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Prosthodontics

3D PRINTING TECHNOLOGIES IN MAXILLOFACIAL PROSTHETIC REHABILITATION

Dr Priya C	Post Graduate, Department Of Prosthodontics, College Of Dental Sciences Davangere, Karnataka
Dr Veena S Prakash	Professor, Department Of Prosthodontics, College Of Dental Sciences Davangere, Karnataka

ABSTRACT Conventionally, maxillofacial prostheses were fabricated by manually sculpting the missing anatomical structures in wax, followed by mold preparation and processing of pigmented silicone elastomers. With advances in science and technology, three-dimensional (3D) printing has gained considerable attention, particularly in head and neck surgical specialties such as maxillofacial surgery, otorhinolaryngology, and plastic surgery, due to its ability to fabricate complex, customized models, implants, prostheses, and surgical guides with high precision . Three-dimensional printing is an additive manufacturing technique in which objects are produced by the successive layering of materials.

KEYWORDS : 3D Printing, Maxilla-facial Prosthesis, Surgical Guides, Additive Manufacturing

INTRODUCTION

Maxillofacial prosthetics is the art and science of anatomical, functional, and cosmetic rehabilitation using non-living substitutes to restore missing or defective structures of the maxilla, mandible, and face caused by trauma, pathology, surgical procedures, or congenital anomalies. Loss of facial structures results in functional and aesthetic deficits along with significant psychological and social impact. The growing demand for maxillofacial prosthetic rehabilitation emphasizes the need to restore both function and appearance. Recent advances in computer technology and software, particularly 3D printing as an additive manufacturing technique, have greatly enhanced the fabrication of three-dimensional prostheses through successive layering of materials.

Techniques in 3D Printing (Additive Manufacturing) have greatly enhanced the fabrication of three- dimensional prostheses through successive layering of materials.Additive manufacturing into seven major process categories, though continuous innovation makes the list dynamic.

- Vat Photopolymerization (VPP)
- Material Extrusion (MEX)
- Material Jetting (MJT)
- Binder Jetting (BJT)
- Powder Bed Fusion (PBF)
- Directed Energy Deposition (DED)
- Sheet Lamination (SHL)

Most commonly used 3D Printing technologies used in dentistry:

- ➢ Stereo Lithography Apparatus (SLA)
- ➢ Selective Laser Sintering (SLS)
- ➢ Fused Deposition Modelling (FDM)
- ➢ Material jetting
- ➢ 3D Bioprinting

Table No.1. Indirect vs Direct 3D Printing in Maxillofacial Prosthesis

Indirect 3D Printing	Direct 3D Printing
3D printing used to fabricate molds/models; silicone cast conventionally	Prosthesis fabricated directly using additive manufacturing
Printed mold → silicone casting	Printed structure → silicone coating/infiltration
Reduced chairside time	Faster fabrication theoretically

STEREOLITHOGRAPHY (SLA)

SLA 3D printing- It works by using a high-powered laser to harden liquid resin that is contained in a reservoir to create the desired 3D shape. In a nutshell, this process converts photosensitive liquid into 3D solid plastics in a layer-by-layer fashion using a low power laser and photopolymerization.

When SLA resins are exposed to certain wavelengths of light, short molecular chains join together, polymerizing monomers and oligomers into solid, rigid, or flexible geometries.

Applications in MFP

- Facial prosthesis patterns (nose, ear, orbit)
- Surgical guides and diagnostic models
- Wax pattern fabrication for silicone prostheses

Materials Used

- Photopolymer resins (acrylic-based, epoxy-based)

Advantages:

- Extremely high precision and surface detail
- Smooth surface finish; minimal stair-step effect
- Excellent dimensional accuracy and marginal fidelity

Disadvantages:

- High equipment and material cost
- Resin materials are brittle and limited in colour options
- Requires support structures and post-curing

Fig 1-Commercially Available SLA

FUSED DEPOSITION MODELING (FDM)

Fused deposition modeling was developed by S. Scott Crump in the late 1980s, Fused Deposition Modeling (FDM) is the second most commonly used 3D printing technology after SLA. A plastic or wax filament is fed from a coil into a heated nozzle, where it melts and is extruded layer by layer. Each layer hardens immediately and bonds to the previous layer.

The process occurs in a temperature-controlled chamber maintained just below the material's melting point.

