RESEARCH ARTICLE

REDEFINING PROSTHODONTICS WITH 3D PRINTING

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Manuscript Info

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Abstract

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Dentistry is amidst a digital revolution and patients are the definitive recipients of these innovative technological advancements. Three-dimensional (3D) printing is no more considered 'the future', but is'the reality' for daily clinical practice. The term '3D printing', additionally referred as 'rapid prototyping', is commonly used to depict an additive manufacturing method which adds numerous layers under computerized control in order to create a three-dimensional object. Using this procedure, 3-Dimensional printed restorations, crowns, bridges, surgical guides and implants can be manufactured rapidly with extreme accuracy and precision. The benefits of this innovative technique exceed its drawbacks. 3D printing has prompted a change in digital dentistry with it's broad learning, penetrating opportunities and a wide scope of applications. This article will facilitate an understanding of the digital workflow, methods and current uses of 3D printing in prosthetic dentistry.

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Introduction:-

Digital dentistry' is an umbrella term for several advanced innovations, like- the utilization of intraoral scanners, CAD/CAM programming, 3D imaging aids and 3D printers, which enhance efficiency in contrast to conventional analogue techniques (Hoang et al., 2016). Today dental profession is accepting digital manufacturing technologies and a significant part of the laboratory work which was earlier delivered by distinctive artisanal techniques is currently being created digitally, leaving only the final refinement of restorations to be accomplished by hand (Dawood et al., 2015).

There has been a long relationship of dentistry with subtractive manufacturing- commonly referred as 'milling'. In subtractive manufacturing, a solid block of material is cut successively in order to construct a 3D object (Azari and Nikzad, 2009). This innovative technology utilizes power driven machines to precisely cut a block of material into an ideal shape and geometry. However, subtractive manufacturing carries with it disadvantage of increased wastage due to removal of excess material and failure of mass production (Beuer et al., 2008).

Rapid prototyping (RP) is a great transformative technology that has advanced swiftly in different fields of dentistry since it has the ability to overcome the known limitations of the subtractive techniques (Wang and Shaw, 2006) .Through this technique, the clinicians are able to create physical objects out of liquid resins in a futuristic

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fashion.Various methods are utilized in 3D printing namely, Stereolithography, Fused deposition modelling ,Selective laser sintering, Digital Light Processing, Photopolymer jetting, etc (Somasundaram and Maiti , 2020).

The harmonious use of scanning, visualization, CAD, milling and 3D printing, along with professional creativity has resulted in new approaches to manufacture dental restorations (Jain et al, 2016). It is promising to view these innovations, however the current need is- assessment of printing accuracy, evaluation of properties of materials utilized, and extensive clinical use (Ciobota, 2012), (Alharbi et al., 2017).

Applications of 3D Printing In Prosthodontics:-
1. 3D printing is used to fabricate complete and partial acrylic dentures in acrylic resin or metal frameworks (Yilmaz et al., 2017), (Malara et al., 2015).
2. 3D printing can be employed for the fabrication of metal structures(Kruth et al., 2005) either directly in metal or indirectly by printing in burn-out waxes (Venkatesh and Nandini, 2013).
3. Fabrication of chrome-cobalt dentures with improved fit is possible utilizing using rapid prototyping (Hussein, 2014). This technique is particularly valuable in cases of hybrid dentures with precision attachments, as it offers reduction in errors and great accuracy (Torabi et al., 2015).
4. In fixed prosthodontics, usage of 3D printing is done in the fabrication of interim and final restoration. PEEK material is utilized to fabricate interim restorations and metal or ceramics are used to create final restorations (Fasbinder, 2010).
5. 3D Printing is used for the fabrication of inlays, onlays, copings, crowns, bridges, bridge frameworks and implant retained prosthesis (Fasbinder, 2010).
6. 3D Printing is used for manufacturing ceramic casting molds(Bassoli et al., 2007) without the need of making wax pattern and the accompanying steps involved in wax elimination (Sun and Zhang, 2012).
7. Customized occlusal supports which are utilized to address TMJ problems can be manufactured through rapid prototyping. (Salmi et al., 2013).
8. Rapid Prototyping is also employed for the manufacture of surgical guides which create seamless dental implant process by imparting accurate information about the location, size and angulation of implants (Ramasamy et al., 2013).
9. Rapid Prototyping is utilized to produce 3D printed models which reproduce the minute details of anatomical structures and furthermore overcome the drawbacks of plaster models which are burden of their storage, risk of damage & difficulty in sharing data with other professionals/technicians (Hao et al., 2018).
10. 3D Printing is used to manufacture facial prosthesis moulds which is an alternative to the conventional flasking and investment procedure. This fabrication of facial prosthesis moulds permits multiple pourings from a single mould (Cheah et al., 2003).

