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Review Article

3D SCAFFOLDS BY 3D BIOPRINTING

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ABSTRACT

When it comes to tissue engineering, 3D printing is a crucial technique for creating intricate constructions using biocompatible materials, cells, and supporting elements. The concept of "3D bioprinting" is concerning 3D printing, which may be used to design personalised implants, paving the way for new bio-manufacturing methods. The method of 3D bioprinting is promising because it can create biomimetic 3D structures that mimic the extracellular matrix and build extremely accurate multifunctional scaffolds with uniform cell distribution for tissue repair and regeneration. The focus of this review is on the 3D printed constructions made from various synthetic and natural materials. With an emphasis on the most recent developments, this study aims to provide an overview of the state-of-the-art field of 3D printing techniques in applications for tissue engineering. An evaluation and overview of using 3D bioprinting, viewpoints of bio-ink, printing technology, and application are presented in this review.

Keywords: 3D printing, 3D bioprinting, Scaffolds, Bio Ink, Tissue Engineering, Printing

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INTRODUCTION

A scaffold is a biocompatible three-dimensional construct that mimics the extracellular matrix of a tissue and plays a key role in cell adhesion, proliferation, and differentiation [1]. In tissue engineering, scaffolds are used to seed cells and transplant them into an organism while providing physical and biological support [2-4]. Scaffolds have been tested for tissue regeneration and medication administration, both of which are important for Tissue Engineering. The evolution of biomaterials in the field of material science was started by the search for the optimal scaffold and its design and manufacture [5]. Scaffolds with innovative small-scale and large-scale designs were produced using the three-dimensional printing (3DP) technique [6]. It is a fabrication method that can create the interior structures and geometries of 3D objects in a controlled way, such as pore sizes [7]. In tissue engineering and regenerative medicine, this fabrication method has been widely employed to create scaffolds or cell-laden constructions with improved control characteristics for material and cell placement in 3D technologies [8]. By printing biological material in three dimensions (3D), we are able to create a wide variety of materials, from muscle tissue to brain tissue to cartilage to a full organ. To use this method, we first create a 3D model by scanning patient X-rays, CT scans, or MRIs. As the model is printed layer by layer, every aspect of the tissue is taken into consideration, both macroscopic and microscopic. The model is then printed one layer at a time then treated so that it can be used as one unit after being treated [9]. Making a 3D object of the desired shape and size from a 3D model is called 3D printing [10]. When it comes to bone regeneration, rehabilitation, and reconstruction, 3D-printing technology plays a crucial role in the medical profession by promising quality, being close to the original [11, 12], and expanding surgical treatment options. A method that enables customised production through computer-aided design is three-dimensional (3D) printing, often called "additive manufacturing" [13]. The term "3D bioprinting," which integrates 3D printing with biology, refers to the layer-by-layer deposition of biomaterials on layers using the most advanced Additive manufacturing technology [14]. In other words, the technique involves printing and patterning the cells using an automated dispensing system on a substrate or tissue [15]. The choice of Biomaterials is associated with the usage of finished product and the variation in 3D bioprinting technology. The use of 3D bioprinting has the potential to address many issues research in medicine, including regenerative medicine, drug delivery and functional organ replacement [16]. It was created for the first time using laser-based bioprinting to create cells in the 1990s [17]. A number of 3D bioprinting studies have been carried out in a variety of ways, including in situ skin printing, 3D tissue printing, and bioprinting employing inkjet technology. Aside from treating burn wounds with prosthetic skin, 3D bioprinting is also used for testing of drug, making models of damaged tissues to assess an effectiveness of treatment before administering it to a patient, heart valve replacements and bladder implants. Only a small number of people will benefit from this technique, leaving the impoverished to wait for a donor [18]. The primary objective of using 3D bioprinting is replacing the damaged or non-functioning tissue or organs with a new bio-printed one that, physically and functionally, acts similarly to the original organ. When placed inside the body of the patient, this bio-printed tissue must be capable of self-regeneration and differentiation [19].

