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Research Article

3D-Printing of Scaffolds for Various Human Parts Regeneration: Surveying the Latest Development

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Abstract

The recent advances in the technology of three-dimensional (3D) printing has great potential for making synthetic bone graft substitute as well as various parts of the human body with much better results over the present methods. The same applies in the field of Bioprinting, which is a new and highly encouraging field of research. We shall survey the latest advances in this technology(2017), with the major emphasis' on the equipment used in three dimension printing, as these printers play a great role in the medical and industrial advancement. Also samples of products required in the medical field are shown, as well as references to the software presently available for 3D printing and Bioprinting.

Keywords: *3D printing, medical, bioprinting, scaffolds, bone graft*

1. Introduction

3D printing, also known as additive manufacturing (AM), refers to processes used to synthesize a three-dimensional object in which successive layers of material are formed under computer control to create an object. Objects can be of almost any shape or geometry and are produced using digital model data from a 3D model or another electronic data source such as an Additive Manufacturing File (AMF) file.

Some researchers claim that 3D printing signals the beginning of a third industrial revolution, succeeding the production line assembly that dominated manufacturing starting in the late 19th century.

The term 3D printing's origin *sense* is in reference to a process that deposits a binder material onto a powder bed with inkjet printer heads layer by layer. More recently, the United States and global Technical standards use the official term additive manufacturing for this broader sense.

What is 3D Printing?

Three-Dimensional printing is an additive process used to make a three-dimensional object.

It involves the following processes: 1) Modeling, 2) Printing, and 3) Finishing

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Modeling

3D printable models may be created with a computer-aided design (CAD) package, via a 3D scanner, or by a plain digital camera and photogrammetry software. 3D printed models created with CAD result in reduced errors and can be corrected before printing, allowing verification in the design of the object before it is printed.

The manual modeling process of preparing geometric data for 3D computer graphics is similar to plastic arts such as sculpting. 3D scanning is a process of collecting digital data on the shape and appearance of a real object, creating a digital model based on it.

Printing

Once modeling is completed, the produced software file needs to be processed by a piece of software called a slicer, which converts the model into a series of thin layers and produces a G-code file containing instructions tailored to a specific type of 3D printer (FDM printers). This G-code file can then be printed with 3D printing client software (which loads the G-code, and uses it to instruct the 3D printer during the 3D printing process).

Printer resolution describes layer thickness and X-Y resolution in dots per inch (dpi) or micrometers (µm). Typical layer thickness is around 100 µm (250 DPI), although some machines can print layers as thin as 16 µm (1,600 DPI). X-Y resolution is comparable to that of laser printers. The particles (3D dots) are around 50 to 100 µm (510 to 250 DPI) in diameter.

Construction of a model with contemporary methods can take anywhere from several hours to several days, depending on the method used and the size and complexity of the model. Additive systems can typically reduce this time to a few hours, although it varies widely depending on the type of machine used and the size and number of models being produced simultaneously.

Traditional techniques like injection moulding can be less expensive for manufacturing polymer products in high quantities, but additive manufacturing can be faster, more flexible and less expensive when producing relatively small quantities of parts. 3D printers give designers and concept development teams the ability to produce parts and concept models using a desktop size printer (https://en.m.wikipedia.org/wiki/3D_printing).

Finishing

Though the printer-produced resolution is sufficient for many applications, printing a slightly oversized version of the desired object in standard resolution and then removing material with a higher-resolution subtractive process can achieve greater precision.

Some printable polymers such as ABS, allow the surface finish to be smoothed and improved using chemical vapor processes based on acetone or similar solvents.

Some additive manufacturing techniques are capable of using multiple materials in the course of constructing parts. These techniques are able to print in multiple colors and color combinations simultaneously, and would not necessarily require painting.

Some printing techniques require internal supports to be built for overhanging features during construction. These supports must be mechanically removed or dissolved upon completion of the print.

All of the commercialized metal 3D printers involve cutting the metal component off the metal substrate after deposition. A new process for the GMAW 3D printing allows for substrate surface modifications to remove aluminum or steel (https://en.m.wikipedia.org/ wiki/3D_printing, Ferris *et al*, 2013)

3. Discussion about Bioprinting

Industrial 3D printing has been around since the 1980s and was initially known as rapid prototyping because of its most popular application – making prototypes for manufacturing. The term additive manufacturing includes such technologies as stereolithography, fused deposition modeling (FDM), laser sintering, and electron beam sintering. Recent advances in additive manufacturing reveal that bioprinting, i.e., the additive manufacturing of tissues and organs, is about to open up a whole new realm of possibilities. Though this technology has much in common with traditional additive manufacturing, and indeed adopts certain elements, there are a number of unique technical and legal challenges to implementing the use of bioprinted materials.

