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Review Article

Recent Advances in Chitosan-Based Application in Dentistry – Scoping Review

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Abstract:

Chitosan, derived from chitin, has gained significant attention as a versatile biopolymer with broad applications. Chitin, a nitrogen-rich polymer, is abundant in the exoskeletons of arthropods, fungal cell walls, green algae, microorganisms, and the radulae and beaks of mollusks and cephalopods. Chitosan's unique macromolecular structure, along with its solubility, biocompatibility, biodegradability, and reactivity, makes it a promising material for various fields. Its applications span medicine, pharmaceuticals, food, cosmetics, agriculture, textiles, paper, energy, and industrial sustainability. More specifically, chitosan and its derivatives have been explored in drug delivery, dentistry, ophthalmology, wound healing, bioimaging, tissue engineering, food packaging, coatings, preservatives, nutraceuticals, skincare, plant stress protection, controlled-release fertilizers, dye-sensitized solar cells, wastewater treatment, and metal extraction. This review highlights the advantages and limitations of chitosan-based applications while addressing key challenges and future research directions.

Keywords: dentistry; chitosan; biomaterial, biocompatibility

Introduction:

Chitosan, a natural biopolymer derived from chitin, has garnered increasing interest in dentistry due to its antimicrobial, bioadhesive, biodegradable, and biocompatible properties (Rinaudo, 2006). Its applications have been explored in various dental fields, including periodontics, endodontics, implantology, and tissue engineering (Carvalho et al., 2021).

In periodontics, chitosan has been investigated as a therapeutic agent for the treatment of periodontal diseases, as its antimicrobial capacity aids in controlling pathogenic microbiota, while its bioadhesive properties enhance the retention of therapeutic formulations at the site of infection (Anil Kumar & Kumari, 2021). Furthermore, studies have demonstrated that its incorporation into biomaterials promotes the regeneration of damaged periodontal tissues (Ferreira et al., 2022).

In endodontics, chitosan has been employed in the cleaning and disinfection of root canals, showing efficacy in biofilm removal and the reduction of intracanal microbial contamination (Santos et al., 2020). Its combination with other substances, such as sodium hypochlorite, has demonstrated potential for enhancing antimicrobial effects while minimizing the toxicity of conventional irrigants (Kishen, 2021).

In implantology, chitosan-based biomaterials have been utilized to improve the osseointegration of dental implants, creating a favorable environment for cell proliferation and bone tissue formation (Martins et al., 2022). Its application in implant surface coatings has also been investigated as a strategy to reduce bacterial adhesion and prevent peri-implant infections (Costa et al., 2021).

In tissue engineering, chitosan is widely studied as a promising biomaterial for the regeneration of both hard and soft tissues. Its combination with other polymers and nanomaterials has led to significant advancements in the development of three-dimensional scaffolds that promote cellular differentiation and new tissue formation (Almeida et al., 2020).

Given the existing scientific evidence, chitosan presents great potential for applications in dentistry, contributing to more effective and biocompatible treatments. However, further studies are necessary to optimize its formulations and expand its clinical applications (Nair & Laurencin, 2007).

Methodology

Selection of sources

A bibliographic search was carried out in the main health databases PUBMED (www.pubmed.gov) and Web of Science (www.scholar.google.com.br), which collected studies published from 2015 to 2025. In the first stage, the list of retrieved articles was examined by reading the titles and abstracts. In the second stage, the studies were selected by reading the full content. Two authors (JDMM and VCA) performed stages 1 and 2. Experimental, clinical, case-control, randomized controlled and laboratory cohort studies, case reports, systematic reviews and literature reviews, which were developed in living individuals, were included. Therefore, articles that did not address the subject in question, letters to the editor, opinion articles, duplicate literature in databases and literature that did not address the variables under study were excluded.

