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# 3-D PRINTING AND ITS APPLICATION IN INTERDISCIPLINARY DENTISTRY – AN OVERVIEW

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## INTRODUCTION

3-D printing is basically a seamless collaboration of dentists, engineers, and technicians. In today's era, customization and precision regarding patient care is of paramount importance. 3-D printing helps in providing exceptional dental care and treatment results with cutting- edge technology. Three-dimensional printing, often referred to as rapid prototyping or additive manufacturing, is a technology that is progressively becoming a part of daily life, and dentistry is no exception. The precision and ability to customize products made through 3D printing make it a perfect fit for the dental field. As stated by the International Organization for Standardization and the American Society for Testing Materials, 3D printing technologies work by adding material in successive layers based on a geometric design to create objects.[1] It allows dental practitioners, technicians, and engineers to combine their knowledge and yield customised solutions for patients. It provides unprecedented precision and efficiency in manufacturing patient-specific implants, crowns, and aligners by using combinations of digital scanning, CAD/CAM system and sophisticated materials. The revolution of conventional dental procedures has taken place since the introduction of the multidisciplinary nature of 3-D printing in dentistry. Dentists and technicians need to work hand in hand with the engineers and designers to fully use the potential of it, and this will lead to faster turnaround times, better treatment planning and more patient comfort. In today's ever- hanging times, 3-D printing is at the forefront of innovation in many areas including dentistry and it provides a window into personalised patient care soon in the future. It is an excellent example of how technology and healthcare come together to generate realistic models, prosthesis, surgical guides etc leading to precise outcomes.

## HISTORY

In the year 1980, Hideo Kodmann at the Nego Industrial Development Research Institute, Japan, for the very first time, came up with the concept of layer-by-layer manufacturing of parts. In 1983, Charles hull developed the first 3-D printer, known as stereolithography. He is thus considered the father of 3-D printing technologies.[2]

In 1987, Carl Deckard at Texas state university filed a patent for another technology called selective laser sintering (SLS). In 1992, Emanuel Sachs coined the term 3-D printing. What was called additive manufacturing in the science and technology world is now also called 3-D printing.[2]

In 1993, Solingen commercialized direct shell production casting (DSP) using ink-jet mechanisms. In the year 1995, zcorp obtained a license from MIT to create starch and plaster models. In 1999, the first 3D-printed organ — a bladder — was used for transplantation (Wake Forest Institute for regenerative medicine).[2]

In 2006, Reprap initiated an open-source project to extend its popularity. From here, the disruption of this technology began. In 2007, a selective laser sintering printer became available for 3-D part fabrication from fused metal or plastic. In 2012, the first 3D-printed of jaw was done. In 2015, the University of Michigan first implanted a 3D-printed bioresorbable scaffold for periodontal repair. In 2020, the 3d printer for personalized medicine, M3-D maker (fabrx). Presently, 3-D printing has found its place across various sectors.[2]

## BENEFITS

The following are some benefits of 3-D printing

- **Precision and accuracy** – models, crowns, implants, aligners and other dental material is created with accuracy and extreme precision, producing results more consistent and dependable.
- **Patient comfort** – compared to conventional procedures, 3-D printing is more patient-friendly since it eliminates the pain associated with impression taking making the patient feel more comfortable.
- **Time-efficient** – with 3-D printing and intraoral scanning enables a faster. transmission of impressions and instant work commencement,

helping in saving time.

- **Cost effectiveness** – it cuts labour cost, improves quality of appliances and lowers the overall manufacturing cost, making it a more affordable option.

**TECHNIQUES USED**

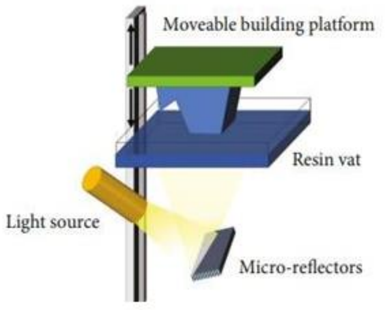
- The most common technologies used in 3-D Printing include.
- Fused Deposition Modelling (FDM)
- Stereolithography (SLA)
- Selective Laser Sintering (SLS)
- Direct Laser Printing (DLP)
- SLM (Selective Laser Melting)
- DMLS (Direct metal laser sintering)
- EBM (Electron Beam Melting)
- Material Jetting
- Binder Jetting
- Sheet Lamination[1,2]

Out of them, commonly used techniques for 3-D printing include stereolithography, digital light processing, and material jetting. These techniques use additive manufacturing processes to create dental products.

