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BIOPOLYMER USE IN FABRICATION OF ARTIFICIAL ORGAN BY 3D BIO-PRINTERS

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ABSTRACT

Polymers function as adaptable mediums for the creation and design of biomaterials employed in biomedical bias; still, these styles must be employed to construct complex natural organ systems integrating the rearmost inventions in 3D bioprinting technology. These biomedical(biopolymers) appear from a series of natural and synthetic resources available in nature, with current sources including(natural polysaccharides) similar as alginate, hyaluronic acid, chitosan, and starch, in addition to proteins like collagen, fibrin, along with various(synthetic polymers) similar as poly(glycolic acid), poly(lactic acid), poly(vinyl alcohol), poly(ethylene). Both natural and synthetic polymers play an important part in the establishment vascular and neural networks within 3D printed organ structures, attributed to their specifically acknowledged properties such as physicochemical, natural, physiological, tensile features, and the toxicity levels of biopolymers. This composition concentrates on advanced polymers that demonstrate exceptional biocompatibility and biodegradability. also, it details the most recent ways for the 3D printability of mortal organ rejuvenescence, alongside the operations in tissue regeneration and the fabrication of artificial organs reviewed and presented.

KEYWORDS: Polymer, Three-dimensional (3D) printing, artificial organ, tissue regeneration.

GRAPHICAL ABSTRACT

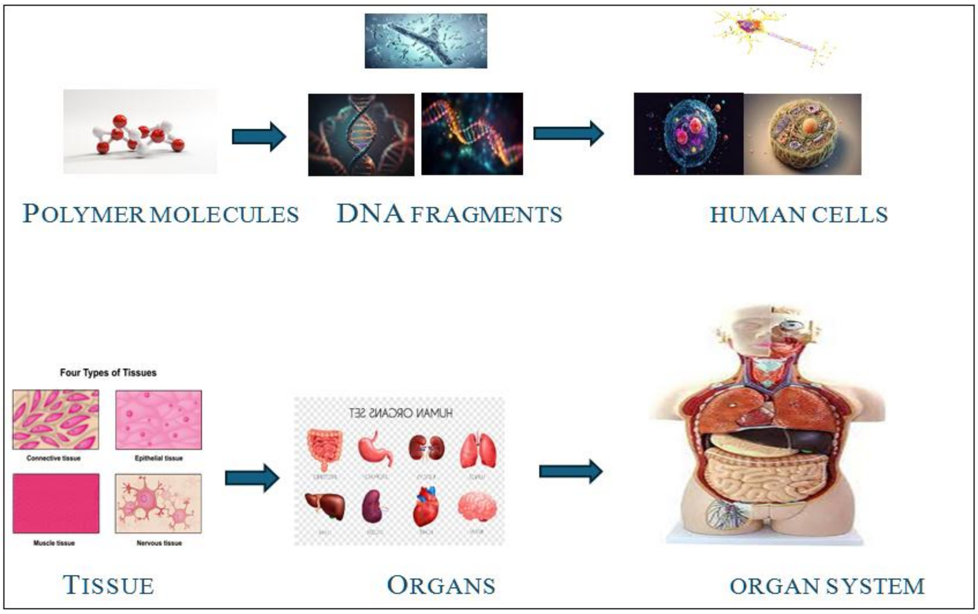

Figure 1: Formation of organ system.

• INTRODUCTION

3D printing represents a groundbreaking advancement in the creation of artificial organs, utilizing a variety of processes and raw materials to construct macromolecular cells that can develop into tissues and ultimately entire organ systems, organ layer.[1-3] Thus, introduction this artificial bio printing technology in last century a significant milestone across various domains, including pharmaceuticals, tissue engineering, and medicine. The swift progress and ongoing research in this area have streamlined the process, with computer-assisted design (CAD) playing a crucial role in the growing success of this innovative technology.[4]

The main aim of this technology is to recreate, repair, and revive lost or harmed tissue using bioelement, artificial cells, human stem cells and various other elements.[5,6,7] Nearly decade have passed since the debut of this 3D bioprinter, and regenerative medicine has achieved remarkable progress in tissue reconstruction by leveraging various biopolymeric substances for the generation of tissue restoration or formation.[8,9]

Organ failure is currently a leading cause of death worldwide, with millions of people suffering from either complete or partial organ dysfunction each year. This condition has adversely affected human life expectancy over the last few centuries, primarily due to the limitations in medical treatments and formulations available.[10] However, significant technological progress has development of various organ transplantation techniques. Despite current research and development in organ transplantation and tissue regeneration, traditional methods encounter substantial challenges, particularly in finding suitable organ donors and managing the problem of transplant rejection. Considering obstacles, the field of artificial organ development has made considerable strides, exploring multiple approaches such as tissue engineering, genetic modification, DNA replication, stem cell research, and the creation of artificial and bio-organ technologies, along with the innovation of tissue scaffolding.[11-13] The rapid progress in these domains, which combines engineering, biological sciences, and synthetic organ development, is balanced to play a crucial part in organ failure in the upcoming.[14]

