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HYALURONIC ACID IN SOCKET PRESERVATION: A REVIEW

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Abstract

Tooth extraction commonly results in alveolar bone resorption and soft tissue remodeling, which can complicate future dental implant placement. Alveolar Ridge Preservation (ARP) techniques are employed to minimize these dimensional changes and optimize restorative outcomes. Hyaluronic acid (HA), a naturally occurring glycosaminoglycan, has gained attention for its regenerative properties, including osteoinduction, anti-inflammation, and antimicrobial effects. HA supports wound healing, angiogenesis, and enhances the activity of osteoblasts and fibroblasts. Clinical applications range from standalone HA gels to combinations with xenografts or membranes in guided bone regeneration. Preclinical and clinical studies indicate that HA can improve bone density, reduce resorption, and promote soft tissue healing. However, variations in study design, HA formulations, and outcome measures have led to inconsistent findings. Despite these limitations, HA remains a promising adjunct in ARP. Larger, standardized, long-term studies are essential to establish its definitive role in socket preservation.

Keywords: Hyaluronic Acid, Alveolar Ridge Preservation, Socket Preservation, Bone Regeneration, Soft Tissue Healing.

Introduction

Tooth extraction initiates a complex cascade of biological events that often lead to significant alterations in the alveolar ridge, including both vertical and horizontal bone resorption, as well as soft tissue remodeling.[1] These dimensional changes can compromise the functional and esthetic outcomes of subsequent dental implant placement or prosthetic rehabilitation. Studies have shown that the greatest amount of bone loss occurs within the first three to six months following extraction, with up to 50% reduction in ridge width and substantial loss in height, particularly in the buccal aspect of the alveolar ridge.[2] In response to these challenges, *Alveolar Ridge Preservation (ARP)* techniques have been developed to maintain the hard and soft tissue architecture of the extraction socket.[3] These procedures aim to minimize ridge atrophy and create a more favorable foundation for future restorative procedures. ARP strategies often involve the use of bone graft materials, membranes, growth factors, and biological agents that promote wound healing and bone regeneration.[4,5] One such biological agent that has gained increasing attention is Hyaluronic Acid (HA), a naturally occurring, non-sulfated glycosaminoglycan present in the extracellular matrix of connective tissues. HA plays a critical role in modulating tissue hydration, inflammation, cell migration, proliferation, and angiogenesis.[6] It is particularly abundant in granulation tissue during early wound healing phases, highlighting its physiological relevance in tissue regeneration[7]. Recent research has explored the application of HA in dental and maxillofacial surgery, especially in socket preservation. Its osteoconductive and osteoinductive properties make it a valuable adjunct to traditional grafting materials. Moreover, HA exhibits anti-inflammatory, bacteriostatic, and wound-healing effects, which can contribute to accelerated and more

predictable socket healing. When combined with autogenous or xenogenic bone grafts, HA has demonstrated the ability to improve graft stability, enhance new bone formation, and support better soft tissue integration.[8] Clinical and preclinical studies have supported the use of HA-based gels, membranes, and composites as beneficial in reducing post-extraction complications, preserving alveolar ridge dimensions, and improving the quality of regenerated tissue.[9] Given these potential advantages, HA represents a promising biomaterial in the context of ARP, capable of addressing both hard and soft tissue challenges.[10] This review aims to provide a comprehensive overview of the biological functions of hyaluronic acid and its clinical applications in socket preservation.

