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3D Printing in Medical Field

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***Abstract*: The main objective is to develop 3D printing technology in the medical field. Medical field plays an important role in today's world. Nowadays more number of accidents are happening all over the world. Thus number of hospitals is increasing day by day. To economically create bones and other skull related parts, the 3D printing can be used effectively.**

***Keywords*: Rapid prototyping, Manufacturing and geometries**

1. Introduction

The first step of creating a layer by layer 3D object using computer-aided design was rapid prototyping, developed in the period of 1980's for creating models and prototype parts mainly for industrial purpose only. Rapid prototyping is one of the earlier additive manufacturing (AM) processes. But in later years, it allowed for the creation of parts (i.e) product that we required, that this process presented to product development are the time and cost reduction, human interaction, and consequently the product development cycle , also the possibility to create almost any complex shape that could be difficult to machine, Since it forms like layer by layer. Now, it is completely modern manufacturing and many other industries with new processes, materials and applications. In addition to prototypes, complex components, houses, and even human body parts can now be 3D printed. With the rapid advancement of 3D printing and 3D bio-printing technologies, a huge body of research and practical applications exists for these technologies. Now, doctors can build a model of a damaged body to analyze it and plan better the procedure, market researchers can see what people think of a particular new product, and rapid prototyping makes it easier for artists to explore their creativity. The applications of rapid prototyping in sand mold and core printing simply substitute the conventional molding and core making process without changing the shape or size of the sand mold (core). Importantly, 3D printing not only provides an alternate method for conventional manufacturing but also revolutionizes the topological structure design of products. 3D printing technology can also bring new elements to casting design and mold design in the casting industry. Kang et al. proposed the application of a hollow mold to aluminium alloy castings according to the idea of a shell-truss mold based on 3D printing technology and achieved outstanding results. Layered manufacturing of metal frameworks is a promising technology in dental practice. The mechanical properties of metal frameworks fabricated by using different layered manufacturing methods are affected. This technique recently used as tool in medical field for manufacturing of customized implants and bio-models. AM presents capacity of building highly complex geometries directly from a CAD model, which permits fabrication of custom implants from computed magnetic resonance data from a patient. Some advantages of these implants are shorter surgery times, improved bio-mechanical compatibility, reduction in rejection and infection risks, better ergonomic and aesthetic results and increasing the probability of success of the implant. New applications are emerging as novel materials and AM methods are continuously being developed. One of the main drivers for this technology to become more accessible is attributed to the expiry of earlier patents, which has given manufacturers the ability to develop new 3D printing devices. Recent developments have reduced the cost of 3D printers, thereby expanding its applications in schools, homes, libraries and laboratories. Initially, 3D printing has been extensively used by architects and designers to produce aesthetic and functional prototypes due to its rapid and cost-effective prototyping capability. The use of 3D printing has minimized the additional expenses that are incurred in the process of developing a product. However, it is only in the past few years that 3D printing has been fully utilized in various industries from prototypes to products. Product customization has been a challenge for manufacturers due to the high costs of producing custom-tailored products for end-users. On the other hand, AM is able to 3D print small quantities of customized products with relatively low costs.

A. File format

Three (3D) printing is utilized for the rapid prototyping of 3D models originally generated by a computer aided design (CAD) program, e.g., Auto Desk, AutoCAD, Solid Works, or Creo Parametric. The original design is drafted in a CAD program, where it is then converted to a .STL (Standard Tessellation Language or Stereo- Lithography) file. The .STL file format, developed by Hull at 3D systems, has been accepted as the standard for data transfer between the CAD software and a 3D printer. The STL file was created in 1987 by 3D Systems Inc. when they first developed the stereo lithography, and the STL file stands for this term. It is also called Standard Tessellation Language. There are other types of files, but the STL file is the standard for every additive manufacturing process. The STL file creation process mainly converts the continuous geometry in the CAD file into a header, small triangles, or co-ordinates triplet list of x, y, and z coordinates and the normal vector to the triangles. This process is inaccurate and the smaller the triangles the closer to reality. The interior and exterior surfaces are identified using the right-hand rule and vertices cannot share a point with a line. Additional edges are added when the figure is sliced. The slicing process also introduces inaccuracy to the file because here the algorithm replaces the continuous contour with discrete stair steps. To reduce this inaccuracy, the technique for a feature that has a small radius in relation to the dimension of the part is to create STL files separately and to combine them later.