Biomaterials used in regenerative technology differentiate into two main categories: natural and synthetic polymeric biomaterials. These materials play a important part in the regeneration or restoration of variety artificial organs. For a polymer to be effective in tissue regeneration, it must demonstrate excellent biocompatibility, biodegradability, and bioactivity. Furthermore, it should have appropriate physical, chemical, and physiochemical properties, such as mechanical strength, thermal conductivity, tensile strength, permeability, and mechanical turbidity. The elasticity of the polymer is also important, as it enables adaptation to various three-dimensional organ shapes. Among these factors, the adjustable bioactivity of both the polymers, along with this potential composition, greatly impacts the success of tissue restoration and regeneration.[15]

The primary categories of biomaterials utilized in regenerative medication can be identified into bio polymeric materials. Natural sources include collagen, chitosan, alginate, gelatine, cellulose, hyaluronic acid, and starch, while synthetic options encompass polycaprolactone, polyvinyl alcohol, polystyrene, nylon, polyurethane, and polyvinyl chloride. Natural polymeric materials are particularly favoured in organ regeneration due to their superior biodegradability and biocompatibility are counterparts of such materials. Notably, collagen and alginate, along with other natural biopolymers, have found applications the regeneration of cells, tissue, cartilage, bones. Conversely, synthetic polymeric materials are also employed for their cost-effectiveness, processing, customizable chemical, tensile strength. Among these bio-synthetic, poly (lactic acid), polycaprolactone, poly(lactic-co-glycolic) acid (PLGA), and poly(ethylene glycol) (PEG) have been studied for their roles in skin, nerve, and bone regeneration.[16,17]

In this century, there has been a notable amalgamation of natural biopolymeric substances biosynthetic polymers to good bioactivity and biocompatibility, to refine mechanical and chemical properties, including regulated release mechanisms for tissue repair. The structure of multi-polymer compositions is vital in enhancing mechanical durability, degradation rates, cellular adhesion, and overall chemical features.[18-21] Surface alterations have been thoroughly examined to facilitate cellular attachment and proliferation across various polymeric substrates. Earlier studies have shown that the regulation of cellular growth, attachment, and tissue development is significantly affected by the density and porosity of polymeric biomaterials, along with their mechanical stability and physical characteristics. As a result, the investigation of tissue repair has increasingly cantered on the collaborative use of bio natural and synthetic materials to form an environment that supports the restoration of damaged or injured tissues following implantation.[22,23]

A variety of innovative automatic and semi-automatic bioartificial organ fabrication technologies are emerging, encompassing fields such as computer science, biomaterials (e.g., polymers), chemistry, and science.[24,25] This advanced ideology have the potential to address numerous long-standing challenges in organ transplantation tissue engineers, researchers for over five to six decades. Issues such as large-scale production of tissues/organs, the construction of complex vascular and nerve networks with fully developed tissues layer by layer, stepwise differentiation stem cells within intricate 3D frameworks, long-term storage of bioartificial tissues/organs, drug testing, and in vivo biocompatibility of implanted biomaterials are being tackled.[24,25] Various polymers have been crucial in the production of bioartificial organs, facilitating the integration of diverse cell types, stem cells, organized neural systems. An extensive range of 3D bioprinting methods has been utilized, resulting in the fully automated creation of artificial organs for diverse medical applications, including drug identification, cell transplantation, artificial /repair/formation/transformation, pathological assessments, metabolic studies, and the preservation of living tissues/organs. Technologies employed include inkjet-based, laser-based, extrusion-based, stereolithography (SLA), among others for bioartificial organ production. A discussion on future directions is provided in the conclusion. This review holds significant importance due to the growing research interest in 3D printing for organ applications, detailing the processes by which artificial organs are developed.[26-29]

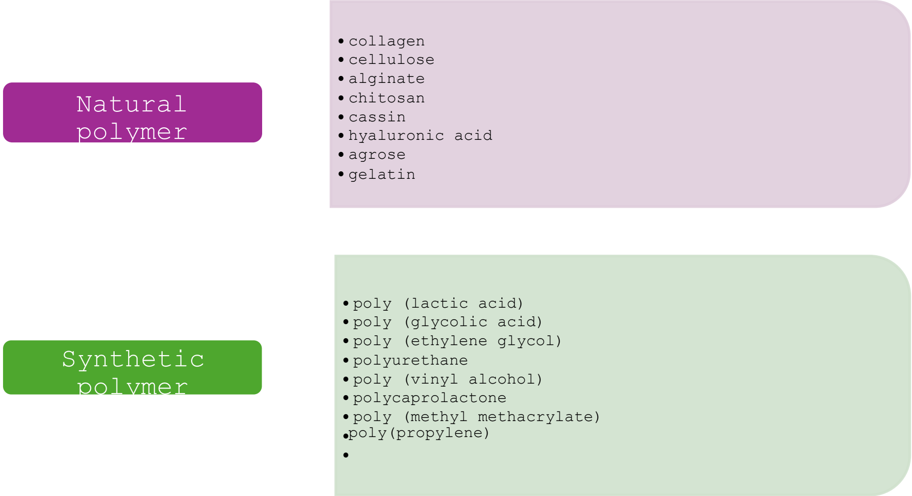

Figure 2: Types of Polymers.