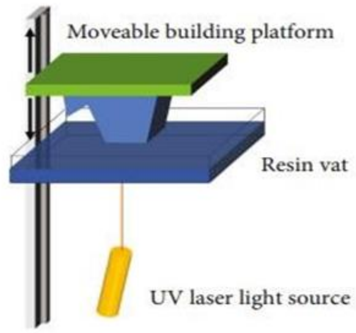
Stereolithography (SLA) uses a UV laser to cure liquid photopolymer resin into layers, making it fast and high-resolution. Digital light processing (DLP) is similar to stereolithography but uses a digital light projector to cure resin, offering high accuracy and speed. Material jetting involves printing with proprietary blends of materials, making it suitable for crowns, prostheses, and surgical guides.[2,3]

Each technique is specific to its post-manufacturing procedures to ensure that the final dental product is accurate and free of imperfections. The overall quality of dental products is influenced by printer quality, materials, technology used, software settings and post- processing refinements.[2,3]

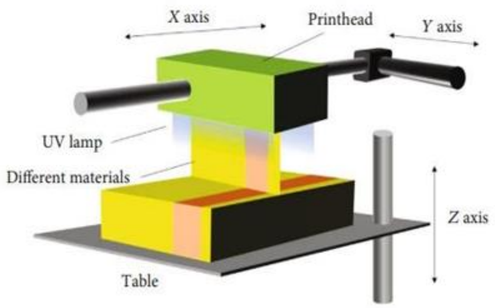
**SCHEMATIC DIAGRAM OF THREE-DIMENTIONAL TECHNOLOGIES**




IGITAL LIGHT PROCESSING




STEREOLITHOGRAPHY




FUSED DEPOSITION MODELING

**STEPS IN 3-D PRINTING**

The process for creating patient-specific 3D models can be broadly divided into 7 steps enumerated below.

1. Service request/order/intake process: This process typically starts with the physician identifies the need for a patient specific model and sends a request for the service. The process is known as the intake process. All essential information required to make the model should be provided by the requestor.

2. Image data acquisition: Any volumetric image data acquired for diagnostic purposes as standard of care can be used for 3D reconstruction of anatomy. 2D DICOM stack radiological images are very simply used for 3D reconstruction of patient specific the anatomy in the region of interest. Recently 3D scanning is being used to collect surface contour data, more commonly in dental and maxillo- facial applications.

3. Image data processing: Image data processing consists of segmentation, thresholding and region growing followed by 3D model creation to realize a computer/

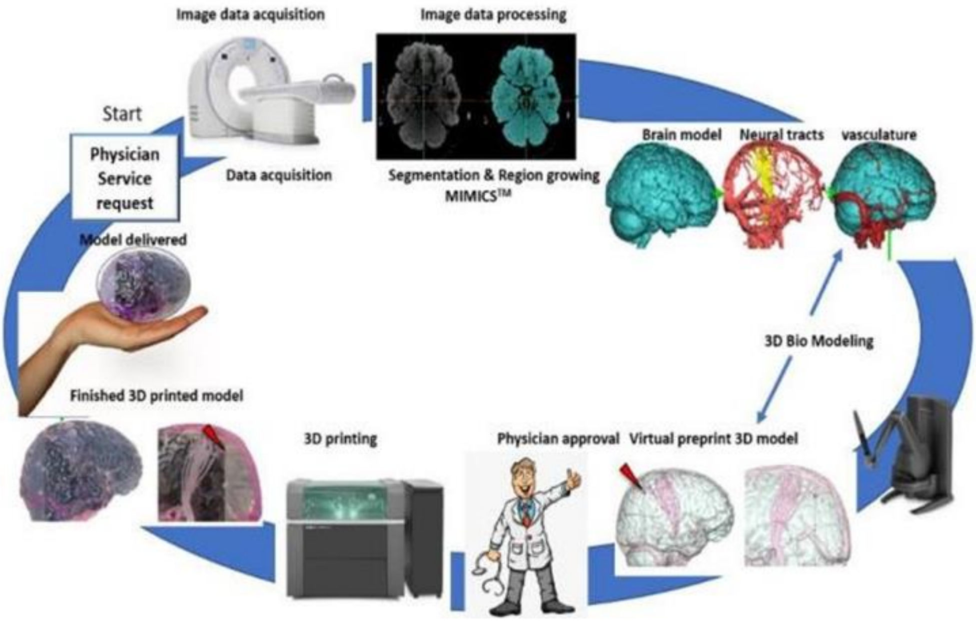
virtual model that can be printed or subjected to other downstream processes as virtual surgical planning, biomechanical analysis, or flow studies. Several commercial, non-commercial, and opensource programs are available with semi-automated and manual processes for the purpose of segmentation.