Review of Literature

Eeckhout et al.,[11] Husseini et al.,[12] and Abaza et al.[13] evaluated the efficacy of combining hyaluronic acid (HA) with deproteinized bovine bone mineral (DBBM) for socket or alveolar ridge preservation post-tooth extraction, focusing on bone regeneration, volumetric bone loss, and graft integration. While Husseini et al. and Abaza et al. generally support HA's beneficial role, showing reduced bone resorption and improved graft integration when applied intraoperatively with DBBM, Eeckhout et al. presented contrasting results, with increased horizontal bone loss in the HA-treated group where HA gel was applied topically by patients post-operatively, highlighting a critical difference in application methodology. The studies also varied in DBBM type (with/without collagen) and HA form (cross-linked vs. linear), which may contribute to the observed discrepancies. [10]Although all studies utilized CBCT for volumetric assessments, their primary outcomes differed, impacting direct comparisons. Husseini et al. and Abaza et al. indicated positive outcomes for HA in bone preservation, while Eeckhout et al. did not find significant improvements. The review also briefly notes the promising role of injectable platelet-rich fibrin (I-PRF) as observed in Abaza et al. for soft tissue stability. Risk of bias assessments rated Husseini et al. as low, and Eeckhout et al. and Abaza et al. as medium. Despite these insights, the significant heterogeneity among the studies, particularly concerning HA application methods and biomaterial specifics, precluded a meta-analysis, thereby limiting definitive statistical conclusions.[11,12,13]

Biological Properties and Mechanisms of Hyaluronic Acid in Socket Preservation

Hyaluronic acid (HA), a naturally occurring glycosaminoglycan, is a fundamental component of the extracellular matrix and plays a pivotal role in tissue repair and regeneration.[14] Its multifunctional biological activity makes it particularly valuable in alveolar ridge preservation. HA regulates key cellular behaviors such as migration, adhesion, and proliferation, which are essential during the healing cascade following tooth extraction. It promotes angiogenesis and stimulates fibroblast and osteoblast activity, thereby enhancing both soft and hard tissue repair.[15] HA exists in various molecular weights and forms—including injectable gels, membranes, and composites—allowing for versatile application in clinical settings. High molecular weight HA is known for its anti-inflammatory and bacteriostatic properties, while lower molecular weight forms are more active in promoting cell proliferation.[16] By modulating early inflammatory responses and accelerating clot stabilization, HA supports the initial stages of healing. It further facilitates the granulation and proliferation phases by enhancing endothelial and fibroblast activity, contributing to rapid and organized tissue repair. In the context of bone regeneration, HA supports osteoconduction and osteoinduction, especially when used in conjunction with bone graft materials.[17] It also plays a supportive role in maintaining hydration, stabilizing grafts, and acting as a carrier for bioactive molecules and growth factors.[18] Additionally, HA exhibits antimicrobial and antiadhesive properties, reducing the risk of post-operative infections. These combined effects make HA a highly effective agent in preserving socket dimensions and improving the overall quality of post-extraction healing.[19]

Clinical Applications of Hyaluronic Acid in Socket Preservation

Hyaluronic acid (HA) has demonstrated versatile clinical applications in socket preservation, either as a standalone agent or in combination with other biomaterials. When used independently in gel form and applied directly into extraction sockets, HA has been shown to promote early healing and reduce postoperative discomfort.[20] More commonly, HA is combined with bone graft materials such as xenografts, allografts, or synthetic substitutes, where it exhibits synergistic effects enhancing graft stability, maintaining ridge volume, and improving overall healing outcomes.[21] In guided bone regeneration (GBR) procedures, cross-linked HA-

based membranes are employed as bioactive barriers that not only facilitate osteogenesis but also support soft tissue integration. Evidence from preclinical studies using animal models has consistently indicated that HA accelerates new bone formation and decreases inflammatory responses, regardless of the condition of the extraction socket.[22] Clinically, several studies have reported significant improvements in bone density, socket fill, and radiographic outcomes when HA is used, particularly in combination with grafting materials. These benefits include higher-quality bone regeneration, reduced resorption, and less graft shrinkage within the healing period, typically evaluated after four months. In terms of soft tissue healing, some clinical trials have documented better epithelialization, early wound closure, and improved gingival architecture following HA application.[18,20] However, findings across studies are not entirely uniform, with certain randomized controlled trials reporting no significant advantage in wound healing or patient-reported outcomes when compared to conventional methods. Additionally, the use of HA has been associated with reduced postoperative pain, especially in procedures such as third molar extractions, though its analgesic benefit appears to be less prominent in routine extractions.[21] Despite some variability in results, the growing body of evidence suggests that HA is a promising adjunct in alveolar ridge preservation protocols, with notable benefits in enhancing both hard and soft tissue regeneration.[22,23]

