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3D printing- creating a blueprint for the future of orthopedics: Current concept review and the road ahead!

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ABSTRACT

The use of 3D printing in Orthopedics is set to transform the way surgeries are planned and executed. The development of X rays and later the CT scan and MRI enabled surgeons to understand the anatomy and condition better and helped plan surgeries on images obtained. *3DGraphy* a term used for 3D printed orthopedic patient models and Jigs has gone a step further by providing surgeons with a physical copy of the patient's affected part that can not only be seen but also felt and moved around spatially. Similarly 3D printed Jigs are patient specific devices that are used to ensure optimal screw trajectory and implant placement with minimal exposure. While the use of 3D printed models and Jigs have now become routine, a similar revolution is happening in the field of designing and printing patient specific implants. Metal printing along with enhanced capability to print other biocompatible materials like PEEK and PLA is likely to improve the current implant manufacturing process. On the horizon is another interesting development related to this field — 3D Bio printing. Printing human tissues and organs is considered the final frontier and impressive strides have been made in printing bone graft substitutes and cartilage like material. This paper is an overview of all the current developments and the road ahead in this invigorating field.

1. Introduction

3D printing was originally called “rapid prototyping”. It was primarily meant to create prototypes of industrial designs in a quick and inexpensive manner. The technology used was radically different from conventional methods, which were primarily casting or machining. The method used was additive manufacturing or layered manufacturing in which the material passed through an extruder, and its layers were deposited on top of each other in a pre designated manner and fused to form the final product. This three-dimensional product creation was computer control driven and hence very accurate. Currently there are various technologies available for additive manufacturing and these are collectively referred to as 3D printing in popular vernacular language.

In 1984 Charles Hull, the co founder of 3D systems, set the foundation for this industry, when he filed a patent for stereolithography fabrication system.[1] In this system of manufacturing the layers were added by curing the photopolymers with ultraviolet light lasers. Charles Hull invented STL (Stereolithography) file format, introduced the concept of digital slicing and infill strategies and defined this particular printing process as a “system for generating three-dimensional objects by creating a cross sectional pattern of the object to be formed”. It was in the year 1988 that the technology most commonly used in 3D printing today — Fused Deposition Modeling (FDM) involving special extrusion of plastic material, was developed by Scott Crump and commercialized by Stratasys.[2] The patent for this technology expired in the year 2009, and led to an exponential growth in the field with numerous low cost machines being available to end user.

1.1. Various types of 3D printing technologies used for biomedical applications

There are three key types of rapid prototyping technologies used for biomedical applications: Extrusion (Nozzle), Laser, and Printer based (Fig. 1). Of these Nozzle based FDM, laser based SLA and SLS are more commonly used and are described below. Inkjet printing is multi coloured and used for educational and teaching purposes.

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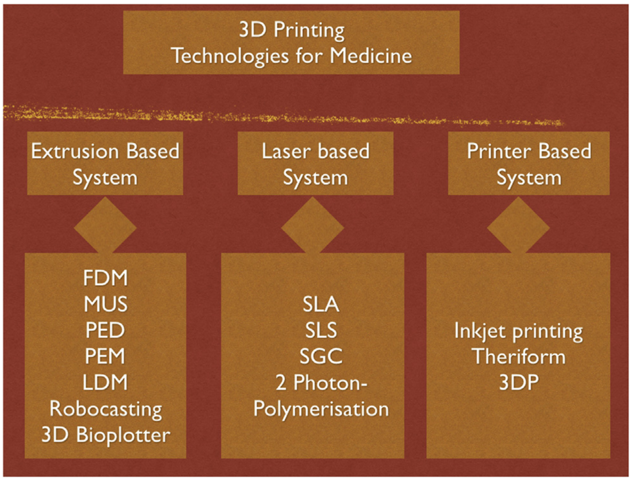

Fig. 1. Various types of 3D printing.

1.2. Nozzle based Fused Deposition Modeling (FDM)

In the FDM the product is manufactured by extrusion of tiny beads or streams of material that immediately harden post extrusion to form solid layers (Fig. 2). A filament of material usually thermoplastic or metal wire is fed into the extrusion nozzle head that heats up this filament and extrudes it out turning the process off and on depending on the design giving it the desired shape.[3]

1.3. Stereolithography (SLA)

This is a fast and very accurate technique to manufacture the desired products.[4] The technology works by converting a special type of plastic typically a liquid photopolymer into a solid three-dimensional object in a layered fashion. The photopolymer is turned into semisolid with heat and it then hardens on contact. The whole process uses ultra violet laser triangulated on to surface using X and Y Scanning mirrors (Fig. 3).

