Biomaterials and 3D printing for sustainable applications

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Abstract: 3 Dimensional bio printing is an emerging across the globe with better quality and high precision work of producing biomaterials parts such as teeth, body parts etc. with high precision layer by layer plating of tissue with printing which work in addition of layer on layer manner. As the printing evolved there are many new innovations which change things in medical field and reduce difficulty to patients and industries as well as by providing their required part in less time with high precision. In this paper reviewed about printing different printing technologies, about printing process, biomaterials, needs in printing and about sustainable application with future trends.

Index Terms: 3D printing, Biomaterials, Biomaterials Inks, Types of 3D printer, Additive Manufacturing.

1. INTRODUCTION:

As the population of world increasing day by day accordingly requirements of humans is also increasing. To fulfill these requirements humans are developing many things with lot of researches and compatibility. These researches are mainly raised due to the human need and to fulfill these humans are developing a way or any machine to accomplish the task with ease. Across the world many researches and projects are going on with the support of government, social groups and institution to develop the world to next level with conservation of resources for future generation [1]. Nowadays, one of innovation is in demand with lot of ease and better result with high precision is printing. There are many different printing technologies or printers are available in the market as per requirement such as Stereo lithography, selective laser sintering, fused deposition modeling, Digital light processing, Multi jet fusion, Poly jet etc. These printers are designed for different requirement and materials. For example if a person need to want good surface with good quality with nylon based material then that person need Stereo lithography printing technology or printer[2]. Mainly is using making small parts or functional prototypes which consist complex geometry and take time on creation from traditional manufacturing. Printing complete work much faster than traditional manufacturing as well as provide good quality with high durability [3-4]. In 1980s printing was new concept it was using for some application as aesthetic or functional prototype because at that time printing not evolved so much and many did not know about this technology. As the goes and many researches help by year by year this technology gets evolved and Humans stats this technology use for many application as industry, medical, organ making, dental application etc. Biomaterials are one of common materials that is most popular in printing. Biomaterial is that materials which make combination of two or more substances that originates naturally. These materials can use heal the body parts by replacing that part with biomaterial part which engage body system. Main feature of these material are their integrity with biological system comfortably which improve the working of individual. Many companies working on researches on Biomaterials and trying to develop new products. Biomaterials with Printing now a day's using in organ producing, dental, forensic, prototyping and producing small parts [5].

2. 3D PRINITING OVERVIEW:

3DPrinting is also known as additive manufacturing technology. It is nowadays widely using for physical components, models and functional prototype. For this technology mainly we work on CAD model. CAD model are develop with help of CAD Software in laptop/desktop. For design a CAD model there are lot of software are available such AutoCAD, ZW-CAD, Catia, Solid works etc. Software may vary company to company as per convenience. Other part of printing technology is printer (technology) [6-8]. There are variety of printers (technology) is available in the market as per requirement of work such as:

2.1 **Stereo lithography (SLA):** These printers mainly known as industrial printers for printing. This printer parts contains high smooth surfaces, very close tolerances, parts are look nice and also contains strength. This printer parts are mainly used for medical purpose (application) as micro fluids, anatomical models.

2.2 **Selective Laser sintering (SLS):** These printers are used to make pure thermoplastic material parts. It melts nylon based powders (together) into solid plastics. These printer parts are more durable and suits for functional testing but it consist rough surface as compare to SL technology. These printers mainly used for making prototypes.

2.3 **Fused Deposition Modeling (FDM):** It is printing technology for plastic parts. It is also known as desktop printing technology for parts of plastics and it works as extruding a plastic material onto platform layer by layer. It is used to produce physical models but it's having rough surfaces.

2.4 **Digital light process (DLP)**: It cures liquid using light and all things are similar to SLA. These printers are consisting Light projector screen and it's having high building speed so it recommended for low volume production of plastic parts.

2.5 **Multi jet Fusion (MJF):** It also makes nylon powder functional parts. To sinter the powder uses inkjet array to act as fusing agent to nylon powder (bed of nylon powder). To fuse each layer passes the heat element over the bed of nylon powder. This method gives more improved mechanical properties and good surface finish as compare to SLS printers. It lowers the production cost because its building speed is quite good.

2.6 Polyjet: These printers consist ability print material with multiple properties as colour and materials. These are mainly considered to print prototype of elastomeric or over molded or silicon rubber design.

