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`3D PRINTING IN IMPLANTDENTISTRY-A REVIEW

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ABSTRACT

Three-dimensional (3D) printing is an additive manufacturing method in which by laying down successive layers of material a 3D item is formed. Charles Hull created the 3D printer which used the technique of stereolithography, as well as the first program for virtualization.Various types of polymers,gels , resins and powders are the materials employed in 3D printing.3D printing techniques includes liquid based, solid based and powder based using which surgical guides and implant abutment can be fabricated .The accuracy of 3D printed implants is assessed by global deviation, angular deviation, depth deviation and lateral deviation. Even though the complications and disadvantages are associated with 3D printing, they can achieve higher precision and accuracy in implant placement. However, further studies are needed to evaluate their clinical outcome over time and function..
KEY WORDS: 3D printing, Dental implants, surgical guides, Guided surgery.

INTRODUCTION

Dental implant placement requires precision which poses challenge to the dentists and it depends on anatomic conditions such as sufficient bone height and thickness. Individualized dental implants seem to offer benefits for patients with receded alveolar bone. There are various methods in digital dentistry of which additive manufacturing or rapid prototyping has allowed for the fabrication of custom implants with microscale resolution and it is a potential process for manufacturing dental implants which provides customization, flexibility and freedom in implant design. Three-dimensional (3D) printing is an additive manufacturing method in which by laying down successive layers of material a 3D item is formed. 1,2 This review will highlight the history, materials used ,techniques, steps, accuracy, complications of 3D printing and its various utilities in the field of implant dentistry.

HISTORY

The earliest record of 3D printing through the additive process was by Japanese inventor Hideo Kodama in 1981. He created a product that used ultraviolet lights to harden polymers and create solid objects. Charles Hull printed a three dimensional object for the first time in 1983.He was the one who first created the 3D printer which used the technique of stereolithography, as well as the first program for virtualization.2,3 Specialists in general medicine started to implement in their fields due to its millimetric precision in 1990s. 3D Printing was first used for medical purposes as dental implants and custom prosthetics in the 1990s. Eventually, scientists were able to grow organs from patient’s cells and used a 3D printed scaffold to support them.

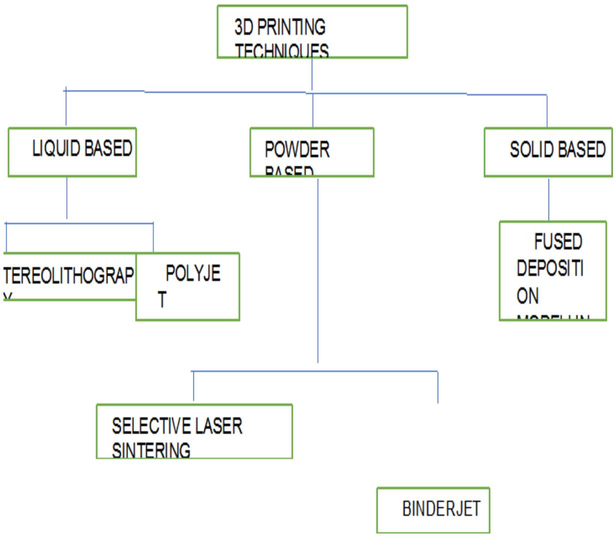
MATERIALS USED IN 3D PRINTING

Thermoplastic polymers such as polylactic acid (PLA), acrylonitrile butadiene styrene (ABS), polycarbonate (PC), polyether ether ketone (PEEK), etc.

A variety of resins for photopolymerization, ceramic filled resins, etc.
Powder such as alumide, polyamide, glass-particle

filled polyamide, rubber-like polyurethane, etc.

A variety of photopolymers



Cell-loaded gels and inks based on collagen, photopolymer resins, agarose, alginate, hyaluronan, chitosan, etc

STEREOLITHOGRAPHY

SLA technique allows the solidification of liquid photopolymer by using ultraviolet (UV) laser source. After converting the 3D digital model into 2D cross-sections, a coherent light source is emitted in a particular manner by specific points located in a photosensitive resin-containing platform, thus inducing selective photo- polymerization and forming the very first layer. The platform is then lowered into the vat by a one-layer thickness, allowing the liquid to cover the first layer. The same process is then repeated over and over again, until the intended 3D model is physically manufactured.

POLY-JET MODELLING

Poly-Jet modelling (PM) is performed by jetting liquid photopolymer materials in ultra-thin layers (16 μm) onto a build tray layer by layer, until the model is completed.

SELECTIVE LASER SINTERING

In SLS technique, the 2D slice data are fed into the SLS machine that directs the exposure path of the laser over a thin layer of powder, previously deposited onthe build tray and levelled with a roller. The CO_2 laser beam heats the powder particles, fusing them to form a solid layer, and then moves along the x-and y- axes to design the structures according to the CAD data. After the first layer fuses, the build tray moves downward, and a new layer of powder is deposited and sintered and the process is repeated until the model is completed, without support during manufacturing.

