*IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)*
*e-ISSN: 2279-0853, p-ISSN: 2279-0861.Volume 22, Issue 6 Ser.15 (June. 2023), PP 24-29*
*www.iosrjournals.org*

# 3d Printing: A Step Towards Future-An Overview.

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***Abstract***
***Introduction:*** *- The World As We Know Is Going Digital And The Field Of Dentistry Is Also Going Through This Digital Revolution. Using Digital Tools, The Dentist Can Collect A Whole Series Of Accurate 3 Dimensional Information Of The Patients (Cbct And Intraoral Scanning), Which Is Ultimately Helping With The Correct Diagnosis And Treatment Plan. Once The 3-D Information Has Been Acquired Planning Takes Place Through Powerful Surgical Prosthetic And Orthodontic Computer Assisted Design Software. The Final Three Dimensional Digital Model/Prosthesis Can Be Fabricated Through Variety Of Means Including Computer Aided Milling And 3-D Printing.*
***Review:-*** *The Word 3d Printing Implies Variety Of Methods By Which Different Materials Are Used To Deposit, Join Or Solidify To Make Final Design A Reality. Three Dimensional Printings Are Commonly Done With The Following Technologies:- Fused Deposition Modelling (Fdm) , Selective Laser Sintering (Sls), Stereolithography (Sla) , Polyjet Printing And Bioprinters.*
*3-D Printing Used In Field Of Prosthodontics For Fabrication Of Components Of Removable Denture, Complete Denture , Fixed Denture And Dental Implants . 3-D Printing Technology Is Extremely Versatile And Rapid Process. With The Advent Of New Materials And Technology 3d Printing Has Revolutionized The Field Of Rehabilitation, Reconstruction And Regeneration With The Digital Manufacturing Technology.*
***Conclusion****:-Digital Dentistry Is Transforming Just About Every Aspect Of Professional Oral Care. This Paper Aims At Presenting An Overview Of Types Of 3- D Printing Technologies And There Clinical Implications. This Paper Will Also Present A Comprehensive Review Of Various Materials Being Used In 3d Printers For Various Types Prosthetic Devices .*
***Keywords:-*** *3d Printing , Additive Manufacturing, Stereolithography.*

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Date of Submission: 19-06-2023 Date of Acceptance: 29-06-2023

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## I. INTRODUCTION :-

The term 3D printing covers a host of processes and technologies that offer a full spectrum of capabilities for the production of parts and products in different materials. Applications of 3D printing are emerging almost by the day, and, as this technology continues to penetrate more widely and deeply across industrial, maker and consumer sectors, this is only set to increase. It is widely believed that 3D printing or additive manufacturing (AM) has the vast potential to become one of these technologies[1].

The 3D printing technology applications are not far away from manufacturing, construction, medical, electronics, defence and food industry where it is not only used for making models and prototype but also different assembly parts[2]. Digital dentistry stands for the involvement of the computer-based tools during diagnosis, recording, communicating and treatment of patients. It has been the biggest advancement in the past few years in the dental industry[3]. It may be defined in a broad scope as any dental technology or device that incorporates digital or computer-controlled components in contrast to that of mechanical or electrical alone[4].

## II. HISTORY :-

Concept of 3D printing has been imagined back in 1970's, first experiment was done in 1981. First 3D printing attempts are credited to Dr.Kodama for his development of a rapid prototyping technique. He introduced the layer by layer approach for manufacturing, creating an ancestor of Stereolithography : a photosensitive resin was polymerized by an UV light. Charles Hull was also interested in the technology and submitted a first patent for stereolithography (SLA) in 1986. He founded the 3D Systems Corporation and in 1988, released the SLA-1, their first commercial product. In the meantime, Scott Crump, a co-founder of Stratasys Inc. filed a patent for Fused Deposition Modelling (FDM). In 1992, the Fused Deposition Modeling patent was issued to Stratasys, which developed many 3D printers for both professionals and individuals[5]. Initiation of the RepRap Project consisted of a self-replicating 3D printer in year 2004. The very first high – definition color 3D printer was launched by the ZCrop with the name of Spectrum Z510 in 2005. In 2008, the first 3D printed prosthetic limb was constructed.

