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Review Article

Hyaluronic Acid in Modern Dentistry

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Abstract

Introduction

Hyaluronic acid (HA) is a naturally occurring polysaccharide and is recognized as an important biomaterial due to its regenerative and biocompatibility properties, demonstrating its usefulness in numerous dental applications. This review aims to address the current applications of HAs in dentistry, focusing on periodontal therapy, bone regeneration, and implantology, the mechanisms of action of AHs, their challenges, and the prospects for the future.

Methods

A systematic literature search of electronic databases (PubMed, Scopus, and Google Scholar) for relevant articles published from 2016 to 2025 was used. The keywords that were used were "hyaluronic acid," "dentistry," "periodontal therapy," "bone regeneration," and "dental implants." Preference was given to studies published in English, including both in vitro and in vivo studies and including clinical trials.

Discussion

HA is thought to be a promising therapeutic in periodontics because of its anti-inflammatory, antibacterial, and wound-healing capabilities. It is used as an adjuvant in the treatment of periodontal diseases and contributes to tissue healing and regeneration. As a skeleton or carrier of bioactive parts, HA promotes osteogenesis and mineralization in bone regeneration. HA is also used in titanium implant surfaces to enhance osteo-conductivity for earlier loading of dental prostheses. HA mediates cellular signaling and regulates cell adhesion and proliferation, which is the reason for its effectivity.

While HA has many promising uses, the standardization of HA use has been challenging because of the variability of products in terms of their molecular weight and concentration. Further studies will be needed to optimize the HA formulations with dental applications and verify the efficacy and safety through further investigations.

Conclusion

Hyaluronic acid: an emerging biomaterial in dentistry. It has benefits in periodontal therapy, bone regeneration, and implantology. These are unmatched by any other material in terms of its regenerative, anti-inflammatory and wound healing actions that not only improve clinical results but also change the future of dental treatment innovations. However, ongoing research is crucial to optimize its application, overcome issues in various formulations and evaluate its efficacy for dental applications. Thus, the application of HA in its fullest capacity is going to change the future of dental medicine and the future of dental care for patients.

Literature Review

From the Past to the Future Hyaluronic acid (HA) is a newly developing and aspiring biomaterial that has attracted much attention in modern dentistry due to its wide application in various biological properties. These properties also include the promotion of tissue regeneration, enhancement of wound healing, and anti-inflammatory action. HA is now used in periodontal therapy, bone regeneration, and implantology, and a lot of publications support the versatility and effectiveness of HA to enhance clinical results. This review describes the mechanism of action of HA, its use in major dental practices, obstacles to its usage, and the potential future for this bio ceramic.

Key words: hyaluronic acid; dental implant; dentistry; bone regeneration; periodontal therapy

Introduction

Hyaluronic acid is a naturally occurring glycosaminoglycan that is key in the homeostasis of tissue hydration, elastic feature and resistance. It is present in a number of tissues, such as skin, joints, and eyes, thus providing valuable candidate for the medical and dental applications because of it is positive characteristics (Entity & Olszewska-Czyż, 2020; Zhai et al., 2019). In dentistry, HA has been used in periodontal disease treatment, bone regeneration, and the success of implants.

The increasing interest in HA into the dental field is related to its several properties such as tissue regeneration, wound healing, anti-inflammatory property, and angiogenesis (Mucchi, 2021; Zhao et al., 2016). Due to these advantages, HA is a promising agent to improve dental therapies in different situations, particularly in complicated cases like periodontium treatment and bone regeneration (Miglani et al., 2023). While HA has great possibilities, optimizing its use as a dental application presents challenges, which will be the focus of this review.

2. Hyaluronic Acid in Periodontal Therapy

Periodontal diseases are among the most common oral health problems and involve inflammation of the tissues around the teeth, which in untreated cases, may result in loss of teeth. The main objective of periodontal treatment is to limit and eliminate bacterial infection, alleviate inflammation, and recover lost tissue. HA has been used as an adjunct to conventional periodontal therapy (CP) in clinical settings (Shukla & Pebbili, 2022).

2.1 Mechanisms of Action in Periodontal Therapy

HA has anti-inflammatory, antibacterial, and wound-healing properties that make it useful in periodontal therapy. It suppresses inflammatory processes by decreasing activation of inflammatory cells that will ultimately prevent tissue damage (Yarikov et al., 2024). Moreover, HA can trigger fibroblast proliferation and collagen production, which is vital for tissue regeneration (Khuwaja et al., 2024; Ahmad et al., 2024). Recent studies show that HA are useful in enhancing clinical attachment levels and reducing mortality over probing depth, both of which are robust clinical measures of periodontal health (Ali et al., 2023).

