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Awareness On Medicinal Applications Of Chitosan Nanoparticles Among Dental Students

Research Article

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Abstract

Introduction: The development of advanced nanomaterials and technologies is essential in biomedical engineering to improve the quality of life. Chitosan based nanomaterials are on the forefront and attract wide interest due to their versatile physicochemical characteristics such as biodegradability, biocompatibility, and non-toxicity, which play a promising role in biological applications.
Aim: This survey was conducted for assessing the awareness about medicinal application of Chitosan nanoparticles amongst dental students.
Materials and Method: A cross-section research was conducted with a self-administered questionnaire containing ten questions distributed amongst 100 dental students. The questionnaire assessed the awareness about Chitosan nanoparticles therapy in medical applications, their antibacterial properties, antifungal activities, wound healing properties and their role in targeted drug therapy, The responses were recorded and analysed.
Results: 17% of the respondents were aware of the medicinal applications of Chitosan Nanoparticles. 13 % were aware of antibacterial properties of Chitosan Nanoparticles, 12 % were aware of antifungal properties of Chitosan Nanoparticles, 10 % were aware of wound healing properties of Chitosan Nanoparticles and 9% were aware of their role in targeted drug therapy.
Conclusion: There is limited awareness amongst dental students about use of Chitosan nanoparticles therapy in medical applications. Enhanced awareness initiatives and dental educational programmes together with increased importance for curriculum improvements that further promote knowledge and awareness of Chitosan nanoparticles therapy.

Keywords: Awareness; Chitosan; Nanoparticles; Students; Medicinal.

Introduction

In biomedical engineering, the development of new nanomaterials and technologies is critical for improving quality of life. The diverse physicochemical features of chitosan (Ch)-based nanomaterials, such as biodegradability, biocompatibility, and non-toxicity, which play a promising role in biological applications, are attracting a lot of attention. Chitosan and its derivatives are used in pharmaceuticals and biomedical engineering, among other applications [1].

The use of nanomaterials in pharmacological and biomedical research is currently gaining traction. Nanoparticles (NPs) with a diameter of less than 100 nm have a superior ability to improve patient compliance, biodistribution, and site-specific drug delivery [2]. The biomedical and pharmaceutical industries use a variety of sophisticated nanomaterials [3]. Magnetic nanoparticles, silica-based nanomaterials, metal and metal-oxide nanomaterials, and biological and carbon nanostructures are only a few examples of sophisticated functional nanomaterials [4]. Nanomaterials are also becoming a more ecologically friendly and cost-effective solution for medicinal applications such as gene transport and transfection, drug delivery carriers and antibacterial agents, wound healing, nano systems against cancer, and therapeutic delivery systems [5].

Biopolymers such starch, cellulose, silk fibroins, collagen, gelatin, albumin, and chitosan (Ch)-based nanoparticles provide bio-

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compatibility, biodegradability, and low toxicity to synthetic NPs. In a variety of biological and biomedical applications, such as medication delivery, therapies, and gene delivery, biocompatible nanomaterials with high specific surface area are desirable. Several investigations have concentrated on advancements in this topic in recent years, leading to replacement biocompatible nanomaterials that take into account alternative resources, inventive features, and constraints.

Ch is a non-toxic, biocompatible linear polysaccharide cationic and hydrophilic polymer made from randomly dispersed -(1, 4)-linked d-glucosamine and N-acetyl-d-glucosamine units produced by alkaline hydrolysis of chitin. Chitin is a naturally occurring amino polysaccharide that is derived from the components of fungal cell walls and some hard structures in invertebrates and fish. Ch has a lot of hydroxyl and amine functional groups, which can be used to react with cross-linking agents in order to do chemical cross-linking in real time. Ch is not only biocompatible and non-toxic, but it is also biodegradable into non-toxic oligosaccharides by particular enzymes, making it suitable for therapeutic application [6].

Ch-based nanomaterials have shown considerable promise in biomedical applications such as antibacterial agents, membrane separation, drug transport carriers, biomolecule monitoring sensing materials, and tissue engineering [7]. Furthermore, Ch derivatives and Ch nanoparticles (ChNPs) have shown to be effective in ophthalmology, dentistry, bio-imaging, bio-sensing, and diagnostics [8]. Ch, derivatives, and ChNPs are historically among the most investigated natural biopolymer materials for biomedical purposes. Our research experience has prompted us in pursuing this research [9-20]. This survey was conducted for assessing the awareness about medicinal application of Chitosan nanoparticles amongst dental students.