It incorporated all parts of a biological limb, it was printed 'as is', without the need for any later assembly. Nowadays, combined with 3D scanning, 3D printed medical prosthesis and orthosis are more and more cheaper and faster to get for the patient[5].

In 2010, Urbee was the first 3D printed car made . Its body was fully 3D printed using a very large 3D printer. Now, the 3D printed car is progressively becoming a reality, and additive manufacturing is taking more and more space in the automotive sector. Indeed, from the integration of 3D printing technology for the tooling process, to 3D printed car parts, additive manufacturing appears to be quite helpful on many levels, helping to go through brand new challenges.

In 2013, President Barack Obama mentioned 3D printing as a major issue for the future in his State of the Union speech, which made "3D printing" an absolute buzzword.

In 2016 Daniel Kelly's lab announces being able to 3D print bone[5].

## III. 3D PRINTING TECHNIQUES

There are mainly three types of techniques

1) Subtractive manufacturing technology:-
2) Formative manufacturing technology
3) Additive manufacturing technology[6]

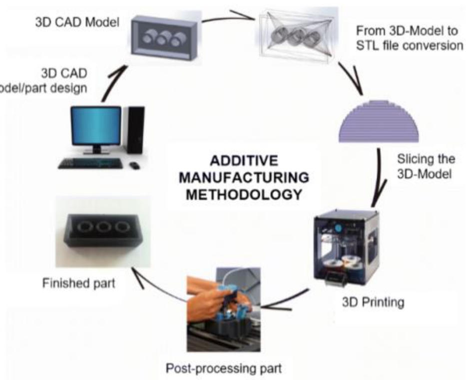
## IV. Additive Manufacturing :

The objectives and goals of Design for Additive Manufacturing ( DfAM) comprise the three levels of abstractions of traditional Design for Manufacturing and Assembly (DfMA):

1) to offer tools, techniques and guidelines to adapt a design to a given set of downstream manufacturing constraints;

2) to understand and quantify the effect of the design process on manufacturing (and vice-verse) in order to improve the performance of the manufacturing system and product quality; and

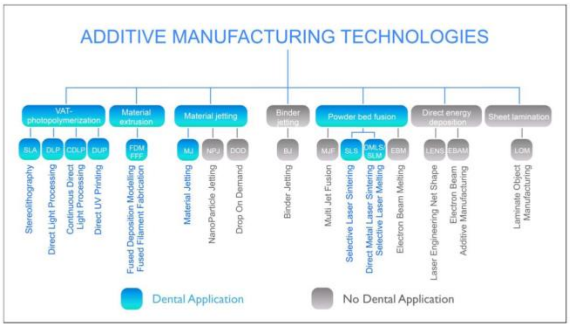
3) to know the relationship between design and manufacturing and its impact on the designer, the design process and the design practice[7].




(**FIGURE 1**:- :- cycle describing about the process of additive manufacturing methodology)

Thus ,this article discusses about the additive manufacturing which is being mainly used in the field of dentistry.

EN ISO 17296-2 describes the process fundamentals of additive manufacturing. It also provides an overview of the existing process categories, although such an overview can never be comprehensive, given the dynamic development of innovative technologies[8].




(**FIGURE 2**:- overview of the exisiting process categories in additive manufacturing.( According to EN ISO 17296-2)

1. ***STEREOLITHOGRAPHY*** : Stereolithography (SL) is widely recognized as the first 3D printing process. SL is a laser-based process that works with photopolymer resins, that react with the laser and cure to form a solid in a very precise way to produce very accurate parts. It is a complex process, in which the photopolymer resin is held in a vat with a movable platform inside. A laser beam is directed in the X-Y axes across the surface of the resin according to the 3D data supplied to the machine (the .stl file), whereby the resin hardens precisely where the laser hits the surface. Once the layer is completed, the platform within the vat drops down by a fraction (in the Z axis) and the subsequent layer is traced out by the laser. This continues until the entire object is completed and the platform can be raised out of the vat for removal[1].

