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Research article

Protein and Polysaccharide Base Biomaterial for The Formation of Composite Bone Scaffold

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ABSTRACT

In the past, bone scaffold was nearly new and best method for fixing the destructed body parts and the development of the tissues. Different types of natural and synthetically made biomaterials have been used by the analyst for the evolution of scaffold. The biomaterial that is derived naturally have some favorable properties such as biodegradable, biocompatible, non-toxic, non-antigenic and are safe in use while synthetic biomaterials have some disadvantages because they are made up of synthetic materials which has low biodegradable properties. But in this paper, we mainly focus on natural biomaterial which is used for formation of composite bone scaffold. Protein and polysaccharides based natural biomaterials used for making scaffold. There is another type of natural biomaterials that is bio-ceramics that joins various body parts such as bones and teeth. The main consideration is to give the short scheme about protein based, polysaccharide based and bio-ceramics based biomaterials and their future prospects.

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INTRODUCTION

During the transplant, favorable outcome will be obtained and it depends upon the biomaterials used. In the past, autogenous techniques have been practiced for the reconstruction or recovery of body tissue and deface or broken body parts[1]. But it has some side effect because there is a risk of transferring disease from donor to recipient and immune rejection[2]. Alternatively," tissue engineering" can be used to repair the damaged body parts and the regeneration of tissues. In tissue engineering, different cells and materials are combined and form medicine via engineering that is used to repair defect. A lot of variety of biomaterials utilized to rebuilding broken bone, tissues and other body parts[3,4].

Natural synthetic and ceramic based biomaterials have been used for the development of scaffold. The scaffold has some properties as it must be porous and have connected pores for the gas diffusion and for the transport of fluid materials. Natural biomaterials have the advantages over the synthetic biomaterials because they are biocompatible as they allow the cell growth cell attachment proliferation differentiation and allow it to function normally. They are also biodegradable

as the waste materials should have less cost and easy to process and nontoxic as their waste material can remove from the body without any type of involvement. Moreover, Natural biomaterials are ecologically safe and have no cytotoxic effect[5].

The 3-D porous scaffold can be developed by combining more than two types of biomaterials to increase the application of scaffold while it is applied. The 3-D porous materials should be effective for supporting the tissue and regeneration of different damaged body parts[6]. The scaffold behaves being as template for the restoration of injure tissue. It function being a bioreactor which provides chemical and mechanical stimuli to cell [7]. The biomaterials are selected for the development of scaffold. The synthesis techniques play a key role and provide all the requirement of the scaffold synthesis. The scaffold is synthesized by combining the different types of biomaterials or more than one substance that are derived from natural or synthetic source which help the replacement of bone and regeneration of tissue[8].

Synthetic biomaterials have some disadvantages because they have low cell growth, lack of cell adhesion and also lack of functional group which is necessary for the modification of cell surface[9]. Metallic scaffold sometimes, releases the toxic metal ion which causes corrosion and also cause allergic reaction. Metallic scaffold also lacks the biological recognition on material surface[10]. Ceramics type of scaffold show the characteristics of brittle which are hard to shape for implantation[11]. Naturally derived biomaterials used for the formation of scaffold include protein, polysaccharides and bioceramics were used as biomaterials in manufacturing of scaffold.

In this paper we focused naturally based biomaterials such as protein, polysaccharides and bioceramics for the tissues engineering. The protein related natural biomaterials contain Fibrin, Collagen and Silk polysaccharides and bioceramics are including Cellulose, Agarose, Alginate, Chitosan Hyaluronan Hydroxyapatite (HAp), corals and Shells were used for the development for scaffold are described here which are also used.