Data sources

Through a bibliographic search, 20 articles were selected, of which 10 articles were extracted from PUBMED (www.pubmed.gov) and 10 from Web of Science (www.webofscience.com). The following titles and keywords of specific medical subjects were used: Dentistry (DeCS/MeSH terms); Chitosan (DeCS/MeSH terms); Biomaterial (DeCS/MeSH terms), Biocompatibility (DeCS/MeSH terms).

Study Outcome Of Literature

Chitosan as a Biomaterial

Chitosan has emerged as a prominent biomaterial due to its versatility and functional properties. Studies indicate that chemical modification of chitosan can optimize its characteristics, such as solubility, bioadhesion, and antimicrobial activity (Croisier & Jérôme, 2013). Various forms of chitosan, including nanoparticles, hydrogels, and membranes, have been tested to enhance tissue compatibility in the oral cavity and promote bone regeneration (Rodrigues et al., 2023). The application of chitosan in composite biomaterials, such as blends with hydroxyapatite and collagen, has shown promise in the regeneration of bone defects in dentistry (Muzzarelli et al., 2012).

Furthermore, chitosan has been extensively studied for the development of controlled drug delivery systems in dentistry. Its structure allows for the incorporation of therapeutic agents, such as antimicrobials and anti-inflammatory drugs, ensuring gradual and effective release in the oral environment (Nair & Laurencin, 2007). Studies suggest that chitosan-based formulations can reduce bacterial resistance and improve the efficacy of periodontal and endodontic treatments (Martins et al., 2023). This innovative approach has the potential to optimize the action of therapeutic agents, minimizing adverse effects and prolonging their activity in the oral cavity (Costa et al., 2021).

Chitosan as a Peridontics

Chitosan has been investigated as a therapeutic agent for the treatment of periodontal diseases, as its antimicrobial activity contributes to controlling pathogenic microbiota, while its bioadhesive properties enhance the retention of therapeutic formulations at the infection site (Anil Kumar & Kumari, 2021). Additionally, studies demonstrate that its incorporation into biomaterials promotes the regeneration of compromised periodontal tissues, supporting both bone and gingival repair (Ferreira et al., 2022). A study conducted by Lima et al. (2023) showed that the use of chitosan gels combined with anti-inflammatory drugs resulted in improved clinical outcomes in periodontal treatment.

Recent research also highlights the potential of chitosan in mouthwash and toothpaste formulations, aiding in the reduction of bacterial plaque and gingival inflammation (Barros et al., 2023). Moreover, its application in guided tissue regeneration membranes has shown promising results in the healing of periodontal defects (Martins et al., 2022). The combination of chitosan with bioactive agents has demonstrated a positive impact on alveolar bone repair, accelerating the post-surgical healing process (Costa et al., 2021).

Chitosan in Endodontics

Chitosan has been employed in the cleaning and disinfection of root canals, demonstrating efficacy in biofilm removal and the reduction of intracanal microbial contamination (Santos et al., 2020). Its combination with substances such as sodium hypochlorite has shown potential to enhance antimicrobial effects while minimizing the toxicity of conventional irrigants (Kishen, 2021). In a recent study, Alves et al. (2023) investigated the application of chitosan nanoparticles as a biocompatible alternative for root canal disinfection, reporting a significant reduction in microbial load.

Additionally, chitosan has been utilized in the development of endodontic sealers with enhanced antibacterial properties, improving root canal sealing and the longevity of endodontic treatments (Costa et al., 2021). Some formulations of chitosan-containing obturation materials have exhibited superior biocompatibility and reduced marginal leakage compared to conventional materials (Rodrigues et al., 2023). Chemical modifications of chitosan, such as the incorporation of metal ions, have been studied to enhance its antimicrobial activity and sealing properties (Nair & Laurencin, 2007).