Advantages of 3D Printing:-
Additive manufacturing processes are opted in comparison to the traditional manufacturing methods because of the accompanying distinct benefits:
1. Less material is needed for production since there is reduced waste generation (Kohli, 2019).
2. Higher efficiency in resources since there is no requirement of auxiliary resources (Malara et al.,2015).
3. Products of objects with complex geometries can be produced ensuring good quality of work and reliable results (Kohli, 2019).
4. Additive manufacturing processes are efficient and increase production flexibility (Malara et al.,2015).
5. The fabrication process itself is rapid. This facilitates fast delivery of single objects manufactured in small quantities (Kohli, 2019).
6. CAD/CAM manufactured prostheses provide intimate tissue adaptation (Dawood et al., 2015).

Disadvantages of 3D Printing:-
Although Rapid prototyping techniques are alluring, still they are constrained by specific drawbacks which are as follows:
1. High cost of equipment (Kohli, 2019).
2. An inherent inbuilt weakness present in the final product (Grames ,2019).
3. Finishing of final product is a time-consuming procedure (Grames 2019).
4. Resin used has a limited shelf -life and cannot be heat sterilised. Moreover, it is messy and can lead to skin sensitisation on contact (Dawood et al., 2015).

5. Additional treatment might be needed in specific cases depending on the material used, in order to accomplish full strength (Grames, 2019).
6. Surface and microstructural imperfections might occur in the finished product (Malara et al., 2015).
7. These technologies are quite challenging for large scale manufacturing because of the time involved (Malara et al., 2015).
8. There are limitations on size of parts that can be manufactured through such techniques (Grames, 2019).

Digital Workflow:-
Firstly digital acquisition of the data is obtained through the use of an 'Intraoral Scanner' which consists of -a mini camera, integrated software, and a computer. The Intraoral Scanner possesses extreme precision and after capturing the 3D images of the object, stores the data acquired as STL (Standard Tessellation Language) file. This data is encoded by the tessellation process which involves the stitching of these files (Revilla and Özcan, 2019). After the desired support structures are designed through the software, 'slicing' of the structure is done in order to create a stack of layers. The sliced data is then sent to the printer, where successive layers of material are deposited to create a three dimensional object by the 3D printing process (Dawood et al., 2015). The post-processing of the printed object is then achieved which involves -removal of support material, sandblasting and jet-washing. This essential workflow is employed for various 3D printing processes, incorporating the use of materials such as polymers, metals or ceramics (Dawood et al., 2015).

3D Printing Technologies:-
Additive manufacturing includes multiple fabricating techniques which differ with respect to the material and the technology utilized in the manufacture of components (Prakash et al., 2018). The most widely used additive manufacturing methods are as follows:

Stereolithography (SLA) is a method which involves curing of thin layers of photopolymer resins such as, epoxy and acrylic resins through the use of laser beams produced by a UV laser source (Wang et al., 2017) The laser beam is activated and falls on the scanning mirror (Fig. 1). This laser beam is directed by the mirror and is made incident on the resin reservoir. Firstly, the photocurable resin polymerizes to form a 2- dimensional patterned layer. After each layer is cured, the lowering of curing platform takes place in order to facilitate another photocuring cycle for deposition on the solidified freshly printed layer. Hence this process involves layer-by-layer curing (Melchels et al. 2010). The manner in which curing reactions are optimized throughout the polymerization process determines the quality of the final printed product. The benefits of SLA technique are- Rapid fabrication and creation of complex shapes with exceptionally realistic details (Tian et al., 2016). The limitations of this technique include high machine cost, wastage of materials, warpage induced shrinkage and availability with light curable liquid polymers only (Dawood et al., 2015).
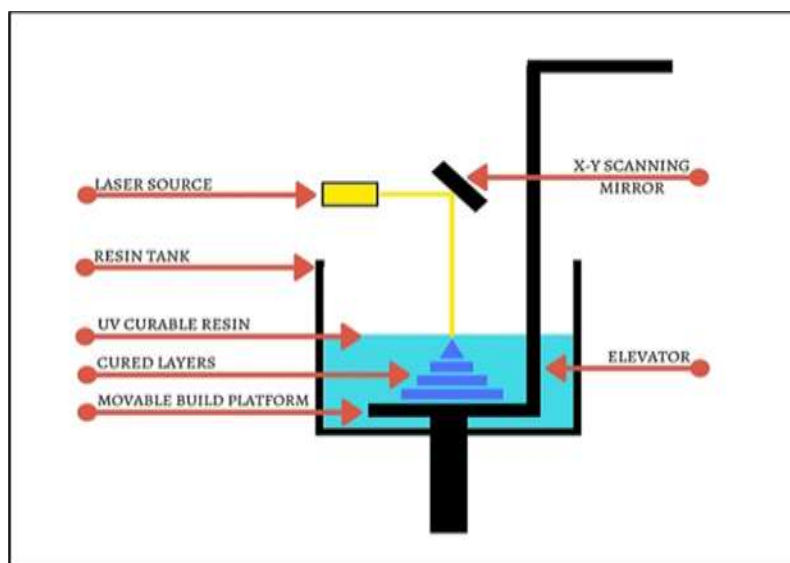
**Fig.1:-** Diagrammatic Representation of the working of Stereolithography.
(Source: MANUFACTUR 3D, How Stereolithography 3D Printing Works? January 31, 2018)

Fused deposition modelling (FDM), is an extrusion-based technique involving the use of thermoplastic materials, such as- Polylactic acid (PLA) , polypropylene (PP) and polyethylene (PE), which are exposed to high temperature to form filaments (Chameettachal et al, 2019). The nozzle of the 3D printer expels the molten filaments by either pneumatic or mechanical forces (Fig. 2). The filament is continuously fed through the extruder and nozzle by means of two rollers which rotate in opposite directions. Deposition of material is accomplished on the build plate layer-by-layer until the desired dimensions of the product are achieved (Carneiro et al., 2015). FDM is the most widely used and cost effective additive manufacturing technology which is used by 'home' 3D printers (Dawood et al., 2015). This technique is the most economical method of manufacturing custom thermoplastic parts and prototypes. The disadvantages of this technique are- lack of dimensional accuracy and precision, hence it is unsuitable for parts with minute details. Warpage occurs when the extruded material cools during solidification. Moreover, there is presence of noticeable layer lines, so post-processing is needed to attain a smooth finish (Varotsis, 2019).
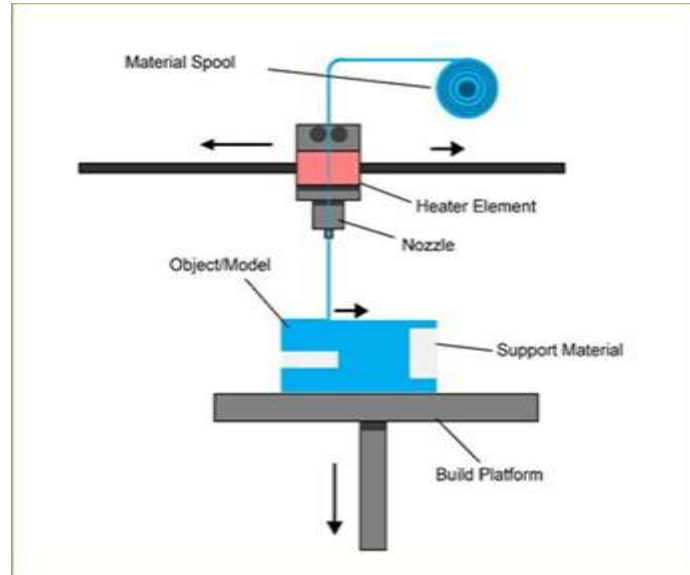