2. ***FUSED DEPOSITION MODELLING (FDM):*** The process works by melting plastic filament that is deposited, via a heated extruder, a layer at a time, onto a build platform according to the 3D data supplied to the printer. Each layer hardens as it is deposited and bonds to the previous layer. The FDM/FFF (FREEFORM FABRICATION) processes require support structures for any applications with overhanging geometries. For FDM, this entails a second, water-soluble material, which allows support structures to be relatively easily washed away, once the print is complete. Alternatively, breakaway support materials are also possible, which can be removed by manually snapping them off the part[1]

3. ***POWDER BED FUSION (PBF)*** : A PBF process uses a thin layer of powder to build a plate and energy source, such as a laser or an electron beam fuses, to fuse the powder accordance with the geometry of the component made . This process allows the laser to selectively deliquesce powders layer-by-layer, resulting in three-dimensional sections. PBF processes unfold pulverized material over the antecedentaly joined layer, preparing it for the subsequent layer's process, resulting in a distinct rather than continuous output (nevertheless every layer is conjoined to vicinal layers).A hopper delivers the pulverised powder, which is then spread evenly over the powder bed to create platform space by a roller or brush. Conditions of processes and content used determine the best thickness of each sheet of unfolding powder[10].

4. ***SELECTIVE LASER SINTERING*** : Dr. Carl Deckard and Dr. Joe Beaman of the University of Texas at Austin invented this method in the mid-nineteen eighties . Selective Laser Sintering (SLS) is a rapid prototyping method that enables the creation of detailed geometry by consolidating consecutive powdered material layers over one another . The solidification of layers takes place with the help of CO2/ Nitrogen lasers counting on the sort of surface end and fusion needed. During this method, the chemical compound powder is employed for the aim of producing the object. The powder may be of thermoplastic, ceramics, glasses, metals, etc. If the powder used is created from metal, then this method is thought of as Direct Metal Laser Sintering (DMLS). SLS printers are composed of two chambers, the transfer of power takes place from the first chamber to the second one, where actual manufacturing occurs. The powder is heated at a temperature below the melting point of the equivalent substance. The leveller or roller present at the top surfaces the powder by forming layers. After the manufacturing gets completed, finishing operations are required[10].

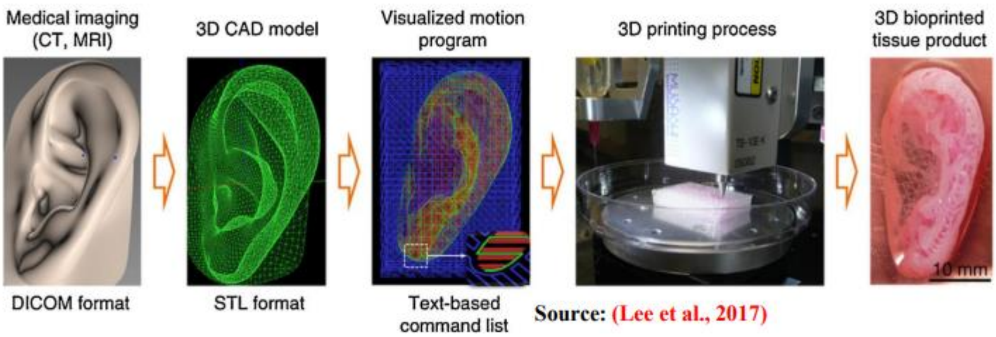
5. ***BINDER JETTING*** :- Jetting uses a modified version of Inkjet technology. Massachusetts Institute of Technology (MIT) introduced this process. Instead of using lasers to bind this process, it uses an inkjet to bind the objects. It uses a 2D printer technology in inkjet and goes up in layers forming a 3D project. In this process, with the help of a printhead, moving on two axes, a liquid binder is precisely deposited. This process also begins like any other 3D printing process, that is by creating a 3D drawing and then importing it into printer software. Since constant supply is required during printing, thus, a dispenser ensures that supply by placing powder in it that is to be used. Following the application of a powder sheet of varying thickness, the printing head attaches