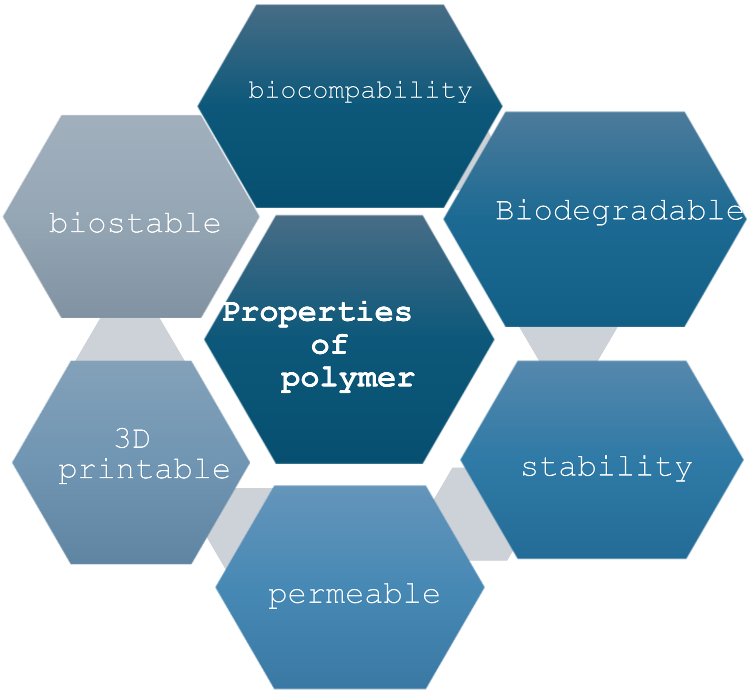

Figure 3: Basic Requirements for Selection of Polymer.

- **Polymeric material: Naturally obtain polymers**

Naturally inferred polymers such as collagen, silk, chitosan, alginate, and hyaluronic acid originate from variety of biological sources, encompassing, epithelial layers, bacteria, algae, silkworms. The primary materials go through a purification process to remove any extraneous biological elements, facilitating the isolation of the sought-after polymer. This purification step is essential for allowing further alterations that can enhance the polymers' functionalities, making them appropriate for uses such as bio solvents and hydrogels. These organic polymers have the capability to be developed into bioinks when mixed with seed cells, owing to their natural mobility. However, because of their distinct physicochemical, and natural properties, these polymer solutions or hydrogels can't be in 3D printing without undergoing a soul-gel alteration during the printing sequence. They are often utilized as additives alongside thermosensitive or chemically cross-linkable polymers, including gelatin, agar/agarose, and alginate, to augment the characteristics of hydrogels applied in 3D bioprinting. The viability of these bionatural polymers in a 3D bioprinting scenario is influenced by numerous factors, such as polymeric weight, viscosity and crosslinking capability of th ebio polymer arrangements. Moreover, the precision of printing with bionatural polymer solutions is greatly impacted by polymer concentration, viscoelastic properties, gelation rate. These key advantages of leveraging these polymers in the bioprinting of synthetic organs include their capacity to encase live cells and bioactive materials before printing, protect these elements throughout the printing process, and form semi-permeable membrane substrates after printing.[30-34]

3D printing offers sophisticated and precise capabilities for creating intricate organ systems, including skin, dental structures, the heart, lungs, and liver. This technology enables the engineering of entire organs or specific parts, facilitating reconstructive and restorative functions. However, it is essential to customize the polymers used to meet the specific requirements for organ printing and their functional roles. This article discusses key polymers that are critical for bioprinting applications in tissue reconstruction and artificial organs, such as skin, cornea, arteries, cancer treatment, dental solutions. Currently, the most widely utilized polymers in 3D organ printing include gelatin, alginate, collagen, starch, hyaluronan acid, chitosan, silk etc. Which are considered the most promising materials for this innovative field.

- **Collagen**

1. Collagen serves as a fundamental protein that forms a substantial part of the extracellular matrix in musculoskeletal tissues across mammals, representing about 25–35% of protein in body.[35] There are 25 different categories of collagens, with types I through IV being the most utilized in various fields. This natural protein is for maintaining the structural of tissues, particularly in humans, where it creates fibrous networks that engage with primary receptors like integrins. The collagen with other inorganic or organic polymers contributes to the development of biopolymeric scaffolds, which are known for their impressive strength and durability. These scaffolds, characterized by their unique porosity and surface characteristics, find applications in wound healing.[36]
2. Type I collagen is especially recognized for its superior tensile strength and high porosity, which foster cell attachment and abundance, particularly suitable for wound healing and dermal regeneration. Furthermore, collagen hydrogels have demonstrated effectiveness in fostering the growth and maturation of neurons and astrocytes[37], aiding in the establishment of neural networks.[38] In the context of osteogenesis and bone repair, collagen is utilized with various fabrication techniques that allow for the modification of mechanical properties through adjustments in fibril density and crosslinking.[39,40] The integration synthetic polymers with collagen has guided to groundbreaking strategies for tissue regeneration, significantly improving the functionality and efficacy of scaffolds in medical applications.

