scan to plan the prosthesis using the mandibular and temporal bone that are still there, and a second surgery to implant the TMJ device. Delays like this lengthen the course of treatment and make patients more morbid. As a result, each system's components osteotomies, design guidelines, and intraoperative placement are planned using VSP.[12]
   The growing use of 3D printing technologies to create scaffolds and devices has prompted discussions about improvements in regulatory science to better understand and use the most effective method for assessing the efficacy and safety of tools and scaffolds. Personalized TMJ replacement prosthesis has been shown to have better clinical outcomes and longer lifespans than stock joints. Data on 3D printed total temporomandibular joint replacement (TMJR) are currently scarce, though. Depending on the device or scaffold to be made, additional technical or regulatory considerations may be needed during the product development process.[13]
4. Bone tissue engineering:
   This technology's use in the field of bone tissue engineering (BTE) has led to the development of a novel strategy for the regeneration and repair of tissue damage. The benefits of 3D printed scaffolds include their capacity to adapt to the specific needs of each patient through intricate architecture, design, and shape customization; all of this is achieved while maintaining cost-effectiveness.[14–16]
   We anticipate that in the coming years, novel bioactive synthetic materials will be created, along with strict guidelines for translational cell therapies, and the application of growth factors that can direct molecular and cellular pathways to enhance the healing of maxillofacial restorations following surgery.
   Replicating the intricate 3D architecture and dynamic functions of maxillofacial bone tissue is a difficult idea that necessitates patient-specific, tailored, and demand-driven tissue replacement procedures, which have not yet been accomplished.[14–16]
   Reconstruction of extensive maxillofacial abnormalities may become less invasive than the current standard, which involves autogenous bone transplants taken from several anatomical locations. This will lessen the requirement for a second surgical site, shorten the duration of the procedure, minimize patient morbidity, and cut down on the expense of interventions. With each patient receiving personalized care, it will be feasible to plan and restore geometrically difficult bone abnormalities.[14–16]
5. Maxillofacial prosthodontics:
   Almost all extraoral and intraoral structures could be replaced by maxillofacial prosthodontics. The most popular prostheses are those for the eyes, ears, and nose.[17]
   A variety of materials, including polylactic acid (PLA), acrylics, polypropylene, polyethylene, and polyurethane, are utilized in the production of 3D printed implants tailored to individual patients.[18] PLA is a thermoplastic polyester that is perfect for 3D printing because of its low melting point, low shrinkage, high strength, lack of tissue toxicity, and exceptional layer adhesion. PLA is affordable since it can be made from renewable resources.[17] Using 3D printing to create a patient-specific prosthesis for oral and maxillofacial reconstruction is a time-saving method that yields more consistent outcomes that are unique to each patient.[18]
   Clinical evidence supports the successful use of 3D printed components in the following ways: direct 3D printing of flexible nasal prosthesis with improved acceptability and reproducibility,[19] hollow obturator prostheses for patients

requiring partial or complete maxillectomy,[20] and a 3D printed auricular prosthesis for patient rehabilitation that eliminates traditional laboratory steps and optimizes the fabrication of a silicone prosthesis.[21] It should be noted, nonetheless, that there may be certain restrictions on the direct 3D printing of definitive prosthesis (such as orbital, nasal, and auricular). One instance relates to the alignment of the ocular prosthesis and silicone orbital prostheses, as well as the color matching of the 3D printed silicone with the surrounding skin tones.[22]

6. Patient Communication:

   The surgeon–patient relationship can also be strengthened with a functional 3D printed model. Changes to functional occlusion or restricted mouth opening following unmanaged Le Fort or mandibular fracture can be difficult to comprehend for a trauma patient. A demonstration of posttraumatic malocclusion through an articulating 3D printed model could improve patient comprehension and enhance the informed consent process.[23] 3D printed models can be used by oral and maxillofacial surgeons in pre-operative assessments, but there are further advantages in terms of patient education and communication. It would be challenging for patients without medical knowledge to interpret CT and MRI results.

   The extra tangibility and tactile dimension of 3D printed models have been shown to contribute to a higher patient understanding of both the pathology and the processes of its remedial surgery, even though surgical cases can be displayed to patients through 3D photos and software.[24]

FUTURE SCOPE OF 3D-PRINTING IN OMFS

Beyond its current applications in the construction of research models, surgical planning, training, the use of guide splints, and the creation of custom-fit implants, 3D printing in maxillofacial surgery has a promising future. Increased printing resolution, quicker manufacturing times, and lower costs would greatly increase the application's popularity. In order to lower the risk of infection and transplant rejection, it is necessary to be able to print materials that are more biocompatible. The flexibility and stiffness of materials utilized for patient-specific implants should be comparable to those of native bone. An even better result will come from the production of 3D printed scaffolds with internal channel networks for cell proliferation, and eventually bone ingrowth.[25]

Two different kinds of 3D models are employed in face cosmetics. Among them are patches and microneedles (MNs), both of which produce excellent outcomes. These methods are applied to remove wrinkles and acne, and patches can be used to apply topical medications. Furthermore, 3D printed Microneedles (MNs) would take the place of patches for both medicinal and cosmetic applications, and dissolving MNs is the most promising of all of them. Using 3D printing technology appears to be a viable approach for developing efficient platforms for the delivery of personalized cosmetics.[26]

CONCLUSION

According to an assessment of the available research, 3D printing has benefits beyond just serving as an addition to or replacement for conventional procedures. CAD/CAM technologies enhance the options accessible to physicians in any situation, whether it's by optimizing patient outcomes, selecting the right material, or achieving finer precision results. In the coming years, as 3D printing technologies become more widely used, we should expect to see more advancements in the creation of novel materials and modifications to printing processes that will help researchers and medical professionals get around some of the current challenges.

Ethical approval

Institutional Review Board approval is not required.

Declaration of patient consent

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Conflicts of interest

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Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The author confirms that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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