GIAP

International Journal of Students Research in Technology & Management
Vol 3 (05), May 2015, ISSN 2321-2543, pg346-349

3D-BIOPRINTING

(Application of 3D printer for Organ fabrication)

Y.Aishwarya[1], B.Gourangi[2]
Department of Biomedical Engineering, Thadomal Shahani Engineering College
Mumbai, Maharashtra, India
[1] aishwaryayadav1234@gmail.com
[2] grbhoir@gmail.com
Guided By: Prof.K.Abhijeet.
Department of Biotechnology, Thadomal Shahani Engineering College
abhijeet.kadam@thadomal.org

Abstract— Chronic shortage of human organs for transplantation has become more problematic in spite of major development in transplant technologies. In 2009, only 27,996 (18%) of 154,324 patients received organs and 8,863 (25 per day) died while on the waiting list. As of early 2014, approximately 120,000 people in the U.S. were awaiting an organ transplant. The solution to this problem is 3D bio-printing. This technology may provide a unique and new opportunity where we can print 3D organs. It incorporates two technologies, tissue engineering and 3D printing. 3D bioprinting involves dispensing cells onto a biocompatible scaffold using a successive layer-by-layer approach to generate tissue-like three-dimensional structures. It uses instruction in the CAD file for formation of the object, high level computer programming and ability to build highly advanced computer systems, it offers hope for bridging the gap between organ shortage and transplantation needs.

***Index Terms*— Introduction, 3D Bioprinting and its Working, Organ Fabrication, Advantages, Disadvantages, Future Scenario, Conclusion.**

I. INTRODUCTION

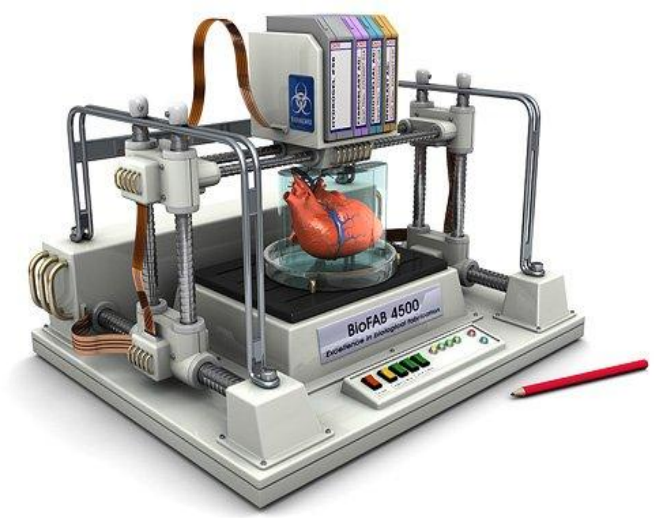
3D printing called as “stereolithography” was invented by Charles Hull in early 1980s when he was working on making plastic objects from photopolymers at the company Ultra Violet Products in California. Advances made by other researchers in Charles work has revolutionized manufacturing, and is poised to do the same in many other fields—including medicine. Medical applications for 3D printing are expanding rapidly and are expected to revolutionize health care. Actual and potential uses of 3D printer, can be organized into several broad categories, these include tissue and organ fabrication, creation of customized prosthetics, implants, and anatomical models, and pharmaceutical research regarding drug dosage forms, delivery, and discovery. Organ transplant surgery and follow-up is expensive, costing more than $300 billion in 2012. Additionally organ transplantation involves the often difficult task of finding a donor who is a tissue match. Everyday almost 79 people receive the organ they need, while 18 die on the waiting list. This problem could likely be eliminated by using cells taken from the organ transplant patient’s own body to build a replacement organ. This would minimize the risk of tissue rejection, as well as the need to take lifelong immuno suppressants.