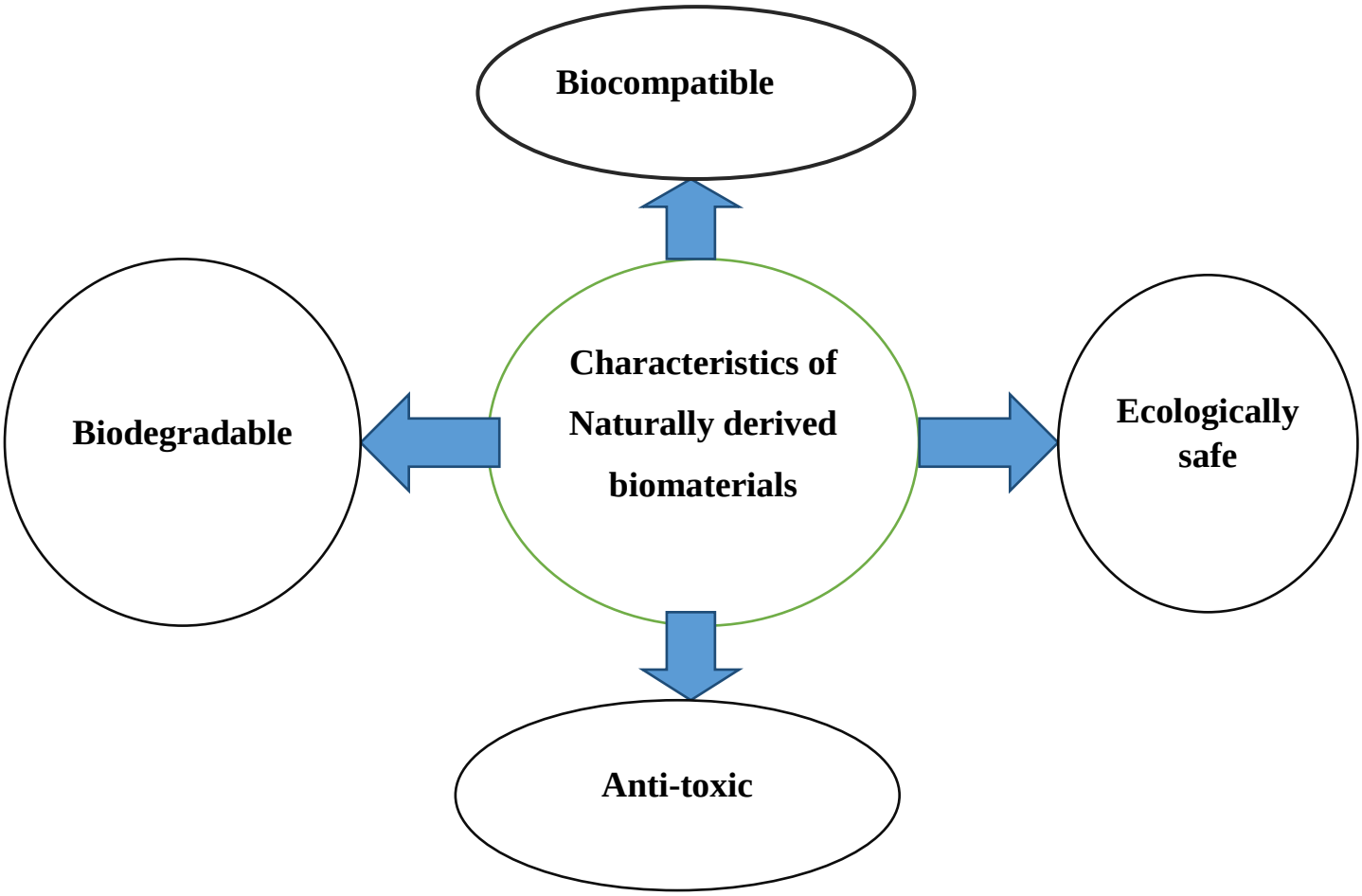

Figure 1. Diagrammatic representation of the characteristics of naturally derived biomaterials.

Naturally Originate Bio Materials

Naturally obtained bio materials comprise material that are innate in source and adapted for the evolution of composite bone scaffold. The types of natural bio materials are here illustrated with schematic representation.

