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3D PRINTING – IMAGING THE FUTURE LAYER BY LAYER

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ABSTRACT

Objectives- With the replacement of conventional OPG, lateral cephalogram to Digital OPG, digital Cephalogram, CBCT technology, conventional models to digital models and emergence of CAD-CAM technology, we can now hope for instant 3 dimensional manufacturing of digital appliances. A three-dimensional (3-D) printing is a process of making 3-D solid ob8qkjects from a digital file. The digital 3-D model is saved in STL format and then sent to the 3-D printer where the layer by layer design of an entire 3-D object is formed. Each of these layers can be observed as a thin sliced horizontal cross-section of the eventual object. Automated model-making with the 3-D printer dramatically reduces fabrication times and exponentially increases output per technician. Thus by transitioning to a fully digital process, there is no need to store bulky physical models and keep all your cases digitally, for as long as you need. The properties, performance, lifetimes and recycling potential of printed parts must also be considered. In dentistry, mass customization and digital inventory aspects, which are areas where additive manufacturing excels, will almost certainly drive significant further growth. The ability to locally create accurate, working models for individual patients along with predictable low cost and rapid turnaround times are appealing factors that will likely drive mainstream acceptance to this technology in some form within dental practices.

Keywords: 3D Printing, CAD-CAM, Additive manufacturing, 3D Printer..

INTRODUCTION

With the newer advances in Orthodontics, the clinician has now shifted from 2D to 3D technology. Additive Manufacturing (AM) is a manufacturing process that deposits materials layer-by-layer to build a tangible product[1]. The most common, and the most popular currently, is 3D printing.

HISTORY[1,2]

Stereolithography – foundational CAM technology:

Stereolithography (stereo,from the Greek stereos, meaning "hard, physically" and lithographie, from the Greek lithos, meaning "stone", and graph meaning "letters") is a technical principle of rapid prototyping.

3D model of the object created with CAD software or a scan of existing model is sliced into cross-sectional layers, creating a computer file that is sent to the stereolithography machine. The manufacture begins in a bath filled with the basic monomers of the photosensitive plastic. The light hardening plastic, such as epoxy resin, is hardened by laser in thin layers. The standard layer thickness ranges from 0.05 to 0.25 mm. A building platform is immersed in the tank filled with liquid photosensitive resin. A laser beam is projected onto selected regions of the resin surface. When the laser hits the resin, the monomer solidifies from a photochemically induced reaction. After the laser beam has scanned all regions of the layer to be solidified, the object is coated with a fresh layer of liquid resin. This function is typically achieved by lowering the object on the building platform and recoating the surface using a wiper blade. Because a solid model in a liquid is being developed, supporting structures are necessary. In large construction projects, overhanging objects must be removed from these supporting structures[3,4,5].

APPLICATION[3,5]

1. Surgical guides (dentistry)
2. Hearing aids (medicine)

What is 3-D printing ?????

In 3-D printer object is printed layer by layer. Therefore, the whole process termed as rapid prototyping or 3-D printing.

Materials used to print 3-D object1,6:

Various materials that can be used for 3-D printing are –

- ABS plastic,
- PLA,
- polyamide (nylon),

- glass filled polyamide,

The historical evolution is shown in Table: 1	
1965	rapid development of rapid prototyping by Magnus.
1971	further development of rapid prototyping by Swainson.
1984	seems to be the beginning when Charles (Chuck) Hull of 3-D systems developed the first working 3-D printer.
1986	Charles Hull founded 3-D Systems and developed the first commercial 3-D Printing machine and it was called as Stereolithography Apparatus. He obtained patency for this Stereo lithographic technique.
1987	Dr Carl Deckard developed the selective laser sintering(SLS) process.
1989	Scott Crump invented fusion deposition modeling and went on to cofound Stratasys. Stratasys and 3D systems are the leaders of 3D printing industry.
1991	Release of: fused deposition modeling(FDM) by stratsys, and solid ground curing and cubital and laminated object manufacturing by Helisys.
1993	Massachusetts Institute of Technology (MIT) patented "3-D Printing techniques." It is similar to the inkjet technology used in 2D Printers
2006	**'RepRap'** was developed. It is a free, self-replicating, desktop three-dimensional (3D) printer that anyone could build in given time and materials, capable of printing plastic objects.
2010	Organovo, Inc., a regenerative medicine company prioritized on bio printing technology, announced the release of data on the first fully bio printed blood vessels.

