APPLICATION OF 3D PRINTING IN MAXILLOFACIAL SURGERY: A LITERATURE REVIEW

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Abstract

3D printing also known as rapid prototyping is a manufacturing technique that constructs objects one layer at a time, adding several layers to create an entity. In order to recreate a physical model, this method uses specifically calculated tomography (CT) data. Among the first to implement this technology were Orthopaedics and OMFS surgeons. The key fields benefiting from this technology are restoration, rehabilitation and regeneration, as it possibly provides reproducible, reliable and robust models which are specific for patient, available for various surgical applications; however, it was further expanded to include education as well as teaching.

Key Words: 3D printing, Rapid prototyping, Stereolithography (STL).

INTRODUCTION

3D printing also known as rapid prototyping/additive manufacturing in general, is used to describe a production technique that creates objects by incorporating several layers.[1]In the 1980s, three-dimensional printing (3D) first came into existence. Scientists have been modifying this technology, materials used and its precision since than. They have made huge improvements and advances over the past three decades. 3 dimensional prototypes have been used in the area of craniofacial surgery as guide for extracting grafts of bone, to customize implants which are bio prosthetic, for bending of plates, osteotomy cutting guides, and for intraoperative oral splints. It has been shown that using 3D models and guides shortens the operating period and decreases the difficulties related to it. The definitive aim of any operating practice is to focus on improving peri-operative shape & function & to reduce surgical and post-operative complications. Over the last few years, many exhilarating and novel technical developments have unlocked a new age in the field of Maxillofacial surgery, and 3D printing is one of the most innovative.[2]Objects in this technology are created by controlled material addition rather than subtraction. Charles Hull first patented the invention, which began as a tool used for rapid prototyping, in 1984. Hull, is regarded as the creator of the process of stereolithography (SLA), which is created by solidifying the sheets on photopolymer resin. 3dimensional printing has traditionally been used for industrial and engineering needs. The idea of using 3dimensional medical imagery, precisely CT data (tomography), was first introduced in 1979 to recreate a physical model. With the expanding access to 3dimensional medical imaging practices in late 1980s, its applications in the health field started to be seriously thought-through with the launch of the first industrial 3D printing system. The first 3D printing technique which was available was SLA and, in 1994, it was the first one to be used in the biomedical field. The first specialties to embrace this technology were orthopedic & maxillofacial surgery. Almost every, operating specialty currently has a published application for 3dimensional printing. RP (Rapid prototyping) is a technique of add on production that goes by constructing a prototype from the very beginning, by placing material in layers. RP first was used in the late 1980s, and was built to apply CAD (computer assisted design) precision and functionality to production. Using this technology, it was possible to rapidly create a prototype that accurately reflected the draft of engineers. In addition, engineers were able to effortlessly digitally modify the preliminary form (draft) & print the reformed component if adjustments needed to be made. The aircraft and automotive industries rapidly adopted this idea for the rapid development of prototype components. The word Rapid prototyping is, therefore. The key areas benefiting from this 3d printing technique were restoration, recovery and regeneration, as it theoretically provides reproducible, reliable and robust customized patient models for various surgical applications; its application was further expanded for training & education purpose.[5]

DISCUSSION

The 3dimensional printing process includes data collection of 3D imaging, often using CT or MRI. After that the image collected from these modes are saved in DICOM format (Digital Imaging and Communications in Medicine) and later with the help of CAD software (computer-aided design),a virtual 3dimensional prototype with STL (Standard Tessellation Language) format is created to allow 3dimensional printing & layer-by-layer material deposition is done to accomplish the ultimate structure. Reasonable printing techniques are chosen depending on the application, and the printed items ultimately pass through a post-printing adjustment to achieve the finished printed body.
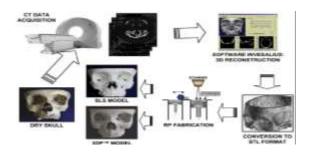
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Fig.1. Step by step sequence to fabricate a 3DP and SLS model[7]

The different materials used for 3D printing include

- Stereolithography (STL)
- Photo jet
- Digital light processing
- Selective laser sintering
- Electron beam melting
- Fused deposition modeling

Usage	Description
Contour models	Positive-space models to allow preapplication of hardware before surgery
Guides	Negative-space models of actual patient data to guide cutting and drilling
Splints	Negative-space models of virtual postoperative positions to guide final alignment
Implants	Negative-space 3D printing implantable materials or 3D printing molds into which nonprintable materials are poured

Table1. Classification of the use of 3-D printing methods for craniomaxillofacial surgery.

Categories of surgeries	Specific operations
Mandibular surgeries	Mandibular reconstruction
	Mandibular resection
	Orthognathic surgeries
	Osteoradionecrosis
	Mandibular angle ostectomy
	Mandibular condyle repair
Maxillary surgeries	Orthognathic surgeries
	Maxillary reconstruction
Orbital surgeries	Hypertelorism
	Orbital fracture repair
Nasal surgeries	Nasal reconstruction
	Nasal prosthesis retention
Cranial surgeries	Cranioplasty
	Surgery for craniosynostosis
	Fronto-orbital advancement surgery
	Frontal sinus reconstruction

Table 2. Specific surgeries of craniomaxillofacial that use 3-D technology.[8]

ADVANTAGES of using 3d prototyped models include:
- Save time
- Improves precision in regards to symmetry, as they are designed from healthy side by mirroring techniques[9]
- Better understanding of anatomy
- proper adaptation of plate i.e reduced bone-plate distance
- pre-bending of the plate
- Accurate bone harvesting by the use of negative defect templates, decreased time period of surgery
- Less loss of blood, and reduced time period of G.A (general anaesthesia) are the key benefits of using this technique.

LIMITATIONS
1 Rapid Prototyped Model Artifacts
2. Increased cost and time

CONCLUSION
A modern and evolving technique with the potential to create physical items from digital files is three-dimensional printers. This technology has been made reasonable for its use in the environment of office by declining the costs of hardware. 3D printing technology allows patient consultations to be more effective, increases the efficiency of diagnostic, improves the planning of surgery, by aiding in orientation during operative procedures, & manufactures segmental resections directing (guiding) prototype. In the coming future, organ bio-printing may perhaps be possible by additive manufacturing. Surgery is a realistic art. Surgery for each patient should be precisely planned, to avoid complications and to maximize its benefits. Potential applications of 3d printing in maxillofacial surgery lengthen to preparation of surgery, education, designing & creation of prosthetic devices. In traditional clinical applications, RP is not used, but in the coming future, it might revolutionize the field of oral and maxillofacial surgery. Time taken for the manufacturing of the object & cost also should be studied to explain and appreciate what is the prime estimate hereafter; regarding the future of technology. Various analysts have suggested that, they have identified a reasonable technology for 3D printing. Some other investigators, however, have questioned the RP's efficiency and price. Compared to other methods, 3d printed copies are known to be extra reliable and reasonable for patient as well as trainees education. This technique also excludes the need for animal experiments. In the twenty-first century, 3dimensional printing technique is here; to better our everyday life and wellbeing program.[2]

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