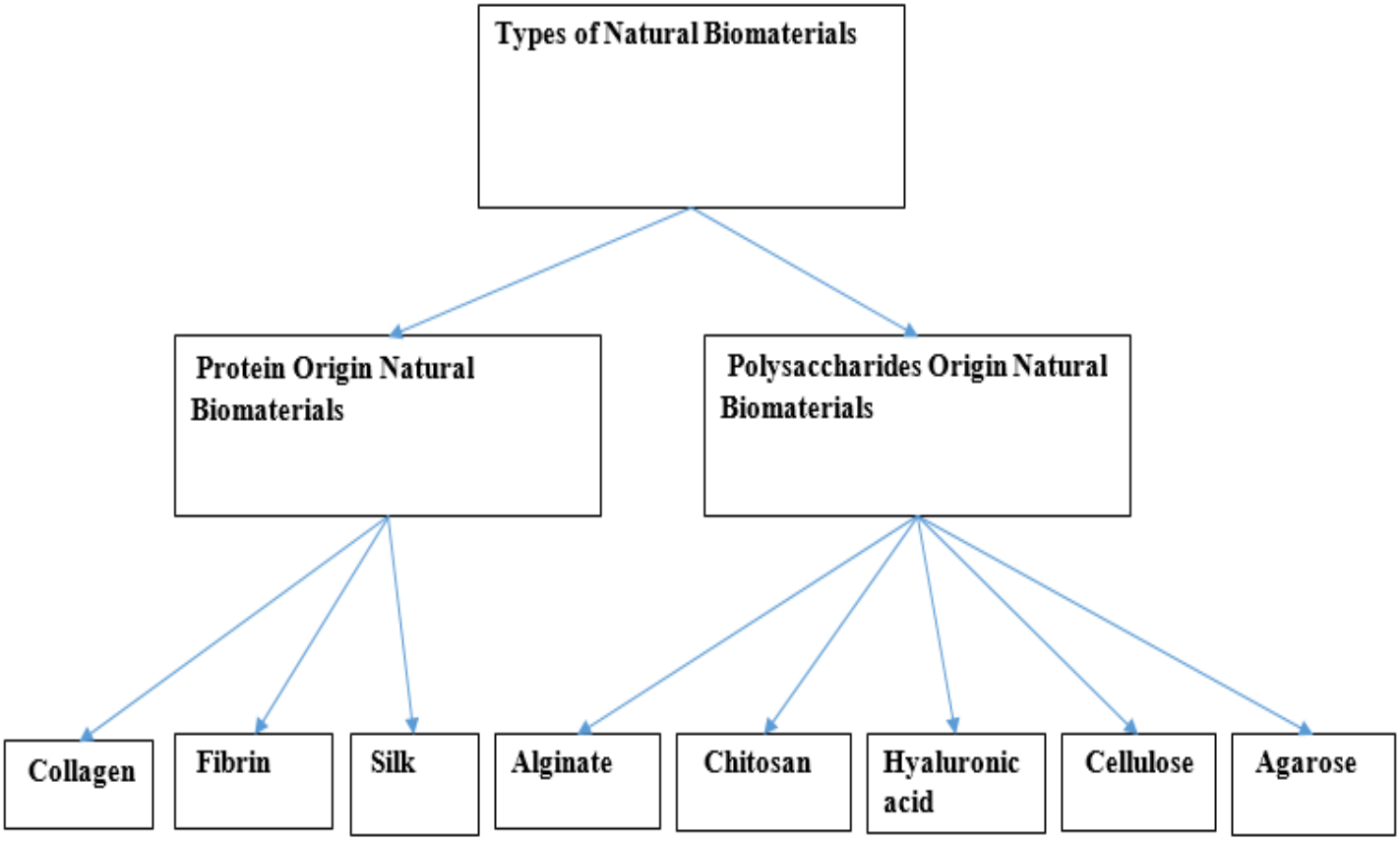

Figure 2. Schematic representation of types of natural biomaterials and their derivatives for the formation of composite bone scaffold.

Protein based biomaterial

Protein based natural biomaterials are including the substances that have protein origin and have functional group of amino acid [12]. The biomaterials derived from the protein are used for the development of scaffold, have biological and mechanical properties that promote cell adhesion and cell growth. They have also some other properties such as biodegradability and allow to produce their own extracellular matrix(ECM) [13,14].

Collagen

In human, Collagen is present in massive amount. It has important role in providing the structure to your skin and also help in blood clotting. It is found in tendons, ligaments, muscles, bones, skin and blood vessels [15]. Scaffolds which are formed from the collagen provide the strength and the structure to the body and also have some other properties like, they are biocompatible and biodegradable and are having good cell adhesion properties which are used for the formation of composite bone scaffold. Collagen have different types, but Collagen type 1 is most abundant and about 90% of all types of collagen in human body [16]. It combine with other biomaterials and are used for formation of porous composite bone scaffold which show extraordinary characteristics such as anti-bacterial, anti-fibrotic and anti-inflammatory [17,18].

Fibrin protein

Fibrin which helps blood clotting is formed from fibrinogen. [19]It is involved in wound healing, cell proliferation and migration. It combined with some other materials and has a potential for tissue engineering. Fibrin sealant which is also called fibrin glue has many clinical applications because it is biodegradable and has cell adhesion properties and control the bleeding in any surgical situation. Fibrin based scaffold provide the machinal strength to the body and also fixing the fibrinogen base scaffold [20]. Fibrin hydrogel scaffold are also used for the tissue engineering and fixing the damaged body parts such as cartilage [21].

