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Proceeding Paper

Silver Nanoparticles in Dentistry: Investigating Research Prospects for Silver-Based Biomaterials

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Abstract: Objective: to provide an overview of the current knowledge and highlights areas where further research is needed and to address the limitations and enhance the understanding of silver-based biomaterials in dental practice. Methods: A comprehensive literature review was conducted to evaluate existing research on silver-based biomaterials in dentistry. Relevant research articles were collected from electronic databases, including PubMed, Web of Science and Scopus. The identified literature was critically analyzed to identify areas that require further investigation. Results: The review revealed several research gaps in the application and use of silver-based biomaterials in dentistry. First, there is a need for long-term clinical studies to evaluate the performance and durability of silver-based biomaterials in various dental applications, including restorative materials, implant coatings, and orthodontics. Additionally, studies focusing on the biocompatibility and tissue response to silver-based biomaterials are required to ensure their safety and minimize potential adverse effects. A deeper understanding of the mechanisms of action of silver-based biomaterials, including the release of silver ions and their interaction with oral microorganisms, would provide valuable insights for clinical decision-making. Conclusions: Despite the growing interest in silver-based biomaterials in dentistry, there are several issues that need to be addressed to fully explore their capabilities and limitations. Long-term clinical trials, investigations into biocompatibility and tissue response, and understanding of mechanisms of action are necessary to expand the knowledge base and ensuring their effectiveness, safety and improved patient outcomes.

Keywords: biomaterials; silver-based biomaterials; silver nanoparticles; biomaterials in dentistry

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1. Introduction

Exploring many research prospects, the field of dentistry is witnessing transformative growth through the application and use of silver-based biomaterials. Taking advantage of silver's unique properties, these materials offer promising opportunities for innovative advances in dental practice. This exploration of the realm of silver-based biomaterials reveals possibilities, encouraging researchers to delve into unexplored areas and help make way for improved oral health care solutions. This study aims to present a synopsis of the prevailing knowledge while shedding light on domains demanding additional inquiry. Furthermore, it seeks to tackle limitations, and enrich insights concerning the integration of silver-based biomaterials within dental practice.

2. Materials and Methods

Employing an extensive literature review, this investigation delved into the evaluation of current research concerning the application of silver-based biomaterials in dentistry. Pertinent scholarly articles were amassed from electronic repositories encompassing platforms such as PubMed, Web of Science, and Scopus. A meticulous analysis of the compiled literature ensued, with a focus on pinpointing sectors that merit further in-depth exploration.

3. Results

3.1. Silver-based biomaterials in conservative dentistry and endodontics

The dentistry is currently witnessing a dynamic shift driven by the application of silver-based biomaterials. The integration of silver nanoparticles (SN) into dental materials like for example in Portland cement has not only enhanced antibacterial effectiveness but also positively influenced mechanical properties. This underscores the potential of silver-Portland cement nanocomposites (SPNC) as promising dental biomaterials for the future. However, to ensure its clinical viability, it is imperative to conduct additional research, encompassing the exploration of inhibitory mechanisms, in vivo assessments, and long-term investigations [1].

Although the incorporation of silver nanoparticles into glass ionomer cement (GIC) offers advantages in terms of antimicrobial properties and caries prevention, some studies have shown a notable adverse impact on the release of fluoride. This situation may place clinicians in a position where they need to strike a balance between harnessing the antimicrobial benefits of SN and preserving the remineralization advantages of fluoride, it is advisable to conduct additional studies [2]. However, it is worth noting that the combined usage of silver nanoparticles (Ag NPs) with various dental materials did not compromise the biocompatibility of these materials. Both the disinfection liquid and GIC demonstrated antibacterial properties, effectively targeting all examined bacterial species.[3] The recent study by Niska et al., demonstrated the potent synergy achieved by combining silver nanoparticles with lipoic acid (Ag NPs-LA) in combating *Staphylococcus epidermidis* and *Streptococcus mutans* in a 1-day biofilm, without causing toxicity to gingival fibroblast cells at the tested concentration. The research indicates the possible beneficial application of Ag NPs in dental practices, but it also emphasizes the need for comprehensive evaluations of their pharmacological activity and risk profile to ensure safe and responsible use [4].

Furthermore, the combined solution of CHX-Ag NP showed superior effectiveness in comparison to individual solutions, representing an exciting stride in improving dental interventions [5]. Similarly, nanoparticle solutions exhibited comparable antimicrobial effectiveness against *Enterococcus faecalis* biofilm when contrasted with traditional endodontic irrigants ($P > 0.05$). However, none of these solutions could consistently eliminate bacterial counts entirely, signaling the need for innovative strategies to achieve improved outcomes. In particular, the most potent impact was observed with 2% CHX, which led to a reduction of 76.81% in colony-forming units (CFUs) compared to the control group. Following that, 5% NaOCl demonstrated a reduction of 70.02%, and 1% Ag Np resulted in a decrease of 57.28% in CFUs [6]. The Ag-MCSNs (nanosilver-incorporated mesoporous calcium-silicate nanoparticles) exhibited remarkable antibacterial efficacy against *E. faecalis* and demonstrated a strong ability to adhere to dentin, suggesting the potential development of a novel and efficient intra-canal medicament for human teeth [7]. Another study has highlighted the additional role of silver Ag NPs in enhancing root canal disinfection, offering a promising pathway to elevate treatment standards [8]. In conclusion, the ongoing pursuit of leveraging silver-based biomaterials in dentistry unveils a tapestry of opportunities, ushering in transformative advancements that hold immense potential for shaping the future of oral healthcare. Further investigations are needed to examine the antibacterial effects of silver nanoparticles when incorporated into different types of dental materials, such as resins, glass-ionomer cements, and varnishes [9]. These investigations will contribute to a more comprehensive understanding of the benefits and challenges associated with silver-based dental biomaterials in various clinical scenarios.