1.4. Selective Laser sintering (SLS)

This type of printer can be used to print plastic, metals and ceramic. In this the laser draws the shape of the desired object fusing it together with upcoming layer when a second set of the

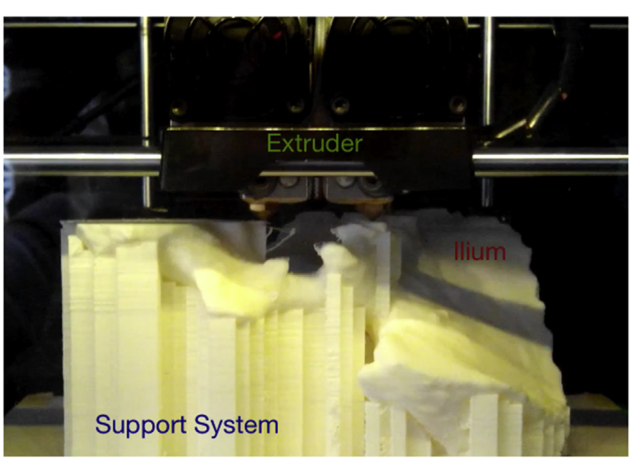

Fig. 2. FDM machine printing a *3DGraphy* model of Acetabulum.

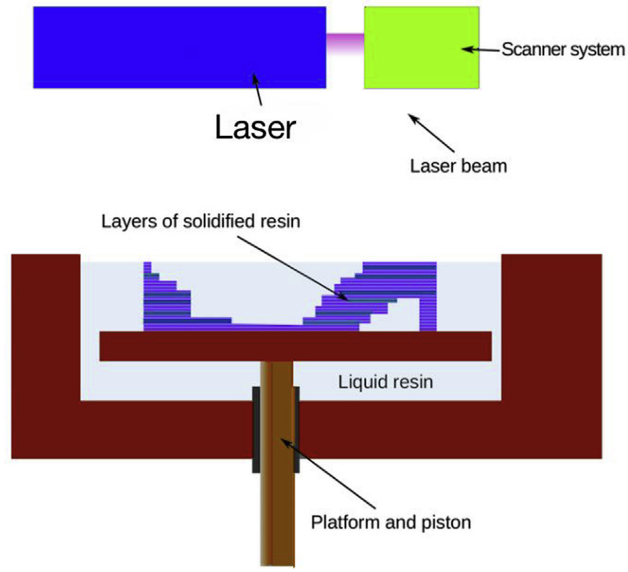

Fig. 3. SLA process.

powder in desired shape is laid down by the laser (Fig. 4). It can be used to create extremely accurate representation as the accuracy is limited only by the laser and the fineness of the raw material powder.[5] Selective Laser melting also called, as SLM is a subtype of SLS and used mainly for metal printing and implant manufacturing.

1.5. Materials available for biomedical use

The various materials that are used for 3D printing are listed in the table below.[6–9] Of these for preparation of 3D Models and Jigs –

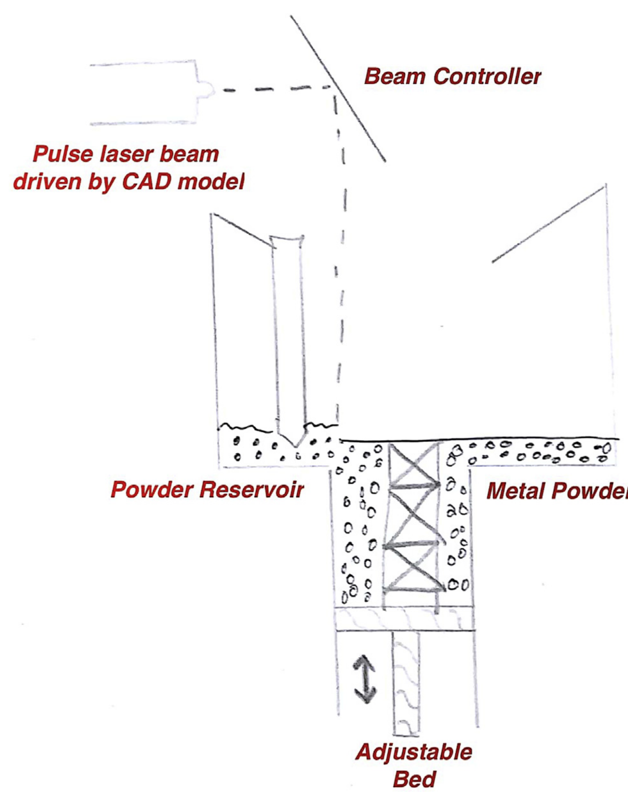

Fig. 4. SLS process.

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