A Review

Applications of 3D Printing in Prosthodontics: A Review

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Abstract

3D Printing is a new emerging technology which involves Computer Aided Designing and Computer Aided Manufacturing (CAD/CAM) of 3-Dimensional objects. In the recent few years there is increased use of digital technologies in healthcare sector. The 3D printing technology first used in dentistry to produce dental implants. Computer Aided Designing and Computer Aided Manufacturing (CAD/CAM) involves subtractive and additive manufacturing of object. This review article aims to discuss various types of computer aided additive manufacturing technology with their advantages and disadvantages.

Keywords: 3D printing, Digitalization, Bioprinting, Additive Manufacturing.

INTRODUCTION

Three-dimensional printing is an all-inclusive term for variety of methods that uses data indigital form to fabricate 3D objects by different types of materials. 3D printing is nothing but an "additive manufacturing" as in this process there is deposition of material layer after layer until the desired product is constructed and is also referred as "rapid prototyping".[1]

3D printing technology is not new, it began in early 1980s when Kodama invented an automated method for fabricating 3D models with photo hardening polymer at the Nagoya Municipal Industrial Research Institute.[2] In 1984 three French inventors, conceived the idea and filed a patent for a stereolithography (SLA) process, which is a method for 3D printing that produces objects through photopolymerization, a process by which polymers are formed by adherence of molecules under light.[3] The term "3D printing" was coined in 1995 by Prof. Emanuel Sachs at Massachusetts Institute of Technology (MIT).[4] Currently, various 3D printing methods exist, with a typical resolution of 100 μm per layer and nozzle diameter of 0.4 mm.The main difference between various processes is the way layers are deposited on each other during production and the choice of materials used. Two main methods include Extrusion and Sintering, Extrusion the process in which melted material is pushed through nozzle and the process in which powder or liquid is deposited one layer at a time; then light is applied to harden the powder is sintering.[5] These two methods has both advantages and disadvantages. The production of a 3D model may take minutes to several days, depending on the size, resolution, choice of material, choice of printing method, the printer used, and complexity of the model. 3D printing is significantly decreasing the time span of manufacturing as well as reducing the cost of product with almost zero wastage.[6,7]

Search & Study Selection Criteria

Publications related to implementation of 3D printing in prosthodontics were reviewed particularly. A computerised search on online electronic database PubMed using keywords "3D", "printing", "dental prosthetics" and "bioprinting" was done. Articles with non-English languages, English translation not available were excluded. The relevant article were analysed from reference list as well.

3D Printing in Medicine

The ability to rapidly produce 3-dimensional model of any object that to with less cost led to implementation of this technology to healthcare system. In 1990s, the first anatomical model produced by 3D printing of cranial bone derived from CT scan, illustrating internal anatomical details, including sinuses and foramens.[2] Since then, this technology is successfully applied in variety of medical fields like neurosurgery, cardiology, orthopaedic surgery and more. There are endless applications of 3D printing technology.

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Growth of 3D Printing in Dentistry

The first use of 3D printing in dentistry was in late 1990s to produce dental implants. Other applications of 3D printing technology in dentistry are 3D study models, surgical guides for implant placement and temporary crowns.[2,4] It is cost effective as high quality, accurate products can be fabricated, alsominimizing the number of repeats and bypassing the need for dental laboratories. The demand for 3D printed objects in oral health carehas undeniably increased in past years. The growing demand of dental prosthesis due to aesthetic awareness, is one of the main reason prosthodontics hold a high share in market of 3D technology in dental field. (Fig. 1) the main capability of 3D printing is its low-cost mass customisation of products in less time.

3D Printing Applications in Dentistry

- **Implants:** 3D-printed implants are biocompatible and have similar mechanical properties to human teeth. Maxillofacial dental implants can also be 3D-printed.[2,3]
- **Crowns and bridges:** 3D printers can produce precise crowns and bridges for both provisional and definitive fixed prosthesis. Burn-out resins can be printed to fabricate metal coping by lost-wax technique. Patterns for casting are printed based on Standard tessellation Language (STL) files obtained after scanning the object by intraoral scanner.
- **Surgical Guides:** Dentists use 3D printers to create surgical guides for drilling and cutting. These guides assist the surgeons in dental implant surgery and also the maxillofacial surgeries.
- **Anatomical Models & Replicas:** 3-dimensional anatomi-cal replicas of a patient's mouth and jaws can be produced with 3D printing technology. This gives the dentist a tangible model that can be useful to better understand a patient's anatomy of oral cavity before beginning treatment.[2]

Fig. 1. 3D Printing Applications

3D Printing Technology

3D printers are simple robotic devices. The apparatus includes computer aided designing software that allows objects to be designed in a virtual system. Various processes involved in additive manufacturing are depicted in Fig. 2. CAD software is commonplace in industrial design, engineering, and manufacturing environments, and is also common in the dental laboratory; it is even becoming a future of many dental surgeries. Different types of printing technologies exist, each with their own advantages and disadvantages (Table 1).