As shown in Figure 1, in order for additive manufacturing of biomaterials to work, the supply, applicator, and support structure must be constructed so that the biomaterial remains viable before, during, and after the construction of the tissue and/or organ. They must also be able to thrive and grow in the environment it is intended for (after application). The high temperatures associated with traditional fused deposition modeling (FDM), for example, could never work because the biomaterial would be destroyed. Further, something must hold the biomaterial together to shape it for its application, much like a support structure in traditional additive manufacturing.

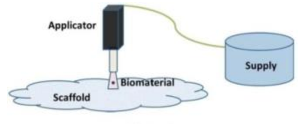


Figure 1

For many applications, a suitable support structure, known as a scaffold, must be carefully constructed. The scaffold holds the biomaterial in place and allows the living tissue to live and regenerate. In addition, scaffold materials must have suitable strength, biocompatibility, and shaping characteristics. Currently, the materials being used for scaffolds are selected either because of their compatibility with cell growth and function or because of their cross-linking or extrusion characteristics. Polymers, such as alginate and fibrin hydrogel materials, have been used in cell-based direct biofabrication techniques in which cell-laden hydrogels are printed. Common materials include synthetic or natural polymers and decellularized extracellular matrix (ECM). Examples of naturally derived polymers include alginate, gelatin, collagen, chitosan, fibrin, and hyaluronic acid, often isolated from animal or human tissues.

Synthetic materials are also employed and include polyethylene glycol (PEG)(4), polycaprolactone (PCL)(5), polylactic acid (PLA)(6), polyglycolic acid (PGA), and poly(lactic-co-glycolic) acid (PLGA)(7). The use of whole-organ decellularization to create a three-dimensional (3D) extracellular matrix (ECM) helps to preserve the native tissue architecture, including the vasculature.

The system, known as the Integrated Tissue and Organ Printing System, was developed over a 10-year period. The system deposits both biodegradable, plastic-like materials to form the tissue shape and water based gels that contain cells. A major challenge of tissue structures is to ensure that the implemented structures live long enough to integrate with the body. This was addressed by creating a hydrogel that holds the cells and a lattice structure of micro channels that allows nutrients and oxygen from the body to provide nutrients until the tissue regenerates its own system of blood vessels (https://www.pinterest.com /pin/527132331366754259/).

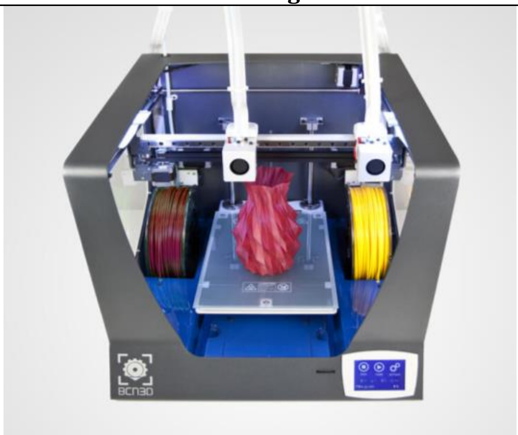
Here are some samples produced by 3D printing in the medical field

		
A 3D printed femoral chondyle implant. [Image: Andrew Francis Wallace] University of Waterloo Engineer Builds 3D Printer for Bone and Joint Replacements by Scott J Grunewald | May 11, 2016 | 3D Printers, 3D Printing, 3D Printing Materials, Medical 3D Printing	A sample 3-D printed scaffold that matches the lower jaw of a female patient. Johns Hopkins Medicine	3-D Printer Can Now Make Body Parts – Ears, Bones, and More.
https://3dprint.com/133667/bone-and-joint-replacements/	ttp://www.hopkinsmedicine.org/news/media/releases/the_search_for_better_bone_replacement_3_d_printed_bone_with_just_the_right_mix_of_ingredients	Reference:http://www.thetrentonline.com/far-tech-skin-bones-oh-body-parts-can-make-3-d-bio-printers/

 From left to right: a normal spine model, a spine model implanted with a traditionally used titanium tube, and a spine model implanted with a 3D-printed artificial vertebra. Reuters/Jason Lee		 The BioPen allows surgeons to draw bio-ink directly onto damaged bone or cartilage to repair damage. Image source: University of Wollongong; used with permission.
http://www.businessinsider.com/3d-printing-can-create-replacement-bones-2014-8	https://3dprint.com/125300/swedish-3d-printed-cartilage/	http://www.nova.org.au/people-medicine/bioprinting