Materials and Methods

A cross-section research was conducted with a self-administered questionnaire containing ten questions distributed amongst 100 dental students. The questionnaire assessed the awareness about Chitosan nanoparticles therapy in medical applications, their antibacterial properties, antifungal activities, wound healing properties and their role in targeted drug therapy, The responses were recorded and analysed.

Results

17% of the respondents were aware of the medicinal applications of Chitosan Nanoparticles (Fig 1). 13 % were aware of antibacterial properties of Chitosan Nanoparticles (Fig 2), 12 % were aware of antifungal properties of Chitosan Nanoparticles (Fig 3), 10 % were aware of wound healing properties of Chitosan Nanoparticles (Fig 4) and 9% were aware of their role in targeted drug therapy (Fig 5).

Discussion

Furthermore, Ch-derivatives and ChNP composites are being developed to improve the original Ch's performance, such as minimising agglomeration and increasing overall stability. For example, gene transfer of DNA and RNA into mammalian cells can be utilised to treat diseases by expressing new proteins or

Figure 1. Awareness of the medicinal applications of Chitosan Nanoparticles.

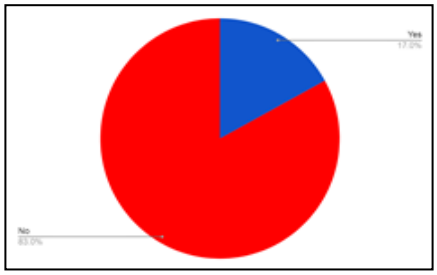


Figure 2. Awareness of the antibacterial properties of Chitosan Nanoparticles.

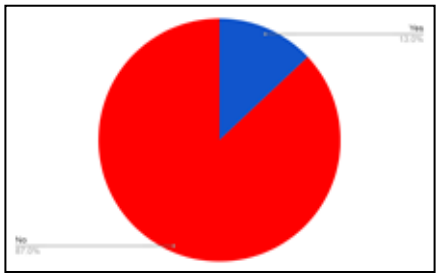


Figure 3. Awareness of the antifungal propertiesof Chitosan Nanoparticles.

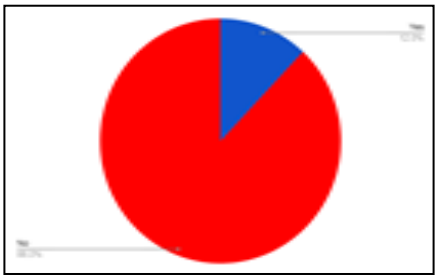


Figure 4. Awareness of the wound healing properties of Chitosan Nanoparticles.

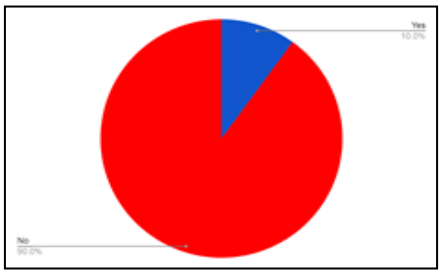
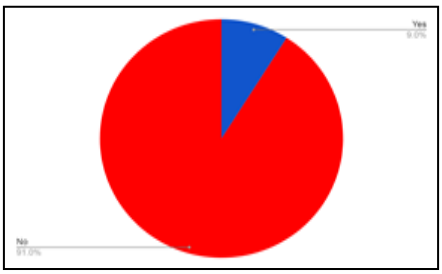


Figure 5. Awareness of the role of Chitosan Nanoparticles in targeted drug therapy.



preventing the production of existing proteins [21]. Because of its biocompatibility and biodegradability, Ch is utilised as a polycationic non-viral vector for gene transfer; nevertheless, chemical alterations to its structure are required to successfully and practically transfect under physiological settings. To counter this, encapsulated ChNPs are created utilising a new synthesis approach that does not require chemical modifications or organic solvents. These biocompatible Ch nanocomposites were used to create excellent gene delivery vehicles for in vivo applications, providing fresh insights into the field of non-viral gene therapy [22]. Ch structural modification or additive inclusion is another effective way to improve the polyplex's stability in biological fluids while also improving focused cell distribution [23].

