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3D Printing in Biomedical Applications – A Review

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Abstract: **--This study deals with the 3D Printing technology, a type of additive manufacturing in which the 3D object is imitated to be visual within the allocated period of time interval that resembles similar in considered aspects of real world object. The material used here includes powders of polymer mass that are solidified by directional laser heating. While talking about BIO-PRINTING, the material used is living tissues, calcium source, vascular tissue, placental fluid, embryonic stem cell etc., and the entire organ is regenerated from the tissue, which was printed in the enzymatic incubation medium. The organ is similar to the patient's organ; the patient's organ information is get read from many scanning devices. Coupling all the images will result in the three dimensional structure. The printing is done with the help of the 3D printer on the basis of obtained 3D image and the artificial organ (imitation of real organ) is being made. The making of organ is controlled by, speed of filling tissue, temperature at which the process is carried out, bonding agent to bond the tissues together, incubation medium, type of tissue, body immunity, stem cell growing phenomenon, filler head movement respective to all the axes, slicing path, etc.. The procedure is simple related to the rapid prototyping; the produced artificial organ (human bone, human kidneys, bladder, etc., can be replaced with the defected organ. Thus, the controlled action of all the parameters can lead to the organic replacement with the birth similar organs.**

Index Terms: — 3D Picturization, Build-Up, Slicing, Organic Growth.

I. INTRODUCTION

3D printing is the process by which, the real world object is produced as a prototype model that helps in analysis of various aspects. 3D printing concept arises from the RP Method, in which the fluid fill is replaced by the layer of additive powder fill, which gets solidified due to intensive laser head [1]. Laser solidify the powder of thermosetting plastic, then the new layer of powder is filled by special arrangement, here the depth of each fill depends on the additive layer's depth. The operation is repeated up to the attainment of required shape and size of the component is achieved. The operation depends on the parameters such as type of laser; pointed laser radius (controls the thickness of additive single layer, i.e. the radius of laser spot is the single fill thickness, if we want two time thickness, we have to led the laser to move two times), material of the powder, depth of layer fill, speed of laser head movement, distance between the point the laser tip and the solidifying powder layer. The 3D printing is adopted to print the complex and intricate components. It is adopted at the place where the subtractive machining is not possible.

II. 3D BIO-PRINTER PRINCIPLE

The 3D Bio-Printer works on the principle of RAPID PROTOTYPING. It is one of the additive manufacturing processes, where layer by layer addition of material based on the sliced CAD Model. The CAD model defines the shape and size of final required object.

A. Mechanism of printing artificial human kidney

3D biological printer is the device that makes use of living tissues, material calcium, connecting tissue, protein (keratin substance), etc. and it is built in the sequence of sliced patterns. The patterns are then made to form the real object. It absolutely does the function of the organ. (Kidneys, bones, skull, heart valve, etc.,).

Scanning electron microscope image of RED BLOOD CELL shows the diameter of RSC as 6-8 micrometers in diameter, while urea and other components present in the human urination is of diameter 9 to 12 Armstrong. Thus, the filtering of blood along with impurities is simple with the use of set of Nanotubes. The nanotubes allow the impurities to flow through, but block the blood to flow through it. Thus, the impurities are getting collected from the one end and allowed it to flow through the collecting tube followed by storing in the bladder.

Scaffolding is a temporary structure used to support people and material in the construction or repair of buildings and other large structures [2]. It is usually a modular system of

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metal pipes or tubes, although it can be from other materials. Scaffold structure is the base for making kidney in this process. The various contents present in the urine are salts (Na, K, P etc.,), vitamin, water, urea, creatinine, etc. The atomic radius of urea is comparatively smaller than the other components present in the urination. Thus removal of the urea is made easy and the collection of urine in the bladder can also be made.

B. Major factors affecting the 3d-printed kidney in body

The kidney should purify the blood for that the nanotubes arrangement is provided in the tubular-spiral-bundle, blood enters at one side of the tube during purification and leaves at the other side of the tube after purification. The two major factors that affects filtering is,

(i) Blood Pressure

Fluid in the tube exerts circumferential pressure to the walls of the tube, the filtering is made easier. A person's normal blood pressure is the dialyzing source. It works faster for the persons having higher blood pressure and slower for the person having the low blood pressure.