II. 3D BIOPRINTING AND ITS WORKING

3D bio-printing is a regenerative science and process for generating spatially-controlled cell patterns in 3D, where cell function and viability are preserved within the printed construct. Using 3D bio-printing for fabricating biological constructs typically involves dispensing cells onto a biocompatible scaffold using a successive layer-by-layer approach to generate tissue-like three-dimensional structures. The idea of 3d printers are from inkjet printers, driven by a motor, moves in horizontal strips across a sheet of paper.The limitation of inkjet printers is that they only print in two dimensions i.e along the x-axis and y-axis. A 3-D printer overcomes this by adding a mechanism to print along an additional axis, usually labeled the z-axis in mathematical applications. Organ printing takes advantage of 3D printing technology to produce cells, biomaterials, and cell-laden biomaterials individually or in tandem, layer by layer, directly creating 3D tissue-like structures. Various materials are available to build the scaffolds, depending on the desired strength, porosity, and type of tissue, with hydrogels usually considered to be most suitable for producing soft tissues. 3D bioprinting incorporates two technologies, tissue engineering and 3D printing. Tissue engineering provide the basis of a 3D bioprinter. Cells are manipulated so that they can fix or replace a biological function. A 3D printer is used to make a prototype of the product and given a material can construct any object. It uses rapid prototyping where complex hierarchical scaffold designs can be created by adding material layer by layer, this is also called as additive manufacturing.
A typical 3D bioprinter consists of:
(1)A Print head mount is attached to a metal plate running along a horizontal track. The x-axis motor propels the metal plate (and the print heads) from side to side, allowing material to be deposited in either horizontal direction. (2)Elevator is a metal track running vertically at the back of the machine, it is

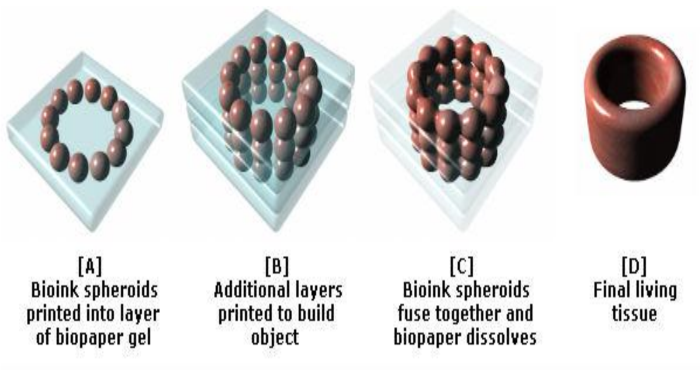
driven by the z-axis motor and moves the print heads up and down. This makes it possible to stack successive layers of material, one on top of the next. (3)The platform may supports a scaffold, a petri dish or a well plate, which could contain up to 24 small depressions to hold organ tissue samples for pharmaceutical testing. A y-axis motor moves the platform front and back. (4)Reservoirs equivalent to the cartridge of an inkjet printer is attached to the print head and contains the biomaterial to be deposited. (5)Print heads or syringes is a small nozzle above the platform. When material is passes from reservoirs through these syringe it forms a layer on the platform. (6)Triangulation sensor software communicates with the machines to know about the exact location of the print heads in d process as it moves along x, y and z –axis respectively. (7)Micro-gel helps the bioink to remain suspended and prevents them from settling or clumping. (8)Bioink is a special material formed of cells whose organ is to be produced and also the surrounding supporting cells.

The organ printing concept of how 3D functional organs are printed from the bottom up using living cells in a supportive medium is shown in the figure given below.

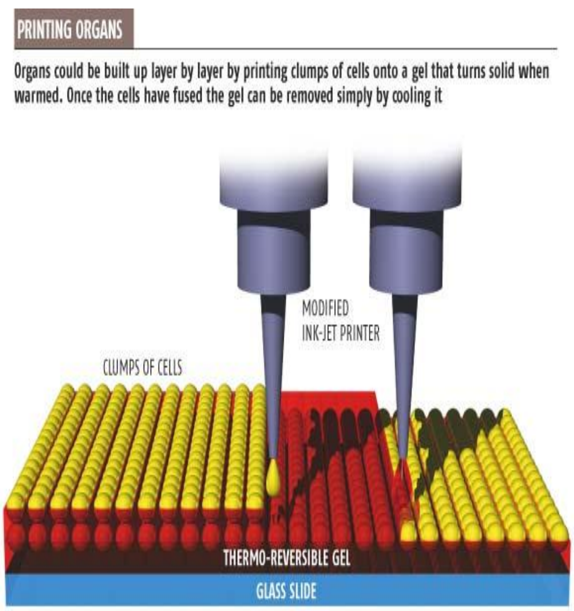


A process of bioprinting has emerged: (1) 3D blueprint of desired organ is made from a CT or MRI image loaded in the computer, using CAD software. (2)Slice-by-slice model of the patient's organ is build in a three dimensional space. (3) Hitting the Print button will send the modelling data to the bioprinter. (4)Printer outputs the organ one layer at a time, using bio-ink and gel to create the complex multicellular tissue and hold it in place. (5) Organ is removed from the printer and placed in the incubator , so that it starts living and working. (6)Printed organ cells are deposited in its required three dimensional space where they differentiate into mature cells.