the binder according to the specification. Before continuing onto the subsequent layer, the solvent containing the binder is desiccated using fluorescent or electric lamps. After that, the powder bed is de-escalated and a new sheet of powder is applied. The binder is then placed in a furnace after the completion of the cycle. Factors such as temperature and time required are dependent on the nature of the binder used. The metals and ceramic parts must undergo sintering, in-filtration, heat treatment, or hot isostatic pressing before being used. However, most of the metals and plastic materials do not require any post-processing and are ready to use as soon as they come out of the printing systems[10].

6.***LAMINATED OBJECT MANUFACTURING*** : Laminated Object Manufacturing (LOM) process developed by Helisys in the 1990's due to similarities in layering and shaping paper to form the final part. The process builds parts layer by layer using standard copier paper. Each new layer is fixed to the previous layer using an adhesive, which is applied selectively according to the 3D data supplied to the machine. This means that a much higher density of adhesive is deposited in the area that will become the part, and a much lower density of adhesive is applied in the surrounding area that will serve as the support, ensuring relatively easy "weeding," or support removal. After a new sheet of paper is fed into the 3D printer from the paper feed mechanism and placed on top of the selectively applied adhesive on the previous layer, the build plate is moved up to a heat plate and pressure is applied. This pressure ensures a positive bond between the two sheets of paper. The build plate then returns to the build height where an adjustable Tungsten carbide blade cuts one sheet of paper at a time, tracing the object outline to create the edges of the part. When this cutting sequence is complete, the 3D printer deposits the next layer of adhesive and so on until the part is complete[1].

## V. MATERIALS USED FOR ADDITIVE MANUFACTURING6

| MATERIAL | MAIN APPLICATIONS | BENEFITS | CHALLENGES |
|---|---|---|---|
| 1. METAL AND ALLOYS | -aerospace and automotive<br>-military<br>-biomedical | -mass-customization<br>-reduced material waste<br>-fewer assembly components<br>-possibility to repair damaged or worn metal parts. | -limited selection of alloys<br>-dimensional inaccuracy and poor surface finish<br>-post-processing may be required. |
| 2. CERAMICS | -biomedical<br>-chemical industries | -controlling porosity of lattices.<br>-printing complex structures and scaffolds for human body organs<br>-reduced fabrication time<br>-a better control on composition and microstructure. | -limited selection of 3d – printable ceramics.<br>-dimensional inaccuracy and poor surface finish.<br>-post-processing may be required. |
| 3.POLYMERS AND COMPOSITES | -sports<br>-medical<br>-architecture<br>--biomedical | -fast prototyping<br>-cost-effective<br>-complex structures<br>-mass-customization | -weak mechanical properties.<br>-limited selection of polymers and reinforcements.<br>-anisotropic mechanical properties. |




**(Figure 3:- Steps of processing.)**

## VI. IMPORTANCE IN PROSTHODONTICS

### APPLICATION OF 3D PRINTING IN REMOVABLE PROSTHODONTICS

***a) Fabrication of mould using 3D printing for complete denture prosthesis***

Fabrication of complete dentures is now possible with additive manufacturing. The process of complete denture fabrication using 3D printing encompasses the establishment of a 3D graphic database for positioning, arrangement of the artificial tooth as well as getting data of edentulous models and rims in centric relation. After the formation of mould complete denture utilizes traditional techniques of manufacturing. One of the major drawbacks of the 3D printed dentures is their lack of physical properties. Very few kinds of literature are there on the fabrication of 3D printed denture[4].