2. 3D printing methods

Methods of additive manufacturing (AM) have been developed to meet the demand of printing complex structures at fine resolutions. Rapid prototyping, the ability to print large structures, reducing printing defects and enhancing mechanical properties are some of the key factors that have driven the development of AM technologies. The most common method of 3D printing that mainly uses polymer filaments is known as fused deposition modeling (FDM). In addition, additive manufacturing of powders by selective laser sintering (SLS), selective laser melting (SLM) or liquid binding in three-dimensional printing (3DP), as well as inkjet printing, contour crafting, stereo lithography, direct energy deposition (DED) and laminated object manufacturing (LOM) are the main methods of AM.

A. Stereo lithography

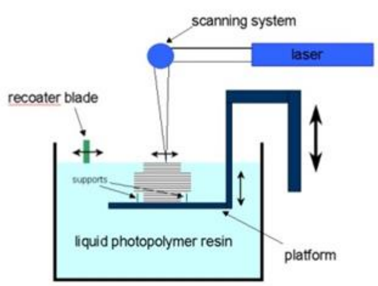

Fig. 1. Stereo lithography

Stereo lithography employs photo curable polymer resin which solidifies into solid when exposed to high intensity light. Initially, curing was only possible with UV light, but recently polymers cured with visible wavelengths have been introduced. Highly focused lasers or LED beams with high intensity are used, and the spot size of the light beam determines printing resolution. Each layer of the object is printed as a point-by-point 2D cross section cured by the scanning focused beam onto a printing platform immersed in a photo curable tank that holds the liquid resin. Recently, projection-based stereo lithography has been introduced with promise to decrease print time while maintaining almost the same resolution as line-based stereo lithography. The basic principle of this process is the photo polymerization, which is the process where a liquid monomer or a polymer converts into a solidified polymer by applying ultraviolet light which acts as a catalyst for the reactions; this process is also called ultraviolet curing. It is also possible to have powders suspended in the liquid like ceramics. The energy of the light source and exposure are the main factors controlling the thickness of each layer. SLA can be effectively used for the additive manufacturing of complex Nano composites.

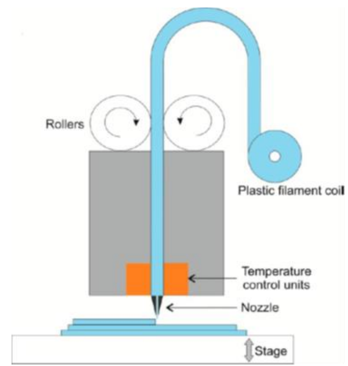

Fig. 2. Fusion deposition modeling

B. Laminated object MFG

Laminated Object Manufacturing (LOM) is a process that combines additive and subtractive techniques to build a part layer by layer. In this process the materials come in sheet form. The layers are bonded together by pressure and heat application and using a thermal adhesive coating. A carbon dioxide laser cuts the material to the shape of each layer given the information of the 3D model from the CAD and STL file. The advantages of this process are the low cost, no post processing and supporting structures required, no deformation or phase change during the process, and the possibility of building large parts. The disadvantages are that the fabrication material is subtracted thus wasting it, low surface definition, the material is directional dependent for machinability and mechanical properties, and complex internal cavities are very difficult to be built. This process can be used for models with papers, composites, and metals.