2.7 Direct metal laser sintering (DMLS): this printer technology is used to make metal parts. This method is applicable to both production of parts and prototyping. Electron Beam melting (EBM)-: This is metal printing technology (printers). It is used electron beam that is produced with help of electromagnetic coils to melt metal powder. On the bed parts produce must be heated and also vacuum condition during printing [9-10].

These printer must contains various parts as printer frame; whole get stand with the help of these frames and gets align together with the help of these frames, printer movements head related mechanics; movement of head in x, y and z direction movement as per required command, Head of printer; it is a nozzle which deposits filament(processing material) or it can be colour and liquid binders, Building bed; it is the platform at which whole object or part has to be processed, printer motor (stepper motor); motors must not be less than 4 and theses are responsible for speed control with precise positioning, printer electronics, Firmware for printer; software to control printer each aspects of printer, software; not part of printer but it needs fulfill printing process[11].
3D printers have their own language which known as standard tessellation language (STL) format file which consist triangle collection known as facets which fit to each other in jig saw manner. In conversion of CAD file into STL format creates some error in STL file which could be disturb the produced part. Conversion error related STL file from CAD file as holes, face normal's, self intersections, noise shells and manifold error. This error should be removed in original file/model. After the successful conversion of CAD model to STL file then the next step is known as Slicer. In this process STL file will be processed in the software called Slicer which slice the STL file into thin layers into code containing file which G- code. Then this file processed to print the product in printer by using printer client software. Then fill the material in the filament of nozzle head then printer starts printing the material. Completion of work depends upon the complexity of product or prototype. There are some point need to be considered while selecting printer to required work are printer cost, print quality, print speed, printer capability and practicality with expectation [12].

3. BIOMATERIALS:

Biomaterials play an important role in today's medical science they are used in restoring function and healing after injury or any decay disease. Biomaterial can be natural or synthetic according to their need. They are used in medical application to support or to take place any damaged Organelle, or Biological functionalities. Firstly, Biomaterials was used by the Egyptians. The modern field of Biomaterials unites physics, chemistry, biology and medicine. Now it is influencing tissue advancement and material science. In past ten years, this field has grown drastically in every area like regenerative medicine and tissue advancement. Biomaterials can be made by living cells as well as metal, plastics and glass. This can be made into molded, machine parts, coating and biomedical products. Biomaterials can be used to make heart valves, hip-joint replacement and dental implants etc. One major quality of Biomaterials is that they are bio-degradable and bio absorbable which means they can be removed gradually from human body after fulfilling their purpose.

3.1 Biomaterials in 3D printing: The development in printing advancements in the course of recent years has carried these technologies to numerous new fields. Clinical device and tissue engineering is one specific region where printing has accumulated critical interest. With the possibility to create patient-explicit, customizable gadgets in brief timeframe outlines and for lower costs, printing is an ideal innovation for the coming time of customized medication. A wide scope of biomaterials has been utilized as inks framing constructions with a wide range of size and solidness. In this segment, we will outline the material properties that are critical to creating biomaterial inks for each printing technique and survey as of now utilized biomaterial inks utilized in printing, including their particular advantages and disadvantages[13].

3.2 Polymeric biomaterials inks: Polymers make up most of the biomaterial inks utilized in printing due to their simplicity of process ability, minimum cost, and properties like biocompatibility, debasement and mechanics. Polymer inks come as fibers for Fused Deposition Modeling FDM, dabs (powders) for Selective laser sintering (SLS), arrangements and gels for Direct Ink Writing (DIW), and answers for Stereo lithography (SLA). Every one of these strategies requires explicit material boundaries for printability. Solutions for Direct ink writing DIW are regularly contained a polymer disintegrated in a quickly vanishing natural dissolvable, like dichloromethane, tetrahydrofuran or diethyl sulfoxide that quickly scatters upon expulsion, leaving a strong polymer swagger behind [14].

3.2.1 Poly (lactic acid) PLA: PLA is the most regularly utilized bioplastic, obtained from the starch of agricultural plants like corn, sugarcane, sugar beets, and wheat. PLA is perhaps the most examined thermoplastic aliphatic polyester framed from ring-opening polymerization of lactide or polycondensation of lactic corrosive monomers. PLA can be found in semi crystalline or undefined evaluation. Unadulterated poly (l-lactic corrosive) (PLLA) or poly (D-lactic corrosive) is semi crystalline, while PLA with 50–93% L-lactic corrosive is formless [15].