3D bioprinting technology for the construction of 3d scaffolds

Inkjet printing

In this kind of bio-printing technique, a bio-ink made of living cells is combined with a chamber that is attached to the print head [20]. The print head is distorted as a result of the piezoelectric transducer. The method's primary benefits are its affordability and good cell survivability [21]. But, there are many issues with this approach, including print head clogging, uneven cell distribution, and the difficulty of printing viscous materials. Inkjet printing has the benefits of high resolution, cheap cost, high throughput, reproducibility, and simplicity of use. Additionally, inkjet printers can simply customised to print biomolecules and cells. However, biological materials were handled and printed with increasing speed, accuracy, and resolution using inkjet printers that were specially developed for the task [22].

Extrusion printing

In the extrusion bioprinting technique, a pressurised syringe is used to extrude liquid (paste or solution) by means of a needle into a solution with regulated density in the bioprinting process [23]. To produce complicated structures, extruding the materials in the in the shape of lengthy threads or dots. Natural biomaterials, particularly hydrogels, can be printed using this method at room temperature [24, 25]. Direct ink writing (DIW) and pressure-assisted bioprinting are two approaches for extrusion-based bioprinting. Materials that are suitable for DIW should have appropriate rheological characteristics that make printing simple. To facilitate extrusion out of the printing nozzle, the material needs to be shear-thinned. It

needs to have shear yield stress as well. A shear stress greater than the resin's yield stress is used to boost flow. When the resin is applied to a substrate, the shear pressure is then removed, and the resin regains its rigidity [26].

Laser-assisted bioprinting

The typical laser-assisted bioprinting (LAB) process uses specialised layers to create structures, including a bio-ink layer, a donor (quartz or glass), an energy-absorbing layer, and a collecting layer [27]. A laser beam is employed throughout the procedure to target the layer that absorbs energy. After that, this layer vaporises, separating the donor and bioink layers by an air bubble. The desired quantity of bioink is ejected onto the gathering layer as a result of a bubble forming. Droplets are assembled one by one to form a tissue structure [28]. For laser-assisted 3D bioprinting (LAB), three essential components are required: a pulsed laser source, a ribbon coated in bio-ink, and a receiving substrate on which the bio-ink is to be deposited. The energy source is a UV laser or a laser with a near-UV wavelength and a nanosecond pulse wavelength. The laser is used to cause the heat-sensitive bioink to release itself from the "ribbon." A target plate consisting of either quartz or material that permits laser transmission is coated with the bio ink. Since the bio ink is flammable by nature, when a laser pulse is applied, it sends a high-speed jet of bio ink onto the substrate with cells embedded in it [29].

Selective laser sintering

In the process, a laser beam gently warms the polymeric powder particles above the temperature at which they transition to glass [30]. This causes the particles to partially melt [31], which causes molecular diffusion to occur on the surface and the fusion of the particles. Lowering the building platform after each layer of the object is constructed, and a fresh a, thin coating of powdery particles is distributed on top and adhered to the preceding layer. A computer-aided design (CAD) programme is used by a designer to create a 3D model. Thin (2D) layers are used to split up the design. The Selective Laser Sintering printer receives the split design. The build platform of the printer is covered with a thin layer of powdered material [32].

Stereolithography

A high-quality printing technology based on the polymerization of very sensitive polymers was created in the 19th century [33]. This technique's primary mechanism is based on projecting a light beam onto the surface of the liquid photocurable resin using a UV laser and a directed mirror array. To set up the 3D pieces, this is repeated along the Z-direction in each layer. The primary drawback of this technique is the UV light source, which damages biocellular cells and leads to skin cancer [34]. PEG diacrylate (PEGDA), PEG diacrylate (PEGDA) PEG dimethacrylate (PEGDMA) and, two acrylate derivatives of polyethylene glycol (PEG), are a few of the commonly used moieties for photopolymerizing tissue engineering scaffolds [35].