4. 3D biomodelling: 3D Biomodelling is the process by which the virtual model derived by reconstruction of the image data is optimized for 3D printing. The process involves, eliminating parts of the model that will not be printed and retain only the specific region of interest. Enhancements to the model for structural integrity is designed during this phase of processing.

5. Physician approval process: Several images of the final model are organized in a presentation format. A 3D PDF created using the STL files. This will give the physician the ability to zoom in and out, see individual structures collectively and individually by switching on and off layers. To overcome the deficiency programs like MIMICS viewer can be used where in the physician can review the model in relation to raw data.

6. 3-D Printing and Post processing: 3-D printing is the layer-by-layer manufacturing process that converts the virtual model to a physical part. The output from the manufacturing process is the tangible model the - end product. Recent advances in 3D printing technology have ushered in a new era of producing complex physical models that are precise replica of the human anatomy. Each printing process deposits layers of support material concurrently along with model material that will need to be separated once the print job is completed to realize the clean final model.

7. Labelling, packaging, and delivery
8. Post-delivery surveillance[2]




**WORKFLOW FOR PATIENT SPECIFIC 3-D MODELLING AND PRINTING**

**MATERIALS USED:** Material choice for realizing a 3DP model depends on the end use and printer/ material availability in the 3DP facility. Based on use 3-D printing materials are classified into 2 types.

1) Non-implantable
- Polymers – Photopolymers,
- Epoxies – Acrylate Epoxies
- Thermoplastics – Nylon

2) Implantable
- Organic Materials – Chitosan, Hydrogels, Alginate, Gelatin, Fibrin, Alginate.
- Polymers – Polycaprolactone (PCL), Polymethyl Methacrylate (PMMA), Polylactic Acid (PLA), Poly (Lactic-Co-Glycolic Acid) (PLGA).
- Pre-Alloyed Metal Elements Titanium and Its Alloys Co-Cr.
- Ceramic Matrix - Glass, Zirconia, Alumina Ceramics.[2]

**APPLICATIONS IN VARIOUS BRANCHES OF DENTSITRY**

Use of 3-D printing in various dental branches comprises of a wide range of applications that revolutionize dental practices and patient care. The following are some key applications of 3- D printing in various dental branches.

- **Restorative dentistry**

Restorative Dentistry encompasses several areas where rapid prototyping technology can be applied. The use of a digital workflow appears capable of producing clinically acceptable results, whether it's for creating tooth dies, wax patterns, intracoronal or extracoronal restorations, or even fixed prostheses.

Resin material is commonly used for 3- D printing with only one major disadvantage of polymerisation shrinkage. A study was done to assess the degree of shrinkage of interim resin crowns, fabricated using photopolymer jetting, milling and compression molding methods. It showed that proximal and marginal regions in both polyjet showed no significant difference, concluding that 3-D printing can produce temporary crowns with greater accuracy than conventional methods.

Combined with the use of either an intraoral scanner, the dies for a tooth can be 3D printed without the need for a plaster model. Fabrication of wax patterns is an important step in making a cast restoration. They can be made by hand, milled or can be 3D printed, usually by the material extrusion technique. Rapid prototyped wax patterns have been fabricated for implant abutments, onlays made with lithium disilicate, metal copings and metal crowns.[4-7]

Studies found the wax patterns to be adequate for clinical use though they were not always superior to the ones made by milling or by hand. Inlays and onlays have been printed using resins and wax patterns for ceramic inlays have been manufactured using rapid prototyping.s[8-10]

- **Endodontics**

3-D printing of endodontic guides for accurate access cavity preparation, apicoectomy, endodontic microsurgery and file placement is revolutionising endodontics. It is also employed to create patters used in casting dental items like inlays, onlays, crowns, endocrowns etc, streamlining the production process and enhancing the end products. Endodontic guides proved to be a quick and more predictable and can be preferred as a best option for location of calcified canals and in preventing failures. There are many studies reporting the high accuracy of guided cavity preparation using a 3D-printed access guide.[12,13,14]

Buchgreitz et al. reported the mean deviation of access cavities lower than 0.7 mm.[12] Similarly, Zehnder et al. and Connert et al. reported small deviations of 0.12–0.34 mm from the intended access and a mean angular deviation of less than two degrees.[13,14] 3D-printed guides for apicoectomy allow for easier inspection of root apices, smaller osteotomies, lower risk of nerve or sinus perforation, better root-end preparation, better healing, and shorter surgical time.[11,15,16]

The main challenge is that it requires space for template and difficulty in placement of instrument in posterior region, used only in the straight canals or straight part of curved canals. It takes immense amount of technical effort but might become standard for future micro-guided endodontics.