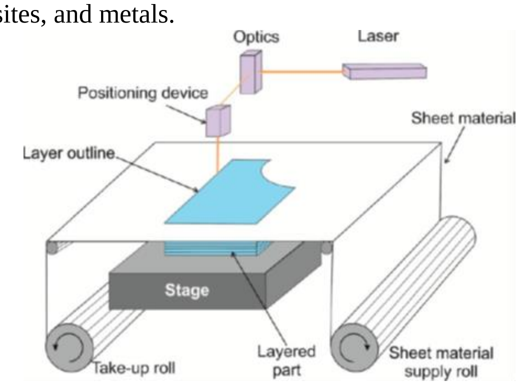

Fig. 3. Laminated object manufacturing

LOM can result in a reduction of tooling cost and manufacturing time and is one of the best additive manufacturing methods for larger structures. However, LOM has inferior surface quality (without post-processing) and its dimensional accuracy is lower compared to the powder-bed methods. The excess materials after cutting are left for the support and after completion of the process, can be removed and recycled. LOM can be used for a variety of materials such as polymer composites, ceramics, paper and metal-filled tapes. Post-processing such as high-temperature treatment may be required depending on the type of materials and desired properties.

C. Laser engineering net shaping

In this additive manufacturing process, a part is built by melting metal powder that is injected into a specific location. It becomes molten with the use of a high-powered laser beam. The material solidifies when it is cooled down. The process occurs in a closed chamber with an argon atmosphere. This process permits the use of a high variety of metals and combination of them like stainless steel, nickel based alloys, titanium-6 aluminium-4 vanadium, tooling steel, copper alloys, and so forth. Alumina can be used too. This process is also used to repair parts that by other processes will be impossible or more expensive to do. One problem in this process could be the residual stresses by uneven heating and cooling processes that can be significant in high precision processes like turbine blades repair. Figure 2.4 is an illustration of how the part is made in this process.

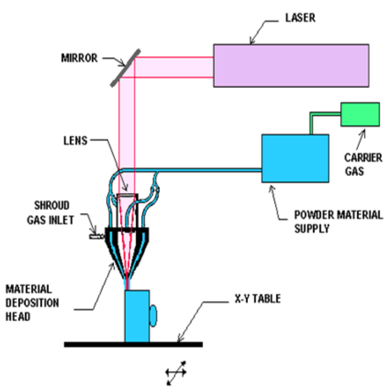

Fig. 4. Laser engineering net shaping

D. Selective laser sintering

This is a three-dimensional printing process in which a powder is sintered or fuses by the application of a carbon dioxide laser beam. The chamber is heated to almost the melting point of the material. The laser fused the powder at a specific location for each layer specified by the design. The particles lie loosely in a bed, which is controlled by a piston, that is lowered the same amount of the layer thickness each time a layer is finished. This process offers a great variety of materials that could be used: plastics, metals, combination of metals, combinations of metals and polymers, and combinations of metals and ceramics. Examples of the polymers that could be used are acrylic styrene and polyamide (nylon), which show almost the same mechanical properties as the injected part. It is also possible to use composites or reinforced polymers, that is, polyamide with fiberglass. They also could be reinforced with metals like copper.

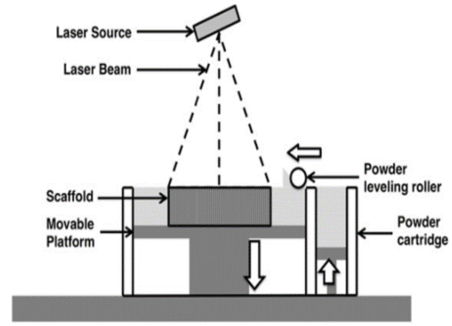

Fig. 5. Direct metal laser sintering

E. Inkjet printing

Inkjet printing is one of the main methods for the additive manufacturing of ceramics. It is used for printing complex and advanced ceramic structures for applications such as scaffolds for tissue engineering. In this method, a stable ceramic suspension e.g. zirconium oxide powder in water is pumped and deposited in the form of droplets via the injection nozzle onto the substrate. The droplets then form a continuous pattern which solidifies to sufficient strength in order to hold subsequent layers of printed materials. This method is fast and efficient, which adds flexibility for designing and printing complex structures. Two main types of ceramic inks are wax-based ink sand liquid suspensions. Wax-based inks are melted and deposited on a cold substrate in order to solidify. On the other hand, liquid suspensions are solidified by liquid evaporation. The particle size distribution of ceramics, viscosity of the ink and solid content, as well as the extrusion rate, nozzle size and speed of printing, are factors that determine the quality of inkjet-printed parts. Maintaining workability, coarse resolution and lack of adhesion between layers are the main drawbacks of this method.