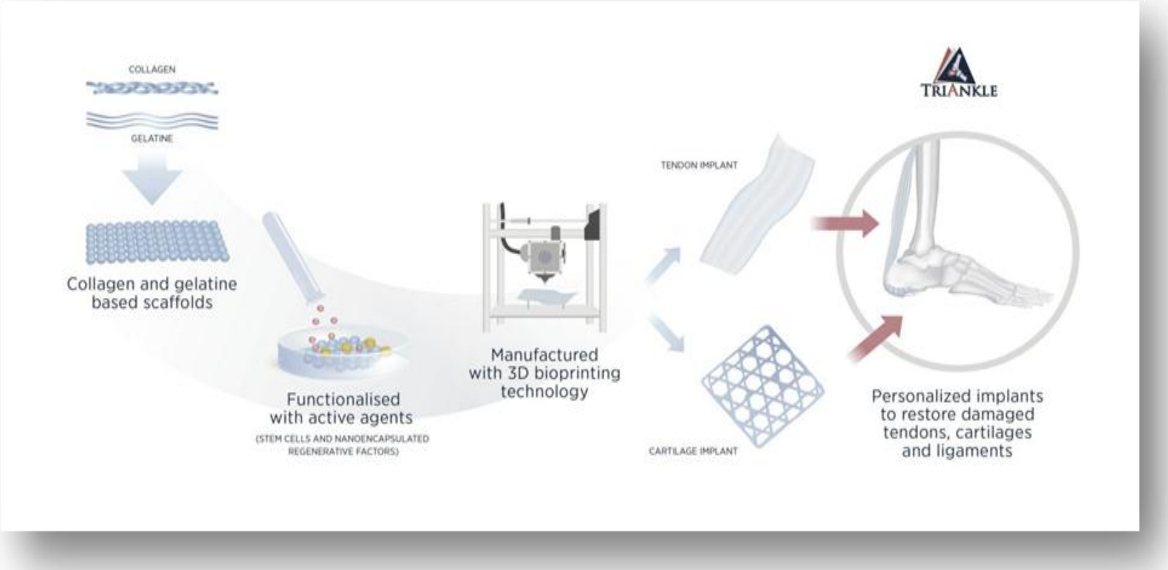

Figure 5: Application of Collagen.

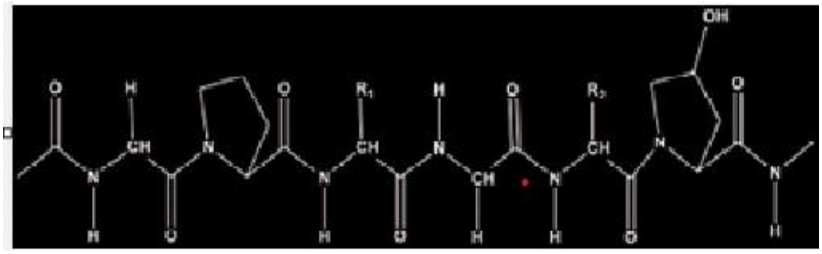

Figure 6: Collagen.

- **Chitosan**

1. This is a polymer that originates from the deacetylation of chitin, a substance found abundantly in nature, particularly within exoskeletons like shrimp and crabs, certain marine animals and certain fungi.[42] This multifunctional polysaccharide is gaining traction in various biomedical fields due to its non-toxic, biodegradable characteristics. Chitosan is known for its notable activities, which include antimicrobial, and antioxidant that promote cell bond, propagation and differentiation. Its formulation process both economic and environmentally sustainable, making it an ideal candidate applications in food, cosmetics, and pharmaceuticals.[43]
2. In the biomedical sector, plays avital role in 3D printing, where it is utilized as a bio-ink to produce hydrogels and scaffolds that replicate the (ECM) of various tissues, such as tendon, skin, and neuron cells. The printability of chitosan is affected by its physical attributes, including viscosity, and it is frequently combined with other materials like PEG, pectin, and gelatin to enhance extrusion and minimize the risk of device clogging. When pectin is crosslinked the amino groups, at a pH range of 3-5, it can produce 3D printable bio-inks. Nevertheless, challenges such as limited mechanical strength, swelling behavior, contamination, sterility, and biodegradation management pose obstacles to its use in drug delivery systems.[44,45]

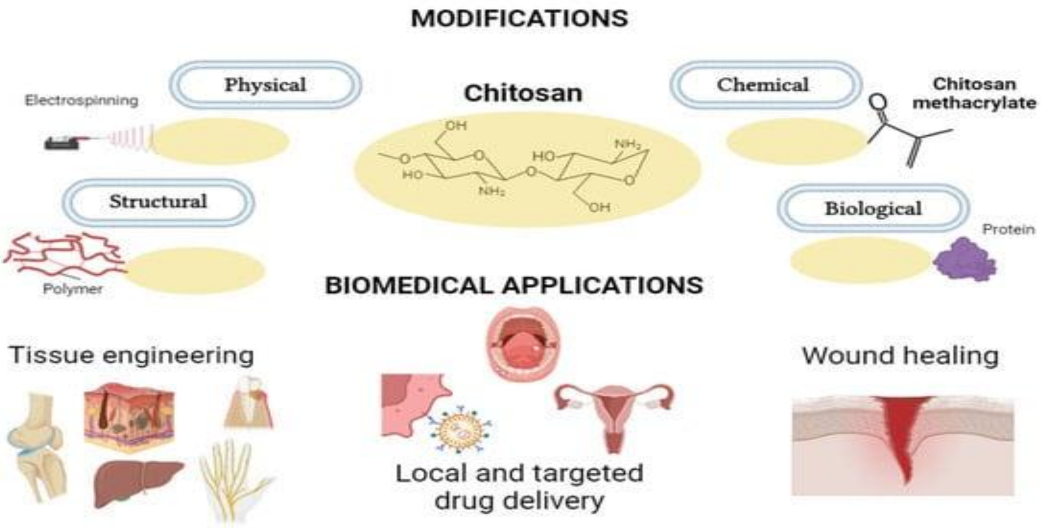

Figure 7: Modification of Chitosan and Its Applications.

