Three-dimensional printing in the field of oral and maxillofacial surgery

ABSTRACT
Advanced imaging techniques and modalities coupled with computer-assisted surgical planning and simulation has been in use in the field of medicine. However, it is worth noting that it is now being frequently used for the evaluation and exploration of the craniofacial structures. It had gained ingress in the planning as well as forecasting of the surgical outcomes of oral and maxillofacial surgical interventions. Numerous surgical guides and devices which are tailor-made can be fabricated using three-dimensional (3D) printing technology. The article is intended to put forth an overview of 3D printing technology and its applications in the field of oral and maxillofacial surgery.

Keywords: Orthognathic surgery, reconstructive surgery, three-dimensional printing

INTRODUCTION
It is a well-known fact that a three-dimensional (3D) object can be fabricated in 3D printing by incremental addition of multiple layers of material with the aid of a computer. In the field of medicine, an anatomical area can be fabricated by slicing it into several thin layers and the geometric data are used to build each layer sequentially by the manufacturing equipment. Hence, 3D printing is also popularly recognized as additive manufacturing (AM), rapid prototyping, layered manufacturing, or solid freeform fabrication.1-3

David E. H. Jones in 1974 laid out the concept of 3D printing. However, Charles Hull first engineered 3D printing technology in 1984 and termed it Stereo Lithography.4 3D printers were very expensive and were not readily available. In the 21st century, a significant reduction in the costs of the 3D printers allowed them to be affordable to the general market.5 Following its application in the military, food industry, and arts, it has gained responsiveness in the field of surgery. Brix and Lambrecht (1985) are considered to be the pioneer in the usage of Stereo Lithography in the field of oral and maxillofacial surgery.6 Mankovich et al. employed in craniofacial deformities to simulate the bony anatomy of the cranium using computed tomography (CT).7

ADVANTAGES AND DISADVANTAGES
3D printing noticeably has an edge over conventional subtractive manufacturing techniques. Its superior efficiency, passivity, flexibility, and superior material utilization are its benefits over the other techniques.8 The biggest shortcoming with 3D printing includes its high cost9 [Figure 1].

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CLINICAL APPLICATIONS

Literature reveals that 3D-printed objects that are used for clinical applications can be grouped into five categories. They can be employed for obtaining anatomic models, surgical guides, occlusal splints, patient-specific implants, facial epithesis [Figure 2].

Considering the fact that 3D printing can discriminate traumatic and pathologic defects more effectively, it can play a pivotal role in the diagnosis and treatment planning of clinical scenarios pertaining to the maxillofacial region. The adjunctive role played by 3D printing facilitates precise decision-making. A huge advantage with 3D printing is its capability to provide spatial relationships to surrounding anatomical structures, particularly when one encounters pathologies in the maxillofacial region.[10] The critical information obtained by 3D printing can minimize operative complications.[11] 3D printing can produce models rapidly with acceptable accuracy and structural details to allow for better outcomes and reduced operating durations.[12]

3D customized reconstruction of orbital wall defects with titanium mesh can be used in patients with orbital wall fractures. In the pre-operative phase, titanium mesh or plate can be adapted precisely on the 3D printed replica which would aid in improving the precision of the procedure as well as shortening the duration of surgical procedure.[13,14] Post-operative enophthalmos or diplopia which is frequently encountered when there is the inaccurate reconstruction of orbital walls can be avoided by using 3D printed titanium mesh which is fabricated using the contralateral orbital anatomy as a guide.

| S. No | Advantages                                                                 |
|-------|----------------------------------------------------------------------------|
| 1.    | Aids in preoperative counseling with patients                               |
| 2.    | Aid in gaining informed consent                                             |
| 3.    | Can reduce duration of the surgical intervention                           |
| 4.    | Aid in obtaining a better morphological outcome in mandibular reconstruction|

| S. No | Disadvantages                                                                 |
|-------|----------------------------------------------------------------------------|
| 1.    | Surgical interventions require larger surgical approaches due to the bulk of the guides |
| 2.    | Planning time coupled with the printing time may at times take several weeks |
| 3.    | In dealing aggressive tumors, resection margins require reevaluated before using the cutting guides |
| 4.    | Expensive                                                                   |