Fused filament fabrication

The field of tissue engineering has used a variety of additive manufacturing methods. According to the type of power source utilised during fabrication, either heat or light, they can be divided into two major types. This method involves heating a coil of polymer filament and extruding it via a platform-mounted nozzle. It solidifies when the polymer comes into contact with the platform. Spatial resolution and potential thermal breakdown of the polymeric material are the main drawbacks of employing fusion Filament Fabrication printers in tissue engineering. Utilising thermoresponsive polymers like polylactide (PLA), polycaprolactone (PCL), or polyglycolide (PGA) is possible with Fused Filament Fabrication. High thermal stability is one criterion for selecting a material that is appropriate for Fused Filament Fabrication. The approach has drawbacks, such as the inability to create scaffolds with proteins or living cells inserted into the fibre structure due to an excessively high polymer processing temperature [36].

Vat polymerization

The most developed and popular 3D printing process, vat polymerization, has the advantages of high resolution and printing effectiveness. Stereolithography appearance (SLA), digital light processing (DLP), liquid crystal display (LCD), continuous liquid interface production (CLIP), two-photon 3D printing, and computed axial lithography are some of the divisions that can be made within it. A photosensitive liquid resin can be used as the raw material in vat polymerization, which is based on photopolymerization [37]. Three methods are frequently utilised in vat polymerization. 1) Creating a model using computer assistance 2) Vat polymerization development 3) dispensing for practical applications During the printing process, a layer of liquid photosensitive resin is projected with a pattern of light by laser emitters or a projector, which hardens into the desired shape. As the printed object advances through the layer thickness and the resin is replenished, the platform is engaged. Until the final 3D item is successfully constructed, this process is repeated [38].

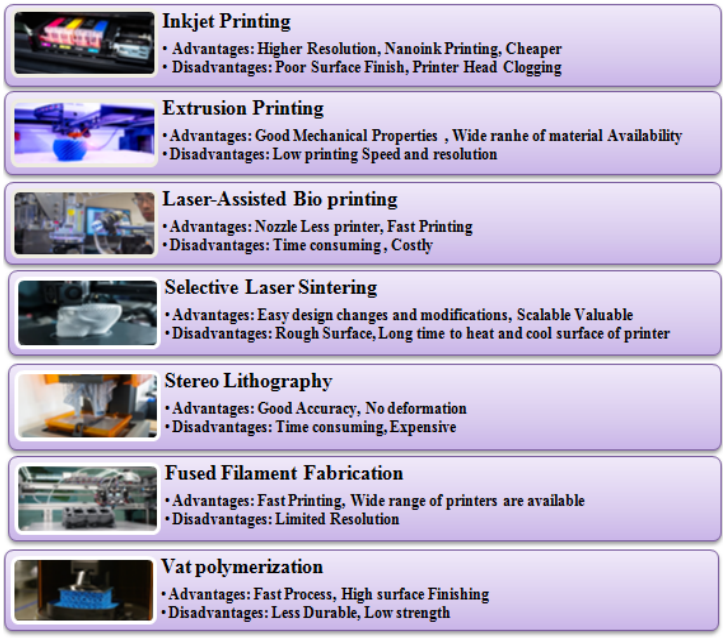

Fig. 1: Schematic representation of advantages and disadvantages of 3D bioprinting techniques

Bio-ink used in 3D bio-printing

Natural polymer

Many physical, biological, or chemical processes can be used to create naturally occurring polymers. In addition to being compatible, natural polymers can contain fluid and are, therefore, easy to dissolve in many solvents, such as cell culture solutions and phosphate buffers. When placed in a stable environment, this model will resemble a natural organ when created layer by layer [39]. Following are some natural polymers used for 3D bio printing.

Sodium alginate

A family of brown algae called Phaeophyceae produces alginate, which is used to make alginic acid salts. Wang used sodium alginate at 0 °C as the first material for 3D bioprinting, even though it can be printed at room temperature. As a result, it was cross-linked alongside other metals, including barium and calcium to enhance its mechanical strength and compatibility [40]. If used in high concentration, all processes, such as proliferation, development, and maturation, are altered.