Latest Three-Dimension Printers (2017)

Original Prusa i3 MK2 	Topline features of the Original Prusa i3 MK2 are a new MK42 heatbed, a PEI print surface, integrated leadscrew Z axis, full mesh bed as auto-leveling, improved construction, faster printing and more materials with an E3D V6 hotend, plus improved firmware and printer self-test. A substantial portion of this 3D printer's components have been fabricated in sturdy ABS plastic.

BCN3D Sigma	Formlabs Form 2
	
The BCN3D Sigma is a large, semi open-frame 3D printer that's geared for use primarily by hobbyists and professionals. It has an easy setup that's comparable to the Ultimaker 2 series, which makes it a good fit for a general audience	This premium device is equipped with a peeling mechanism, a heated tank, a touchscreen display, wireless controls, and an automated resin system. It also has some cleverly designed software to make fabricating models as painless as possible, and the customer support is well established.
https://www.bcn3dtechnologies.com/en/phylosophy/	https://formlabs.com/3d-printers/form-2/

3D Printer 2017: PowerSpec 3D

Features: an LCD screen; new acrylic door and hood to keep the build chamber temperature stable; LED strip lighting; pre-assembled chassis; power supply automatically supports 110-240 VAC input

Features: an LCD screen; new acrylic door and hood to keep the build chamber temperature stable; LED strip lighting; pre-assembled chassis; power supply automatically supports 110-240 VAC input Source: http://www.microcenter.com/product/435491/3D_Pro

Software for 3D printing

Table 1: 20 Best 3D Printing Software Tools (Most are Free)

Software	Function	Level	Price	System
123D Catch	3D Design, CAD	Beginners	Free	PC, Android, iOS, Windows Phone
3D Slash	3D Design, CAD	Beginners	Free	PC, Mac, Linux, Web Browser
3D-Tool Free Viewer	STL Viewer, STL Checker	Intermediate	Free, Pro: $695	PC
3DTin	3D Design, CAD	Beginners	Free	Web Browser
Blender	3D Design, CAD	Professional	Free	PC, Mac, Linux
CraftWare	Slicer, 3D Printer Host	Beginners	Free	PC, Mac
Cura	Slicer, 3D Printer Host	Beginners	Free	PC, Mac, Linux
FreeCAD	3D Design, CAD	Intermediate	Free	PC, Mac, Linux
Meshfix	STL Checker, STL Repair	Intermediate	Free	Web Browser
MeshLab	STL Editor, STL Repair	Professional	Free	PC, Mac, Linux
Meshmixer	STL Checker, STL Repair, STL Editor	Professional	Free	PC, Mac
Netfabb Basic	Slicer, STL Checker, STL Repair	Intermediate	Free	PC, Mac, Linux
OctoPrint	3D Printer Host	Professional	Free	PC, Mac, Linux
Repetier	Slicer, 3D Printer Host	Intermediate	Free	PC, Mac, Linux
Sculptris	3D Design, CAD	Beginners	Free	PC, Mac
Simplify3D	Slicer, 3D Printer Host	Professional	$149	PC, Mac, Linux
SketchUp	3D Design, CAD	Intermediate	Free	PC, Mac, Linux
Slic3r	Slicer	Professional	Free	PC, Mac, Linux
TinkerCAD	3D Design, CAD	Beginners	Free	Web Browser
ViewSTL	STL viewer	Beginners	Free	Web Browser

Conclusion

Great advances happened to the technologies in the last decade. A large number of 3D printing processes are now available at very economical prices, as well as prices of printers. This is mainly due to the competition between the manufactures, and the huge demand for products made by 3D printing. The main differences between these new technologies lies in the methods the way layers are deposited to create parts and in the materials that are used to melt or soften the material to produce the layers, for example. selective laser melting (SLM) or direct metal laser sintering (DMLS), selective laser sintering (SLS), fused deposition modeling (FDM), or fused filament fabrication (FFF), while others cure liquid materials using different sophisticated technologies, such as stereolithography (SLA). With laminated object manufacturing (LOM), thin layers are cut to shape and joined together (e.g., paper, polymer, metal).

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Explore Printing Bioprinting, Medicine Cranial, and more! https://www.pinterest.com/pin/527132331366754259/

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