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The Use of Natural Biopolymers in Bone Tissue Engineering: A Review

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Abstract

A key component of patient care is the use of tissue engineering, which is a tried-and-true method for developing practical substitutes for regenerative medicine. In-depth research is being done on a number of natural-origin biopolymers for use in a variety of biomedical applications, including chitosan, hyaluronic acid, gelatin, collagen, etc. The very advantageous characteristics of these polymers, such as their high biocompatibility, delayed degradation, mechanical tenability, structural resemblance to biological tissues, bioactivity, etc., have led to their exclusive investigation in tissue engineering applications. The recent developments in biopolymers for bone tissue engineering are summarised in the current review. Along with discussing the best ways to deal with them, it also discusses the topic of natural polymer modification to produce superior qualities, particularly mechanical properties toward bone regeneration. In light of this, the review may influence the creation of bioinspired materials for futuristic applications.

Keywords: Biopolymer; Tissue engineering; Polymers

Introduction

Bone, which makes up the majority of the body and provides support throughout our lifetimes, is a dense, porous, mineralized connective tissue. A baby has about 270 bones, which typically fuse to form 206 bones in adults. One of the best examples of a natural composite is bone, which is mostly made up of water (ten percent), a solid organic matrix (30 percent), and inorganic components (sixty percent). The matrix structure, which resembles a honeycomb, is what gives bone its rigidity. The bone is a type of dynamic tissue in our body that looks after the body's structural and metabolic needs. The body's soft organs are primarily protected by bone, which also serves as a warehouse and a support structure for the body. The main jobs of the bones are to guard the delicate organs, support the body by acting as the internal framework, store various minerals, particularly calcium and phosphorus, and aid in the creation of various blood cells. [1].

Polysaccharides and their products

For bone regeneration, many natural polysaccharides have been investigated. The majority of polysaccharides have a role in the transmission of numerous biological cues in addition to having inherent bioactivity. The comprehensive study of polysaccharides such as chitosan, alginate, dextran, and hyaluronic acid has changed the paradigm in tissue engineering to favour the use of natural polymers. The intriguing characteristics of these polysaccharides include the ability to create water-soluble gels, adaptable rheological characteristics, the presence of a surface functional group, and inherent electrical charges. Electrostatic contact with the biological system is easily induced by the presence of the surface functional group and the electrical charges. Through sophisticated purification and backbone structural alteration, the polysaccharide's cellular selectivity can be adjusted. It shows the structural representation of a well-known natural biopolymer. The next section has reviewed the polysaccharide with a focus on it [2].

A naturally occurring chitin derivative is chitosan (CS). It is a positively charged polysaccharide that contains N-acetyl glucosamine (NAG) in a specific ratio with d-glucosamine monosaccharides that are - (14)-linked. The properties of chitosan are significantly influenced by the ratio. As the NAG ratio grows, the crystallinity of the chitosan also rises. Furthermore, NAG is referred to as chitin when it exceeds 50%, but N-glucosamine is referred to as chitosan when it exceeds 50%. CS has a molecular weight of 10 to 1000 kDa. The polymer generally has a pH over 7; however it can dissolve in an acidic environment. Free amino and N-acetyl groups are necessary for chitosan to be soluble. Its rigid, dense crystalline structure and robust intra- and intermolecular hydrogen bonding are to blame for the result. Typically, chitin is extracted from the shells of shrimp and crabs or is created by fermentation processes and subsequent deacetylation in alkaline environments [3, 4].

Due to its medicinal and cosmetic benefits, hyaluronan, often known as hyaluronic acid (HA), has attracted a lot of attention and demand in recent years. It is taken out of the tissues of the animals. It is a non-sulfated glycosaminoglycan (GAG) with 1, 4-linked disaccharide units of negatively charged monosaccharides, 1, 3-linked D-glucuronic acid (Glu), and n-acetyl-D-glucosamine as part of its structural makeup (GlcNac). Chondroitin sulphate, dermatan sulphate, and heparin sulphate are other members of the GAG family, but HA is distinct from the others. It is the only non-sulfated GAG found in the ECM and is created at the plasma membrane's inner surface where hyaluronan synthases, an enzyme required for HA synthesis, are found [5,6].

The natural extracellular matrix (ECM) component HA provides the appropriate external environment for cells.

Given the advantages of cell adhesion, proliferation, and differentiation, HA, a component of the extracellular matrix (ECM), offers the ideal external environment for regenerative therapy. 5000–30000 sugar molecules with a higher molecular weight make up its backbone chain. A number of developments in bone regeneration, such as HA and its composites, which include super calvarial, subchondral, alveolar bone regeneration, and many more, have been made in light of this. Crosslinked hydrogels have attracted the most attention among all the innovations in the field of regenerative medicine because they may possess the adjustable characteristics necessary for their kind.

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The HA-hydrogel beads were created by Sadegh et al. for chondrocyte proliferation. A bio-imitating calcium phosphate mineralized organic-inorganic scaffold composed of chondroitin sulphate, chitosan, and Nano-hydroxyapatite (CSA) [7].

In order to have good mechanical strength, biocompatibility, and improve osteoblast adhesion, a bio-mimicking calcium phosphate mineralized organic-inorganic scaffold made of nano-hydroxyapatite (nHAP), chitosan (CS), chondroitin sulphate (CSA), and hyaluronic acid (HA), with hierarchical structures, has been used in the application of bone tissue regeneration. This chondroitin sulphate works by inhibiting the creation of the cartilage-degrading enzymes, which aids in tissue regeneration and cell adhesion qualities. Numerous biomaterials of natural origin, polymers, and ceramics, including hydroxyapatite, natural corn silk extract, -TCP, biphasic calcium phosphate, and chitosan, have been employed as composites in regenerative bone surgery in addition to HA [8,9].

Fe (III) doped ZnO integrated hybrid scaffolds were created by Et al. and produced good physical and biological characteristics. By using the co-precipitation approach, Florina et al. created composites including the biopolymers chitosan/HA/bovine serum albumin/calcium phosphate/magnetic nanoparticles (MNP) (biomimetic procedure). The osteoblast cells, which exhibit good biocompatibility, respond favourably to this. Fig. 6 demonstrates how the scaffold's component and released biopolymers enter cells to promote osteogenic differentiation and bone regrowth.

Conclusion

The nanocomposite scaffold made of various natural biopolymers has great promise for the development of bone tissue. The ingredients used to produce scaffolds must meet certain requirements, such as having inherent biofunctionality and the right chemistry to encourage molecular biorecognition by cells and improve cell proliferation, adhesion, and activation. To guarantee the crucial structural functioning and to achieve the rate of new tissue development, the scaffold's mechanical characteristics and kinetics of disintegration in the selected materials must be specially tailored to the TE application. The potential of nanocomposites made of various natural polymer matrices, including collagen, SF, CS, alginate, and HA, has been revealed through research into designing an optimal nano-construct biomaterial for the healing and restoration of injured tissues. In a nutshell, it may be said that the ideal natural nanocomposite. In a nutshell, it may be said that the ideal natural nanocomposite scaffold has not yet been created, matching the structure and morphology of bone while offering a temporary function of bone. The creation of various bio composite scaffolds made of naturally occurring biopolymers, which are most frequently utilised in platforms for bone tissue engineering, was the focus of this review [10].

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Conflict of Interest

The authors affirm that they have no known financial or interpersonal conflicts that would have appeared to have an impact on the research presented in this study.

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