Ch's antibacterial action is influenced by environmental parameters such as medium pH, pathogen type, and structural features such as acetylation degree, MW, concentration, and source of Ch. The quantity of Ch binding to the bacterial cell wall is similarly dependent on the same parameters, according to the researchers [24]. Low pH raises the positive charge of the Ch polymer, increasing its affinity for the bacterial cell wall. This is most likely owing to the polymer's increasing amount of protonated amino groups, where the positively charged –NH3+ groups encourage attachment to the bacteria's negatively charged membrane components [25]. Because Ch is a cationic polyelectrolyte polymer, it has antibacterial properties. Low-molecular-weight Ch can pass through microbial cellular areas, bind to DNA, and restrict DNA interpretation and mRNA activities, but high-MW Ch can combine with the negatively charged components of microbial cellular areas [14]. It generates an impenetrable coating around the cell, alters its permeability, and prevents transit into it. Microbes can rapidly attach to the exterior of ChNPs in as little as 30 minutes, indicating that ChNPs have antibacterial potential [26].

The antimicrobial activity of Ch also depends on the type of microorganism [27]. Due to Gram-negative bacteria's hydrophilicity and negative charge on their cell surface, ChNPs have more advanced interactions with them than Gram-positive bacteria, resulting in higher antibacterial activity against them. Staphylococcus aureus, Bacillus cereus, Bacillus megaterium, Listeria monocytogenes, Lactobacillus plantarum, Lactobacillus bulgaricus, and Lactobacillus brevis are among the Gram-positive bacteria that the polymer can kill. Gram-negative bacteria such as E. coli, Salmonella typhimurium, Pseudomonas fluorescens, Pseudomonas aeruginosa, Vibrio parahaemolyticus, Vibrio cholerae, and Enterobacter aerogenes are also susceptible to Ch [28].

The risk of bacterial colonisation of biomedical equipment is a major concern for the biomedical and clinical science areas. Antimicrobial coatings are made from a variety of nanomaterials to overcome this problem. Because of their non-cytotoxicity, biocompatibility, and good antibacterial capabilities, Ch-based nanoparticles are already used in a variety of healthcare and industrial applications [29]. Various Ch-based antibacterial nanocomposites have been created to improve stability, antibacterial activity, and application. [30]. Several other investigations have found that other Ch nanocomposites, such as diisocyanate, quaternized, metal oxide, and carboxymethyl modified Ch nanocomposites, had improved antibacterial activity against Gram-positive and Gram-negative bacteria. Antibacterial coatings made from the synthetic nanocomposites can be used in a variety of biomedical applications [31].

Because of the effects of MW and the degree of acetylation of Ch, the antifungal action of Ch differs depending on the fungus. Ch has antifungal properties against a variety of phytopathogenic fungus, including Botrytis cinerea, which is found in cucumber plants [32], This activity, which inhibits growth, spore germination, and tube elongation, is thought to be fungistatic rather than fungicidal. The mechanism of action involves cell wall morphogenesis, which directly inhibits cell proliferation. Furthermore, Ch is thought to act faster on fungi than bacteria [33]. Because of the quantity of free amino groups that contribute to antimicrobial action, deacetylation (DA) of Ch has an impact on its antimicrobial activity. When a result, it's thought that activity rises as DA falls [34].

Electrospun fibres made of cross-linked collagen and Ch were found to increase wound healing and tissue regeneration when compared to gauze and collagen dressings in a study by Chen *et al.,* [35]. Qasim et al. produced an electrospun Ch fibre with polyethylene oxide for periodontal disease, reporting that the fibres

could be used as surface layers that mimicked local tissue structure while also regenerating the wound site [36]. Sponges are flexible materials with strong fluid absorption and hydrophilicity, but they are mechanically weak when it comes to maintaining their shape until new tissue grows. As a result, they can be utilised as burn dressings. We created and characterised a Ch–gelatin sponge wound dressing. The sponge outperformed penicillin in antibacterial activity against E. coli K88 and cefradine in antibacterial activity against Streptococcus [37].