Silk

Silk is a natural polymer which is turned into the fiber where it used as scaffold for the formation of tissue and regeneration of tissues during the burning of a victim[22]. It is flexible and has the cell adhesion characteristics. It is an important biomaterial for the regeneration of tissues because it is proved to be biocompatible. It is produced from silkworm, flies, mites and spider[23]. Silk protein have been used as biomaterials for the formation of scaffold because it is biocompatible and biodegradable nontoxic and anti-inflammatory[24]. Silk proteins have the excellent mechanical and physical properties while tailoring the structure of the cell and damaged body tissue.

Polysaccharide based biomaterial for the formation of composite bone scaffold

Multiple types of the poly saccharides are utilized as biomaterials in medical discipline or department like bio macromolecules which used for the regeneration of tissue and formation of composite bone scaffold[25,26]. Polysaccharides consist of many types of monosaccharides. Many of the polysaccharides have the structural role that are derived from both plant and animals. It contains polymeric saccharides that are linked through covalent bond to form amino acid[27]. Polysaccharides which are used for the formation of composite bone scaffold include alginate, chitosan, hyaluronic acid, cellulose and agarose. The biomaterials which are derived from these polysaccharide sources are biocompatible and biodegradable and proved to be excellent cell growth and attachment because of their natural origin[28,29].

Alginate

Alginate is also called alginic acid and it is important polysaccharides that are extracted from seaweeds and brown algae having excellent properties like biocompatibility[30]. It is biopolymer which is effective while mixing with other substances it forms hydrogels which are anti-toxic, biodegradable and low cost[31]. Alginate combines with different types of biomaterials such as calcium chloride ($CaCl_2$) and hydroxyapatite (Hap) which are used for the repair of joints, cartilage and the regeneration of tissues as they show cell adhesion properties and osteogenesis[32,33].

Chitosan

Basically, chitosan is a sugar molecule. It is a true poly saccharide acquire by the de acetylation means by the removal of acetyl group of chitin [34]. Scaffold which are formed from the de acetylation of chitin have some properties. It supports the cell attachment, migration, cell differentiation, regeneration of tissues, damaged body parts and the formation of composite bone scaffold. It also has antibacterial and antifungal properties[35]. Chitosan have good biological properties. Its combination with other biomaterials like gelatin also shows the properties of biocompatibility, cell adhesion, low cost availability, low cytotoxic effect and easy to be functionalized[36]. It also cross-linked with gelatin and form composite scaffold that upgrade the good cell adhesion, good biocompatibility, spreading and cell viability[37].

Hyaluronic acid

Hyaluronan is a linear glucosamine that is combined with glycan that have function in the treatment of tissues like joint pain and many other body parts, is distributed all over human body mainly human extracellular matrix (ECM)[38]. It promotes the cell motility and cell adhesion.[39]. As it is an integral constituent of extra cellular matrix (ECM), used being bio material in the regeneration of tissue, wound healing, imperfection bone and the formation of composite scaffold.

The unique feature of Hyaluronan include biocompatibility, viscoelasticity, cell adhesion, migration, anti-oxidant, anti-inflammatory properties[40-42]. Because of these properties, it is used to repair the damaged body parts, promote the angiogenesis, help in wound healing and also bind the fibrin and collagen. Hyaluronic acid crosslinks with gelatin and provides a biomaterial that facilitates the wound healing, regeneration of tissues, develops bone and regenerates the cartilage because it provides the warm and moist environment[43].

Cellulose

Cellulose is a polysaccharide containing linear glucose molecules that are biodegradable in nature which are used in tissue engineering and the formation of composite bone scaffold[44,45]. It is biocompatible, biodegradable, renewable, has non cytotoxic effect and also cost effective[46]. Cellulose is derived from many sources such as forest, algae, and many types of bacteria. Its derivatives are used for the for 3D cellular engineering[47]. Cellulose sulphate like polysaccharides such as green algae and Carrageenan's are also used for the synthesis of composite bone scaffold[48]. It is a good delivery vehicle for the cartilage, body tissue engineering and also support the cell growth.

Agarose form of bio material

Bio material extracted from agarose is biocompatible obtain from the seaweed[49]. Agarose based biomaterials form well interconnected pores which take part little role in cell adhesion, infiltration and also cell proliferation[50,51]. The biomaterials which are established by the association of agarose with hyaluronic acid (HA) are biocompatible, biodegradable and also have mechanical stability. It combines with collagen and hydroxyapatite (HAp) and scaffold which is form is used for the fabrication of cartilage, bone and teeth regeneration[51,52].

