Role of 3D Printing in Dental and Maxillofacial Surgeries – A Review

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Abstract

An additive manufacturing method that has gained popularity across a variety of industries is 3D printing, including healthcare, especially in producing complex and entangled geometries like maxillofacial structures. The range of biomaterials satisfying the printability criteria is limited and generally falls under classes such as metals, ceramics, polymers, composites and hydrogels. In maxillofacial structure development, 3_D printing is used for manufacturing surgical guides, models, splints, patient-specific implants and facial prostheses. 3_D printing has a major-effects on dentistry and maxillofacial surgery, as practitioners regularly rely on precise medicine. Procedures improved by 3_D technology include those for trauma, orthognathic surgeries, and complete replacement of joints therapy.

Introduction

Rapid prototyping, often referred to as additive manufacturing, or 3D printing, are both being used more and more in oral and maxillofacial surgery (OMFS). The first 3D printers appeared more than 30 years ago. Today, the computer revolution is gaining popularity and attention, with a particular focus on OMFS-related applications [9, 10].

Dental and maxillofacial surgeries are highly complex and demanding procedures that require a high degree of precision, extensive planning, and advanced surgical techniques. Traditionally, these surgeries have relied on manual techniques and standard instruments, which can limit the precision of the procedure and result in longer recovery times for patients. However, recent advances in 3_D_printing technology have revolutionized the field of dentistry and maxillofacial surgery, offering new possibilities for personalized and highly precise treatment options.

According to a report by Marketsand-Markets, the global 3_D printing on dental market were estimated at $780 million in 2k20 and is projected to achive $3.1_billion by 2025, increasing at a ‘compound annual growth rate (CAGR)’ of 31.2% [11]. This success number is being driven by the growing demand for customized dental implants and prosthetics, along with the rising adoption of 3_Dprinting technology in dental & maxillofacial surgeries [12, 13].

Additive manufacturing is another name for 3_D_printing [13], is a technology that allows for the creation of complex structures and shapes using a layer-by-layer approach. This technology has transformed the fields of facial surgery and dentistry by enabling the creation of patient_specific implants, prosthetics, & surgical-guides. With 3_D printing [13], surgeons can now plan and execute procedures with greater accuracy and efficiency, leading to better outcomes for patients.

1 of the key benefit of 3D_printing technology is its ability to create highly customized and patient-specific treatment options. For example, 3D printing can be used to fabricate custom implants that precisely match the contours of a patient's jaw or facial structure, leading to better functional outcomes and improved quality of life. Similarly, 3D-printed surgical guides can be used to guide the surgeon during the procedure, reducing the risk of errors and improving surgical outcomes.

Another advantage of 3D printing technology is its ability to reduce the time and costs associated with dental and maxillofacial surgeries. With 3D printing, the production of custom implants and prosthetics can be done more quickly and efficiently than traditional manufacturing techniques, reducing the time patients spend in surgery and in recovery. Additionally, 3D printing can also lower the overall cost of treatment by reducing the need for repeat surgeries and reducing the amount of time patients spend in the hospital.

In this research paper, we will explore the role of 3D_printing technology in dental & maxillofacial surgeries in greater detail. We will examine the latest research and case studies in the field, highlighting the benefits of 3D printing technology, including its ability to improve surgical precision, reduce surgery time, and lower costs. Furthermore, we will analyze the current state of 3D_printing technology in dentistry and maxillofacial surgery, discussing latest advancements and their potential to transform the field and improve patient outcomes.

Overall, this article intends to provide a comprehensive review of the [14, 15] role of 3_D printing technology in dental and maxillofacial surgeries. By exploring the latest research and advancements in the field, we hope to demonstrate the potential of this technology to revolutionize the way these procedures are performed and to improve the quality of life for patients.