The process of Bioprinting is given in Figure 2(a) and 2(b).



2(a)



2(b)

III. APPLICATIONS OF 3D BIOPRINTING

3D bioprinting has been applied in medicine since the early 2000s, when the technology was first used to make dental implants and custom prosthetics. Since then, the medical applications for 3D bioprinting have evolved considerably. Recently published reviews describe the use of 3D bioprinting to produce bones, ears, exoskeletons, windpipes, a jaw bone, eyeglasses, cell cultures, stem cells, blood vessels, vascular networks, tissues, and organs, as well as novel dosage forms and drug delivery devices. A discussion of some of these medical applications follows:

Liver Tissue:

Organova, a bioprinting company which specializes in successful printing of bones, blood vessels heart tissues have recently accounced the bioprinting of 3D liver tissue. This tissue is made from three types of cells found in the human liver. Liver cells need to be arranged in a pattern or they don't work. That means 3D tissue can give clearer results than the 2D collections of cells that labs currently use because the cells interact and mimic a full liver more convincingly. Organovo said it also makes the drug discovery process faster and, as a result, cheaper. Organovo prints its liver tissue with a machine that isn't that far removed from the inkjet printers that can be found on a desktop. Needle-like nozzles lay down the cells in a precise pattern. The tissue can survive for up to 42 days while researchers expose it to exploratory drugs.

The liver tissue is shown in Figure. 3.

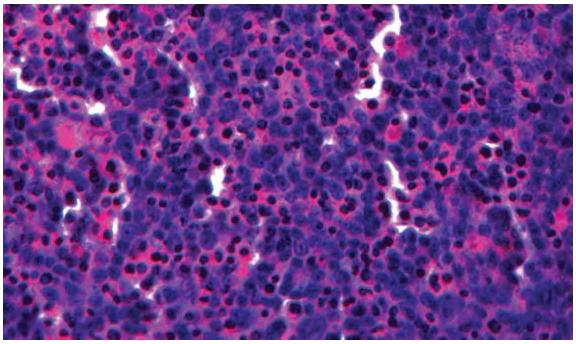


Fig. 3

Human Ear:

Professor Alex Selfalian and his team at University College London have discovered that the structure of the ear can be printed using a biological 'ink' which builds the shape of the organ. It is then implanted under a flap of skin in the arm where it develops blood vessels before being attached to the side of the head. It is already proven that the ears can be created on the back of rats. When children are born with severe facial deformities, surgeons must take cartilage from other parts of the body, such as the ribs, which is an invasive and painful procedure. Then they fashion the shape of a nose or an ear by hand, before placing this 'scaffold' under the skin of a patient. However the new technique allows scientists to scan the undamaged ear and flip the picture to make a mirror image copy. The image is then printed in 3D using a type of spongy plastic to form a scaffold. That scaffold is then implanted under the skin of the patient's arm where the skin grows over it. The scaffold remains under the skin for between four to eight weeks until the skin has grown completely around it and blood vessels are functioning correctly. After that, a surgeon removes the ear and attaches it to the side of the head. Trials will begin in India and the UK early next year. There are already more than a dozen children waiting to take part in Mumbai where there is a desperate need for facial reconstruction.

A 3D printed ear is shown in Figure. 4.