Clinical Evidence: Osteoconductive Potential, Soft Tissue Healing, and Methodological Variability

Emerging clinical evidence supports the beneficial role of hyaluronic acid (HA) in alveolar ridge preservation, particularly in enhancing bone regeneration and soft tissue healing. Studies have shown that when HA is combined with autogenous bone grafts, it significantly accelerates bone deposition and increases bone density compared to grafting alone, highlighting its capacity to enhance osteoconduction (Taman et al., 2017).[24] Furthermore, HA has been linked to improved outcomes in bone formation and reduced post-extraction bone resorption, especially when used alongside other grafting materials (Nistor et al., 2025).[25] In terms of soft tissue management, HA's anti-inflammatory properties contribute to enhanced wound healing and reduced postoperative inflammation, leading to more favorable soft tissue outcomes (Masurkar et al., 2023; Karakostas et al., 2022).[26,27] Its application in periodontal therapy has also demonstrated symptomatic relief and improved healing in inflamed periodontal tissues, reinforcing its utility in soft tissue repair (Bhati et al., 2022).[28] However, despite these promising findings, the literature presents variability in reported outcomes. Some studies have not observed significant radiographic differences in bone changes when HA was used, indicating inconsistent efficacy across different clinical scenarios (Nistor et al., 2025).[25] These discrepancies are likely due to methodological differences, including variations in HA formulations, sample sizes, treatment protocols, and outcome measures. As such, there is a clear need for more rigorous and standardized research to better define the clinical utility of HA in socket preservation and to develop consistent application protocols (Nistor et al., 2025; Karakostas et al., 2022).[25,28]

Limitations and Future Directions

While hyaluronic acid (HA) has shown considerable potential as an adjunctive material in alveolar ridge preservation (ARP), its clinical outcomes are not uniformly consistent across studies. Several investigations have reported no statistically significant differences in bone regeneration or soft tissue healing when HA is compared to standard ARP techniques. This inconsistency is partly due to variations in study design, differences in HA formulations and molecular weights, inconsistent dosages, small sample sizes, and heterogeneity in outcome measures, making it challenging to draw definitive conclusions or perform meaningful comparisons. Moreover, many existing studies suffer from moderate to high risks of bias and often have short follow-up periods, limiting the strength and reliability of the available evidence. The cost of HA products may also pose a practical limitation to their widespread adoption in routine clinical settings. Despite these challenges, HA remains an attractive option due to its biological compatibility, anti-inflammatory effects, and ease of application. Its synergistic benefits when combined with bone grafts have shown promise in enhancing bone regeneration and minimizing ridge resorption. However, current evidence does not yet justify its preferential use over more established materials. To better define HA's role in ARP, future research should focus on large-scale, well-controlled clinical trials with standardized protocols, consistent HA formulations, and long-term follow-up, which are essential to validate its efficacy and optimize its clinical application in socket preservation procedures.[29,30]

Conclusion

Hyaluronic acid offers a biologically active, minimally invasive option for enhancing socket healing and preservation. Its use as an adjunct to traditional graft materials may improve clinical outcomes in post-extraction ridge preservation. Further robust, long-term clinical trials are warranted to define its optimal application. Hyaluronic acid is a biologically active adjunct in socket preservation, capable of enhancing bone regeneration and potentially improving soft tissue healing, especially when used with grafting materials. However, due to inconsistent outcomes and methodological variability, further research is required before HA can be recommended as a standard or superior choice in alveolar ridge preservation protocols

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