- **Prosthodontic**

3-D printing helps in fabrication of full dentures, providing removable plastic frames with full sets of teeth for patients without remaining teeth by direct printing. It is used for the fabrication of crowns, bridges and other restorative dental treatment with precision and efficiency.

Compared to manual investing and casting procedures, time taken for preparation is less and probability of errors showed results in favour of 3-D printing. Robocasting was another method introduced by silva et al, in which object is printed layer by layer fashion onto a flat substrate directly from digital file. Ebert et al introduced customised inkjet printing process to build up high strength zirconia ceramic prosthesis.[17-20]

- **Periodontics**

3-D printing is used to create accurate replicas of patient's teeth, aiding in fabrications of appliances like splints and in treatment planning. It is also used in regeneration of hard and soft tissue, guided gingivectomy and to fabricate and placement of implants. Digital light processing is an efficient method for printing customised zirconia dental implants with dimensional accuracy. Mechanical properties are close to traditionally produced implants.

Another method used is selective laser melting, shows increased dentistry, strength and dimensional accuracy. It is efficient for printing fully dense customised implants with sufficient strength. Customised subperiosteal implants can also be printed using 3-D printing but requires an extra oral donor tissue or bone and use of allografts.[17-20]

- **Oral surgery**

Surgical guides – 3-D printed surgical guides help in the precise placement of implants and other surgical procedures, ensures accurate positioning of implants, and minimizes the risk during surgery. Occlusal splints which are used to treat TMJ disorder and prosthesis to treat maxillofacial defects can be manufactured with 3D Printing.[17-21]

- **Orthodontics**

Dental aligners are the most trending treatment for correcting malocclusion in today's world. It should be customised according to each patient's need such as invisalign. 3-D printing is extensively used for this purpose and yield excellent results by fabricating accurate models of patient's teeth. Working model manufactured with this technique has the advantage of light weight, high accuracy, better durability, high wear resistance, good surface quality.[17-20]

## FUTURE DIRECTION AND INNOVATION

3-D printing as a technology is rapidly growing because of its advantages like superior efficiency, high accuracy. Hence, it is the best time to understand and learn basic concepts of 3-D printing. Currently, there are initiatives has been taken to use 4-D printing in the dentistry. In endodontics 4-D printing technology can be used to prevent instruments separation in curved canals, since it has the property of shape memory it will adapt to canal curvatures.

## CONCLUSION

3-D printing technologies have a wide variety of applications in dentistry, because of which it's possible to create new and more efficient methods for manufacturing dental products. Three-dimensional printing transforms 3d manufacturing into simple 2-D superposition, which greatly reduces the complexity of design and manufacturing.

It helps in creating a complex geometrical form using a variety of materials. The commonly used 3-D printing materials are polymers, ceramics, and metals. Even though there are some limitations with the use of 3-D printing technologies in terms of printing and accuracy, 3-D printing technologies have a wide variety of applications in the field of dentistry, including prosthodontics, implantology, oral and maxillofacial surgery, orthodontics, endodontics, and periodontics. The quality of patient care, education, and research will be enhanced by 3-D printing in the coming years as more research is conducted.

