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Recent Trends of 3-D Printing in Dentistry- A review

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Abstract

3D printing has been acclaimed as a disruptive technology which will change manufacturing. This technology is used in various fields such as aerospace, defense, art. Recently it has become a subject of great interest in virtual surgical planning. The technology has a particular resonance with dentistry. It has become of great importance with advancement in 3D imaging and modelling technologies such as CBCT, intraoral scanning and CAD CAM in dentistry. Uses of 3D printing include the production of drill guides for dental implants, the production of physical models for prosthodontics, orthodontics and surgery, the manufacture of dental, craniomaxillofacial and orthopedic implants and the fabrication of copings and frameworks for implant and dental restorations. This paper reviews the types of 3D printing technologies available and their various applications in dentistry and in maxillofacial surgery.

Keywords: Three-dimensional printing, Rapid additive manufacturing, Selective laser sintering, Stereo lithography

Introduction

3D printing is also known as additive manufacturing (AM), rapid prototyping, layered manufacturing or solid free form fabrication. It is the process in which multiple layers of material is added one by one under computer control to create three-dimensional object. The key idea of this innovative method is that the three dimensional model is sliced into many thin layers and the manufacturing equipment uses this geometric data to build each layer sequentially until final desired product is completed. It all starts with creation of a virtual design of the object. Scanner may be used to scan buildings, rock formations, etc., to produce a 3D model. The 3D model is sliced and then it is ready to feed into the 3D printer of compatible brand and type. This can be done via USB, SD or Wi-Fi. When a file is uploaded in a 3D printer, the object is ready to be 3D printed layer by layer. The 3D printer reads every slice (2D image) and creates a three dimensional object. Objects of any geometry can be made by this technology. This is what we call slicing.[1-2]

3D printing over CAD CAM technology

1. Subtractive methods such as CAD CAM has some limitations in relation with 3 D printing.
2. Large amount of raw material is wasted because of unused portions of the mono-blocks which are discarded after milling and recycling of the excess ceramic is also not feasible.
3. Milling tools are prone to heavy abrasion and wear which shortens their cycling time.
4. Due to brittle nature of ceramic microscopic cracks can be introduced during the process of machining.

Stereolithography

History of Stereo lithography dates back to 1980 and was introduced by Charles Hull. Principle of making solid objects involves successive printing of thin layers of UV curable photopolymer layer by layer. T It is used to make implant surgical guides because of high mechanical strength, obturators, surgical stents, duplication of prosthesis and burn stents. The curing time and the thickness of the layer polymerized is affected by the dynamics involved in the entire procedure. The kinetics can be controlled by the power of the light source, the scanning speed and the chemistry and amount of the monomer and photo initiators. In addition, UV absorbers can be added to the resin to control the depth of Polymerization. The main disadvantage of SLA is the scarcity of biocompatible resins with proper SLA processing properties. Additional challenges are the use of photo initiators and radicals which may be cytotoxic (with long processing times), entrapment of unreacted monomer and residual photo initiator, and inability to create compositional gradients along horizontal planes.[1,3,4] (Fig. 1)

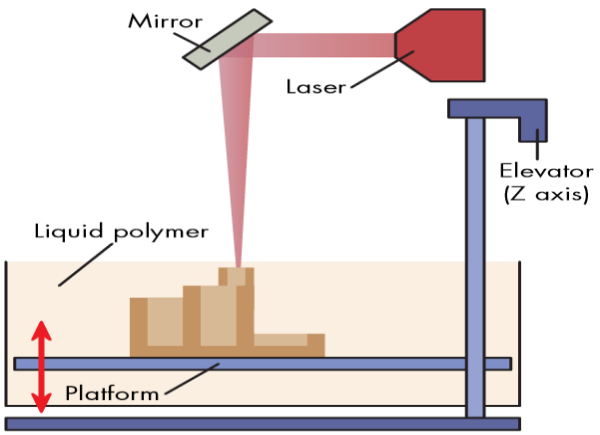

Fig. 1: Stereo Lithography

Fused Deposition Modelling

Fused Deposition Modelling developed by Schott Crump. A thermoplastic filament material is extruded through a nozzle controlled by temperature and the material hardens immediately (within .1 sec) after extrusion. Th

e motion of the nozzle head is controlled by a processor and traces and deposit the material in extremely thin la yer on to a subsidiary platform. Materials such as acrylo nitrile butyro styrene ABS, polycarbonates and poly sul fones are used. Building complex geometries usually ne cessitates the usage of a second extruder – for example, might extrude a water soluble support material.[5] Accur acy will depend upon the speed of travel of the extruder , as well as the flow of material and the size of each 'ste p'. This is the process that is used by most low cost 'ho me' 3D printers. It allows for the printing of crude anato mical models without too much complexity, for exampl e, printing an edentulous mandible.[6,7] (Fig. 2)