The antibacterial effect of HA is also important and has been shown to promote healing by reducing the microbial load in periodontal pockets (Zhao et al., 2016). Previous studies also indicate that HA presents an increased potential of soft tissue healing and periodontium regeneration post-scaling and root planing or surgical intervention (Eliezer et al., 2019; Aydinyurt et al., 2020). This is further supported by the ability of HA to induce further migration of gingival fibroblasts and consequently enhance healing rates and optimal clinical outcomes (Miglani et al., 2023).

2.2 Combination with other Biomaterials

Various studies have examined HA in combination with amino acids and growth factors to improve therapeutic efficacy (Miglani et al., 2023). In chronic periodontitis patients, HA in combination with amino acids has led to a significant probe depth reduction and bleeding on probing (Yarikov et al., 2024). This further demonstrates that use of HA can bring better results in periodontal treatments.

HA is present in greater degrees within non-mineralized periodontal tissues than in mineralized tissues, indicating its necessity for periodontal health and tissue regeneration (Zhai et al., 2019; Casale et al., 2016). Guided tissue regeneration membranes (stabilized with HA) enable better healing and tissue integration, exhibiting their potential for clinical applications (Miglani et al., 2023).

3.HA In Bone Regeneration

Bone regeneration plays a crucial role in several dental therapies, especially at the time of tooth extraction. HA is known for its osteoconductive potential, especially in alveolar ridge preservation (ARP), as it can inhibit the resorption of alveolar bone after tooth extraction and promote bone generation (Mucchi, 2021).

3.1. Hyaluronic Acid in Alveolar Ridge Preservation

HA is indicated to be used with bone grafting materials such as xenografts or autografts in ARP according to systematic reviews (Ahmed et al., 2024). Previous studies have shown that HA-enhanced grafts yield better radiographic and histological results than grafts alone (Ebrahimi et al., 2023; Eliezer et al., 2019). Moreover, HA can enhance bone density and reduce graft shrinkage, both of which contribute to improved implantation success (Ali et al. 2023).

However, research data have shown that HA can improve not only the initial stages of bone healing by the stimulation of osteoblastic proliferation and differentiation (Masurkar et al., 2023). Furthermore, the use of HA with platelet-rich fibrin has demonstrated the significant outcomes and improvement in bone and soft tissue healing (Mahmood, 2022).

3.2 Future Directions in Bone Regeneration

Innovative HA-based systems targeting the appropriate molecular weight, concentration, and delivery systems are being studied to expand the regenerative capacity of HA (Masurkar et al., 2023; Ahmad et al., 2024). This emphasizes the importance of standardization and protocols in dental applications, as investigations are ongoing to investigate clinical outcomes associated with different formulations of HA combined with biomaterials (Ali et al., 2023).

The combination of HA with bioactive molecules and growth factors can improve the regenerative process resulting in better clinical outcome for dental procedures (Zhao et al., 2016; D'Albis et al., 2022).

4. Implantology and Hyaluronic Acid

Dental implants represent the current gold standard for prosthetic treatment of lost teeth; success for osseointegration is vital for their long-term success. HA has become a prominent coating material employed for implants to improve osseointegration and success rates (Kaya & Muğlalı, 2016).

4.1 Enhancing Osseointegration with Hyaluronic Acid

The ability of HA to enhance osseointegration by promoting the healing of peri-implant tissue and reducing inflammation makes it an important agent to prevent implant failure (Miglani et al., 2023). Moreover, current studies indicate that HA may decrease the effects of systemic conditions, for example: diabetes on implant success (Ahmed et al., 2024). In another investigation, osseointegration was significantly improved in HA-coated implants as compared to non-coated ones, further illustrating the essential contribution of HA in facilitating successful dental implant integration (Zhao et al., 2016).

In addition, HA was combined with other modalities such as fibrin-based scaffolds to further enhance peri-implant tissue regeneration and stability (Yarikov et al., 2024). Novel carrier formulations of HA, such as its incorporation into nanocarriers, have also demonstrated potential for localized delivery with prolonged release, potentially enhancing therapeutic efficacy (Miglani et al., 2023).

Study	Application	Findings
Entity & Olszewska-Czyż (2020)	General dental applications	Hyaluronic acid as a biomaterial enhances healing processes.
Zhao et al. (2016)	Bone formation	Promotes osteogenesis and enhances bone regeneration.
Zhai et al. (2019)	Bone regeneration	Effective in promoting bone healing and integration.
Mucchi (2021)	Dental applications	Demonstrates biocompatibility and efficacy in wound healing.
Miglani et al. (2023)	Versatile applications	Discusses multiple uses including periodontal treatments.
Meng & Chen (2024)	Treatment of periodontal disease	Highlights effectiveness and safety in periodontal therapy.
Casale et al. (2016)	Perspectives in dentistry	Systematic review supports its use in various dental procedures.
Shukla & Pebbili (2022)	Healing agent in dentistry	Shows positive effects on tissue regeneration.
Ali et al. (2023)	Gingival black triangles	Hyaluronic acid reduces the presence of black triangles.
Pilloni et al. (2023)	Early wound healing	Clinical and histological support for its use in gingival healing.

