3d Printing: Reshaping Dentistry

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ABSTRACT

3D printing is one of the immediate emerging and fastest growing trends in medicine and dentistry. In contrast to traditional method of subtractive manufacturing, 3D printing is an additive manufacturing method in which a item is made by laying down successive layer of material. Complex anatomical structures can be printed using high resolution resin with great precision. Commonly used techniques in dentistry are stereolithography, fused deposition modelling, selective laser printing. These techniques are used in orthodontics, cutting guides and drills, implantology. With the advent of 3D imaging and modelling technology there is significantly increased rate of success in implantology and surgery with the use of custom-made drills and guides, there is marked increase in accuracy and quality of work. This review paper includes the various technologies, advances of 3D printing and its dental applications.

Keywords: Additive Manufacturing, 3D printing, digital dentistry, stereolithography,

I. INTRODUCTION

Evolving technology along with the integration of digital solutions has transformed the ability to diagnose and to achieve precise planning of from a traditional 2D approach to more advanced 3D technology. Digital technology has made possible for multiple doctor practices, and enhanced patient volume growth. It also facilitates efficient and convenient storage, records retrieval and easy sharing of the records (1) .The progress from gypsum laboratory to 3D printing technology constitutes a major paradigm shift in orthodontics(2). The physical impressions and traditional stone poured casts have been replaced by intra-oral digital scans and 3D printed models. With this technology, a new workflow is seen in orthodontic offices.

The invention of additive manufacturing is credited to Chuck Hull. He presented the idea of additive technology through a procedure known as “stereolithography (SLA)”(2). Chuck’s apparatus was in effect, the “world’s first 3D printer”, therefore he is rightly known as “Father of 3D Printing”. The additive technology gained enormous popularity in various fields like engineering, medicine etc. It was useful, especially in those fields in which needed millimetric accuracy.

II. MODES OF 3D PRINTING

Various methods of additive technology are employed in dentistry are as follows:

(1) Stereolithography (SLA).

(2) Fused Deposition Modeling (FDM).

(3) Selective Laser Melting and Selective Laser Sintering

(4) Photo Polymer Jetting

(5) Electron Beam Melting (EBM)

(6) Digital Light Processing (DLP)

STEREOLITHOGRAPHY (SLA)

The term “stereolithography” was first put forward by Charles W. Hull in 1986 as a technique used to manufacture 3-dimensional objects by successively printing thin layers of material which is solidified by a concentrated ultraviolet laser light. Stereolithography (SLA) is the first “rapid prototyping” process(3). This technique utilizes liquid ultraviolet which is a photopolymer resin which is curable. Ultraviolet laser is used to build layers sequentially. Each layer is traced by the laser beam. The ultraviolet laser light is used to cure the pattern and then solidifies it and joins the subsequent layers together. It mainly used to print implant surgical guides due its increased strength, surgical stents, obturators, duplication of prosthesis(3). This technique is invariably utilized as a part of the field of maxillo-facial prosthodontics such as obturators, surgical stents etc.

FUSED DEPOSITION MODELLING (FDM)

Fused deposition modelling are often used for modelling, manufacture applications, and prototyping. In 1980’s, S. Scott Crump introduced this technique and it was then popularized by Stratasys, Ltd in 1990(4) . The computer aided model is used or the scan information is used by the 3D printer, from which the thermoplastic polycarbonate in a melted form extrudes and the objects are built from bottom to top in a layered manner. This method makes complex parts easy to produce as the melted plastic combines with each other instantly(2).

SELECTIVE LASER MELTING (SLM) AND SELECTIVE LASER SINTERING (SLS)

Selective laser melting (SLM) utilizes laser beam in order to melt various materials like, ceramics, metal and polymer powders. Inspite of the fact that SLM is very similar to SLA, there are 2 main differences. Firstly, in SLM instead of a photosensitive resin powder is used (5). Secondly, the solidification mechanism in SLM relies on the melting of the powder as opposed to the cross-linking of the photopolymer. In dentistry selective laser melting is employed to manufacture 3D metallic structures. Both Co-Cr and titanium are extensively used in the production of 3D dental structures and 3D porous implants by the process of SLM(6).

The selective laser sintering (SLS) method quite similar to SLM, with the only difference being the fusion mechanism. In SLM, powder particles are first brought to their melting point and fuse together. In contrast, in SLS technique the powder particles are heated using a laser beam to their critical temperature. This enables the small powder particles to fuse at molecular level(6). SLS is the process which is commonly used in low-cost home 3D printers. These are employed for printing structures which do not require a lot of precision and are of less complexity, for example printing edentulous mandible(7).

POLYJET PHOTOPOLYMERIZATION (PPP)

Polyjet photopolymeriazation uses the same technique as that of a inkjet printer. It prints a pattern on a thin layer of powder substrate by means of propelling a liquid binding substance using a nozzle. First a support structure is laid down on friable support material. Light sensitive polymer is flown onto the stage and is cured layer by layer on an incrementally plunging platform (3). Stratasys and 3D Systems are currently the only manufacturers of PPP printers (2).

ELECTRON BEAM MELTING (EBM)

The technology uses electron beams as the energy source, rather than the lasers that 3D print metal. The powder is liquefied by an electron beam layer by layer in a high vaccum

and this facilitates full liquefication of metal powder(3). This technique works by laying down successive layers and creates highly porous or near-net-shape metal parts which are void-free and possess good strength and are dense(8). Various alloys such as stainless steel, copper and titanium are printed with this technique. It is used commonly in orthopaedic and oral and maxillofacial surgery for making of customized implants(4).