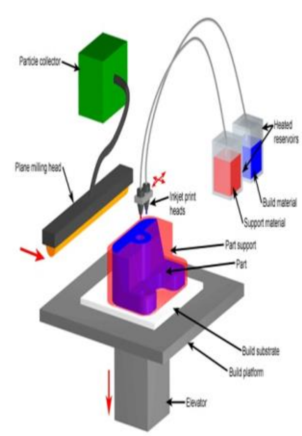

Fig. 6. Inkjet printing

3. 3D printing materials

Materials in additive manufacturing technology systems are defined by the fabrication processing technology. Each 3D printing technology transforms material through external heat, light, lasers and other directed energies. The ability of a material's mechanical composition to react positively to a certain directed energy marries that material to a technology which can deliver the desired change. These material-technology partnerships will expand as materials are advanced and material chemistry explored. Advancing technologies encourages more positive material reactions, layer by layer, to directed external energies. The mechanism of material change-unique to individual 3D printing technologies and processes-defines the material in terms of state changes, final mechanical properties and design capabilities. By extension, developments in 3D printing materials correspond with developments in 3D manufacturing; as the build process improves to encourage more positive reactions from materials, material selections will expand. The 3D printing materials are available in different material types and states such as powder, filament, pellets, granules, resin etc.

A. Plastics

Nylon, or Polyamide, is a strong, flexible, reliable and durable plastic material commonly used in powder form with the sintering process or in filament form with the Fusion Deposition Modeling (FDM) process. It is naturally white in color but it can be colored pre -or post-printing. This material can also be combined (in powder format) with powdered aluminum to produce another common 3D printing material for sintering- Alumide. ABS is another strong plastic used for 3D printing, in filament form. It is available in a wide range of colors useful option for some applications. Lay Wood is a specially developed 3D printing material for entry-level extrusion 3D printers. This special filament is a composite material of recycled wood and polymer parts that can create wood-like objects that have the look, feel and even the smell of wood. It can be printed between 175-2500OC. It is available in light and dark color wood.

B. Metals and alloys

The most common metals and metal composites are titanium, aluminum and cobalt derivatives. Metal additive manufacturing is showing excellent perspectives of growth. It is also used in the biomedical, defense and automotive industries. Metal AM provides great freedom for manufacturing complex geometries with special connections compared to conventional manufacturing methods. In particular, multi-functional components can be developed to provide solutions to structural, protective engineering and insulation problems at the same time. Many metallic materials such as stainless and tool steels, some aluminium alloys, titanium and its alloys, and nickel-based alloys can be manufactured using PBF-based AM processes. PBF technologies can manufacture components with good mechanical properties and complex shapes with high accuracy (±0.02 mm). Titanium and its alloys, steel alloys, a few aluminum alloys, nickel alloys, and some cobalt-based and magnesium alloys have been optimized for AM. In particular, titanium and its alloys are high performance materials commonly used in various industries. They are characterized by high machining costs and a long lead-time based on conventional manufacturing methods.

C. Ceramics

Ceramics are a relatively new group of materials that can be used for 3D printing with various levels of success. The ceramic parts need to undergo post-processing processes same as any ceramic part made using traditional methods of production — namely firing and glazing. Extrusion of ceramic paste or filament is also known as extrusion free-forming of ceramics (EFF), fused deposition modeling of ceramics (FDC) or rapid prototyping (RP). The main methods of post-curing for extruded ceramics are phase changing (i.e., crystallization of liquid phase by freezing or freeze-drying), evaporation of water or solvent and UV or heat curing. Besides the particle size distribution and packing of particles in the paste, the liquid to solid ratio, air-entrapment, temperature, drying and de-binding procedure, solidification kinetics and inter-layer adhesion can affect the properties of 3D printed ceramics. Stereo lithography, in spite of being developed for 3D photo polymerization (UV, laser or LEDs can also be used) of monomerinto polymers, has been extended.