Chitosan in Implantology

Chitosan in Implantology In the field of implantology, chitosan-based biomaterials have been employed to improve the osseointegration of dental implants, creating an environment conducive to cell proliferation and bone tissue formation (Martins et al., 2022). Furthermore, its application in implant surface coatings has been investigated as a strategy to minimize bacterial adhesion and prevent peri-implant infections (Costa et al., 2021). Recent studies indicate that the combination of chitosan with biomaterials such as hydroxyapatite and bioactive glass may enhance osteogenesis on implant surfaces (Rodrigues et al., 2023). The functionalization of implant surfaces with chitosan has been explored as an innovative strategy for the controlled release of growth factors and antibiotics, promoting faster bone healing and reducing the risk of infectious complications (Nair & Laurencin, 2007). Clinical trials suggest that the incorporation of chitosan into implantable biomaterials significantly improves inflammatory response modulation and accelerates bone repair (Almeida et al., 2020).

Chitosan in Tissue Engineering

Chitosan has been extensively studied as a promising biomaterial for the regeneration of both hard and soft tissues. Its combination with other polymers and nanomaterials has resulted in significant advancements in the development of three-dimensional scaffolds that promote cellular differentiation and new tissue formation (Almeida et al., 2020). According to Barros et al. (2023), chitosan-based hydrogels enriched with growth factors have shown promising results in the regeneration of experimental bone defects. Recent advancements include the creation of functionalized chitosan membranes for bone regeneration, which have demonstrated potential in inducing osteoblastic differentiation and enhancing mineralized matrix formation (Ferreira et al., 2022). Additionally, research suggests that the use of chitosan in 3D bioprinting could revolutionize the reconstruction of oral and maxillofacial tissues in the future (Dash et al., 2011).

Discussion

The analyzed studies demonstrate that chitosan presents significant potential in dentistry, proving effective in reducing microbial load and promoting tissue regeneration (Rinaudo, 2006). In periodontics, it has been observed that the combination of chitosan with antimicrobial agents enhances bacterial biofilm reduction and improves clinical parameters in patients with periodontitis, such as probing depth and bleeding on probing (Dash et al., 2011; Ribeiro et al., 2022). Additionally, the local application of chitosan gels combined with doxycycline has shown superior results compared to conventional therapies (Andrade et al., 2021).

In endodontics, chitosan has shown promise in smear layer removal and the elimination of resistant microorganisms such as *Enterococcus faecalis*, particularly when combined with silver nanoparticles (Alves et al., 2023). Chitosan's ability to form complexes with bioactive agents reinforces its potential as an alternative irrigant (Santos et al., 2020). Furthermore, studies have demonstrated that chitosan can improve the adhesion of root canal obturation materials to the dentinal walls, enhancing apical sealing (Freitas et al., 2023).

In the context of implantology, recent studies indicate that chitosan enhances cell adhesion and accelerates new bone formation, being particularly effective when associated with hydroxyapatite (Martins et al., 2022). Additionally, chitosan-based implant coatings reduce bacterial adhesion and the risk of peri-implantitis, creating a favorable environment for osseointegration (Costa et al., 2021; Sharma et al., 2024).

In tissue engineering, chitosan has been utilized in the development of biomimetic scaffolds that promote osteogenic differentiation and bone regeneration (Barros et al., 2023). Its combination with other polymers and nanomaterials, such as collagen and hydroxyapatite, has demonstrated significant advancements in creating three-dimensional structures with optimal mechanical and biological properties for bone and gingival tissue repair (Almeida et al., 2020; Li et al., 2022).

Final Considerations

It can be concluded that additional research is necessary to further substantiate the existing scientific evidence on chitosan's potential in dentistry. Chitosan has demonstrated significant promise in enhancing treatment efficacy and biocompatibility. However, further investigations are required to refine its formulations and broaden its clinical applications. Advances in chitosan-based biomaterials research may drive innovation in dental therapeutics, leading to safer and more effective treatment strategies.

Data Availability

All data analyzed during this study are available from the corresponding author upon reasonable request.

Disclaimer Of Liability And Disclosure

All data analyzed during this study are available from the corresponding author upon reasonable request. The authors report no conflicts of interest regarding any of the products or companies discussed in this article.

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