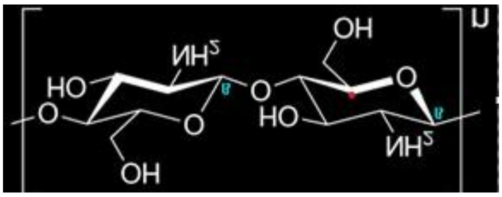

Figure 8: chitosan.

- **Cellulose**

1. Cellulose stands as the most ubiquitous natural biopolymer, primarily sourced from plants such as bamboo, wood, and cotton, while also being present in certain animals, fungi, bacteria, and algae. This polysaccharide is both renewable and biodegradable, exhibiting insolubility in water and a remarkable resistance to degradation. These properties render forms of cellulose employed in scaffolds include nitrocellulose and derivatives of hemicellulose, which closely resemble the natural extracellular matrix.[45]
2. Cellulose is utilized as a scaffolding material, processed into diverse formats such as hydrogels[46], films, and nanofibers, facilitate cell attachment and promote the growth of natural tissues. Its advantageous characteristics include excellent mechanical strength, hydrophilic properties, and adaptability.[47] The diverse applications of cellulose extend to wound healing, bone tissue engineering, dermal tissue support, and ear scaffolding, making

cellulose scaffolds particularly suitable for the proliferation of 3D nerve cells.[48]

Figure 9: Human Ear Scaffolding By Cellulose.

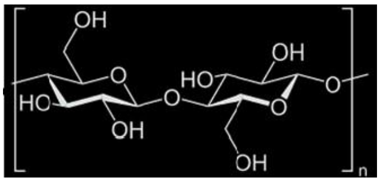

Figure 10: Cellulose.

- **Alginate**

This, are economical biopolymer that is derived from the Ca, mg, and Na alginate salts found in the cell walls of various algae.[49] This biopolymer has the ability to dissolve in solvents such as water and can be crosslinked with cations including (Ca2+), (Ba2+), and strontium (Sr2+) ions through ion exchange reactions.[50] Alginate is a naturally occurring substance that is characterized as non-toxic, biodegradable, biocompatible, consisting of guluronic monomers. When exposed to temperature variations, pure alginate solutions face challenges in being printed in layered formats unless chemical crosslinking is applied. In addition to its exceptional biocompatibility, alginate is an inexpensive marine derived material acquired from algae cell walls that can form hydrogels under mild conditions. Certain 3D bioprinting techniques, such as extrusion, necessitate rapid gelation processes. Alginate solutions provide quick gelling capabilities when combined with multivalent cations, enabling versatility across various biomedical applications including nanoparticle formulation tissue engineering, and regenerative medicine. processes of bioprinting can be executed through different system, such as extrusion-based deposition of cell fibres onto nozzle-assisted crosslinking deposition.[51]

In extrusion bioprinting, bioinks of different viscosities ranging from 30 mpas are utilized. While the bioink can have a high cell density, the shear stress encountered extrusion process can result in a reduction of cell viability by 80% to 90%. Conversely, inkjet-based bioprinting employs contain lower cell densities (under 16 × 10^6 cells/mL), allowing for significantly higher cell viability in this method.[52,53] The use of alginate in applications such as bone and cartilage printing present distinct challenges. While alginate exhibits inadequate mechanical properties for bone bioprinting[55,56], it serves as a biostable hydrogel for cartilage printing, demonstrating suitable biodegradability and mechanical characteristics.[54]

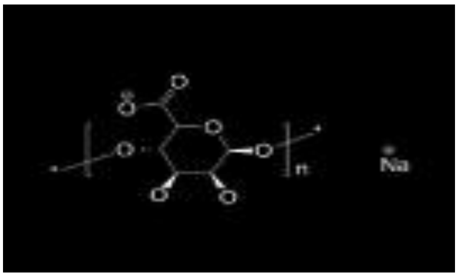

Figure 11: Alginate.

Table 1: Shows Polymer And Its Applications.

Sl. no	Type of Bionatural Polymer	Application	Printing Technique	Advantages	Reference
1.	Collagen	Medical Extrusion, printing photographic, biomedical, food, bone, artificial organ	Inkjet	Good biocompatibility, accurate printability, and cell printing properly	[66]
2.	Chitosan	Neural and Bone regeneration, cartilage regeneration, cardiac tissue	Stereolithography, Extrusion	Biodegradability, biocompatibility, low cost, and no immunogenicity	[67]
3.	Alginate	Wound healing, tissue scaffolding	Extrusion	Good printability and biocompatibility, low cost, low toxicity, fast gelation, Good mechanical strength	[68]
4.	Hyaluronic acid	Biomedicine, tissue regeneration, cosmetics, nutricosmetic	Extrusion stereolithography	High degree compatibility, good absorption, easy to deform any shape and size	[69]
5.	Cellulose	Construction of ear, bone, cosmetics	FDM, inkjet printing,	Low cost and desirability	[70]

Table 2: Polymer Like Alginate, Gelatin, Chitosan, Collagen, and Hyaluronic Acid In Bone Tissue Engineering With Advantages And Limitations.