Chitosan

The hydrolysis of chitin produces chitosan, which is often produced from prawn shells. Identical to other natural polymers, it has low strength and biodegradable properties; as a result, cross-linking using chemical substances is used to increase biodegradability and viscosity in collagen, alginate, and gelatine, which can then be used for repairing rigid structures like bone, skin, and cartilage [41].

Gelatine

Excellent hydrophilicity, non-immunogenicity, and biocompatibility are all characteristics of gelatine. It is completely biodegradable in vivo. Gelatine is a type of thermoreversible gel; at low temperatures, it solidifies, but when exposed to physiological circumstances, its mechanical properties become unstable. Gelatine's chemical properties will be altered to make the structure stable below 37 °C. With the presence of a photoinitiator, gelatine that has been treated with methacrylamide will cross-link. UV irradiation, which is frequently used in 3D bioprinting, makes it simple to extrude methacrylate complex hydrogel (GelMA) for moulding. The gel's concentration, length of cell density and ultraviolet exposure are all strongly correlated with GelMA's printing ability. The length and strength of the ultraviolet light will have an impact on the hydrogel's density and intensity, as well as the vitality of the cells [42]. Collagen is broken down to create the linear molecule known as gelatine. It is a unique polymer as it is a natural chemical with non-toxic, immunogenic, hydrophilic, and highly biodegradable qualities. To make gelatine more durable before printing, it is mixed with culture medium [43]. Gelatine molecules can form crosslinks with a variety of substances, including hormone growth factors. When it gels, heparin and additional organic polymers, including hyaluronic acid, chitin, fibrin, collagen, and agarose, will make it more durable and compatible [44].

Hyaluronic acid

The extracellular matrix, which is a key factor in cell growth and angiogenesis, contains hyaluronic acid as an essential component. It can be used to modify the viscosity of other polymers, such as gelatine, owing to its strong water-absorbing quality and cell adhesive property. Like Hyaluronic acid and other natural polymers, it has been cross-linked with synthetic polymers to improve compatibility [45]. Another name for hyaluronic acid is sodium hyaluronate. There have used extensively in health centre as a joint lubricant and skin filler. It is essential for adjusting cellular behavior and function, including cell division, proliferation, and angiogenesis. Cell viability is higher in 3D-printed hyaluronic acid hydrogel than in collagen hydrogel when it is encapsulated in cartilage tissue. Due to its quick deterioration, hyaluronic acid has poor mechanical properties; however, this characteristic can be enhanced by controlling chemical alterations and its degradation rate. Hyaluronic acid is unsuitable for 3D bioprinting for this reason. However, by photo-curing methyl acrylate (MA) to manage the time of photopolymerization, functional therapy can be used to cross-link hyaluronic acid [46].

Agarose

Because of its low gelling temperature of 32 °C, biocompatibility, and mechanical robustness, agarose, a natural polymer, has been used as a bio-ink. A linear polymer having thermo-reversible and heat-reactive properties is agarose hydrogel. The agarose strands are extruded quickly solidify on refrigeration during the printing of agarose with a low melting point. Mesenchymal stem cells were encapsulated in agarose gel by Campos *et al.* [6] for 3D bioprinting. Fluorocarbon served as the structure's main support. Cell deposition resulted in the formation of a tubular structure, and 21 d later, nearly all of the cells were still alive. Agarose is commonly used in 3D cell culture platforms to sustain cell clusters thanks to the natural inertia of cell adhesion [47].

Fibrin

Fibrin is a naturally occurring polymer because fibrinogen rapidly polymerizes in the presence of thrombin to create fibrin in the blood [48]. Even though fibrin has been proven to be more compatible than other naturally obtained polymers, which increases its usefulness, it is nevertheless mixed with overcoming other natural polymers its shortcomings in terms of viscosity, strength, high degradation, and gelation when used alone [49]. In current years, it has become popular to mix then crosslink them with natural polymers with chemicals to create hybrid polymers. Examples of these combinations include gelatin-chitosan-alginate-fibrinogen and gelatine-hyaluronic acid-glycerol-fibrin. Combining these two elements results in a structure that is sturdier, prints more quickly, and produces models that endure longer in the body's environment.