Fig 2:- Diagrammatic representation of Fused Deposition Modelling process.
(Source: 3D PARTS UNLIMITED, Engman-Taylor)

Selective Laser Sintering (SLS), is a powder-based 3D printing technique which utilizes laser for melting and fusing powders. These fused powders are then stacked layer by layer in order to form a printed part on the basis of 3D model data. The commonly available selective laser sintering processing materials are: polymer, ceramics, metal powders, and their composite powders (Weihao, 2002). The laser specifically examines the cross-sections generated from a 3-D digital data of the part on the surface of a powder bed (Fig.3). After scanning each cross-section, the powder bed is bought down and a fresh layer of material is laid on it. This procedure is carried out cyclically until the creation of final product is accomplished (Xometry: Design Guide, 2021). A high level of resolution of 60 μm can be acquired through this process (Dawood et al., 2015). No additional base support material is required as the printed structures are supported by the encompassing powder (Gan et al., 2020). SLS is viewed as the most appropriate additive manufacturing technology for large-scale production due to huge printing size, high accuracy and use of autoclavable materials (Jain et al., 2016). Disadvantages of this procedure are- expensive technology, powders used are messy and pose increased inhalation risk, and requirement of significant climatic conditions such as compressed air (Dawood et al., 2015).
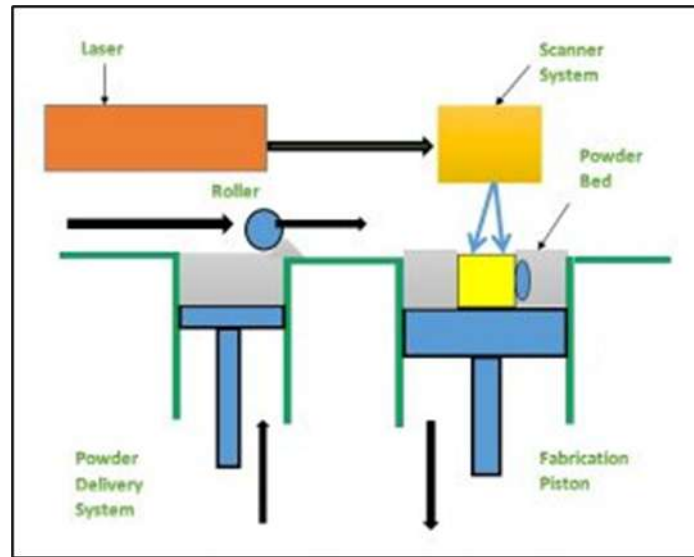
Fig. 3:- Diagram of Selective Laser Sintering process.
(Source: MANUFACTUR 3D, January 28, 2018).