3D PRINTING (BINDERJET):

The Binder Jet system uses a print head to selectively disperse a binder onto powder layers. A thin layer of powder is spread over a tray using a roller similar to that used in the SLS system. The print head scans the powder tray and delivers a continuous jet of a solution that binds the powder particles as it touches them.

FUSED DEPOSITION MODELLING (FDM) :

It uses a similar principle to SL in that it builds models on a layer-by-layer basis. The main difference is that the layers are deposited as a thermoplastic that is extruded from a fine nozzle by computer control. As each layer of plastic cools, it hardens, gradually creating the final model with stability, durability, and mechanical properties.

FABRICATION OF DENTAL IMPLANT ABUTMENT BY 3D PRINTING

Designing of the implant abutment is done with the fusion software initially. Using laser melting system, metals like nickel, steel, titanium, cobaltchromium, aluminium is used for fabrication. The abutment is built by melting and fusing layers of metallic powder .Once a single layer is established, build plate is lowered to reintroduce the powder and subsequent layers is printed.Post processing is done by removal of witness marks and grit blasting, manual creation of threads etc.

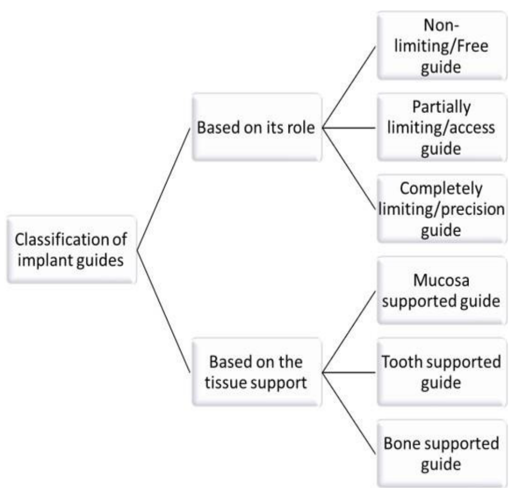
FABRICATION OF DENTAL IMPLANT ABUTMENT BY 3D PRINTING

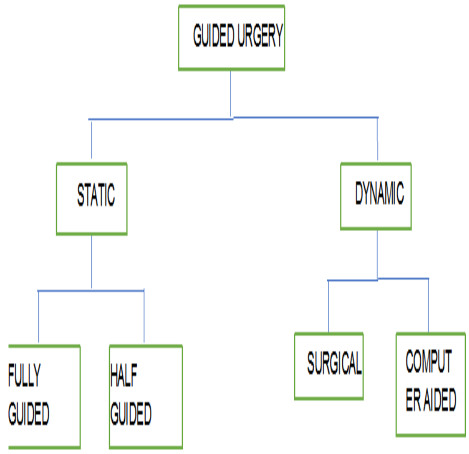
The surgical guide is one which replicates the exact surfaces of the patient's intraoral setting and assists the surgeon to drill implants into the bone with optimal accuracy14 The digital workflow is comprised of three basic phases which includes: First phase- acquiring data regarding patient information, which includes the CBCT and the intraoral impression of the patient. Second phase- this information is digitally processed and the virtual planning is done through a specific dental CAD software. Third phase- production of the surgical guide is done through computer aided manufacturing.

SURGICAL GUIDE FABRICATION

Preoperative CBCT scans were examined using software16 and a virtual implant is created initially. A half-arch surgical guide is designed to achieve optimal stability by using the teeth mesial anddistal to the edentulous area. The stereolithography (STL) file is exported from the planning software and imported into the 3D printing software to set up and complete the print17-20 . The guide was oriented to minimize cross sectional peeling forces during printing and to allow for the drainage of excess resin, and support points were added in areas that did not interfere with an accurate fit of the guide. Then, the guide with the supports were removed and stainless steel guide tube were inserted and sterilized using autoclave. Then the surgical guide was intraorally evaluated for correct fit and guided surgery was performed for the placement of implants.

The surgical guides can be classified as follows
GUIDED SURGERY





Guided procedures is categorized as static and dynamic systems.
Static systems: It transfers predetermined implant sites in the patient's mouth by using surgical templates. Further, static systems is differentiated into half-guided (template-based guided cavity preparation with free-handed, manual implant insertion) and full-guided implant surgery (template- based guided cavity preparation with guided implant insertion).

Dynamic systems: Instead of using rigid intraoral surgical guides, uses visual imaging tools on a computer monitor to communicate the selected implant positions to the operative field. Dynamic systems include surgical navigation and computer-aided navigation technologies which allows the surgeon to alter the surgical procedure and position of the implant in real time using the anatomical information which is available from the preoperative plan and a CT or CBCT scan based on the conditions encountered during surgery.

ACCURACY OF 3D PRINTED IMPLANTS

- To evaluate accuracy using guided surgery, evaluation of the deviation between the virtual implant planning and the postoperative implant position has to be done. 22-39 by measuring four deviation parameters. These are
- Global deviation
- Angular deviation
- Depth deviation
- Lateral deviation.