Synthetic polymer

Synthetic polymers are highly resistant and strong materials that are produced artificially by people in a lab using the right chemicals and conditions. Because they may tolerate changes in pH and temperature and can be treated to meet our requirements due to their enhanced mechanical strength and resistance, synthetic polymers have the main advantage of being simple to modify. Synthetic polymers are excellent candidates for 3D bioprinting models because they have shallower gelation temperatures than natural polymers, which have very high melting points. As a result, the generated polymers are inert, resistant to breakdown, and possess a strong tensile strength.

Polyethylene glycol

A synthetic linear polymer is polyethylene glycol that is suitable for bioprinting due to its compatibility, mild immunogenicity, and high affinity for water. A hydrophilic polymer created by a radical polymerization reaction is polyethylene glycol (PEG). There's a branching or linear structure with asymmetric or dissymmetric tail groups made up of hydroxyl ions. Polyethylene oxide is another term for polyethylene glycol [50]. In order to make polyethylene glycol more useful in order to restore delicate tissues, it is cross-linked with other molecules such as acrylate, carboxyl group, or thiol group. The rate of cell encapsulation and mechanical strength of polyethylene glycol can both be increased by polymerizing it in the presence of UV radiation. PEG has additionally cross-linked with GeIMA to boost its capability for the bio-printing of hard materials like cartilage and bone using the Inkjet bio-printing method [51].

Polycaprolactone

PCL is a less expensive polymer that has excellent bio-ink properties like rigidity, biocompatibility, and degradability. One non-toxic polymer that can withstand significant stability is PCL. Typically, stability lasts for six months and has a biological half-life of three years. The partially crystalline polymer polycaprolactone is easily broken down by human bodies on a biological level [52]. It is a thermoplastic polymer that is created when additional substances are added to it at a temperature of-60 °C to alter its mechanical structure and rate of degradation. It is suitable as a material for 3D bioprinting using fused deposition modelling [53]. In order to boost its capacity as a cell adhesive for cartilage regeneration, polycaprolactone is cross-linked with other bioagents, such as polycaprolactone-alginate, as is done with all other synthetic

polymers. In order to boost the scaffold's durability and stability, polycaprolactone (PCL) has also been coupled with GeIMA using UV light. Widely employed in cartilage and bone regeneration, GeIMA concentration is proportional to scaffold hardness [54].

Polylactic-co-galactic acid

Lactic acid and glycolic acid are two polymers that can be copolymerized to create polylactic-co-glycolic acid. The temperature at which polylactic-co-glycolic acid transitions is typically seen to be between 40 and 60 °C, and glycolic acid and lactic acid are employed in a ratio of 1:3 [55]. It has been found that the amount of glycolic acid utilised during the synthesising process affects how quickly polylactic-co-galactic acid degrades. Where strong mechanical support is necessary, polylactic-co-galactic acid is frequently utilised [56]. It may also be mixed with additional substances, such as growth-stimulating elements or adipose stem cells, to increase its efficacy and suitability for the complex structure of 3D bio-printed organs.

Acrylonitrile butadiene styrene (ABS)

A triblock copolymer with petrochemical origin is ABS. ABS is made up of acrylonitrile butadiene styrene. Styrene terpolymers, which have acceptable strength and toughness, are related to ABS chemically. This material's applications are expanded by its low melting point (105 °C). The ABS is composed of three separate monomers, including acrylonitrile, butadiene, and styrene, which together contribute to the material's heat resistance, powerful impact strength, and imparted rigidity. ABS is a precursor material used in printing processes like fused deposition modeling (FDM) and selective laser sintering (SLS). In cartilage engineering technologies, it is also used.