B) ***Fabrication or components of removable partial denture***

3D printing can also produce components of removable partial denture and studies have claimed that 3D printed frameworks show precise fit in compare to that fabricated conventionally. Process of fabrication includes the acquisition of data, digital designing and digital wax-up of the framework, converting the designed data and fabrication of framework using selective laser sintering or casting of resin printed framework[4].

## VII. APPLICATION OF 3D PRINTING IN FIXED PROSTHODONTICS

a) ***Fabrication of wax pattern for future prosthetic construction:-***

In the traditional technique, fabrication of wax pattern seems to be one of the most critical steps in the fabrication of porcelain fused metal crowns, ceramic crowns as well as removable partial denture framework. With the newer technology like 3D printing these particular steps now seem to be easy. This recent technology utilizes three steps in the fabrication of a wax pattern that includes obtaining the digital master model by using an optical scanner. The full arch as well as opposing arch scanning for digitization should be done. Next step includes digital designing of the wax pattern by utilizing CAD (Computer-aided designing) software. The last step is the fabrication of wax pattern by rapid prototyping technology utilizing fused deposition modelling and 3D printer .

b) ***Fabrication of crown coping***

In fixed prosthodontics, crown coping can also be prepared with rapid prototyping technology. Planned restoration can be designed using CAD software and this scan data can be used to print the coping of crowns.

c) ***Fabrication of direct metal prosthetic restorations***

Now a day's fabrication of direct metal prosthesis is achievable and this can be achieved through newer techniques like selective laser sintering or selective laser melting. These technologies overrule the older concept like making of the wax pattern for the fabrication of prosthesis and subsequent tedious and time taking procedure and thus they eliminate the possible errors that may go to happen at every stage .

d) ***Fabrication of mould using 3D printing for metal casting***

3D printing technologies have the potential benefit in the fabrication of ceramic casting model as they lay down the model through an incremental technique without the need of manufacturing wax pattern and subsequent steps in the wax eliminating procedures

e) ***All ceramic restoration fabrication***

Since the development of CAD/CAM milling system, these techniques are actively used in the production of milled restorations but these techniques have some flaws like wastage of significant amount of raw material, limitations of milling tools in more complex design formation. These drawbacks can be overcome by so-called additive manufacturing technology. A direct inkjet procedure can be employed in the fabrication of all-ceramic restorations. This technique utilizes printing of a suspension with a solids content of zirconia powder and drops on-demand inkjet printhead. Extrusion of slurry from inkjet head depends on several factors like solid loading, Ph value etc. After extrusion of slurry, green part of restoration needs to be sintered for final strength. Hence this restoration sintered in furnace at a temperature range of 9000 C to 9500 C for 5 to 8 minutes[4].

## VIII. APPLICATION OF 3D PRINTING IN IMPLANTOLOGY

a) Dental implant Several manufacturers have tried to produce a dental implant by using 3D printing technology. 3D printing technology can create micro details of complex anatomical structures like bone-like morphology in contrast to milled technology and hence 3D printing technology can also be used in the fabrication of dental implants.

b) 3D printed surgical guide for implant placement:- Accurate placement of an implant at the preset area is most critical and this accuracy can be achieved with rapidly emerging technology like additive manufacturing. Surgical guide fabricates by 3D printing technology offers accuracy as well as safety to treatment so that implant can be placed at the preset area[4].

## IX. CONCLUSION

In the field of dentistry, 3D printing has a wide range of applications, making it possible to create new and more efficient methods for manufacturing dental products. The most common application is to create working models for diagnosis and surgery, followed by a variety of implantable devices, which can help dentists provide patients with more predictable, less invasive, and less costly procedures[11].

The use of 3D printing techniques in any manufacturing industry dependent on the availability of materials, cost of printing process, process parameters of 3D printing machine and build time[11].

This overview is aimed at providing a practical and scientific overview of 3D printing technologies. We have summarized the classification of 3D printing technologies and material used in dentistry.

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