Role of Chitosan Hydrogels in Clinical Dentistry

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Biopolymers are organic polymers that can be treated into intricate designs with porous characteristics that mimic essential biologic components. Due to their superior biosafety, biodegradability, biocompatibility, etc., they have been utilized immensely in biomedical engineering, regeneration, and drug delivery. To obtain the greatest number of results, a literature search was undertaken in scientific search engines utilizing keywords. Chitosan is used in a variety of medical sectors, with the goal of emphasizing its applications and benefits in the clinical dental industry. Chitosan can be dissolved in liquid form and combined with other substances to create a variety of products, including fibers, hydrogels, membranes, microspheres, resins, sponges, pastes, tablets, and micro granules. Chitosan has been studied in a variety of dental applications. Chitosan is used in the prevention of caries and wear, in pulpotomy to accelerate osteogenesis in guided tissue regeneration due to its hemostatic property, and primarily to benefit from its antimicrobial activity by adding it to materials, such as glass ionomer cement, calcium hydroxide, and adhesive systems. With its antibacterial activity and biocompatibility, chitosan is leading the pack as a promising ingredient in the production of dental materials.

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1. Introduction

Chitin is one of the naturally found polymers like collagen, alginate, and cellulose. The recent surge in the research on these polymers is based on their ability to be used as an alternative to fossil fuels and being environmentally friendly. Chitin occurs in the skeleton of arthropods, the cell wall of fungi, insects, and mushrooms and appears primarily as waste from the seafood/fish industry. The limited de-acetylation of chitin converts it into chitosan, which otherwise has a limited existence in the environment. The term chitosan is used for deacetylated chitin, which contains 60% D-glucosamine residues minimally. The deacetylation converts chitin, the water-insoluble polymer, to chitosan, which is partially water-soluble. It is preferred to investigate the characteristics of the final product as the polymer may undergo many changes during the process, and it is difficult to estimate its final structure and the properties it shall achieve after the completion of the manufacturing. Chitosan can be mixed with different components in liquid form and molded into various shapes: fibers, hydrogels, membranes, microspheres, resins, sponges, pastes, tablets and micro granules.

Chitosan has been utilized in dentistry for caries prevention, as well as in nano-materials to increase mechanical integrity, antimicrobial previously damaged tissue regeneration, dentin matrix, and to close the canal space during root canal therapy. Chitosan nanoparticles are resorbable films that can be used to administer antibiotics (such as metronidazole, chlorhexidine, and nystatin) to periodontal tissues in situ, therefore preventing fungal infections and oral mucositis. Chitosan has been identified as a promising substrate material for periodontal tissue regeneration due to its compliance with the aforementioned features. Thambiliyagodage et al. reported on a commercially available non-fluoride chitosan-based dentifrice and found a considerable decrease in tissue loss. A number of chitosan-based restorative formulations have been investigated and are being considered for the effective delivery of organic amelogenin at the location of enamel defects in order to achieve human enamel regeneration. A number of researchers have found that covering dental implants with chitosan has encouraging outcomes. Recent progress in this subject has resulted in the use of chitosan as a carrier for chitosan-mediated stem cell repair.

Knowledge of the structure of hydrogels and the mechanism of gelation of intelligent hydrogels is essential to designing bioinspired hydrogels. As one of the raw materials in hydrogels, chitosan has been highly pursued due to the polymer's biocompatibility, biodegradability and low toxicity. Its good biocompatibility is well documented in animal studies, which implies its usage for the fabrication of implantable biomaterials. The current research aims to provide an update on the structure, properties and numerous applications of chitosan as a frontline biomaterial in various dental procedures.

2. Production of Hydrogel Chitin

Many different life forms, including: insects, fungi, mushrooms, and some aquatic creatures have chitin as a constituent of their biomolecule. However, for commercial production, the majority of raw biopolymer is extracted from sea crustaceans because marine biowaste is a major resource for the mass synthesis of chitin and chitosan. It is available in enormous quantities and at a low cost as byproducts of the seafood processing industry [1][2]. The mineralized shells of contain 15–40% chitin along with two other biological compounds, i.e. Calcium carbonate (20–50%) and proteins (20–40%). Because different species affect the quality and freshness of the shell and season when it is harvested, the amount of chitin greatly varies. Additional sources of chitin include clams and oysters [3][4][5][6][7][8]. The mushrooms serve as better resource as these are cultivable and offer a more controlled production and a safer product than the animal source e.g seafood [4]. The chitosan produced from the mushrooms exhibits a small molecular mass disparity, degree of deacetylation in comparison to the product obtained from seafood. Deproteinization, demineralization, and decolorization are the three key stages that make up the extraction of chitin [9]. Acids are used to remove inorganic components in the conventional chemical process, strong inorganic alkalis are used to extract proteins (often at 50–60°C), and oxidizers are used to remove colour. These procedures often entail the use of sodium hydroxide to break down proteins in order to extract lipids and pigments (melanins, carotenoids), and hydrochloric acid to lyse the salts, especially calcium carbonate and calcium phosphate, leaving behind a colourless substance. It is crucial to take into account the acid content, contact time, and temperature to reduce the hydrolytic and thermal degradation .along with associated chemical changes [10][11][12][13][14].

Both homogeneous and heterogeneous deacetylation processes can be used to create chitosan hydrogel. The heterogeneous approach, which involves amorphous parts of the polymer reacting without affecting the crystalline region, is frequently employed in businesses. In order to deacetylate chitin and create chitosan, the acetamide groups are typically hydrolyzed using concentrated NaOH or KOH (40–50%) at temperatures exceeding 100°C. [8][15].

Properties of Chitosan

Chitosan presents a multitude of characteristics in terms of physical-chemical, biological, and technological aspects. In fact, chitin is the sole naturally occurring biopolymer. The compound exhibits a polycationic property at low pH (below 6.3) however with pH rising above 6.3, chitosan's amine groups lose protons and acquire reactivity. With acetylation well below 50%, it is soluble in all water base media having low pH. There is a great range of solvents for the compound including dilute inorganic acids, concentrated H_2SO_4, in organic acids, and additional organic compounds e,.g tetrahydrofuran, ethyl-acetate, 1, 2-dichlorethane etc [16]. The most popular acids for chitosan solubilization are acetic and formic. Because it depends on a number of factors, including acetylation, ionic concentration, solution pH, and the protonation acid used, the solubility is a fascinating but difficult property to control [15][17]. Additionally, the location of acetyl groups throughout the macromolecular structure influences the ability of chitosan to dissolve, depending on the circumstances surrounding its manufacture. Due to the fact that chitosan can dissolve and then precipitate into a wide range of physical shapes, including beads, films, membranes, fibres, or nanofibers, the protonation reaction is particularly significant for chitosan. In addition, it can be cross-linked to create materials like fibres or sponges that can be used in a variety of ways [18][19]. Chemical treatments to enhance cross linking with epoxides or glutaraldehyde result in more stable configurations of the molecule. Chitosan is comparatively more workable than its parent compound chitin for such chemical modifications, but the resulting compounds from chitosan typically have relatively lesser stability due to its greater hydrophilicity and sensitivity to pH.

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