Table 1. Protein and Polysaccharides based biomaterials types and their range of porosity

Biomaterial type	Scaffold raw material	Porosity
Protein	Collagen	100-200μ pore diameter [53]
Protein	Fibrin	34-83μm pore diameter and 73% porosity [54]
Protein	Silk	10-600μm pore diameter[55]
Polysaccharides	Alginate	150μm pore diameter 82% porosity [56]
Polysaccharides	Chitosan	50-250μm pore diameter[57]
Polysaccharides	Hyaluronic acid	100μm pore diameter 99% porosity [58]
Polysaccharides	Agarose	480μm pore diameter 73% porosity [59]

Bio-ceramics based natural biomaterials:

Ceramics based biomaterials act as template for growing the new tissues and they interact with the cells. Bio-ceramics are the promising biomaterials that are used for the hard and soft tissues regeneration and repair and reconstruction of the bone[60]. Chemical constitution and mechanical characteristics of the hydroxyapatite ceramics is like a bone and are used in the orthopedics, dental implants and bone tissues engineering application because bioceramics based biomaterials are regarded as biocompatible, biodegradable, osteo conductive, and corrosion resistance[61]. Calcium phosphate containing biomaterials are also used for the tissues engineering because they have ability of enhancing the bone cell growth and binding the both soft and hard tissues[62-64]. Some of the natural bioceramics based biomaterials for the formation of composite bone scaffold are:

Coral:

Coral is a marine invertebrate which belongs to the phylum cnidaria,[65] whose exoskeleton contains calcium carbonate ($CaCO_3$) and are used for the formation of composite bone scaffold[66]. Calcium carbonate ($CaCO_3$) is chemically related to mineral segment of bone and is used for regeneration of tissues, bones and facilitates the healing of wound. Coral have interconnected pores which allow the cell attachment and cell growth. Due to its biodegradability and osteo inductivity, [67] it allows the self-regeneration of the damaged body parts and tissues[67].

Shells:

Shells like Cockle and egg shells contain calcium carbonate that are the source for the synthesis of hydroxyapatite(HAp) which are excellent material for reformation of body tissues and rebuilding of destructed bone[68,69]. Marine, egg and cockle shells have the promising properties and have implementation for formation of porous composite scaffold and repair bone[70].

Hydroxyapatite (HAp)

Hydroxyapatite (HAp) is white in color. It is derived from many sources such as bones and many species of marine corals and is obtained by applying high temperature sintering[71]. Hydroxyapatite (HAp) matrix is used for the formation of composite bone scaffold that have excellent chemical and mechanical properties[72]. Ceramics are combining with other small biomaterials and form continuous fibres which are biocompatible for the living tissues and have application in composite bone scaffold[73,74].

CONCLUSION

Initially, auto graft and allograft techniques have been used for the treatment and repair of bone and tissues of the body. Tissue engineering can also be used for reconstruction of tissues stuff and repair the destructed parts of the body like organ. Bone tissue engineering improved with the progress of biomaterials. Biomaterial types and their synthesis techniques are very important for the formation of composite scaffold and that biomaterial are porous and have improved characteristics. The biomaterial which are derived from the natural material have some characteristics as it is biocompatible, biodegradable, non-toxic, ecologically safe, low-cost processing, cell expansion and fasten with minimum possibility of refusal. It is useful for the formation of composite scaffold alternative to manmade bio materials which have some disadvantages.

Two main and important sources of biomaterials are protein and polysaccharides from which composite bone have been obtained. Protein related bio materials being as fibrin, silk and collagen. Polysaccharides contain bio materials related to alginate, chitosan, hyaluronic acid, cellulose and also include agarose which are used for the formation of composite bone scaffold. Bio-ceramics material have been derived from corals, shells and hydroxyapatite (HAp). They are the natural source of calcium carbonate which are used for the rebuilding of body tissues and connect the injured parts of the body. Furthermore, synthetic biomaterials show low cell growth, very hard to synthesize them, are not cost effective and are not compatible. So, this review is about the biomaterials which are derived from the natural source and further investigation are needed for the formation of scaffold from different naturally derived biomaterials with improved characteristics.

Disclaimer

The article has not been previously presented or published, and is not part of a thesis project.

Conflict of Interest

There are no financial, personal, or professional conflicts of interest to declare.

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