3.2. Silver-based biomaterials in orthodontics

The application of silver nanoparticles in orthodontics holds significant promise for improving patient outcomes and oral health. Orthodontic brackets containing silver nanoparticles have shown promise in reducing the occurrence and prevalence of white spot lesions, primarily due to their antibacterial properties. Nevertheless, to confirm their efficacy in patients undergoing orthodontic treatment, additional in vivo research is essential [10].

Also, incorporation of silver nanoparticles on the surface of orthodontic mini-implants exhibited antibacterial efficacy against *Lactobacillus* and *S. aureus* with also evident but slightly smaller antibacterial activity against *S. mutans*. However, further in vivo and extended-term investigations are necessary to comprehensively assess these outcomes [11]. Moreover, titanium microimplants that were enhanced with a Ag NP-coated biopolymer display remarkable antibacterial capabilities, positioning them as a highly prospective biomaterial [12].

In addition to orthodontic brackets and mini-implants, silver nanoparticles found utility in other orthodontic materials. For instance, Polymethyl-methacrylate (PMMA) commonly used for baseplates of orthodontic appliances (BOA), was incorporated with SN, showing excellent antimicrobial efficacy in reducing plaque formation and the risk of dental caries. The findings are promising in reducing plaque formation by carious bacteria and the risk of dental caries during orthodontic treatment [13]**.**

Furthermore, in the context of orthodontic retention, incorporation of SN into the acrylic plate of retainers showed strong antimicrobial activity against *S. mutans*. Notably, the test group exhibited a significant reduction in the number of bacterial colonies after a period of 7 weeks [14]. Additionally, research conducted by Alla et al., highlighted that the inclusion of SN emerges as a favorable strategy for enhancing the surface hardness of denture base materials [15]. These collective findings showcase the expanding role of silver nanoparticles in orthodontics and dentistry, with ongoing research aimed at harnessing their advantages for improved patient outcomes and oral healthcare.

3.3. Silver-based biomaterials in dental surgery

Silver is rapidly emerging as a potential antibacterial material for countering bone infections, owing to its notable merits including rapid antibacterial activity, effective antibacterial performance, and reduced susceptibility to bacterial resistance. Nevertheless, the considerable cytotoxicity of silver poses a hurdle, as it can induce inflammatory reactions and oxidative stress, leading to the impairment of tissue regeneration. This complex interaction underscores a huge challenge in the use of silver-containing biomaterials [16,17].

Furthermore, when considering implant-based factors, such as the features of the surface, could potentially amplify the susceptibility to peri-implant diseases. Consequently, numerous research focused on enhancing the antibacterial attributes of titanium surfaces. Among these methods the integration of silver nanoparticles stands out. Silver has been shown to have a wide spectrum of antibacterial activity attributed to its ability to interfere with the bacterial cell wall permeability, cause DNA damage and inactivation of important proteins [18] [19,20]. As the use of nanoparticles (NPs) continues to rise, it becomes increasingly vital to develop methods for assessing nanotoxicity [21]. This is especially relevant in the context of silver nanoparticles and their potential impact on both antibacterial efficacy and biocompatibility, as understanding the safety and effectiveness of these materials is essential for their successful integration into dental implants. The effectiveness of titanium implants in combating infection can be greatly improved by incorporating silver Ag NPs. The problem, however, is the tendency of silver nanoparticles to translocate, leading to potential cell damage. To address this, the silver plasma immersion ion-implantation (Ag-PIII) technique may provide a solution to alleviate this problem. An in vivo study conducted on dogs showed that the Ag-PIII technique has the capability to decrease the movement of Ag NPs while simultaneously improving the integration of sandblasted and acid-etched dental implants surfaces with bone tissue. This suggests promising prospects for its future application and utilization [22].

4. Conclusions

Biomaterials are revolutionizing the approach to antibacterial protection in the fields of medicine and dentistry. The utilization of advanced materials, such as silver nanoparticles, allows for the efficient elimination of bacteria and pathogens. This synergy between biomaterials and their antibacterial properties paves the way for innovative solutions in infection prevention and patient health improvement. However, to ensure their effectiveness and clinical safety, further research and assessments are essential to strike the optimal balance between antibacterial benefits and biocompatibility aspects.

Additional studies are required to investigate the effects of prolonged exposure and higher doses of silver nanoparticles on various organ systems in order to determine safe levels of human exposure. Further exploration is necessary to establish toxicity thresholds for silver nanoparticulate silver in humans [23]. Gaining a more comprehensive knowledge of how silver-based biomaterials operate, encompassing aspects like the release of silver ions and their engagement with oral microorganisms in long-term research, would offer significant and insightful guidance for making clinical decisions.

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