3D printing in Oral and Maxillofacial Surgery

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Abstract: 3D printing is driving major innovation in many areas as manufacturing education and also in medical science. Recently 3D printers have become more accessible to public and currently can be used to help surgeons to improve surgical outcome.3D printing in oral and maxillofacial surgery is getting more and more popular recently. This review of literature discusses the application of 3D printing in the domain of Maxillofacial Surgery.

Index Terms **- 3D printing in maxillofacial surgery, facial reconstruction, 3D printing**

I. INTRODUCTION

The 3D printing Technology was first demonstrated in 1986[1] and was used in the domain of maxillofacial surgery in 1990[2,3]. But until recently the 3D printing was not affordable to the masses and was in the hand of few selected companies. In the last 5 to 10 years 3D printers became more affordable and its use in various aspects of medical field is being explored.

II. APPLICATION OF 3D PRINTING IN ORAL AND MAXILLOFACIAL SURGERY

There are different aspects in of maxillofacial surgery in which 3D printing can be used:

- Fabrication simple anatomic models for patient education: this will help to explain the proper surgical procedure to the patient.[4]
- Virtual planning in case of reconstructive surgery: cutting guide drilling guide and positioning guide can be made to improve the surgical outcome and reduce or operating time.[5]
- Creating patient specific implants: patient specific implant can be made from 3D printing that will improve the surgical outcome
- In case of dental implants surgical guides are designed to facilitate the the drilling and correct implant placement.

III. TYPES OF 3D PRINTER AND THE CONCEPTS OF 3D PRINTING

There are different types of 3D printer[6,7,8,9,10]. Among them few are listed below:

Stereolithography (SLA)
Digital Light Processing (DLP)
Fused Deposition Modeling (FDM)
Selective Laser Sintering (SLS)
Selective Laser Melting (SLM)
Electronic Beam Melting (EBM)
Laminated Object Manufacturing (LOM)

Stereolithography (SLA)

This works by converting photopolymers into solid 3D objects one layer at a time. Ultra Violet laser is used construct these layers. Advantage of this type of printer is that it can produce finer details than FDM printer. But this type of printing needs post cure to make the object more stable and stronger.

Direct Light Processing Technology (DLP)

This was created by man name Larry Hornback in 1987. This works in the same similar principle as SLA. The major difference is that DLP use a traditional light source rather than ultraviolet light.

Fused Disposition Modelling Technology(FDM)

It was developed by Scott Crump. It uses production rate thermoplastic material and the object is fabricated on the build platform by excluding heated thermoplastic filament through the nozzle over the build platform. It is not as accurate as SLA printer.

Selective Laser Sintering (SLS) Technology:

Dr Card Deckard developed and patented the SLS Technology it uses high power CO_2 lasers to fuse particle together by sintering powder metal materials.

Other than these, there are Selective Laser Melting Technology, Extrusion Based Bioprinting, Inkjet, Polyjet which are being actively developed. With advancement in metal printing and bioprinting we can expect that in future we can directly print patient specific implants or even organs with a fraction of cost than that is available today.

IV. USE 3D PRINTING IN MEDICAL FIELD

Magnetic Resonance Imaging(MRI) or Computed Tomography(CT) scans were used to save patient's anatomical data in DICOM (Digital Imaging and Communications in Medicine) format. The DICOM dataset is then converted to surface representation file such as STL using open source tools or preparatory softwares. Depending on the need of the patient and availability of printing methods appropriate printing technique is usually selected.

V. CHOICE OF MATERIALS

There are various type of materials which are used for 3D printing like ABS (Acrylonitrile Butadiene Styrene), PLA (Polylactic Acid), Nylon, Polypropylene, Resin, PEEK(Polyether Ether Ketone Filament) etc. but all are not appropriate for medical purpose.

Material used to fabricate 3D Printed Models for diagnosis, preoperative planning and for surgical guide: ABS, PLA, PETG are used to create models in FDM printer for the purpose of patient education, diagnosis, orthognathic planning, making implant drilling guides, reconstructive surgery etc. Resin is used for creating models that need more finer details such as dental crowns.

Biomaterials used for FDM based 3D printing[9, 10]:

PCL + Chitosan: 3D printed scaffolds showed greater cell retention and proliferation of Rabbit bone marrow mesenchymal stem cells (BMMSCs) as well as Stronger osteogenesis and higher bone matrix formation.

PCL + β-TCP: The 3D printed PCL/β-TCP membranes showed enhanced bone regeneration capabilities than PCL or collagen membranes alone.(on Alveolar bone defects on beagles)

PLA + biodegradable calcium phosphate glass: PLA based scaffolds increased the production of IL-6, IL-12/23 and IL-10. (on Human Monocytes)

3D Printing used for Drug Delivery:

Tappa K et al.[15] on 2017 published an article as a proof of concept. They described 3D printed biodegradable hormone eluting construct. PCL filaments with female sex hormones (E1, E2, E3 and progesterone) were 3D printed at 110 °C in the shape of commonly used implants including discs, pessaries, subdermal rods, intrauterine devices (IUDs) and surgical mesh.

Weisman J.A. et al.[14] described PLA pellets coated with gentamicin and methotrexate which were extruded as filaments at 170 °C and 3D printed as beads and catheters using Makerbot 3D printer (FDM based) at 220 °C. The beads successfully retained the bioactivity.

Olea-gum-resins (benzoin, myrrha and olibanum) doped with metal oxide nanoparticles (TiO2, P25, Cu2O, and MoO3) were also used in another study by Horst D.J. et al.[16]

VI. CURRENT LIMITATION AND FUTURE APPLIANCE OF 3D PRINTING IN MAXILLOFACIAL SURGERY

Currently in Maxillofacial Surgery, 3D painting is mainly used for diagnosis, virtual planning, for fabricating surgical aids and for patient specific implants. Accessibility to 3D printer with better resolution and better biocompatible material can revolutionize the Medical industry. One of the greatest limitation of 3D printing is not the 3D printing Technology itself but the imaging modalities. With the advancement of imaging modalities, it may be possible to capture imaging data at the cellular levels in the future and with proper biomaterial, may be, it will be possible to 3D print functioning organs. [17]

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