Digital Light Processing (DLP) is an additive manufacturing technique in which photosensitive materials such as polymers and resins are polymerized. This process resembles the Stereolithography technique, the main distinction being the light source. SLA method utilizes a laser which is replaced by a DLP projector in this technique. The projector light source cures the liquid resin layer by layer (Fig.4). The object is built upside down on an incrementally elevating platform. This technology is extremely precise and ensures smooth surface of the fabricated parts. However, this process has the limitation of larger pixels quality of the manufactured parts in cases of use of large work tables (Kadry et al, 2019). Also there is resultant low mechanical strength of the manufactured parts. Additionally, the supporting structures need to be eliminated precisely after the manufacturing process. Resin is messy, has limited shelf life and cannot be heat sterilised (Dawood et al., 2015).
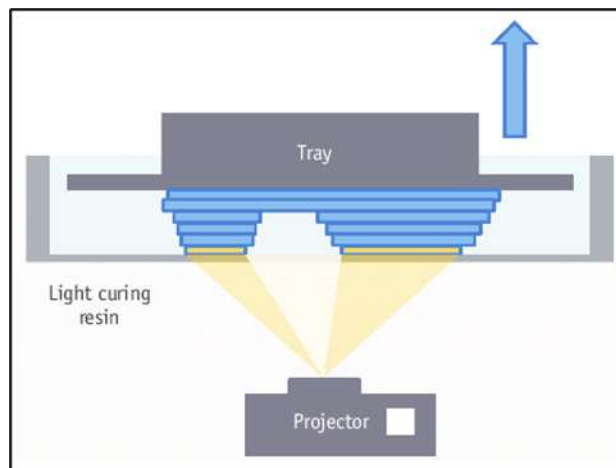
Fig. 4:- Diagram of Digital Light Processing method (Kim et al, 2016).

Photopolymer Jetting is a technology which involves jetting of light sensitive polymer from an inkjet type print head on a build platform. A UV lamp is used to solidify the resin or wax after each layer is jetted (Fig. 5). Layer by layer the cured material is thus laid down incrementally on a descending platform . 3D Jet printers can have either a solitary print head, or array of inkjet print heads which deposit minute drops of build material to form each layer of the printed part ((Jain et al., 2016). A broad range of resins and few silicone-like rubber materials can be printed. This technique is relatively fast , cost-effective, provides high resolution and high-quality finish. Ensuring a resolution of 16 microns approximately, this process facilitates fabrication of fine detailed objects (Ibrahim et al.,

2009). Disadvantages of this method are- expensive materials which cannot be heat sterilised and difficulty to remove tenacious support material completely (Chia et al., 2015).
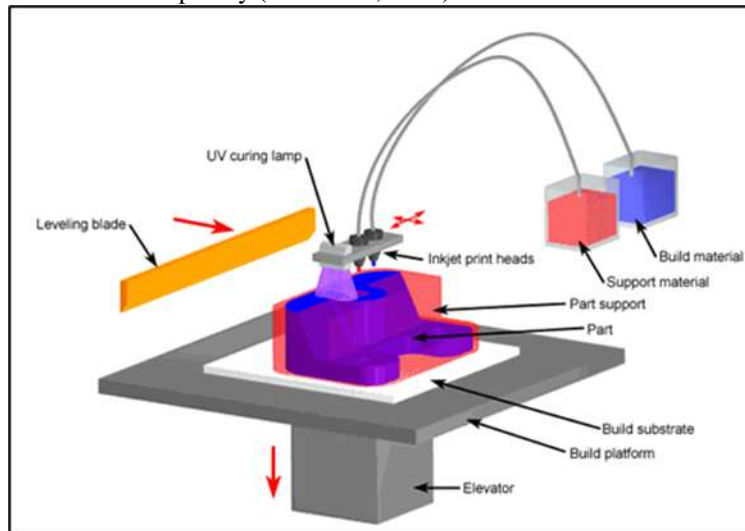
Fig. 5:- Diagram of Photopolymer Jetting method.
(Source: Copyright © 2021 Custom Part Net)

Conclusion:-

The various innovations of 3D printing which facilitate visualization of treatment outcomes, have dramatically transformed the way products are designed, manufactured and delivered, thereby bringing an unfolding revolution in dentistry. Additive manufacturing has a promising task to carry out explicitly in prosthodontics. This driving edge technology has been utilized to reduce the tedious task of a dental technician and provide a more precise framework contrasted with the conventional techniques.

Educational programs using 3D-printed models invigorate development of dental skills amongst dental students who get the chance to foster better proprioceptive skills. 3D printing technologies thus possess the ability to transform research, treatment methods and educational streams of dentistry enhancing oral health care.

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Conflicts Of Interest:-
There are no conflicts of interest.

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