(ii) Body temperature

The presence of foreign particles in the body and the food digestion in the alimentary canal makes the temperature of the body to increase. The killing of foreign body (virus, bacteria, etc.,) by White Blood Cell makes the body temperature to increase and speeds up the action of filtering.

C. Connection with body tissue

The implanted kidney should compatible with the body tissues and blood vessels, and then only the implantation is stable [5]. For that purpose the outermost layer is made to adhere with the body cells.

The outer most layer of printed kidney is coated with pyrolytic carbon, and secured to the surrounding tissue with a mesh of woven fabric called DacronTM (du Pont's trade name for polyethylene terephthalate). The mesh allows for the body's tissue to grow while incorporating the kidney.

D. Materials

The material used to build the layer of kidney is bio-polymers, which are compatible to the body tissues, blood cells and immune system. Biopolymers are polymers produced by living organisms.

E. Polymer

Cellulose, starch, proteins, peptides, DNA and RNA are the examples of biopolymers

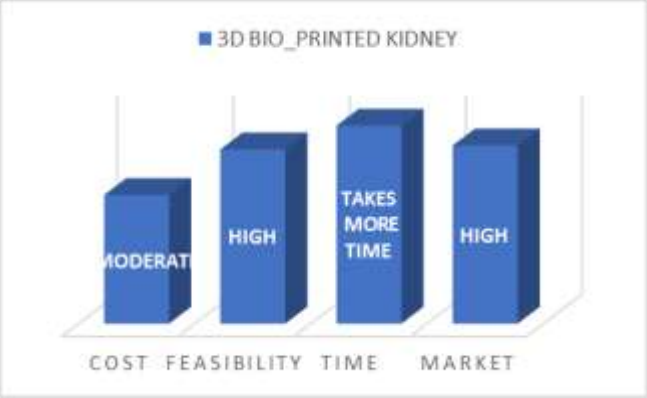
F. Monomer

The monomeric units, respectively, are sugars, amino acids, and nucleotides. Cellulose is both the most common biopolymer and the most common organic compound on Earth. About 33% of all plant matter is cellulose.

Some biopolymers are biodegradable. That is, they are broken down into CO2 and water by microorganisms. In addition, some of these biodegradable biopolymers are compostable [3]. That is, they can be put into an industrial composting process and will break down by 90% within 6 months. Biopolymers that do this can be marked with a 'compostable' symbol, under European Standard EN 13432 (2000). Packaging marked with this symbol can be put into industrial composting processes and will break down within 6 months (or less). An example of a compostable polymer is PLA film under 20 micrometer thickness. Films which are thicker than that do not qualify as compostable.

G. Soft tissue material

In anatomy, soft tissues are the tissues that connect, support, or surround other structures and organs of the body, not being bone [4]. Soft tissue includes tendons, ligaments, fascia, skin, fibrous tissues, fat, and synovial membranes (which are connective tissue), and muscles, nerves and blood vessels (which are not connective tissue). Soft tissues have the potential to grow and remodel reacting to chemical and mechanical long term changes. The rate the fibroblasts produce tropocollagen is proportional to these stimuli (tablets, syrup, can be feed orally).



III. 3D SKIN PRINTING

The skin of kidney should compatible to the body tissues and immune system. The kidney should combine with the body cells at the outermost surface. Bio-compatible materials, say, Poly- Jet photopolymer (MED610) is a rigid medical rapid prototyping material. It features high dimensional stability and colorless transparency [6]. The material is ideal for applications requiring prolonged skin contact of more than 30 days and short-term mucosal-membrane contact of up to 24 hours. Poly-Jet photopolymers combine a wide variety of material properties with thin layers, so we can create true product realism in our prototypes.