D. Concrete

3D printed models made with concrete are safe, environmentally friendly, and easily recyclable and require no post-processing. 3D printed fiber-reinforced concrete composites bring the benefit of controlling fiber orientation in a printed structure compared to traditional fiber-reinforced concrete. Freedom of the orientation of carbon fibers along different printing paths significantly increased flexural strength by up to 30 MPa. A mix of rapid hardening cement and polyvinyl alcohol (PVA) composite was used in order to print with a finer resolution. However, layer delimitation and void formation between the layers were observed, which became less distinct after post curing of the samples in water.

4. Testing methods

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A. Four-point flexural test

The four point bending test provides values for the modulus of elasticity in bending, flexural stress, flexural strain and the flexural stress-strain response of the material. This test is very similar to the three-point bending flexural test. The major difference being that the addition of a fourth bearing brings a much larger portion of the beam to the maximum stress, as opposed to only the material right under the central bearing. This difference is of prime importance when studying brittle materials, where the number and severity of flaws exposed to the maximum stress is directly related to the flexural strength. It is one of the most widely used apparatus to characterize fatigue and flexural stiffness of asphalt mixtures. The test method for conducting the test usually involves a specified test fixture on a universal testing machine. Details of the test preparation, conditioning, and conduct affect the test results. The sample is placed on two supporting pins a set distance apart and two loading pins placed at an equal distance around the center. These two loadings are lowered from above at a constant rate until sample failure.

B. Three-point flexural test

The three-point bending flexural test provides values for the modulus of elasticity in bending, flexural strain and the flexural stress–strain response of the material. The main advantage of a three-point flexural test is the ease of the specimen preparation and testing. However, this method has also some disadvantages: the results of the testing method are sensitive to specimen and loading geometry and strain rate. The test method for conducting the test usually involves a specified test on a universal testing machine. Details of the test preparation, conditioning, and conducting affect the test results. The sample is placed on two supporting pins a set distance apart and two loading pins placed at an equal distance around the center. These two loadings are lowered from above at a constant rate until sample failure.

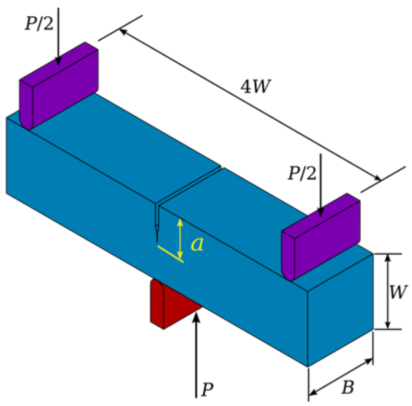

Fig. 7. Three point flexural test

Where P is the applied load, B is the thickness of the specimen, is the crack length, and W is the width of the specimen. In a three-point bend test, a fatigue crack is created at the tip of the notch by cyclic loading. The length of the crack is measured. The specimen is then loaded monotonically. A plot of the load versus the crack opening displacement is used to determine the load at which the crack starts growing. This load is substituted to find the fracture toughness K.

C. Split hopkinson pressure bar testing

Using the split Hopkinson pressure bar (SHPB) test the horizontal and vertical samples can be tested under different compressive strain rate conditions. It is noted that, the samples were setup such that, the direction of compressive shock loads was parallel to the longitudinal axis of all the samples. The samples can be tested at each strain rate ranging from 180 s^{-1} to 3200 s^{-1} to ensure consistency and repeatability. It is important to note that all testing was performed at room temperature. Using compressed gas, a striker was fired to strike the incident bar in order to rapidly deform the test specimen sandwiched between the incident and transmitter bar. By increasing the gas pressure in the firing chamber, a higher impact velocity is achieved, which results in a higher strain rate. When the incident bar was struck, a strain wave travelled through it until part of it passed through the sample to the transmitter bar while the other part was reflected. These strains were measured by placing strain gauges on the respective bars.