Table 1: Applications of Hyaluronic Acid in Dentistry

5. Mechanisms of Action

The biological actions of HA make it a key player in the therapeutic efficacy of dental procedures. By binding to receptors on inflammatory cells, it modulates inflammation by decreasing the release of proinflammatory cytokines (Zhai et al., 2019). Moreover, HA stimulates fibroblast migration and proliferation, angiogenesis, and interstitial matrix development needed for tissue repair (Mucchi, 2021; Khuwaja et al., 2024).

Studies have demonstrated that HA can induce the extracellular matrix to deposit collagen and other required structural components for the tissue to heal (Ahmadian et al., 2019; Eliezer et al., 2019). The mechanisms behind the action of this molecule result in increased proliferation rates for the most different tissue types, including the dental context. In addition, HA has been reported to promote the growth and differentiation of dental pulp stem cells, which adds additional support for its regeneration potential (Ahmadian et al., 2019).

Mechanisms of Action of Hyaluronic Acid	
Property	**Description**
Biocompatibility	Well-tolerated; minimal adverse reactions.
Anti-inflammatory effects	Reduces inflammation in periodontal tissues.
Promotion of cell migration	Enhances healing and tissue repair processes.
Modulation of signaling pathways	Activates genes related to tissue regeneration.

Table 2 Source: Entity & Olszewska-Czyż (2020); Zhai et al. (2019); Mucchi (2021); Miglani et al. (2023).

6. Challenges in Hyaluronic Acid Application

Although having its advantages, a number of challenges still hinder the use of HA in dentistry. The main barrier is that HA formulations have differences such as variability in molecular weight and concentration that would lead to different therapeutic effects (Ali et al., 2023; Ahmad et al., 2024). Because no standardized protocols currently guide the practice of HA in different dental procedures, it warrants further research to provide guidelines to optimize its therapeutic effects (Miglani et al., 2023).

In addition, the clinical applicability of HA is complicated by the absence of consensus regarding the ideal dosage and most effective delivery method (Galini Kalavrytinou et al., 2017). The standardization and application of evidence-based guidelines for HA will be critical in maximizing its treatment effects

7. The future of Hyaluronic Acid in Dentistry

This burgeoning interest in HA from the scientific community has set HA as an important and invaluable tool in modern dentistry. Investigation continues to utilize nanotechnology and co-application of HA with other growth factors and biomaterials, to increase its therapeutic effects (Mehta et al., 2022). Such developments may result in more effective HA localized delivery and increased tissue regeneration.

The use of HA associated with stem cells or other regenerative factors could enhance tissue healing and regeneration (Pilloni et al., 2023). One possible direction is to investigate technologies like injectable hydrogels or HA-based nanocarriers that would allow sustained release of HA at the therapeutic site (Aydinyurt et al., 2020).

Moreover, the use of HA in cosmetic dentistry, especially in terms of correcting gingival aesthetics, is taking on additional film. (Zhao et al., 2016; Mucchi, 2021). The bioproperty of HA lies in its wide distribution in nature, and as such, it is a widespread polymer found in human

structures, such as skin, synovial fluid, and cartilage. Because of its ability to create soft tissue defects and contour improvement, its use in aesthetic procedures has increased (Martins et al., 2023; Al-Halaseh et al., 2022).

8. Conclusion

Hyaluronic is a naturally safer and an excellent biomaterial and has gained much importance in modern dentistry; its extensive applications in periodontal therapy, bone regeneration and implantology. It promotes better patient outcomes because of its regenerative, anti-inflammatory, and wound healing properties. Nonetheless, problems related to the variability of HA preparations, lack of standardized protocols, and best modes of delivery become hindrances to its complete utilization in clinic application.

In the future, the horizon for HA in dentistry looks extremely bright. Emerging growth of nanotechnology, concomitant use of HA in combination with other biomaterials and growth factors, and building more efficient delivery systems such as injectable hydrogels and HA-based nanocarriers may play a major role in changing the nature of dental treatment. Activation of HA in association with stem cells for the regenerative strategy can have massive augmentation of healing and also assisting maximal regeneration in problematic cases of dentistry.

As more research is being uncovered, particularly in the areas of standardized protocols and ideal dosing, HA's role in dentistry will only increase. With new possibilities in aesthetic dentistry, its use in aesthetic procedures like gingival contouring is also growing. With these advancements, HA is positioned to become a more significant factor in determining the direction of dental care in the future by providing highly efficient, less invasive treatments for a variety of dental conditions.

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