- stereolithography materials (epoxy resins),
- silver,
- steel,
- titanium,
- photopolymers,
- wax,
- polycarbonate

The known three PolyJet dental materials, specially engineered for dentistry are1:

1. Clear Bio-compatible (MED610),
   - Can produce orthodontic appliances
   - Delivery and positioning trays and
   - Surgical guides for temporary in
   - Mouth placement.
2. Vero Dent Plus (MED690),

   A dark beige material that creates amazingly fine features and finish, and offers excellent strength, accuracy and durability placement.
3. Vero Glaze (MED620),

   An opaque material with A2 shading designed to provide the suitable color match for veneer try-ins and diagnostic wax-ups. Vero Glaze is medically approved for temporary in-mouth placement, up to 24 hr.

Overview of different types of printer [6,7-37]:

Production of 3D parts can be sorted into three major categories-

1. Forming
2. Subtractive
3. Additive manufacturing

Forming – reshaping of a work piece without reducing or adding material e.g. vacuum forming molding.

Subtractive manufacturing – involves using cutting tools to remove unwanted material, as exemplified by the CNC milling of a precision part.

Additive manufacturing – 3-D printing was originally associated with a specific additive processing technique but it is now commonly interchanged with broader general designation of additive manufacturing. It is an effective means to produce limited-run, customized products with complex structure. The ability to satisfy the demand for patient-personalized models, tools and devices makes 3-D printing a potentially good fit with the profession.

CONTINUOUS LIQUID INTERFACE PRODUCTION (CLIP)

A UV-based 3D printing involves continuous liquid interface production that utilizes a bottom-up building approach that is facilitated through a well-controlled oxygen inhibited dead-zone that avoids attachment of the 3D part to an oxygen-permeable curing window.

MULTIJET PRINTING

Multijet (or polyjet) printing utilizes another UV-cured printing format that can produce smooth parts in highly complex geometries that do not require surface finishing since layer dimensions below 20µm are possible. The UV-curable polymeric materials are applied only where desired for the design and since multiple print heads can be used, a wax or other gel like supporting material can be co-deposited for subsequent removal by heating or water washout.

SELECTIVE LASER SINTERING (SLS)

It employs primarily semi-crystalline particulate thermoplastic prepolymer as the building material.The technique relieson two energy sources accomplish part production. First a bed of polymeric particles is preheated close to the melting transition and above the temperature necessary for recrystallization during the cooling cycle.Localized thermal of the particles is achieved by the controlled additional energy input by a high-power CO2 laser.

FUSED fiLAMENT FABRICATION (FFF)

Fused deposition modeling–FDM was developed in the early 1990s.This method is analogous to conventional extrusion or injection molding except that molds are unnecessary. Heated build chambers can be used to minimize the thermal distortion associated with non-uniform cooling. Since polymer melt extrusion in the FFF method requires processible prepolymers, the ionizing radiation provides a route to convert a thermoplastic polymer to a thermoset final printed part that along with more homogeneous mechanical properties also displays greater solvent resistance that may be important in biomedical and other applications.

Merge between filament deposition 3D Printing and electrospinning has further expanded the possibilities for the preparation of reinforced tissue engineering scaffold structures among other applications.

ADVANTAGES OF 3-D PRINTING[1,6,38,39,40,41]:

1. Enhanced treatment procedures;
2. Patient treatment becomes fast, smooth and with greater precision;
3. Dependably superior appliances.
4. High accuracy
5. Better education of patient through visualization
6. Saves from lengthy lab procedure
7. Reduced patient appointment
8. single appointment repair possible
9. Decrease operative time.

APPLICATION

3D printing helps in making patient specific customized prosthesis, Customized Surgical guides etc . It also helps in patient education.

DENTAL PERSPECTIVE

1. Dental restorations, especially dental prostheses, including crowns, veneers, inlays and onlays, fixed bridges,
2. Dental implant restorations,
3. Surgical drill guides
4. Dentures (removal or fixed)
5. Orthodontic appliances,
6. Print craniofacial structures for reference before complex surgeries.

ORTHODONTIC PERSPECTIVE

1. Various removable appliances
2. Arch expansion appliances
3. Clear aligners(Invisalign)
4. Retainers
5. Arch wires
6. Brackets
7. Auxiliaries
8. Trays for indirect bonding
9. Set up models
10. Study models etc.

LIMITATIONS[1,6,42,43,44]:

1. Financial – the initial cost of setting up is quite costly.
2. Regulatory challenges- A medical device must meet standards set by FDA.
3. Medicolegal challenges- there are many unanswered legal questions about 3D printing. Extensive studies are required.
4. Time – different printers uses different materials to print the model which takes different time for manufacturing the model.

CONCLUSION[45,46]

Many years back digital orthodontics was only a dream. With a 3-D printer doing the hard work, dental labs eliminate the manual modeling and let the business grow.

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