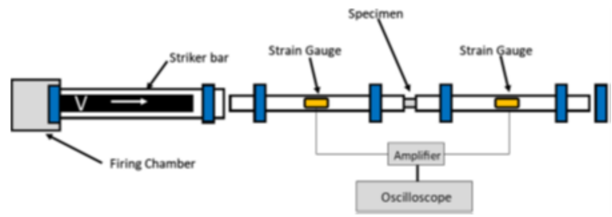

Fig. 8. Hopkinson pressure bar test

D. Wetting test

The wetting tests were carried out by classical sessile drop technique upon contact heating under vacuum. The experimental device has been described]. TheTiB2 substrate (12×12×2.5 mm3) with Al-12Si sample (a weight of 46 mg) was placed on a boron nitride support situated in the middle of a molybdenum resistance furnace inside a stainless-steel chamber. The chamber was evacuated to about 10-5 mbar at room temperature. The Al-12Si/TiB2 couple was constantly heated from room temperature to 1200 °C and then cooled down to room temperature. The wetting behavior of the liquid alloy on the solid substrate was recorded in steps of 10 °C using a charge-coupled device (CCD) camera. The contact angles were determined at both sides of the drop by analyzing the digital photographs using DROP software. The total uncertainty of the average contact angle was about ±5°.

E. Vickers hardness testing

The Vickers hardness test method, also referred to as a micro hardness test method, is mostly used for small parts, thin sections. The Vickers method is based on an optical measurement system. The Micro hardness test procedure, ASTM E-384, specifies a range of light loads using a diamond indenter to make an indentation which is measured and converted to a hardness value. It is very useful for testing on a wide type of materials, but test samples must be highly polished to enable measuring the size of the impressions. A square base pyramid shaped diamond is used for testing in the Vickers scale. Typically loads are very light, ranging from 10gm to 1kgf, although "Macro" Vickers loads can range up to 30 kg or more. The Micro-hardness methods are used to test on metals, ceramics and composites - almost any type of material. Since the test indentation is very small in a Vickers test, it is useful for a variety of applications: testing very thin materials like foils or measuring the surface of a part, small parts or measuring individual microstructures, or measuring the depth of case

hardening by sectioning a part and making a series of indentations.
Sectioning is usually necessary with a micro-hardness test in order to provide a small enough specimen that can fit into the tester. Additionally, the sample preparation will need to make the specimen's surface smooth to permit a regular indentation shape and good measurement, and to ensure the sample is held perpendicular.

5. Fabrication of medical equipment's

Physical medical equipment's have traditionally been produced by means of conventional manufacturing processes such as casting and molding. Such fabrication processes involve time-consuming and often expensive tooling preparation steps. In addition, it is not economical to fabricate individual, patient-specific medical phantoms due to the high tooling cost. Therefore, most of these phantoms are mass-produced, population-averaged, idealized models for general planning and educational purposes.

A. Tissue-mimicking medical phantoms

In medical imaging, phantoms are commonly used for developing and characterizing imaging systems or algorithms, as they provide imaging specimens with known geometric and material compositions. Tissue-mimicking medical phantoms can imitate the proper-ties of biological tissue, and can therefore provide a more clinically realistic imaging environment. In the past, casting or injecting molding processes have been used to fabricate tissue-mimicking medical phantoms. Applications of such phantoms can be found in the development and validation of medical imaging modalities such as ultrasound, MRI computed tomography (CT) and others .With the increasing needs of biomedical research, other applications of tissue-mimicking medical phantoms, such as simulation of the electromagnetic properties of tissues mechanical properties mimicking and focused ultrasound have also been demonstrated. In those applications, phantoms were fabricated as population-averaged, idealized models, and the individual differences among patients were overlooked.