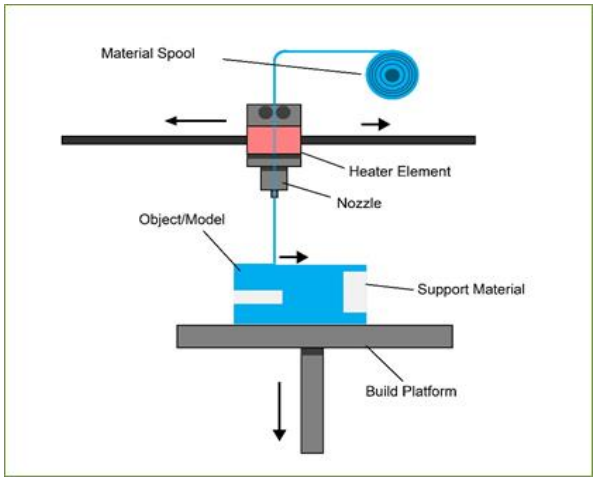

Fig. 2: Fused Deposition Modelling

Selective Laser Sintering

This technology has been brought into usage since mid-1980s and was developed by university of Texas. A fine material powder is fused by scanning laser, to buil d up structures incrementally. As a powder bed drops do wn, a new fine layer of material is spread uniformly ove r the surface. A high (60µm) level of resolution may be obtained. No support material is required as the structur es that are printed are supported by the surrounding pow der.[8] Production of facial prosthesis makes use of poly mers scaffolds (poly amide or poly Caprolactone). Selec tive laser sintering is used in fabrication of anatomical s tudy models, cutting and drilling guides, dental models, and also for engineering/design prototypes.[9] Advantag es are ease of autoclavability of the materials used, full mechanical functionality of the printed objects, lower co st materials if used in large volume. Disadvantages are p owders are messy with increased inhalation risk, techno logy is expensive, and significant climatic conditions su ch as compressed air are required.[9,10] (Fig.3)

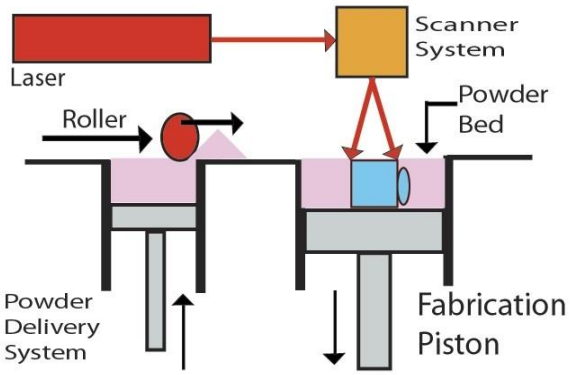

Fig. 3: Selective Laser Sintering

Photopolymer Jetting

- This technology uses either a stationary platform and dynamic print head or a stationary print head and dynamic platform. Light sensitive polymer is jetted onto a build platform from an inkjet type print head, and cured layer by layer on an incrementally descending platform. A support structure is laid down in a friable support material. A wide range of resins and waxes for casting, as well as some silicone-like rubber materials can be printed. This technology gives the resolution of apprx.16 microns and gives the easy access for making complex and fine detailed objects.[1]
- They are useful for printing dental or anatomical study models. Implant drill guides may be quickly and cheaply produced with this technology as they are less bulky. 3D Jet printers may have a single print head like a computer printer, or they may have multiple heads to cover the width of the working platform. Either the print head moves across the working platform, or the platform moves back and forth under stationary print head(s). The 3D systems and printers use a UV lamp or a light source to harden the resin or wax after each layer is jetted.[1,6] Advantages are this technology is fast and cost effective, resolution is high, high-quality finish is possible. Disadvantages are tenacious support material can be difficult to remove completely, support material may cause skin irritation, cannot be heat sterilised, materials cost is high.[3,6] (Fig. 4)