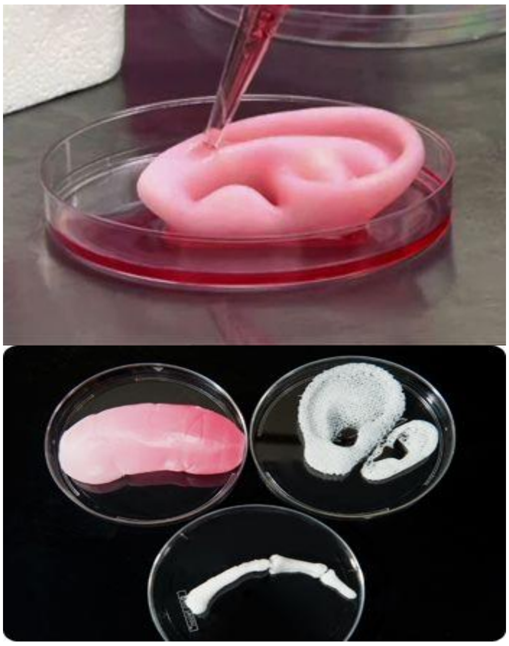


Fig. 4.

Skin:

Engineering students in Canada have created a 3D printer that produces skin grafts for burn victims. Print Alive, the new machine was developed by University of Toronto engineering students Arianna McAllister and Lain Leng, who worked in collaboration with Professor Axel Guenther, Boyang Zhang and Dr. Marc Jeschke, the head of Sunnybrook Hospital's Ross Tilley Burn Centre. While the traditional treatment for serious burns involves removing healthy skin from another part of the body so it can be grafted onto the affected area, the PrintAlive machine could put an end to such painful harvesting by printing large, continuous layers of tissue – including hair follicles, sweat glands and other human skin complexities – onto a hydrogel. Because growing a culture of a patient's skin cells ready for grafting can typically take more than two weeks, the machine prints the patient's cells out in patterns of spots or stripes rather than a continuous sheet, to make them go further. The result is a cell-populated wound dressing that reproduces key features of human skin and can be precisely controlled in terms of thickness, structure and composition.

The process of Skin printing is given in Figure. 5.

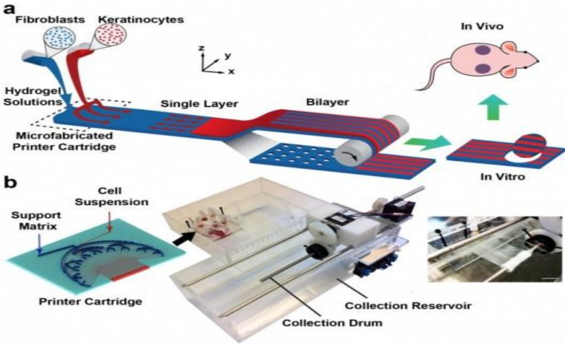


Fig. 5

IV. ADVANTAGES AND DISADVANTAGES OF 3D BIOPRINTING

The technology of 3D bioprinting can prove to be of huge benefit. Most of the human organs can be fabricated using this technology, as long as the fibroblast can be reprogrammed to be that organ cell. Organ transplantation shortage can be overcome and lives could be saved. Once the organ is planted in the body there will be no problem of organ rejection from the body as the organ will be made of the patient's own DNA. It can be used to treat anyone since organ can be developed for an individual. But, despite recent significant and exciting medical advances involving 3D bioprinting, notable scientific and regulatory challenges remain and the most transformative applications for this technology will need time to evolve. Also this technology is still very expensive. The organ being made can die if no blood vessels are created within the organ. Stem cell of a individual can be used for developing an organ but it is costly.

V. CONCLUSION

3D printing has become a useful and potentially transformative tool in a number of different fields, including medicine. 3D bioprinting technology could revolutionize and reshape the medical world. Implants and prostheses can be made in nearly any imaginable geometry through the translation of x-ray, MRI, or CT scans into digital. . Lives could be saved.

REFERENCES

[1] http://www.popsci.com/technology/article/2013-02/scottish-scientists-print-human-embryonic-stem-cells-3-d-printer

[2] http://organprint.missouri.edu/publications/TRENDSBIOTECH.2003.pdf

[3] http://en.wikipedia.org/wiki/3D_bioprinting

[4] http://www.techrepublic.com/article/3d-bioprinting-10-things-you-should-know-about-how-it-works/

[5] http://www.techrepublic.com/article/new-3d-bioprinter-to-reproduce-human-organs/

[6] http://www.organovo.com/science-technology/bioprinting-process

[7] https://gigaom.com/2014/11/18/organovo-begins-selling-3d-printed-liver-tissue/

[8] http://health.howstuffworks.com/medicine/modern-technology/3-d-bioprinting2.htm