3.2.2 Polyhydroxyalkanoate (PHA): PHA is one of the characteristic polymers got from the polymerization of microorganisms by eicosanoic corrosive. According to, under some lopsided developing conditions like the low convergence of nitrogen, phosphorus, oxygen, or magnesium and an abundance carbon; a few microbes get integrated into consideration to frame PHA. In spite of having promising properties like biodegradability, biocompatibility, process ability, and similar mechanical properties, higher manufacturing cost restricts its applications [16].

3.2.3 Acrylonitrile Butadiene Styrene (ABS): ABS is a petrochemical-based, triblock copolymer that has great strength from the acrylonitrile and butadiene components while acquiring sturdiness from the styrene units, giving it a benefit over the to some brittle polyester materials. This joined with a melting point of 105 °C makes ABS is an appealing contender for use in fused

deposition modeling (FDM) and stereo lithography (SLA) frameworks. In any case, ABS has considered restricted to be as a scaffold material outside of ligament designing since it by and large plays out something similar or more regrettable than PLA in spaces of cell combination, process ability and cost**.** Moreover, it isn't biodegradable, which is a significant hindrance in an industry that is going toward restorable materials **[**17-19].

3.3 Hydro gel inks: Hydro gels are three-dimensional polymer networks with the capacity to hold an enormous amount of water. Hydro gels have been misused in an assortment of biomedical applications including 2D and culture frameworks for tissue designing applications, just as cell or potentially bimolecular deliver Hydro gels give wonderful "delicate material" frameworks to emulate local extracellular network (ECM) microenvironments because of their tunable mechanics, corruption and functionalizability [21-24].

3.4 Ceramic-based ink: Ceramic have been a hot pattern in printing materials for some time now. While all the more ordinarily connected with stoneware or kitchenware, Ceramic is in a real sense wherever in our day by day lives and its utilized broadly in different enterprises. The natural printing technique FDM is a typical cycle for mud and other glue like earthenware production, more exact cycles like SLA and binder jetting have additionally been adjusted to deliver more exact ceramic parts [25-27].

3.5 Composite inks:- Composites commonly involve a center polymer material and a supporting material, as cleaved or consistent fiber. The composite material offers higher strength and firmness contrasted with non-supported polymers. Sometimes, it can even supplant metals like aluminum [28].
There are various techniques for manufacturing composite segments, in addition printing. Notwithstanding, the greater part of them have a scope of downsides: the requirement for the manual layup of the layers of a composite and the utilization of costly restoring hardware and tooling, similar to molds [29].

3.6 Properties of Biomaterials [30-34]:
Biomaterials have excellent elasticity and they are physically very strong, and have pore size architecture. They are biodegradable water content and chemically inert as well as non-toxic. Biomaterials releases biological components, they have motifs that cells recognizes. They have very long life and they are very lasting.

3.7Advantages and Disadvantages: Biomaterials are Bio degradable which is both advantage and disadvantage because they can leach and rupture. Biomaterials can absorb important and rare nutrients present in blood plasma and water. Biomaterials are strong and chemically inert and they have high compressive strength but they also minimize the growth of bones. Biomaterial provides high strength to give tendons, and damaged ligaments supports. Sometimes these Biomaterials leave their place of implantation and become disobliged.