Recent advances in 3d bioprinting technology for tissue engineering

Nervous tissue

The most difficult tissues to heal are those of the central and peripheral nervous systems (CNS and PNS). By creating collagen microchannels with the aid of needles and a 3D printing frame, an *in vitro* brain model was created via 3D printing. The collagen micro channels were used to culture mouse brain cells, and this caused the brain's microvasculature to regenerate. The results of this study demonstrated the usefulness of the brain-blood barrier (BBB) model for physiological and pathological testing as well as a wide range of applications, including medication administration, tissue regeneration, and tissue engineering [57]. A few studies focus on printing neural conduits in 3D. In a study by Hu Y *et al.*, cellular zed channels for regenerating peripheral nerves were 3D printed using cryopolymerized gelatine methacryloyl (cryoGelMA) gel that had been cellularized with adipose-derived stem cells (ASCs). The constructed conduits' capacity to re-energise cells was demonstrated *in vivo*. It is important to note that patient-specific casting moulds were created via 3D printing [58].

Ocular tissues

In ophthalmology the use of, 3D printing is yet gaining popularity; however, the vast almost all applications do not include tissue engineering. There are some instances of research on 3D printing and regenerating eye tissue: An attempt to rebuild a 3D retina is presented in the work of Lorber [59]. The 3D-printed retina-like structure contained adult rat retinal glia and ganglion cells. It was demonstrated that certain retinal Types of cells can be printed effectively without losing viability or specific phenotypic characteristics. Another illustration of its use of Ocular tissue engineering using 3D printing is the creation of the TE corneal scaffold, consisting of corneal keratocytes are encased in a collagen-based bio-ink. [60]. According to a proposal made by Tagami *et al.*, lyophilized ocular patches might produce innovative dosages and be tailored to the needs of hospital patients [61]. The first intraocular device created using 3D printing technology was Canabrava's Ring, a 3D pupil enlargement device used in ophthalmic surgery. The pupillary dilatation produced by this instrument is 6.5 mm. additionally, it enables the use of conventional methods in cataract procedures [62].

Ear

The bionic human ear was produced using computer-aided design. During the bio-printing process, a hydrogel matrix including cells, a conductive polymer, and silver nanoparticles was employed. The bio print was made to resemble a human ear. The research made it possible to regulate the impulses coming from the cochlea-shaped electrodes. The tissues of the cartilage on each side of the inductive coil were given access to the *in vitro* culture. It was discovered that the printed ear improved auditory perception. Another study showed that using the subject's lipid tissue and auricular cartilage, 3D bioprinting can create the printed ear. Hydrogels were used to surround differentiated adipocytes and chondrocytes before they were applied to the lipid and cartilage tissue [63]. The 3D-printed TB model successfully assessed the protective role of passive HPDs during burst, and its potential for usage as an acoustic transmission model was explored [64].

Kidney

Calcium sulphate and sodium alginate-infused PEGDA scaffolds were put to the test after construction. The scaffolds were UV-light cross-linked before being used to cultivate human embryonic kidney cells (HEK). The qualities of the aforementioned composite materials that enable cell survival and proliferation have been demonstrated [65]. The creation of A simplified representation of human kidney organoids of a living organ created *in vitro*, was accomplished using extrusion-based 3D bioprinting in the study by Lawlor *et al.* [66]. Organoid size, cell quantity, and conformation can all be precisely controlled by the fabrication technique used. Kidney organoids were designed as an *in vitro* model that might be used for disease modelling or medication testing. The author demonstrates the fundamental principles of 3D printing technology, as well as its state of application and future potential in the treatment of renal disorders [67].