Object 3D Printers are the only additive manufacturing systems in the world than give we multi-material flexibility. We can combine materials within the same 3D printed model or in the same print job, enabling a wealth of

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applications such as over-molding, grayscale coloring, simultaneous prints in different materials and more [7]. We can also combine two materials during printing to create composite Digital Materials with very specific properties. The skin material slowly disintegrates with the body tissues and allows the body tissue to combine with the pyloric carbon at the area where there is the space for combination is being achieves [8]. The skin material disintegrates as patches, thus the area of patches are combine first. The artificial printed skin used here can be used heal the wounds, sores, burns, and the application where temporary skin is needed.

IV. VARIOUS SECTIONS OF 3D PRINTED KIDNEY

The various sections of the kidney that are to be made with the use of this technology are as follows,

(i) Bio-Vessels
(ii) Bio-tubules
(iii) Micro-tubes (spiral) to filter blood and filter active elements
(iv) Chamber to collect urine
(v) Chamber to initial storage of blood
(vi) Minute chambers at the surface.

A. Bio-vessels and Bio-tubules

Vessels for blood flow in and out having connecting tissue at the end to bond with body blood vessels while the Bio-Tubules connect with the urinary bladder. Tubular-spiral-micro tubes of 500 micrometer in diameter and coils up to the size of the kidney and to lengthen of the filtering path [10]. Carbon micro-tubes are among the numerous candidates for tissue engineering scaffolds since they are biocompatible, resistant to biodegradation and can be functionalized with biomolecules.

B. Minute chamber at the surface

Minute chambers present at the surface to grow connective tissues. Tissue engineering utilize living cells as engineering materials [11]. Examples include using living fibroblasts in skin replacement or repair (similar to SOFT TISSUE), cartilage repaired with living chondrocytes, or other types of cells used in other ways [12]. These fibroblast materials occupy the outermost surface of the printed kidney, and it starts growing after the skin of kidney disintegrates as patches. The two chambers available are

(i) Chamber to pressurize blood initially,
(ii) Chamber to collect the filtered urine.

V. KIDNEY MODEL

The kidney model is made to resemble the persons kidney, for that the 3D Image capturing technology can be adopted, where the two dimensional image from various axes are combine to form the 3D model [13]. The image can be processed even by SOLID WORKS after getting conversion from standard IGES Format. The resulting 3D object is sliced by SLIC3R Software, which shows the layer by layer buildup of the kidney.

A. Slicing

Slicing is done by SLIC3R Software and it determines the path of filler head.

B. Kidney Printing

The printing process is similar to the process of rapid prototyping.

C. Proposed design of artificial human kidney

The kidney is the filtering device, filters blood to get away from impurities present in the blood. The filtering action of kidney is done in glomerulus tubule. In artificial kidney, it was done in micro tubule consists of nano-pores. Since, the blood flow is due to pressure of blood. This pressure is enough for the filtering circumferential action to takes place.

D. Active element recapture

The various elements presents in the urine (Say, Na, K, H2O, etc.,) are necessary for the effective functioning of body. This can be captured with the help of capillary tube contains pores of diameter 10-12 meters. The wastes such as uric salts, creatinine, etc., are not able to enter the pica porous tube. Thus, the second phase filtering filters the active elements form the urination and the elements are mixed up with the filtered blood.

VI. APPLICATIONS

The 3D BIO-PRINTER paves its main application in manufacturing and medicinal field (Dual collaboration).

In manufacturing field, prototype of the component can easily be made as the same principle of 3D Printer.

The bones of human body are made based on the above explained process and are succeeded.

The various organs like lungs, heart, liver, ear, bones, etc,can be made with the help of this 3D-BIO PRINTER.

VII. CONCLUSION

There is a fact that the 3D Bio-Printer can print the object as it is being manufactured by a conventional 3D Printer. But, the conventional 3D Printer cannot manufacture the object as manufactured by that of the 3D Bio-Printer. 3D Bio-Printing aids in person's organ failure treatment by replacement of birth similar organ in place of defective one. Thus it can save the human's life.

The artificial kidney can be coupled with the dialyzer machine and used for treatment.

The various 3D-Printed organs can be produced by the

technique similar to the one mentioned above.

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