4. ENGINEERING APPLICATIONS OF PRINTED BIOMATERIALS:-

4.1 Tissue engineering: TE is a multidisciplinary field that applies the principles of engineering and life sciences close to the improvement of organic substitutes. Major to TE is the use of living cells to accomplish natural substitutes for implantation into the body as well as cultivate the redesigning of tissue in some other dynamic way. Inside the field of TE, there are two fundamental methodologies that are utilized; the first is the utilization of platforms as a cell backing to urge the cells to frame their own lattice. The subsequent philosophy takes benefit of the framework as development factor or medication conveyance gadget to instigate and help recovery inside the body [35-38]. Key to the utilization of platforms in TE is three fundamental qualities that the constructions ought to have. Essentially, the framework ought to have the option to impersonate the engineering of the local ECM by giving space to vascularization, new tissue formation and nutrient transport. Moreover, the platform ought to have the option to interface with the cell segment to work with their exercises like multiplication and separation. At last, the framework needs to offer a underlying help while coordinating the mechanical properties of local tissues/organs. Advances in TE have demonstrated to be fruitful in building various tissues that have been utilized in the center, for example, skin and cornea. Nonetheless, developing complex strong organs stays a significant physical and natural test. Among different difficulties are the absences of strategies that can all the while imitate the tissue miniature and macro architecture what's more, strategies that can convey different cell types at exact locations [40-44]. AM has been used to attempt to address these limits in view of its primary benefits of exact control also, customized customization. As of late, the term bioprinting has been begat for a specific class of printing.Bioprinting is a layer-by-layer AM method in which exact situating of natural materials and living cells can be accomplished. In the new years, the utilization of bioprinting for assembling frameworks has expanded as a aftereffect of the advantages of having the option to control pore size, shape, and conveyance. Moreover to this, joined with the capacity of CAD control and clinical imaging, for example, CT, bioprinting grants the creation of patient-explicit builds. Bone recovery was one of the main TE applications to exploit the mechanical propels offered by means of printing of materials[45-47]. The primary frameworks manufactured for this design were produced utilizing a biodegradable polymer, to be specific, poly(caprolactone), furthermore, intertwined affidavit displaying as the printing method .The exact statement control of printing has worked with the investigation of the impact of porosity and pore size on bone ingrowths and vascularization, permitting to make the most satisfactory platforms for have coordination .Various materials have been printed for assembling these platforms, among them are engineered polyesters (i.e., Stake PLA, PCL, and so forth), normal polymers (i.e., alginate, chitosan, gelatine, and so on), clay composites (i.e., calcium phosphate also, hydroxyapatite), and blends of them . A vital illustration ofthe printed mix materials is the hyperplastic "bone" platform, which is created of 90 wt% hydroxyapatite and 10 wt% poly(caprolactone) or poly(lactic-co-glycolic corrosive) . These frameworks turned out to be quickly vascular zed and appeared and osteoregenerative properties when embedded in vivo. Khalyfa et al. have additionally detailed a profoundly biocompatible calcium phosphate powder-cover, which has been utilized to create permea clinical embeds like platforms for cranial reproduction (Fig.1A). Another model of a bioprinting for TE application is heart recovery. Tissue-designed heart valve courses have been manufactured utilizing bioprinting and detailed by Duan et al. The trileaflet valve courses were bioprinted utilizing a mix of methacrylatefunctionalized hyaluronic corrosive and methacrylate-functionalized gelatin with exemplified human aortic valve interstitial cells [48].

4.2 Medicine and drug delivery: The utilization of AM for clinical applications and medication conveyance has filled quickly in the past decade. In the clinical field, printing can be utilized for careful arranging, clinical schooling, and tweaked embed plan. The mix of AM and progressed clinical imaging empowers the formation of patient-explicit inserts and the propagation of the perplexing design of tissues. Consolidating printing with progressed clinical imaging, a set-up of methods remembering the utilization of CT or X-ray for blend with post processing instruments and calculations , a scope of clinical inserts have been printed for an assortment of utilizations, including heart valves, ears , articular surface , meniscus , windpipe support , bone , skull , and mandible to give some examples[49-51] The post processing instruments utilized in cutting edge clinical imaging permit a progression of 2D pictures to be changed over into a view or model of the life systems. After the imaging information are procured, they are then saved in DICOM (advanced imaging and correspondences in medication) design. The DICOM documents are then controlled utilizing post processing apparatuses, which for the most part incorporatethresholding, division, chiseling, managing, and smoothing instruments. The shapes of adivided area of interest can be computationally changed into a triangle network. The cross section information at that point are further prepared utilizing computer aided design programming where extra smoothing and altering is performed to at long last create a STL (stereo lithography) document, which is viable with printer programming . This mix of methods has took into account custom designed what's more, customized embeds and frameworks to be delivered rapidly and successfully. Otology, or the investigation of the life systems and sicknesses of the ear, is one of the primary clinical fields that investigated printing as an assembling strategy for inserts and gadgets to be created.