There have been numerous published uses for Ch-based nanosystems in cancer delivery, including breast, colon, lung, brain, and other malignancies [38]. In 2011, Venkatesan *et al.,* published encouraging results from mouse–human xenograft models for the use of a hydroxyapatite–Ch nanosystem as a transporter and delivery agent for celecoxib and other medicines, with the goal of treating colon cancer [39]. Xu *et al.,* also announced possible results for a ChNP modified with tripolyphosphate (TPP) to deliver interleukin-12 in 2012. (IL-12) [40].

ChNPs have a variety of biomedical applications. They can be used to distribute doxorubicin (DOX), an anticancer medication used to treat a variety of cancers, in a regulated manner. DOX is a drug that is commonly used to treat cancers such acute leukaemia, lymphomas, soft-tissue and osteogenic sarcomas, paediatric malignancies, and adult solid tumours like breast and lung carcinomas. Methotrexate, cisplatin, ifosfamide, vincristine, and etoposide are some of the other medications that are used alongside it [41].

Nanoparticles are constructed into drug delivery platforms for the treatment of a wide range of disorders, as well as scaffolds for tissue engineering, in the field of drug delivery and therapeutics. Because of its cationic functionality and aqueous media solubility, chitosan is one of the most widely used natural polymers in the field of drug administration [42]. Ch is easily eliminated after administration by renal clearance; however, this only applies to Ch with a suitable molecular weight. For Ch with a very big molecular weight, enzyme degradation is required. The most widely used applications of Ch nanoparticles in drug delivery aim to reduce drug side effects, control drug delivery rate, and ensure that only the targeted area is treated [43].

ChNPs have attracted attention as a therapeutic delivery item because of their utility in storing protein treatments, as well as genetic and unfavourable tumour chemical therapeutics, via oral, nasal, and intravenous routes. Due to the positive charge of NPs, which gives them the advantage of high affinity for negatively charged cell membranes, the impacted site-specific delivery of this Ch medicinal conveyance entity is unusually greater [44]. The hydrophobic property of Ch has an impact on how well hydrophilic medicines are encapsulated in ChNPs. ChNPs also have the advantage of increasing drug permeability across absorptive epithelia by breaking intercellular tight junctions by transporting tight junction proteins from the plasma membrane to the cytoskeleton. [45]. Ch's anti-inflammatory properties are derived from its acid hydrolysis to glucosamine hydrochloride and its derivatives. The structural units of proteoglycans are monosaccharides present in connective tissues and cartilage. Damaged or inflamed tissues can be repaired and regenerated by absorbing these monosaccharides. [46].

Because the NPs are absorbed into the cells via endocytosis, they can transfer biologically active molecules into cells without jeopardising the cargo or the cell's integrity [47]. At concentrations of 100 L/mL, Ch–DNA complexes of 50–100 nm in size were efficiently transfected into HeLa cells within an hour of exposure without causing cellular damage. At the same doses, the control polyethylenimine–DNA complexes were found to cause cytotoxicity. This is a significant benefit since the introduction of biopharmaceuticals necessitates benign delivery systems that can preserve delicate biologics like proteins and DNA from enzymatic and chemical degradation [48]. ChNPs can interact with negatively charged DNA and create a polyelectrolyte complex during gene delivery. When DNA was incorporated in these complexes, nuclease degradation was found to be inefficient, resulting in improved transfection efficiency [49].

ChNPs have shown promise as drug delivery vehicles and diagnostic materials in vivo. However, understanding how NPs interact with cells and organs is critical for ensuring their safety in clinical and environmental settings. In our and other laboratories, zebrafish embryos were employed as an in vivo model to assess nanoparticle biocompatibility. The zebrafish model can be used to evaluate nanoparticle toxicity on various levels, including mortality, teratogenic impact, neurotoxicity, hepatotoxicity, and genotoxicity. This model has been used in a number of investigations on Ch nanotoxicology. The toxicities of different sizes of ChNPs, were investigated using zebrafish embryos and observed some mild toxic changes [50].

Conclusion

There is limited awareness amongst dental students about use of Chitosan nanoparticles therapy in medical applications. Enhanced awareness initiatives and dental educational programmes together with increased importance for curriculum improvements that further promote knowledge and awareness of Chitosan nanoparticles therapy.

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