6. 3D printing of medical phantoms

3D printing technologies overcome the drawback of traditional manufacturing processes and are an effective tool for rapidly producing patient-specific, high-fidelity, medical phantoms at low cost, as the need for tooling is eliminated. 3D-printed medical models and phantoms fabricated from CT, MRI, or echocardiography data provide the advantage of tactile feedback, direct manipulation, and comprehensive understanding of a patient's anatomy and underlying pathologies. In many cases, 3D-printed medical phantoms can assist and facilitate surgeries and shorten the cycle times of medical procedures. 3D models have also been used for surgical planning by neurosurgeons. Such 3D-printed neuro anatomical models can provide physical representations of some of the most complicated structures in the human body. These detailed high-fidelity phantoms can help neurosurgeons discover and visualize the intricate, sometimes obscured relationships between cranial nerves, vessels, cerebral structures, and skull architecture that are difficult to interpret based solely on two dimensional (2D) radiographic images. This can reduce errors and avoid potentially devastating consequences in surgery.

7. Recent progress and future trends

Recent advances in AM technologies have enabled several new TE pathways. In particular, the following three strategies are gaining momentum now that new AM technologies have become available:

- The development of hybrid scaffolding materials to achieve tunable properties of scaffolds;
- The design of special microstructures to achieve convertibility of scaffolds; and
- The integration of sensors to achieve built-in process-monitoring capability. The details of and future predictions for each strategy are discussed below.

A. Hybrid scaffolding materials

Biopolymers, such as poly caprolactone (PCL), poly lactic acid (PLA), and poly (lactic-co-glycolic acid) (PLGA), are the most commonly used base materials for scaffolding. In most cases, they are not a perfect fit for TE due to their relatively weak mechanical properties, poor cell adhesion, or near-inert bioactivity. By blending additives into the biopolymers, those disadvantages can be mitigated. Many of these additives are bio-ceramics in powder form.

B. Convertible scaffold

Bio printing technologies provide precise control over the initial cell distribution in the printed construct. However, once the cells start to grow in the bioreactor and regenerate into the tissue via the self-assembly process, no control method is currently available to ensure an optimal microenvironment throughout the scaffold at all times. In other words, when bio printing TE scenarios at present, too much of the cell growth process is uncontrolled. Cell growth is a spatiotemporal process with intrinsically high variability in quality, quantity, yield, and other metrics. Although the behavior of each individual cell is not readily predictable, the growth of a cell culture within a large population is largely controllable with environmental factors, including local cell density and ion-exchange rate. In a cell culture process without a scaffold, certain agitation or perfusion mechanisms are typically used to ensure near-uniform local cell distribution and to promote nutrient, growth factor, and waste exchange. A scaffold will hinder the nutrient, growth factor, and waste exchange of cells. Studies have indicated that cell growth on a scaffold is not optimal in terms of growth rate and cell viability once the cell density reaches a certain point. Using 3D-printed auxetic meta materials as scaffolds may pro-vide a solution in the near future. Auxetic met materials are materials with repeated microstructures that exhibit a negative Poisson's ratio in the macro scale, which allows the volume to change in a unique way for the overall construct. Advances in 3D printing have enabled and accelerated novel designs and applications of auxetic meta materials with auxetic metamaterials.