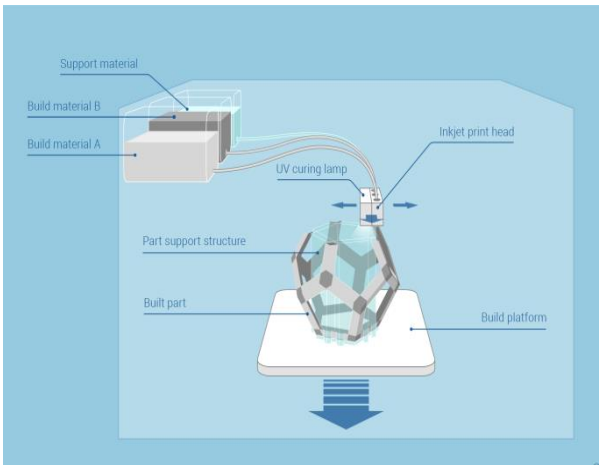

Fig. 4: Photopolymer Jetting

Powder Binder Printer

This apparatus uses a modified inkjet head to print. Liquid droplets are made to infiltrate a uniform and single layer of powder one after the other. Powder bed drops incrementally and a final model is ready which is built of many layers and a new fine layer of powder is swept over the surface. The un-infiltrated powder supports the model, and so no support material is essential. In order to improve the strength and surface hardness in delicate printed model, a cyanoacrylate or epoxy resin is infiltrated during post processing procedures. Although models are fragile and its accuracy is limited but still models are useful as study models or visual prototypes. This technology proved to be an efficient means of constructing an object in full contour. Models are difficult to sterilize which proves to be a major drawback from a surgical perspective. Advantages are the machines and materials are lower cost, but still less expensive. Lower cost materials and technology, can print in colour, Un-set material provides support, process is relatively fast and materials are safe to use. Low resolution, messy powder, Low strength, difficult to heat sterilize are major disadvantages of this process.[1,2,3] (Fig. 5)

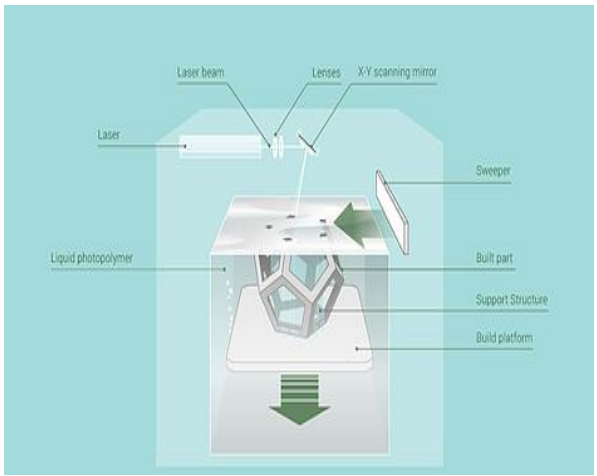

Fig. 5: Powder Binder Printer

Conclusion

There is huge impact of 3D imaging and modelling, and CAD technologies on all aspects of dentistry. With the help of digital data it is possible to make accurate, precise and complex geometrical forms in a variety of materials, locally or in industrial centers through 3 dimensional printing. Although everything we make for our patients can be made by a 3D printer, but still single technology is not sufficient to fulfill all the needs of our patient. Recent advances have an ability to produce lower stiffness scaffolds with high resolution features that allows its application in soft tissue engineering .The technology is gaining importance also in the fields of orthodontics and restorative dentistry with the increase in usage of intraoral scanning systems.

Different 3D printing techniques have become imperative in maxillofacial and implant surgery, to assist the complex treatment planning by constructing virtual anatomical models. It is widely acknowledged that surgery may be less invasive and more predictable with the use of surgical guides printed in resins (commonly) or autoclavable nylon. With the evolution of 3D printing it has become possible to replicate desired geometry without an expensive mold and tooling which were not feasible with conventional techniques. 3D printers are becoming accessible and affordable but the cost of running, materials, maintenance, and skill of operators must be taken into consideration. Health and safety protocols must be strictly followed.3Dprinting takes the efficiencies of digital design to the production stage. The congruence of scanning, visualization, CAD, milling and 3D printing, along with the professions innate curiosity and creativity makes this an exceptionally exciting time to be in dentistry.

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