Sl. no	Polymers	Advantage	Limitation	Reference
1.	Alginate	• Cost effective • 3D printable • Biocompatibility • Simple gelling • Cross linking, • Tensile	• Short-term, restricted stability • Fast mechanical property loss because of in vitro culturing • Restricted capacity for 3D shape	[90-95]
2.	Gelatin	• Faster in gelling process • Biodegradable • reversibly gel thermally	limited mechanical qualities	[96-97]
3.	Chitosan	• molecules are like native tissue's extracellular matrix • Harmless by products • Stimulates the growth of cell • Bio compatible	• Slow gelation rate • Weak mechanical property • PH sensitive molecules and cells	[98]
4.	Collagen	• Low immunogenicity • Great biocompatibility • Inhibits cell adhesion • Differentiation	• Poor mechanical strength • viscosity and gelation are low	[99-101]
5.	Hyaluronic	• Highly hydrophilic acid Anti microbial properties • Visco-elastic properties	• Mechanical strength	[102-103]

- **Synthetic Polymers**

Synthetic polymers are man-made materials produced through various chemical processes, enabling the design of specific chemical structures and physical properties. Unlike their natural counterparts, synthetic polymers often possess unique tensile characteristics and are generally non-reactive biologically. Their role in 3D printing is significant, as these processes frequently involve the use of organic solvents, heat, and potentially harmful activators, which can reduce the bioactivity of cells and growth factors. Nevertheless, many synthetic polymers are designed to be biodegradable, with popular examples including PLA, PGA, PU, PLGA, and PCL.[57-59] These materials are increasingly favored in the 3D printing of hard tissues and organs due to their strong mechanical, physiochemical properties, along with their compatibility with biological systems and thermal stability. The tensile properties of polymers include tensile strength, fracture toughness, elongation percentage, fatigue resistance.

In comparison to bionatural polymers, synthetic polymers provide the benefit of customizable mechanical properties, with molecular weights that can be adjusted from low to ultrahigh to meet specific printing needs. This improves their mechanical performance for applications such as in vitro pulsatile culture with peristaltic pumps and in vivo implantation of 3D printed structures. The advantages of this polymers encompass easy synthesis, abundant availability, straightforward extraction, simple processing, resistance to stress, lightweight design, and cost efficiency, all of which enhance their appropriateness for printing techniques.[60] Numerous synthetic polymer solutions, hydrogels, and scaffolds, such as PLGA, poly(glycolic acid) (PGA), poly(hydroxypropyl methacrylate) (PHPMA), polyurethane (PU), polycaprolactone (PCL), polylactic acid (PLA), and poly(methyl methacrylate) (PMMA), demonstrate restricted cytocompatibility. This limitation is mainly due to their bioinert characteristics, the inclusion of organic solvents, and their inflexible topological configurations. Researchers are investigating these materials for potential applications in a variety of biological systems, including neural and lymphatic networks, as well as in tissues such as bone, dermis, cardiac, and liver.[61]

- **Polycaprolactone**

1. It a synthetic polymer that is highly regarded for its use in tissue engineering, primarily due to its excellent biocompatibility and biodegradability. This polymer maintains stability over a prolonged period within its melting processing temperature range; however, it experiences rapid degradation when subjected to temperatures between 160-170 °C. Its low melting point, customizable viscosity, and versatility render it particularly effective for various melt processing techniques.[62]
2. PCL is frequently employed as an additive in a range of biomedical applications. For example, it can be combined with starch to improve biodegradability and economic costs, or it can be integrated into resins to enhance mechanical properties such as impact resistance. Moreover, PCL acts as a polymeric plasticizer for thermoplastic PVCs, showcasing its flexibility with diverse materials and applications.
3. The distinctive physiochemical properties, biological attributes, and mechanical strength of PCL position it as an outstanding option for

biomaterials. It is capable of enduring physicochemical, and mechanical stresses without losing its fundamental characteristics. Additionally, PCL can be customized through adjustments in molecular weight, crosslinking, and crystallization. Its capacity to provide resistance to water, oil, solvents, and chlorine in polyurethane (PU) production further amplifies its applicability. Furthermore, when blended with carbon black, PCL can be converted into a printable filament known as carbamorph, which is particularly beneficial for 3D printing applications, especially in the development of cost-effective conductive materials for electronic sensors.[63-65]

4. Polycaprolactone (PCL) is utilized in a range of applications, particularly in the fields of cranial bone healing, bone fixation, and various orthopaedic procedures, where it supports the repair of cartilage and bone. Its benefits include stability, affordability, and widespread availability, with a melting point of 60 degrees Celsius. PCL-based scaffolds are particularly effective for skin regeneration, skeletal muscle tissue repair, tendon restoration, and the regeneration of cartilage and bone tissues. Nevertheless, pure PCL lacks adequate osteogenic properties to significantly enhance bone regeneration, which highlights the need to integrate additional inorganic compounds, polymers, and metal elements to improve its performance in these applications.