Figure 1: Advantages and disadvantages of three-dimensional printing

Figure 2: Clinical applications of three-dimensional printing
3D printing technology shows some clinically noticeable inaccuracies that need to be eliminated in the diagnosis and treatment planning for orthognathic surgeries.\[^{13}\] 3D models aid in accomplishing preplanned tasks for performing accurate osteotomies and accurate positioning of the malpositioned jaw. Printing of cutting guides for osteotomies and 3D printed patient-specific fixing plates for accurate positioning of jaws, greatly reduce mistakes made due to human error.\[^{14}\] Similarly, literature is replete with articles indicating that better esthetic and functional outcomes can be accomplished with the aid of 3D printing in comparison to the traditional prosthetics. AM is mainly used for hard-tissue reconstruction. However, it is useful in soft-tissue contouring such as auricular reconstruction in patients using the contralateral ear. There are documented scientific papers on the fabrication of prosthetic nose, ears, eyes, and face in the recent past with aid of 3D printing.\[^{17-19}\]

**Inferences**

Numerous authors have advocated that there is an increase in precision and a reduction of the surgical time even though this parameter has seldom been precisely evaluated or measured. Hanasono and Skoracki indicated that 3D printing can reduce surgery duration up to 1.4 h.\[^{24}\] Taritano et al. demonstrated that the use of 3D printing enabled their them to obtain a better morphological outcome in mandibular reconstruction.\[^{20}\] Seruya et al. concluded that microsurgical craniofacial reconstruction using a computer-assisted fibula flap technique yielded significantly shorter ischemia times compared with conventional techniques.\[^{26}\] The use of 3D printed occlusal splints enables optimal positioning of bone segments, in accordance with pre-operative planning, in orthognathic surgery.\[^{27}\] Several studies that compared preoperative planning on virtual models and the real post-operative X-ray controls revealed that surgical guides permit a gain in precision, whether it is in reconstructive surgery, in orthognathic surgery or in dental implant surgery.\[^{28,29}\]

Literature shows that with 3D printing in addition to generating custom-made scaffolds in the desirable dimensions it is also possible to adjust the properties of these materials with regard to porosity, surface texture, and design. It is possible to add osteoinductive factors, like bone morphogenetic proteins for stimulating osteogenic differentiation to increase the integration of bone tissue into the printed scaffolds for better cell adhesion, proliferation, and vascularization.\[^{30-33}\]

It is also noteworthy that there are definitely some limitations with 3D printing. Surgical interventions may require larger surgical approaches due to the bulk of the guides and this may lead to higher morbidity.\[^{32}\] Planning time coupled with the printing time may at times take several weeks if given to the company and may delay the surgical intervention, which may be detrimental particularly in cancer. In dealing with fast-growing tumors, resection margins should always be re-evaluated before using the cutting guides.\[^{32}\]

In addition to the patients, medical trainees and residents can also benefit from 3D printed models.\[^{33}\] In pre-operative counseling with patients, it is easier for the operator to explain the details pertaining to surgical interventions, and therefore, 3D printed models can aid in gaining informed consent.\[^{33}\] CT/magnetic resonance imaging scans that are generally used to explain the surgical procedure for the patients are usually hard to understand particularly for uneducated patients. Because the specialty of oral and maxillofacial surgery deals with procedures that are life-saving, as well as those that enhance the quality of life by providing better function and esthetics 3D printing can be considered as a viable option.\[^{34}\]
CONCLUSION

The use of 3D printing models in the field of oral and maxillofacial surgery is increasing, as it provides for a much safer, less traumatic, and time-consuming treatment modality. In addition, it increases the standard of care of patients and hence, these techniques should be adapted more and more by clinicians. 3D printed replicas are considered to be more precise and cost-effective and this method may also eliminate the need for animal studies. As the technology develops, there will be an increase in its versatility and ease in its usage. Hence, it is advisable to become familiar with 3D printings. However, the author of the present article advocates that these benefits should however be evaluated more precisely by comparison with more conventional techniques on larger case series. The improved precision does not only come from the printed object itself but also from the pre-operative planning and its execution that is much more demanding than in conventional techniques.

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Conflicts of interest
There are no conflicts of interest.

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