DIGITAL LIGHT PROCESSING (DLP)

Digital Light Processing (DLP) is a type of nanotechnology that uses digital micromirror devices as a power source which cures liquid resins into solid 3 dimensional objects (9). DLP is very similar to SLA with the only exception of the light source. In DLP a projector is used to cure the entire layer at a time, in contrast to the SLA laser, which must draw the entire layer to cure it(2). DLP printer uses voxels rather than layers to build model, therefore there are no visible steps which gives it the best finish quality of all the 3D printing technologies.

III. DENTAL APPLICATIONS

3D PRINTED MODELS

Traditionally, plaster models were used widely as an educational tool for students as well as patient education. It is used for record keeping, treatment planning as well as to make custom guides or splints. Plaster models do not replicate anatomical structures accurately and duplicating is difficult. 3d printed models reproduce the exact details of the anatomical structure and also overcomes the limitations of plaster models. Added advantage of 3D printed models is that they are stored and exchanged electronically(2).

CROWN COPINGS AND PARTIAL DENTURE FRAMEWORKS

Due to the advanced technology of intra-oral and extra-oral scanners, precise virtual model can be created of the dental arch, prepared tooth or the implant position. With the help of CAD software, accurate treatment planning and precise restorations can be designed. The scan data along with the CAD design, we can either print or mill crown or bridge copings, bridge structures and implant abutments(10).

3D PRINTED GUIDES

3D printed guides are of great help in scenarios where the lesions may have perforated the cortical plate(11). In such cases, 3D CT scan of the skull is done along with 3d reconstruction is done and STL was created and 3D skull can be printed. This 3d printed skull is useful for practicing mock surgeries as well as to fabricate a surgical guide which facilitates accuracy and precision. This approach gives an exact impact point for osteotome, accurate orientation in 3D space and precise depth of insertion of osteotome. This technique helps the surgeon to reduce complications(12). 3D guides ensure for a less invasive, more predictable and safe operative procedure (10)

These guides help in implant placement and it should possess adequate support from bone, mucosa or teeth. It also provides guidance for implant preparation and fixture placement procedures with the use of oriented guide sleeves(11).

In endodontics, location of canal orifice in a pulp obliterated tooth is extremely challenging. In such cases, a 3D printed guide of tooth helps in easier location of the canal orifice. With this technique, root perforation or any other iatrogenic errors can be avoided. It helps in accurate placement and angulation of the bur(13).

DENTAL IMPLANTS

Dental implants are now being manufactured using 3D printing technology. This technology has the ability to produce precise details of the anatomic structure along with the surrounding structures such as morphology of bone. These surrounding structures cannot be replicated with milling process. However, the 3D printed structures may require milling / machining to refine the structures. Precise 3D printers and printing materials with high resolution must be used for drill guides for implant, however some of best materials which could be used for this purpose are not autoclavable(14).

AUTO TRANSPLANTATION

Auto transplantation uses the transplant tooth as template for preparation of the recipient site. The extra-oral time and damage to pdl fibres play a vital role in the success of the auto- transplantation. Conventional technique requires multiple fitting attempts to the bone which leads to increase in extra-oral time and a higher chance of damage to the pdl. With the introduction of 3D printing, replicas of teeth can be printed using Computer aided rapid prototyping (CARP). This facilitates the manipulation of recipient site to be completed before the extraction of the teeth to transplanted. This technique significantly decreases the damage to the pdl which would otherwise caused due to repeated insertion and removal(15).

MAXILLOFACIAL PROSTHESES:

3D printing is used for manufacturing implant for surgical prosthesis. They are used for reconstruction and replacement of various osseous structures such as zygomatic bones, temporal bones including calvarial bone, ear ossicles and mandibles. They are also utilised for reconstruction of soft tissue of the head and neck. These prostheses are suitable in cases of trauma or tumour resection. Tumour resection surgeries of ameloblastoma require substantial amount of bone and soft tissue reconstruction. 3D printed implants significantly reduce the cosmetic defects associated with these surgeries(14).

ORTHODONTICS

With the introduction of digital work flow in orthodontics the process of treatment planning, fabrication of appliances and wires are done using intra-oral scanners or laboratory scanners or even CBCT of the patient. With increase in demand for aesthetic options in orthodontics, clear aligners have gained widespread interest. Treatment planning and tooth repositioning can be done in software and a series of 3D models are printed for aligner manufacturing. These aligners reposition teeth over a period of time(16).Indirect bracket bonding splints, printed rigid and flexible materials for precise bracket positioning are being 3D printed(17). There is a huge savings in time as the smile design is done in the software. The patient data can be digitally stored and shared and can be printed only when needed(14).

IV. CONCLUSION

With the emergence of 3D imaging and modelling, CAD technology, there is a huge impact on various aspects of dentistry. It is now possible to accurately fabricate complex structures from digital data. Almost anything a patient needs can be 3D printed, but no one technology fits all needs. 3D printing is already widely used in orthodontics to print models using high resolution resin. Similar technology has been employed in restorative

dentistry to print models and patterns. 3D printed guides in maxillofacial and implant surgeries aids it to be less invasive and more predictable. However, a major requirement of 3D printing is the need for skilled operators. The cost of running the machine and its maintenance should be considered and strict health and safety protocols should be followed. Despite all the concerns, 3D printing is the next big thing in dentistry!

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