Applications in MFP

- Study models and diagnostic casts
- Try-in prosthesis frameworks
- Obturator patterns and interim prostheses

Materials Used

Acrylonitrile Butadiene styrene (ABS) and Polylactide (PLA) thermoplastics are predominantly used in the process.

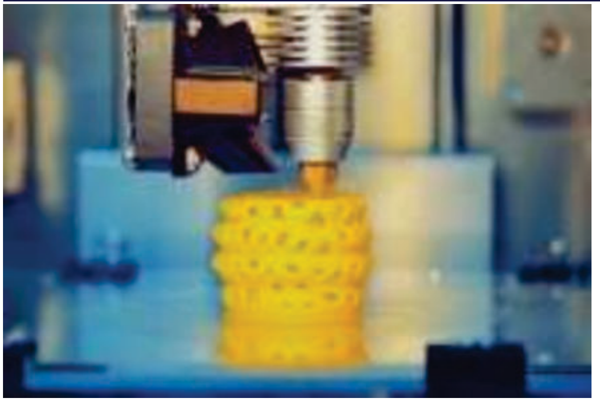

Fig 2-Printbed of a Fused Deposition Modeling Printer

Advantages

- Cost-effective method.
- Short lead time due to wide availability of FDM printers.
- Wide range of thermoplastic materials available for prototyping and limited functional use.

Disadvantages

- Lowest resolution and dimensional accuracy
- Visible layer lines; extensive post-processing required
- Anisotropic mechanical properties

Selective Laser Sintering (SLS)

Selective Laser Sintering (SLS) is an additive manufacturing technique that uses a high-power laser to sinter polymer powder layer by layer from a 3D model, producing functional prototypes and components. Developed in the mid-1980s by Dr. Carl Deckard and Dr. Joe Beaman at the University of Texas, Austin, SLS belongs to the powder bed fusion family, which includes polymer-based SLS and metal-based processes such as DMLS and SLM.

Types of SLS Printers

- SLS printers differ based on laser type, build volume, and system complexity.
- Variations exist in temperature control, powder dispensing, and layer deposition methods.
- Precise temperature control (within ± 2 °C) during preheating, sintering, and cooling is essential to prevent warping.

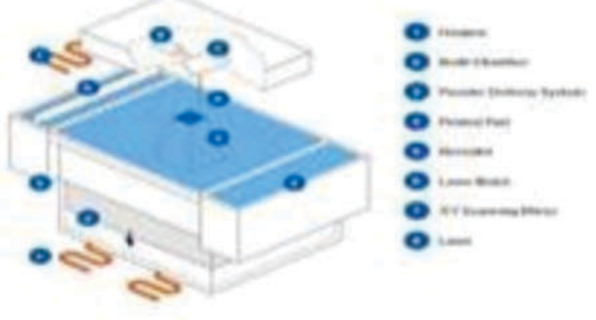

Fig 3-Parts of an SLS printer

Applications in MFP

- Craniofacial frameworks
- Implant-retained prosthesis substructures
- Surgical splints and guides

Materials Used

- Nylon-11, Nylon-12
- Nylon composites (glass/carbon filled)

Advantages:

- Produces strong, functional parts
- No need for support structures
- Suitable for complex geometries[51]

Disadvantages:

- Very expensive equipment
- Long cooling time
- Grainy surface finish

Material Jetting

Material Jetting works similar to 2D inkjet printing, depositing liquid photopolymer droplets layer by layer.The printhead jets photosensitive resin, which is immediately cured by UV light.

PolyJet and Material Jetting are the same technology; Developed in 1998 by Objet Geometries (Israel); later merged with Stratasys in 2012.Capable of full-color and multi-material printing in a single build.

Applications in MFP

- Direct fabrication of nasal and auricular prostheses
- Aesthetic prototypes and patient trials

Materials Used

- Acrylic-based photopolymers
- Rubber-like elastomeric resins

Advantages

- Excellent surface finish
- Multi-material and full-colour printing capability
- High-dimensional accuracy[54]

Disadvantages

- Poor long-term mechanical strength
- Material degradation over time
- High cost

ADVANCEMENT-3DBIOPRINTING

Layer-by-layer deposition of bioinks containing cells and biomaterials to form biological constructs. computer-aided deposition of cells, biomaterials and biomolecules. This procedure enables artificial construction of living tissues and organs by a three- dimensional, layer upon layer deposition of living cells along with a suitable protective and supportive matrix using various printing modalities.