## REFERENCES

1. ISO/ASTM 52900 (en), Additive manufacturing — General principles — Terminology [Internet]. [cited 2020 Dec 13]. Available from: https://www.iso.org/obp/ui/#iso:std:isoastm:52900:dis:ed-2:v1:en.
2. Fundamentals of 3D Printing Technology for Medical & Dental Professionals textbook – Dr Ruchi Pathak Kaul and Dr Jayanthi Parthasarathy.
3. Tian Y, Chen C, Xu X, Wang J, Hou X, Li K, Lu X, Shi H, Lee ES, Jiang HB. A Review of 3D Printing in Dentistry: Technologies, Affecting Factors, and Applications. Scanning, 2021 Jul 17; 2021: 9950131.
4. Fathi, H. M., Al-Masoody, A. H., El-Ghezawi, N., & Johnson, A. (2016). The Accuracy of Fit of Crowns Made From Wax Patterns Produced Conventionally (Hand Formed) and Via CAD/CAM Technology. The European journal of prosthodontics and restorative dentistry, 24(1): 10-11.
5. Onlay, L. D. P. (2018). Marginal and internal gap of handmade, milled and 3D printed additive manufactured patterns for pressed lithium disilicate onlay restorations. European Journal of Prosthodontics and Restorative Dentistry, 26: 31-38. 12.
6. Taha, D., Nour, M., Zohdy, M., El- Etreby, A., Hamdy, A., & Salah, T. (2019). The Effect of Different Wax Pattern Fabrication Techniques on the Marginal Fit of Customized Lithium Disilicate Implant Abutments. Journal of Prosthodontics, 28(9): 1018-1023.
7. Khaledi, A. A., Farzin, M., Akhlaghian, M., Pardis, S., & Mir, N. (2020). Evaluation of the marginal fit of metal copings fabricated by using 3 different CAD-CAM techniques: Milling, stereo lithography, and 3D wax printer. The Journal of prosthetic dentistry, 124(1): 81-86.
8. Homsy, F. R., Özcan, M., Khoury, M., & Majzoub, Z. A. (2018). Marginal and internal fit of pressed lithium disilicate inlays fabricated with milling, 3D printing, and conventional technologies. The Journal of prosthetic dentistry, 119(5): 783-790.
9. Ahlholm, P., Sipilä, K., Vallittu, P., Kotiranta, U., & Lappalainen, R. (2019). Accuracy of inlay and onlay restorations based on 3D printing or milling technique-a pilot study. The European journal of prosthodontics and restorative dentistry, 27(2): 56-64.
10. Prechtel, A., Stawarczyk, B., Hickel, R., Edelhoff, D., & Reymus, M. (2020). Fracture load of 3D printed PEEK inlays compared with milled ones, direct resin composite fillings, and sound teeth. Clinical Oral Investigations, 1-10.
11. Buniag A.G., Pratt A.M., Ray J.J. Targeted endodontic microsurgery: A retrospective outcomes assessment of 24 cases. J. Endod., 2021; 47: 762–769. doi: 10.1016/j.joen.2021.01.007.
12. Buchgreitz J., Buchgreitz M., Mortensen D., Bjorndal L. Guided access cavity preparation sing cone-beam computed tomography and optical surface scans—An ex vivo study. Int. Endod. J., 2016; 49: 790–795. doi: 10.1111/iej.12516.
13. Zehnder M.S., Connert T., Weiger R., Krastl G., Kuhl S. Guided endodontics: Accuracy of a novel method for guided access cavity preparation and root canal location. Int. Endod. J., 2016; 49: 966–972. doi: 10.1111/iej.12544.
14. Connert T., Zehnder M.S., Weiger R., Kuhl S., Krast L.G. Microguided endodontics: Accuracy of a miniaturized technique for apically extended access cavity preparation in anterior teeth. J. Endod., 2017; 43: 787–790. doi: 10.1016/j.joen.2016.12.016.
15. Strbac G.D., Schnappauf A., Giannis K., Moritz A., Ulm C. Guided Modern endodontic surgery: A novel approach for guided osteotomy and root resection. J. Endod., 2017; 43: 496–501. doi: 10.1016/j.joen.2016.11.001.
16. Kim S., Kratchman S. Modern endodontic surgery concepts and practice: A review. J. Endod., 2006; 32: 601–623. doi: 10.1016/j.joen.2005.12.010.
17. Zaharia, Cristian & Gabor, Alin & Gavrilovici, Andrei-Mihai & Stan, Adrian & Idorasi, Laura & Sinescu, Cosmin & Negrutiu, Meda-Lavinia. (2017). Digital Dentistry — 3D Printing Applications. Journal of Interdisciplinary Medicine. 2: 10.1515/jim-2017-0032.
18. Jeong, Min & Radomski, Kyle & Liu, Jack & Lee, Jason & Lee, Sang. (2023). Materials and Applications of 3D Printing Technology in Dentistry: An Overview. Dentistry Journal, 12. 1. 10.3390/dj12010001.
19. Jawahar, Abarna & Maragathavalli, Gopal & Abarna, J. (2019). Applications of 3D Printing in Dentistry - A Review. Journal of Pharmaceutical Sciences and Research, 11: 1670.
20. Reymus M, Liebermann A, Diegritz C, Keßler A. Development and evaluation of an interdisciplinary teaching model via 3D printing. Clin Exp Dent Res.,

2021 Feb; 7(1): 3-10. doi: 10.1002/cre2.334. Epub 2020 Oct 27. PMID: 33108832; PMCID: PMC7853885.

21. Nesic D, Schaefer BM, Sun Y, Saulacic N, Sailer I. 3D Printing Approach in Dentistry: The Future for Personalized Oral Soft Tissue Regeneration. J Clin Med., 2020 Jul 15; 9(7): 2238. doi: 10.3390/jcm9072238. PMID: 32679657; PMCID: PMC7408636.