C. Integrated sensors

Direct-write technologies are a class of AM methods that can fabricate electronic circuits without masking. These relatively new technologies include inkjet printing, aerosol jet printing, syringe dispensing, laser-assisted chemical vapor deposition, laser particle guidance, matrix-assisted pulsed-laser evaporation, and focused ion beam. Direct-write processes are fast and flexible, and have a high tolerance for errors. Some direct-write technologies, such as aerosol jet printing, do not require the substrate to be planar. This provides opportunities to integrate sensors into bio-printed scaffolds. In most cases, direct-write technologies are used to create conductive patterns. Metallic nanoparticle pastes or dispersions are used as inks in such cases. These include silver, gold, and copper nanoparticles as the three most common materials. Carbon-based inks are also a popular family that is recently adopted in many direct-write technologies and their applications. This includes carbon nanotubes, graphite, graphene, decorated carbon nanotubes, and their mixtures. Some researchers have reported that mixtures of inks with carbon-based nanomaterial and metallic nanoparticles have potential in stretchable electronics printing. With more and more complex functions and designs of printed electronics, there are demands for more types of specialized inks, other than conductive inks. For example, boron nitride nanotubes (BNNTs) can be dispersed into certain solvents to create a piezoelectric ink. There are many applications for a thin layer of patterned dielectric material. Both inorganic and polymeric dielectric inks have been developed, and semiconductor nanoparticle inks and polymer semiconductor inks are on the market. Some recent research is developing biological inks that can be printed by aerosol jet printing. On the manufacturing level, the use of direct-write technologies to introduce a sensing capability to smart scaffolds is encountering a set of challenges that include scalability, yield, toxicity, environmental impact, and supply chain design. Different direct-write technologies are at different manufacturing readiness levels (MRLs). In general, this strategy is still in the proof-of-concept stage. The overall outlook for the smart scaffold field suggests that interest and attention in integrating sensors into TE has increased significantly during the last decade. It is reasonable to believe that more and more smart scaffold designs will include certain kinds of direct-write technologies in the near future.

8. Conclusion

Additive Manufacturing technology is used to create 3D parts directly from CAD models and quickly fabricate complex shapes. Additive Manufacturing application in the case of medical applications model is useful for surgical planning. This technology plays a significant role in reverse engineering applications, E-manufacturing Processes, Rapid Tooling, Product design and development, Medical Field, etc. Medical education and training, Designing and development of medical devices, designing of the customized implant, scaffolding and tissue engineering, prosthesis and orthotics, mechanical bone replica, forensics, various problems are solved in dentistry by implementing this Additive Manufacturing technology. AM system provide extensive support in medical applications, providing better accuracy and speed, product visual applications.

References

[1] Dirk-Jan Cornelissen and Alan Faulkner-Jones: Current developments in 3D bio-printing for tissue engineering. Current Opinion in Biomedical Engineering 2017, 76-82.
[2] Cian Vyas, Ruben Pereira, Boyang Huang and Fengyan Liu: Engineering the vasculature with additive manufacturing. Current Opinion in Biomedical Engineering 2017, pp. 1-13.
[3] Sunpreet Singh and Seeram Ramakrishna: Biomedical applications of additive manufacturing: Present and Future. Current Opinion in Biomedical Engineering 2017, pp. 105-115
[4] Sahar Sultan, Gilberto Siqueira, Tanja Zimmermann and Aji P.Mathew: 3D printing of nano-cellulosic biomaterials for medical applications. Current Opinion in Biomedical Engineering 2017 2:29-34.
[5] Shivakalyani Adepu, Nandini Dhiman and Anindita Laha: Three dimensional bio-printing for bone tissue regeneration. Current Opinion in Biomedical Engineering 2017 2:22-28.
[6] Carvalho B, Solorzano RD, Yang MT, Miller JS, Bhatia SN, Chen CS: Geometric control of vascular networks to enhance engineered tissue integration and function. Proc Natl Acad Sci 2013, 110:7586– 7591.
[7] Dias JR, Granja PL, Bártolo PJ: Advances in electrospun skin substitutes. Prog Mater Sci 2016, 84:314– 334.
[8] Huang Z-M, Zhang YZ, Kotaki M, Ramakrishna S: A review on polymer nanofibers by electrospinning and their applications in nanocomposites. Compos Sci Technol 2003, 63: 2223– 2253.
[9] Ercolani E, Del Gaudio C, Bianco A: Vascular tissue engi-neering of small-diameter blood vessels: reviewing the electrospinning approach. J Tissue Eng Regen Med 2015, 9: 861– 888.
[10] Rocco KA, Maxfield MW, Best CA, Dean EW, Breuer CK: In vivo applications of electrospun tissue-engineered vascular grafts: a review. Tissue Eng Part B Rev 2014, 20:628– 640.