Applications in MFP

- TMJ reconstruction
- Cartilage replacement in ear and nose
- Bone-mucosa composite reconstruction

Materials Used

- Hydroxyapatite
- PCL, PEKK
- Hydrogels with chondrocytes

Advantages

- Reduced donor site morbidity
- Minimal risk of host rejection
- Custom tissue engineering possibilities[65]

Disadvantages

- Highly technique sensitive
- Very high cost
- Limited clinical availability

Table No.2. Comparison of 3d Printing Technologies in MFP

Technology	Accuracy	Cost	Surface Finish
SLA	Very High	High	Excellent
FDM	Low	Low	Poor
SLS	High	Very High	Moderate
Material Jetting	Very High	High	Excellent
Bioprinting	Variable	Very High	Biological

DISCUSSION

Digital technologies have revolutionized maxillofacial prosthodontics by improving accuracy, reducing clinical time, and enhancing patient comfort when compared to conventional methods[46]. Each 3D printing technology offers distinct advantages, and no single system fulfills all clinical requirements. Selection depends on the intended application, required accuracy, mechanical properties, and cost considerations.

CONCLUSION

3D printing has become an indispensable adjunct in maxillofacial prosthodontics. While technologiessuch as SLA and Material Jetting provide superior aesthetics and precision, SLS and bioprinting offer promising solutions for functional and biological reconstruction. Future advancements in materials and cost reduction will further integrate digital workflows into routine maxillofacial prosthetic practice[66].