Literature Review

What is 3D printing and how is it used in oral and maxillofacial surgery? **Seied Omid Keyhan et al. (2016) [5]** gave the answer to this question, they describe that the 3_dimensional (3_D) printing is a technology that allows the creation of three-dimensional objects from digital models, layer by layer. In oral-maxillofacial surgery, 3_D printing is used to create surgical models that simulate the anatomy of the head and neck, which can be used for diagnosis, treatment planning, and surgical simulation. These models can also be used to create surgical guides, bone graft templates, bioprosthetic implants, and intraoperative oral splints. 3_D printing can reduce the operative time and postoperative complications associated with surgery. Different 3D printing techniques, such as SL, FDM, and PJ, are used in oral-maxillofacial surgeries, each with its own benefits and disadvantages. The accuracy of 3_D printed models is critical in surgical planning, & CT is the modality of choice for obtaining accurate models. Rebuilding maxillofacial structures via 3D printing requires precision levels from various additive manufacturing technologies. Overall, 3_D printing is a useful technology in modern dental & maxillofacial surgeries that can improve treatment for patients and surgical outcomes.

N. Šimunić et al. (2016) [6] describe that the field of dentistry and oral_surgery has benefited greatly from the use of engineering procedures and techniques, particularly in the area of rapid prototyping (RP). RP technology has proven to improve control and accuracy in surgical procedures, leading to reduced duration of surgery and postoperative pain, resulting in faster patient rehabilitation. The technology is also valuable in educating trainees, surgical planning, and the manufacture of customized implants, guides, and fixtures at a reasonable cost. RP technology has been in use since the 1980s thanks to the development of additive manufacturing and stereolithography (SLA), with many other RP technologies and processes emerging over time. Using RP technology, medical rapid prototyping (MRP) creates dimensionally precise physical models of human anatomy using medical imaging data. In dentistry, the applications of RP technology include education, visualization, preoperative planning, procedure rehearsal, simulation, customized medical implant design, and tissue engineering, among others. Customised operational drilling guides for placing implants, created utilising RP technology, have enabled minimally invasive oral_surgery, shortened operation times, and ideal thickness of bone for implant placement, resulting in the highest level of postoperative comfort in both function and appearance. The success of this multidisciplinary approach is dependent on good communication and cooperation between clinicians and CAD engineers. With ongoing technological advancements, it is expected that the limitations of RP technology, such as Surface finish, a small selection of materials, and unconventional software practises will soon be handled.

Anjali Jayaraj et al. (2019) [1] write that 3_Dimensional (3D) printing has become a revolutionary technology in the field of dentistry. It's a type of additive manufacturing that entails adding material in successive levels to produce a 3D object. The technique is now widely used in a variety of healthcare specialties, including dentistry. The use of 3_D printing has made it possible to accurately rebuild complex anatomical structures, allowing for better treatment planning and patient education. There are several 3_D printing methods, each with advantages and limits, such as stereolithography, selective laser printing, and fused-deposition-modelling. Dentistry has benefited greatly from the use of 3_dimensional scanning, CAD CAM, and CBCT. Through the generation of 3_D pictures, these technologies aid in the evaluation of teeth in relation to surrounding hard and soft tissues. Based on virtual computer-generated renderings of the dentition and related skeletal tissues, automated procedures, known as 3D_printing, are used to create models and guides. Despite the need for skilled operators and the cost of running and maintaining the machines, 3_D printing technology has become widely accepted in all aspects of dentistry, including orthodontics, prosthodontics, oral and maxillofacial surgery, and endodontics. Structural models that aid in sophisticated treatment planning have been made possible by technology, leading to less invasive, more predictable procedures and improved patient results. It is anticipated that 3_D printing will become more prevalent and play a bigger part in dentistry.

Rani D'haese et al. (2021) [3] Guided implant surgery has become an essential component of the digital workflow for implant rehabilitation, providing a host of advantages, including a shorter treatment duration, less postoperative discomfort, and more reliable placing of implants. However, several stages of the process may have errors in guide misfits and deviations in implant position, compromising primary stability and success rates. Maximum deviations were observed to be 2.19 mm at the apical aspect, 1.68 mm at the coronal aspect, and 4.67 degrees in angulation when using mucosa-supported guides. The type of guiding support, bone density, mucosal thickness, surgical technique, smoking, type of jaw, and implant length are some of the variables that can affect the accuracy of the procedure and the ultimate implant position. The precision of implant placing utilising surgical guides supported by mucosa that were created using a desktop 3D printer was assessed in this study, and the findings indicated a level of accuracy that was clinically acceptable. The mucosa's robustness, however, decreased the stability of the guide and increased the deviation in implant location. Improvements in guide design and fabrication techniques may help to further enhance accuracy and reduce deviations.