Bone and cartilage tissue engineering

One method for creating bone tissue is three-dimensional (3D) printing. However, for better bone regeneration, printable ink materials with desirable properties, including structural interconnectivity, mechanical strength, controlled degradation rates, and the incorporation of bioactive compounds, are essential. According to the research paper, tissue engineering has benefited from the use of extended 3D-printed constructs made using inkjet bioprinting. In order to create bone tissue, Gao *et al.* used 3D inkjet printing technology along with bone marrow-derived mesenchymal stem cells (BM-MSC) and polyethylene glycol dimethacrylate (PEGDMA) as the bioink. They upgraded their work on HA and bioactive glass nanoparticles and assessed the differences in order to analyse the osteogenic capacity of the employed bioink. They also came to the conclusion that the HA-based scaffold had greater osteogenic potential than the bioglass-made scaffold [68]. One of the most frequent regeneration treatments is the restoration of bone and cartilage abnormalities. To restore a damaged bone is the main goal of cartilage and bone tissue engineering. As a result, 3D printing techniques attempt to manufacture an artificial bone structure with the necessary characteristics, such as the right mechanical qualities, form, and size [69]. It should be kept in mind that osteochondral scaffolds are frequently bi-or even tri-phasic; the fabrication of osteochondral scaffolds typically necessitates a combination of various printing processes and materials.

Heart valve

There is a lot of research being done on the application of hydrogel materials in heart valve tissue engineering techniques [70]. In recent years, hydrogels have also been used in order to resemble the native ECM environment and good grip cells inside electrospun engineered valves, to create starter scaffolds that are quickly remodelled by cells before being decellularized to form implantable valves and to incorporate regional matrix or mechanical differences directly into engineered valves [71]. With the aid of 3D printing, Hockaday *et al.* created native anatomic and axis-symmetric aortic valve geometrical designs. In this study, they used a 3D printing technique to create a complex and heterogeneous valve scaffold with a variety of inner

diameters of 258 M using UV light crosslinking and PEG-DA hydrogels. P. Mani *et al.*: 12 to 22 mm 3D printing for tissue engineering applications a 3D printer that relies on extrusion was used for the printing system [72].

Skin

Researchers, such as Lee from Harvard Medical School, use an inkjet printer to create skin texture and a layer accumulation technique. After printing two layers of collagen, a layer of fibroblasts is next sprayed on top, followed by six layers of collagen and two layers of keratinocytes. In the printing process, sodium bicarbonate is employed as a cross-linking agent [73]. Due to the relatively thick six layers of collagen in the centre, a channel is printed between the layers of collagen, and gelatine is employed as a sacrifice material in order to increase intercellular communication. Gelatine will turn into a liquid state and flow out of the tube when grown in an environment with 5% CO2, which enables the development of skin texture and may result in the generation of perfusion channels resembling blood vessels. Collagen and gelatine are printed at low temperatures; the texture temperature after printing is 37 °C. Comparing experimental findings, it was discovered that skin texture cells with pores are more likely to survive than cells without pores [74]. A 3D-printed skin was created with the use of lasers. Keratinocytes and Fibroblasts were combined with collagen type I and Matriderm (for matrix stabilisation). By applying a bioprinted construct to the mouse skin, the experiment was also carried out *in vivo*. Mostly an epidermis developing was seen in the effect studied by Lee K. Utilising fibroblasts and keratinocytes suspended in a gelatin-based hydrogel, the approach of bio fabrication of skin equivalents (SE) that are bioprinted utilising an open-market bioprinter was addressed in Layers of SE were directly extruded onto the multi-well plate. The developed structure is made up of the dermis, the laminin/entactin base layer, and the epidermis. The created SE could be applied to the *in vitro* modelling of skin diseases [75, 76].

CONCLUSION

The 3D bio-printing process is highly precise and produces finished products quickly. Many of the tissue engineering demands needed to create bio fabrication systems have been fulfilled by 3D printing. Human organs replaceable at any time in the coming decades in order to extend the human life cycle if "bio-printing" technology is developed. Although there is still a long way to go before with the help of cutting-edge technology we can print an organ can demonstrated promising potential that will alter the lives of the thousands of individuals who die every day due to the lack of a donor organ. For many individuals, though, the idea of implanting a printed organ in a human body is still unsettling. If it is effective, many concerns will be resolved, including the lengthy transplant waiting list and problems with organ rejection, and it will fundamentally alter how medicine is practised. This review article explores the many methods used by 3D printing to create scaffolds for tissue regeneration.

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AUTHORS CONTRIBUTIONS

All the authors have contributed equally.

CONFLICTS OF INTERESTS

Declared none

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