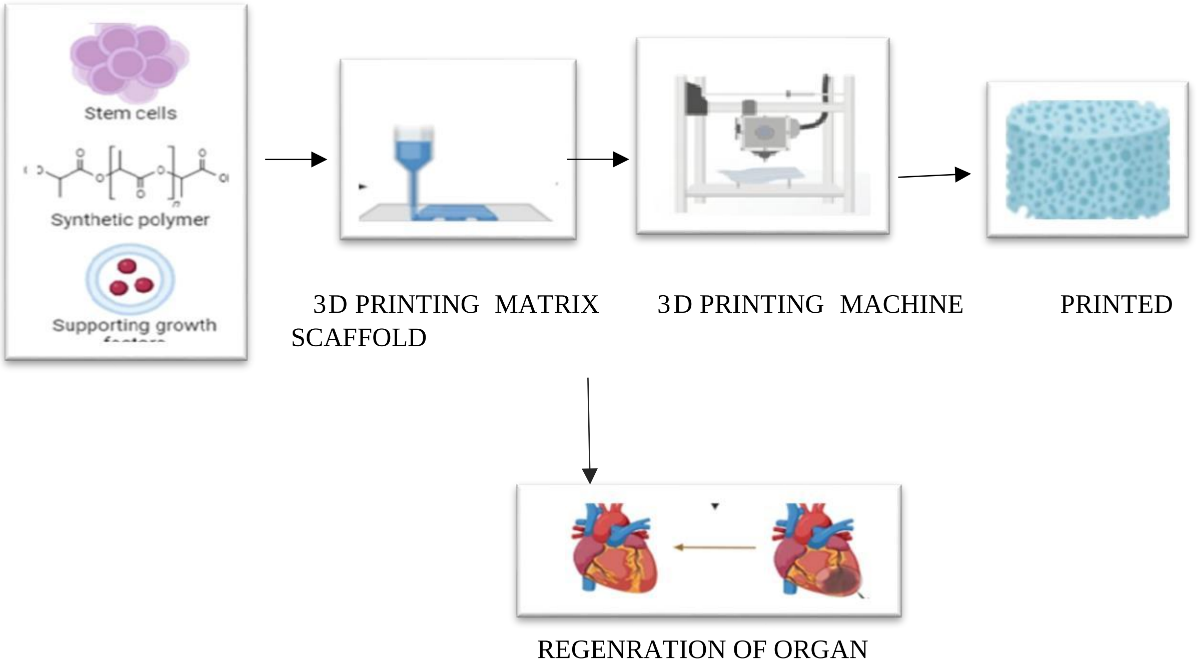

Figure 12:.3D printing of synthetic polymers.

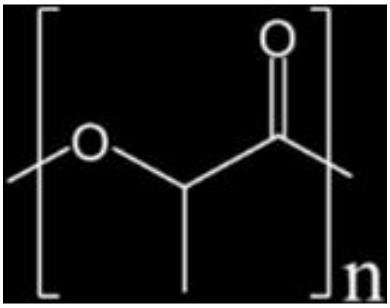

Figure 13: Polycaprolactone.

- **Polyurethane (PU)**

1. (PU) represents a class of synthetic polymers distinguished by organic components interconnected through carbamate (urethane) bonds. These polymers are primarily categorized into two types: biodegradable and nonbiodegradable. The unique physiochemical properties of PUs, such as their sensitivity to chemicals and pH levels, as well as their biodegradability, are determined by their specific chemical configurations. PUs is composed of linearly segmented polymers that are created from polygodial and hard segment units, which are linked by carbamate bonds (–NH–(C=O)–O–).[69,70]
2. Although PUs is thermoplastic, enabling them to melt when heated, nonbiodegradable variants have gained significant traction in the biomedical sector due to their exceptional mechanical strength and bioinert characteristics. These properties make them suitable for a variety of medical applications, including intravenous perfusion tubes and artificial hearts, where mechanical integrity is crucial. Furthermore, PUs can be utilized in 3D printing processes, either independently or in conjunction with other natural or synthetic polymers, such as gelatin and collagen.[71,72]
3. In our previous studies, we successfully engineered a hybrid hierarchical PU–cell/hydrogel construct

using an extrusion-based double-nozzle[73], low-temperature 3D printing method. This PU-based scaffold is designed to create an ideal environment for neural stem cells[74], enhancing their adhesion, proliferation, and migration. As a result, this innovative approach supports the regeneration and repair of damaged central nervous tissue, showcasing the potential of PU in advanced biomedical applications.[75,76]

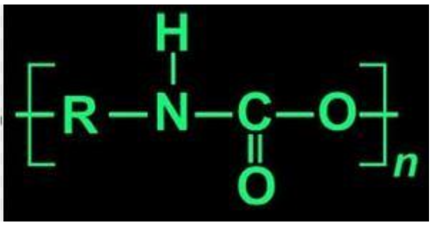

Figure 14: Polyurethane (PU).