Kavya Suresh et al. (2022) [2] said that the field of manufacturing has undergone a significant transformation with the emergence of 3_D-printing mechanism. This additive manufacturing method involves layer-by-layer material addition to produce complex and intricate geometries. The range of 3D printable biomaterials includes metals, ceramics, polymers, composites, and hydrogels, among others. In maxillofacial surgery, 3D printing is utilized for developing patient-specific implants, models, surgical guides, and prostheses. The complex nature of the maxillofacial region and interindividual variability necessitates the need for customized solutions. The advent of 3D printing offers precise and personalized solutions that reduce treatment time, provide better outcomes, and are cost-effective. The materials commonly used for maxillofacial surgery include titanium alloys and PEEK implants. However, there is a need to optimize biomaterials for specific purposes, including chemical composition, architecture, porosity, bioactivity, and mechanical properties. The field of 3D printing continues to evolve, and the future will witness the emergence of resilient scaffolds and a focus on nanoarchitecture. The development of new 3D printable materials and standardized manufacturing guidelines will overcome the current limitations and expand the potential of 3D printing in biomedical applications.

Michael Lawless et al. (2022) [4] in their paper they enumerate the information that is currently available on patient-specific implants and virtual patient-specific planning for the midface with an emphasis on the costs and savings. In reconstructive surgeries, virtual patient-specific planning and patient-specific implants are used as surgical tools. They have a number of advantages, including quicker recovery times, quicker ischemia times, more accurate reconstruction, the ability to perform more complex reconstructions, and fewer complications. However, a major disadvantage is the high expense of the supplies and labour needed for planning. The research also highlights the potential financial consequences of switching to "in-house" surgical modelling and virtual planning at the point of treatment, which has the potential to save a large amount of money. Studies that addressed outcomes like the effect on patient and provider costs, time savings from shorter operating times as well as planning and hospitalisation times, and reconstructive accuracy with resulting complication rates and clinical outcomes were considered in the literature review process. The study comes to the conclusion that virtual patient-specific planning and patient-specific implants have a demonstrable time and cost-benefit in midfacial reconstructive surgery, and their use enables faster treatments, especially for more complicated surgeries.

Rakesh Koppunur et al. (2022) [7] done the study to develop the patient-specific maxillofacial implants using 3D printing methods, specifically Fused Filament Fabrication (FFF) and Direct Metal Laser Sintering (DMLS). The workflow started with the patient's CT scan data, which was used to generate a 3D model. Modeling software was used to design the implant according to the doctor's specifications. The implant prototypes were then 3D printed using FFF with a custom polymer matrix containing Ti-6Al-4V powder, and the printing process was also simulated using CAE software to estimate part deflections and residual stresses. The implant's safety was evaluated by analyzing stress concentration and displacement under various loading conditions to ensure an adequate factor of safety. The findings of this study show that Ti-6Al-4V implants made by FFF can be produced with excellent mechanical properties and precision.

Zainab Chaudhary et al. (2022) [8] done the study on how 3_D-printed models have emerged as a valuable tool for improving surgical planning in maxillofacial reconstructive surgery. This study aimed to evaluate the impact of incorporating 3_D-printed models in treatment planning, resident training, patient education, and record maintenance. The study compared the outcomes of reconstructive maxillofacial surgery between two groups: one with the use of 3
_D-printed models (Group A) and one without (Group B). The study included 50 cases of pathologic and traumatic maxillofacial defects, which were further subclassified based on maxillary or mandibular reconstruction. The study found that the use of 3d-printed models resulted in decreased intraoperative time, reduced post-operative pain, improved patient quality of life, and better treatment predictability. The authors recommend the incorporation of 3d-printed models as a primary tool or technology in maxillofacial reconstructive surgery, despite the comparative cost, as the benefits outweigh the financial aspect.

Conclusion

In conclusion, the use of 3_D-printing technology in dentistry_oral & maxillofacial surgery has transformed the field in numerous ways. It allows for greater precision and accuracy in surgical planning and the creation of personalized implants and devices. The potential for organ bio-printing and other groundbreaking advancements in the future is exciting. However, it is important to remember that skilled operators are required, and that health and safety regulations must be followed. Another difficulty is the substantial expense and the requirement for extra infrastructure & training., but the benefits of this technology are well-established. To advance the area and get it closer to realising its full potential, clinicians must aggressively promote and use 3_D printing technology in our work.

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