4.3 Dentistry: Computerized dentistry and AM are quickly changing the dental business and now printing is utilized for a wide scope of dental applications, including dental and orthodontics models, direct crowns and scaffolds, dental aligners, night watches, careful drill guides, adaptable gingival covers, and dental replacement bases (Fig. 2) . Utilizing AM techniques for the manufacture of dental models is a methodology that has progressively been utilized for careful arranging, reenactment, and orthodontics. Studies have looked at the models fabricated with printing strategies with those made with the customary mortar technique and uncovered that the printed develops are clinically adequate as far as precision also, reproducibility. The benefits of utilizing AM procedures rather than the customary strategy emerge from the capacity to utilize advanced models to manufacture patient-explicit plans, which increment the effectiveness of production and improved solace for the patient. Creation of dental aligners utilizing printing has totally changed the orthodontics treatment. The organization Envisaging utilizes advanced dentistry and SLA innovation to make roughly 220,000 aligners each day, and very nearly 8 million every year .printing empowers each set to be customized effectively to singular patient-explicit needs. The material utilized for creating these aligners can incorporate styrene block copolymers, silicone rubbers, elastomeric composites, thermoplastic elastomers, thermoplastic vulcanization elastomers, polyurethane elastomers, block copolymer elastomers, polyolefin mix elastomers, and thermoplastic co polyester elastomers [52-54]. The principle benefits of these gadgets over traditional aligners or supports are their improved style, expanded solace to wear, and improved oral cleanliness because of the gadget being removable. The principle benefits of these gadgets over traditional aligners or supports are their improved style, expanded solace to wear, and improved oral cleanliness because of the gadget being removable. printing has additionally been utilized for helping periodontal fix. Respiring et al. have detailed the first in-human case treatment of a huge periodontal bony imperfection utilizing a printed patient-explicit framework stacked with development factors. The platforms were printed utilizing specific laser sintering advances and poly (caprolactone) containing 4 wt% hydroxyapatite. The interior piece of the platform had a repository for putting away a human recombinant platelet-determined development factor. The examination revealed that after a year of in vivo implantation the platform stayed flawless; notwithstanding, the development factor discharge energy required further advancement [55].

5. FUTURE ASPECTS:

Rapid prototype to rapid manufacturing, critical components to critical products all are easy applications for printer. It completely decreases both the material wastages and cost. If we talk about traditional printing/manufacturing, it is all about wastage of material and includes non precession activity [60]. A lot of material is wasted, but in printer maximum of the material is saved because of layer to layer deployment. The process starts after the suction of the material required for the layer deployment, the containers supplies the material required for the layer to layer deployment phenomenon [61-63]

NASA and affiliates like relativity space are not only using printing for rocket parts but they also believe that the additive manufacturing will help us colonize mars, other planets and beyond. Now human brain is completely activated toward the space research, a lot of components are required in the space missions, in maximum of the space programs all the required materials are send in the same space craft in which the space scientists are travelling. But past experiences have confirmed that they required some more materials in every mission according to the changing situations in the space [64-67].

Only they will proceed to manufacturing, as if the manufacturing will be quite fast the company can provide the customer a quite satisfactory and new product.

3D printing is completely going to change how industries work. At present we use printer in assembly line, through which the assembly of car or mobile is quite simple and fast. But if we think about the future the printer is going to change the complete scheme of the industries. Not before but now we can change how we purchase personal consumer goods. Printing will take world beyond assembly line. Providing a significant reduction in the cost of components eventually leading to on the fly innovation even more so we would be able to reduce industrial waste too.

6. CONCLUSION:

In this study, Biomaterials and 3D printing for sustainable application is discussed. We briefly described what 3D printing is and logged a literature review in which we discussed different literatures we have studied. Then we came to an overview of what a 3D printing is. The new era of additive manufacturing is discussed in the paragraph. Biomaterials are the most important part of 3D printing, so different Biomaterials, need of biomaterials and different biomaterials to be used were discussed in deep. We came to know there that modern 3D printers require modern Biomaterials so some upcoming biomaterials were also discussed. 3D printing is going to be used in fields of Engineering like Tissue engineering, Medicine and drug engineering, Dentistry and many more engineering aspects used 3D printing at a vital level.

The most important aspect or uses of 3D printing is yet to come. Here we discussed the upcoming or future aspects of 3D printer with sustainability. We contribute our study to encourage the development of 3D printer and increase the use of 3D printing so that we can move to some extreme additive manufacturing where both time and materials used is reduced and humanity can use some sustainable processes like 3D printers.

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