REFERENCES

1. The glossary of prosthodontic terms. J Prosthet Dent. 2005;94:10-92.
2. Fernanda Pereira de Caxias , Daniela Micheline Dos Santos , Lisiane Cristina Bannwart , Clovis Lamartine de Moraes Melo Neto , Marcelo Coelho Goiato. Classification, History, and Future Prospects of Maxillofacial Prosthesis. Int J Dent. 2019;18:7- 11.
3. Avinash De Sousa. Psychological issues in oral and maxillofacial reconstructive surgery. Br J Oral Maxillofac Surg. 2008;46:661-4.
4. Alaa Aldaadaa , NazaninOwji , JonathanKnowles. Three-dimensional Printing in Maxillofacial Surgery: Hype versus Reality. J Tissue Eng. 2018;9.
5. Madhav, V, Daule, Rajendra. Rapid Prototyping and its Application in Dentistry. Journal of Dental and Allied Sciences. 2013;2:57-61.
6. Dawood, Andrew, Marti, Begoña, Sauret- Jackson, Veronique & Darwood, Alastair. 3D printing in dentistry. Br Dent J. 2015;219:521-9.
7. Van Heerden, A. Fossey. Changing world of external maxillofacial prosthesis manufacturing. RAPDASAConferenceProceedings. 2019;978:4.
8. C Lee Ventola. Medical Applications for 3D Printing: Current and Projected Uses. P T. 2014;39:704-11.
9. T J Coward, R M Watson, I C Wilkinson. Fabrication of a wax ear by rapidprocess modeling using stereolithography. Int J Prosthodont. 1999;12:20-7.
10. Joshi (Bhuskute) MD, Dange S P, Khalikar A N. Rapid prototyping technology in maxillofacial prosthodontics: Basics and applications. J Indian Prosthodont Soc. 2006;6:175-8.
11. Subburaj K, Nair C, Rajesh S, Meshram SM, Ravi B. Rapid development of auricular prosthesis using CAD and rapid prototyping technologies. Int J Oral Maxillofac Surg. 2007;36:938-43.
12. Sabol, Jennifer Grant, Gerald, Liacouras, Peter Rouse, Stephen. Digital Image Capture and Rapid Prototyping of the Maxillofacail Defect. J Prosthodont. 2011;20:310-4.
13. Xiao K, Zardawi F, Van Noort R, Yates J M. Color reproduction for advanced manufacture of soft tissue prostheses. J Dent. 2013;41:15-23.
14. Watson Jason, Hatamleh Muhanad. Complete integration of technology for improved reproduction of auricular prostheses. J Prosthet Dent. 2014;111: 430-6.
15. He, Y, Xue, Gh. Fu, Jz. Fabrication of low cost soft tissue prostheses with the desktop 3D printer. Sci Rep. 2014;27.
16. Grant GT, Aita-Holmes C, Liacouras P, Garnes J, Wilson WO Jr. Digital capture, design, and manufacturing of a facial prosthesis: Clinical report on a pediatric patient. J Prosthet Dent. 2015;114:138-41.
17. Lorber, Barbara Hsiao, W.-K. (Kai), Martin, Keith. Three-dimensional printing of the retina. Curr Opin Ophthalmol. 2016;27:262-7.
18. Swati K Jindal, Martyn Sherriff, Mark G Waters, Trevor J Coward. Development of a 3D printable maxillofacial silicone: Part I. Optimization
19. Tack P, Victor J, Gemmel P, Annemans L. 3D- printing techniques in a medical setting: a systematic literature review. Biomed Eng Online. 2016;21:115.
20. B Jamayet N, J Abdullah Y, A Rajion Z, Husein A, K Alam M. New Approach to 3D Printing of Facial Prostheses Using Combination of Open Source Software and Conventional Techniques: A Case Report. Bull Tokyo Dent Coll. 2017;58:117-24.
21. Yu-Hui Huang , Rosemary Seelaus , Linping Zhao , Pravin K Patel , Mimis Cohen. Virtual surgical planning and 3D printing in prosthetic orbital reconstruction with percutaneous implants: a technical case report. Int Med Case Rep J. 2016;31:341-5.
22. Tasopoulos, Theodoros, Kouveliotis, George Polyzois, Grigorios, Karathanasi, Vasiliki. Fabrication of a 3D Printing Definitive Obturator Prosthesis: a Clinical Report. Acta Stomatol Croat. 2017;51:53-8.
23. Huan Liu , Shizhu Bai , Xiaonan Yu , Yimin Zhao. Combined use of a facial scanner and anintraoral scanner to acquire a digital scan for the fabrication of an orbital prosthesis. J Prosthet Dent. 2019;121:531-4.
24. Tasopoulos T, Chatziemmanouil D, Karaiskou G, Kouveliotis G, Wang J, Zoidis P. Fabrication of a 3D-printed interim obturator prosthesis: A contemporary approach. J Prosthet Dent. 2018;121:960-3.
25. Katkar RA, Taft RM, Grant GT. 3D Volume Rendering and 3D Printing (Additive Manufacturing). Dent Clin North Am. 2018;62:393-402.
26. Charles L Palin , Joseph M Huryn , Marjorie Golden , Paul R Booth , Joseph D Randazzo. Three-dimensional printed definitive cast for a silicone obturator prosthesis: A clinical report. J Prosthet Dent. 2019;121:353-7.
27. Obregon F, Vaquette C, Ivanovski S, Hutmacher DW, Bertassoni LE. ThreeDimensional Bioprinting for Regenerative Dentistry and Craniofacial Tissue Engineering. J Dent Res. 2015;94:143-52.
28 Sarathii S S, Ajithkumar K, Abhilash B, Jyothi K N, Vidya K G, Prasanth V. 3D Bio Printing in Maxillofacial Region. The journal of Prosthetic and Implant Dentistry. 2021;4:93-6.
29. Sanchez-Tena MA, Alvarez-Peregrina C, Santos- Arias F, Villa-Collar C. Application of 3D Printing Technology in Scleral Cover Shell Prosthesis. J Med Syst. 2019;43:149.
30. Carole Serrano , Hélène van den Brink , Judith Pineau , Patrice Prognon , Nicolas Martelli. Benefits of 3D printing applications in jaw reconstruction: A systematic review and meta- analysis. J Craniomaxillofac Surg. 2019;47:1387- 97.
31. Cho, Young-Eun, Ohkubo, Chikahiro, Park, Eun- Jin. Application of 3D printing technology for rehabilitating maxillary defects. The Journal of Korean Academy of Prosthodontics. 2020;58:349-55.
32. Ross G Sherwood, Niall Murphy, Gerard Kearns, Conor Barry. The use of 3D printing technology in the creation of patient-specific facial prostheses. Ir J Med Sci. 2020;189:1215-21.
33. Unkovskiy A, Wahl E, Huettig F, Keutel C, Spintzyk S. Multimaterial 3D printing of a definitive silicone auricular prosthesis: An improved technique. J Prosthet Dent. 2021;125:946-50.
34. Cristache CM, Tudor I, Moraru L, Cristache G, Lanza A, Burlibasa M. Digital Workflow in Maxillofacial Prosthodontics-An Update on Defect Data Acquisition, Editing and Design Using Open-Source and Commercial Available Software. Appl. Sci. 2021;11:973.