All parameters, except the angular deviation, are determined for both the coronal and the apical centre. The global deviation is the 3 dimensional distance between the coronal (or apical) centre of the planned and placed implants. The angular deviation is defined as the three-dimensional angle between the longitudinal axis of the planned and placed implant. The lateral deviation is the distance between the coronal (or apical) centre of the planned implant and the intersection point of the longitudinal axis of the placed implant with the reference plane. The depth deviation is defined as the distance between the coronal (or apical) centre of the planned implant and the intersection point of the longitudinal axis of the planned implant with a plane parallel to the reference plane and through the coronal (or apical) centre of the placed implant. The comparison between surgical results and virtual planned implant positions was performed by using STAP protocol (Superimposition Touch Absolute Precision).

Phase 1: A custom-made impression is taken to reproduce the exact position of the implant on a chalk model.

Phase 2: Fabrication of chalk jig, with an implant transfer included, is done to check directly if the implant position obtained on the model was exactly the same as clinical situation. An endobuccal x-ray was made to ensure that the transfer was well tightened to the implant and the surface of chalk should not reveal any cracks.

Phase 3: model analysed using a tactile scanner.

-Phase 4: Scanned presurgical and postsurgical plaster models is superimposed using software and precision analysis.

-Phase 5: Taking as a reference point, a virtual plan is built on 3 points: central pit of right first molar; central pit of left first molar; inter-incisive area of central incisors; linear and angular deviations between planned and surgically positioned implants were finally measured on the superimposed images.

COMPLICATIONS

The complications can be pre-operative, intraoperative and post operative complications 41

PRE-OPERATIVE

Planning errors resulting from use of non-ideal prosthetic setup

Vertical malposition of implant

Lack of occlusal support causing poor orientation of stent

Patient not properly oriented during the scan

INTRAOPERATIVE

Insertion of wider implant than planned

Insertion of shorter implant than planned

Unstable surgical guide

Inadequate interocclusal space for implant placement

Implant placed more superficially

Lack of integration from heating of bone

POST-OPERATIVE

The post-operative complications includes surgical and prosthetic complications

SURGICAL

- Pulling of the soft tissue from the lingual surface
- Infection
- Acute sinusitis
- Implant instability
- Marginal fistula
- Prolonged pain
- PROSTHETIC
- Misfit between suprastructure and abutment
- Extensive adjustments of the occlusion
- Prosthesis loosening
- Speech problems
- Cheek biting
- Midline deviation of the prosthetic rehabilitation
- Esthetic dissatisfaction
- Screw loosening
- Prosthesis fracture
- Occlusal wear

ADVANTAGES

Time saving

Accurate details and reproduction of scan providing good quality of work and consistent results

It is possible to print complex geometric shapes and interlocking parts that require no assembly

Reduction of production-related material loss

It is possible to produce single objects, in small quantities, at low cost and fast delivery.2

Production of implants which are free of distortion, pores, and cracks 43

They can produce implants analogous to the natural tooth.

8.3D printed implant can produce osteoblasts and new bone formation around implants indicating that bone can grow and cover the entire surface of 3D printed implants.

Customization, flexibility, and freedom in implant design and the possibility of manipulating chemical and physical parameters.

Preservation of vital structures without damaging them as they are more accurate.

DISADVANTAGES

High investment cost.

Likely the largest limitation of 3D printing is the final part quality. Due to the way each successive layer is deposited on top of the last in typical 3D printing methods, an inherent weakness is literally built into the design.

Finishing of final product requires skill and technique sensitive .

Depending on the material, it may still need additional treatment to reach full strength. For example, Zirconia and E-max blocks used in restorative procedures require further sintering to attain high strength after the milling procedure.2

Stereolithography can be done only using light curable liquid polymers .

Resin used is messy and can cause inflammation and irritation on contact and inhalation.

Resin cannot be heat sterilized APPLICATIONS IN

DENTISTRY

The use of 3D printing in dentistry is attributed to various fields which includes:46

3D printed models helps in the designing of surgical templates during craniofacial surgeries.

They are used for restoring congenital or acquired maxillofacial defects more efficiently

They are used in orthognathic surgeries by fabrication of personalized orthognathic surgical guide system.

3D printed allogenic bone graft blocks is used for augmentation of bone defects in reconstructive surgeries.

They are used in the fabrication of fixed and removable prothesis.

They are used in the fabrication of orthodontic aligners,orthodontic brackets, mouth guards, expanders, sleep apnoea appliances.

They are used in splint therapy in TMJ disorders by manufacture of customized splints.

3D printed surgical guides are used in guided apicoctemy ,for access cavity preparation .

They are used for esthetic gingival reconstruction.

3D printed biphasic scaffolds are used in tissue regeneration defects and in healing process.

3D printed models are used as education tools for students.

CONCLUSION:

The additive manufacturing (AM) technologies currently available to process polymers is a reliable option in dentistry. Although the initial investment is high and requires training , it helps to reduce the time for actual patient care. Surgical guide templates can achieve higher precision and accuracy in implant placements which is suitable for complicated procedures and insufficient bone height. When guide fabrication is performed in office by using a desktop stereolithographic printer, limitations of the guide should be recognized, such as the guide fit and depth of placement should be considered. However, future studies are needed to evaluate their accuracy, reproducibility, and clinical outcome over time and function.

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