- **Poly (lactic acid)**

1. Poly (lactic acid) (PLA) is a synthetic thermoplastic polymer that is produced from renewable and non-toxic materials, such as sugarcane and starch. This aliphatic polymer consists of two optically active isomers, L-lactide and D-lactide, and exhibits a semi-crystalline structure. Its distinctive characteristics, including a slow degradation rate, robust mechanical properties, and the generation of non-toxic byproducts, render it particularly advantageous for use in tissue engineering, regenerative medicine, and 3D printing applications.[77-80]
2. PLA is primarily employed in extrusion-based three-dimensional (3D) printing, particularly through the fused deposition modelling (FDM) process. Its biodegradable and eco-friendly nature enhances its appeal; however, it does have certain limitations, such as mechanical fragility and a relatively high solubility in water. Nonetheless, FDM is regarded as a simple and cost-effective approach to bio fabrication when compared to alternative 3D printing methods.[81-83]
3. The versatility of PLA allows for its application across various medical domains, including the creation of implants like stents and drug delivery systems. It plays a significant role in tissue engineering, where it is utilized as scaffolding for regenerative medicine, as well as in dental practices. Furthermore, PLA is employed in the production of medical sutures and bone screws, underscoring its critical role and adaptability in surgical applications.[84-89]

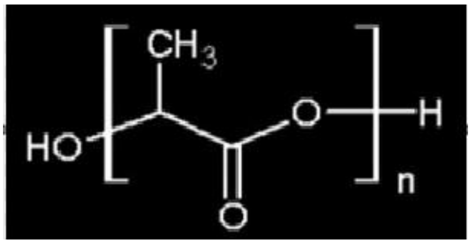

Figure 15: poly (lactic acid).

Table 3: General Characteristics Of Synthetic Polymers.

Polymer	Advantages	Disadvantages	Applications,	Ref.
Poly (lactic acid)	The material exhibits outstanding tensile strength, enhanced dimensions, and improved modulus, while also being biodegradable and demonstrating a favourable inflammatory response.	Toughness, mechanical Strength, improper biocompatibility	Applications, Orthopaedic repair, tissue regeneration	[104-105]
Poly(caprolactone) (PCL)	Excellent biodegradability, biocompatibility, Young's modulus, adjustable physical properties, low degradation rate.	cell adhesion, hydrophobic nature	Scaffolds, cardiac,3D bioprinting,	[106-108]
Poly (glycolic acid)	High crystallinity; good mechanical strength, good cell adhesion, cell proliferation	Hydrophobic property	Scaffolds, bone regeneration, cell regeneration, ear	[109-110]
Poly (vinyl alcohol)	Good Biocompatibility, biodegradability, good compressive mechanical and elastic strength	bioactivity, decreased cell attachment	Scaffolds, drug delivery systems	[111-113]
Poly (ethylene glycol)	Biocompatibility, hydrophilicity, improve degradation, non-toxicity, non-immunogenicity combined with different polymers, enhanced enzymatic stability	Limited tailorable mechanical property and rheological reduced bioactivity	Scaffolds, 3D bioprinting, orthopaedics implant	[109]

CONCLUSION

1. 3D printing stands at the forefront of modern prototyping techniques, allowing for the construction of objects from CAD models through a meticulous layer-by-layer application of interconnected materials. In the specialized field of

3D organ bioprinting, this technology requires the collaboration of multiple scientific and technological fields, such as cell biology, computer science, materials science, chemistry, mechanics, engineering, manufacturing, and medicine. The successful creation of artificial organs hinges on the complex interactions of biological, biophysical, biochemical, and physiological characteristics, which can be optimized through thoughtful design of geometric configurations and the careful selection and processing of suitable biomaterials.

2. The role of both natural and synthetic polymers is vital in the realm of 3D organ bioprinting, with each type presenting unique benefits. Naturally sourced polymer hydrogels, including gelatin, collagen, chitosan, and alginate, are known for their excellent compatibility with living cells, attributed to their inorganic solvents, functional groups, and mild gelation methods. These materials are recognized for their biodegradability, stability, flexibility, mechanical strength, and bioactivity, making them ideal for a wide range of applications. Conversely, synthetic biodegradable polymers such as PLGA, poly (lactic acid), and polyethylene offer significant advantages in tissue regeneration, acting as supportive structures for vascular and neural networks, which enhances the overall integrity of 3D printed constructs.
3. Recent advancements in 3D printing technology have rendered it more affordable and practical for various applications, including organ design, the creation of medical devices, and surgical planning. The incorporation of biomaterials, which may include living cells, growth factors, and other bioactive substances, into the 3D printing process has facilitated the effective production of bioartificial organs. This groundbreaking methodology not only accelerates the development process but also enhances the potential for innovative medical solutions.
4. The advancement of 3D printing technology has made it increasingly cost-effective and practical for applications such as organ design, the production of medical assistance devices, and surgical preparation. By integrating these cutting-edge technologies, we are paving the way for the creation and development of artificial organs that closely mimic physiological functions. Consequently, these organ manufacturing innovations have the potential to significantly enhance healthcare quality and extend human lifespan. The emergence of sophisticated bioartificial organs through advanced 3D printing techniques is set to transform the future of organ transplantation, offering substantial benefits to humanity in the coming years.

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Conflicts of Interest: The authors declare no conflict of interest.

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