Stereolithography (SLA, SL)

A stereolithography apparatus uses a scanning laser to build objects layer-by-layer, one layer at a time in a vat of light-cured-photopolymer resin. Each layer is formed by laser on the surface of the liquid resin, at the point 'build platform' descends another layer of resin is wiped over the surface and the process is repeated. Initially support must be generated by CAD software, printed to resist the wiping action and after complete fabrication, removed from the finished product. After obtaining a finished product, post-processing is to be done that involves removal of excess resin and hardening in a UV (ultraviolet) oven.(10)

Photo-Polymer Jetting (PPJ)

Photopolymer jetting technology uses Ink/Powder light cured resin materials, the light sensitive polymer is jetted on a build platform from inkjet type print head, and cured layer-by-layer in incrementally elevating platform. This technology use either a stationary platform with dynamic print head or dynamic platform with a stationary print head.[2]

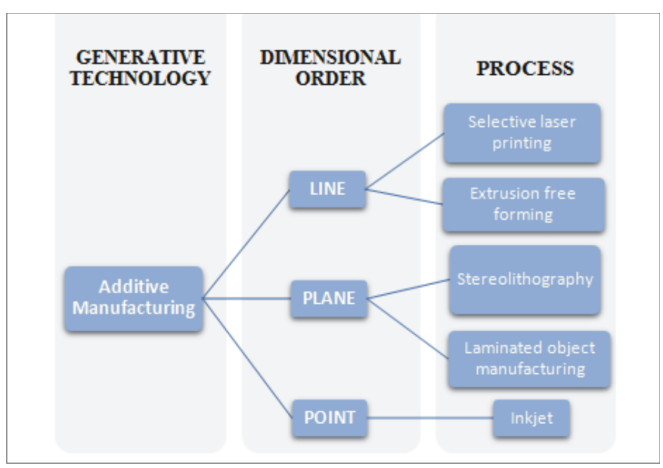

Fig. 2. 3D Printing Process

Powder Binder Printers (PBP)

This apparatus uses a modified inkjet head to print using liquid droplets to infiltrate a layer of powder, layer-by-layer. Typically, a pigmented liquid which is mostly water, is used to print onto the powder. Model is built in layers incrementally, supported by un-filtrated powder so no support material is required. Post-processing is to done to infiltrate printed model will improve strength and surface hardness.[2]

Selective Laser Sintering (SLS)

This technology is available since mid-1980s. To build up structures, scanning laser fuses fine material powder layer by layer, as a powder bed drops down incrementally, and a new fine layer of material is evenly spread over the surface. Polymers used in this process have high melting points and excellent material properties. In this technology also supported by surrounding powder so no support material is required. Materials available include nylon, metal containing nylon mixtures and metal alloys including titanium, cobalt chrome alloys and stainless steel.[10]

Fused Deposition Modelling (FDM)

FDM is one of the earliest 3D printing technology and was used to produce the first medical model. FDM printer is a robotic glue gun; an extruder either have a stationary platform or a platform moves below the stationary extrude. A commonly used material is thermoplastic like biodegradable polymer polylactic acid. Objects are 'sliced' into layers by software and coordinates transferred to the printer.[9]

Techniques	Advantages	Disadvantages
Stereolithography (SLA)	▪ Rapid fabrication. ▪ Lower cost materials if used in bulk. ▪ Able to create complex shapes with high feature resolution	▪ Only available with light curable liquid polymers. ▪ Support materials must be removed. ▪ Resin is messy and can cause skin sensitisation, and may be irritant by contact and inhalation. ▪ Limited shelf life and vat life. ▪ Can not be heat sterilised. ▪ High-cost technology
Photopolymer Jetting (PPJ)	▪ Relatively fast. ▪ High-resolution, high-quality finish possible. ▪ Multiple materials available various colours and physical properties including elastic materials. ▪ Lower cost technology.	▪ Tenacious support material can be difficult to remove completely. ▪ Support material may cause skin irritation. ▪ Can not be heat sterilised. ▪ High cost materials.
Powder Binding Printers (PBP)	▪ Lower cost materials & technology. ▪ Can print in colour. ▪ Un-set material provides support Relatively fast process. Safe materials.	▪ Low resolution. ▪ Messy powder. Low strength. ▪ Can not be soaked or heat sterilised.
Selective Laser Sintering (SLS)	▪ Range of polymeric materials including nylon, elastomers, & composites. Strong & accurate parts. ▪ Self-supported process. ▪ Polymeric materials – commonly nylon may be autoclaved. Printed object may have full mechanical functionality. ▪ Lower cost materials if used in large volume. ▪ Variety of alloys materials including titanium, titaniumalloys, cobalt chrome, stainless steel. ▪ Metal alloy may be recycled. ▪ Fine detail possible.	▪ Elaborate infrastructure requirements. ▪ Extremely costlytechnology moderately costly materials. ▪ Dust and nanoparticle condensate may be hazardous to health. ▪ Explosive risk. ▪ Rough surface. ▪ Elaborate post-processing is required: Heat treatment to relieve internal stresses in printed objects. ▪ Hard to remove support materials. Relatively slow process.

Table 1. Advantages and Disadvantages of 3D printing modalities

CONCLUSION

Several studies and clinical reports suggested that 3D printing technology has huge impact on all aspects of dentistry. The new technology is making it possible to accurately design a 3D object with much less effort and more efficiency and also mass customization at low-cost. The technology is already widely used in dentistry includes prosthodontics for provisional and fixed restorations, printing dental implants, orthodontics and maxillofacial and implant surgery to make surgical guides. Although 3D printers are becoming more affordable, but the cost of running, materials, need of skilled operators should also be considered as well as need of post-processing.

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