Review

Enhancing Ridge Preservation - Emerging Techniques Reviewed

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Enhancing Ridge Preservation—Emerging Techniques Reviewed

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Abstract

Background: The purpose of alveolar ridge preservation (ARP) aims to minimize the physiological changes of ridge reduction occurring after dental extraction which can prevent the need for future alveolar ridge augmentation procedures. By integrating biologics into ARP biomaterials, there is a potential to enhance the regeneration of both hard and soft tissues with greater efficacy. **Aim:** This literature review aims to evaluate the clinical efficacy of the addition of biologics to currently used ARP materials. **Methods:** A search of the PubMed electronic database was conducted, and relevant articles were sifted through. Sixty-three articles met inclusion and exclusion criteria and were included in this review. **Results and Conclusions:** From this literature review, the combination of biologics with ARP materials resulted in similar dimensional changes when compared to using ARP materials alone. Nevertheless, the research has unveiled a noteworthy enhancement in bone density levels, increased wound healing capacity of soft and hard tissue, and a reduction in post-operative pain. Whilst adding biologics to ARP materials have shown an increase in bone density, its effectiveness in improving implant outcomes and reducing the need for future ridge reconstruction is uncertain. Currently, it is not possible to draw any definite inferences about the benefits of integrating biologics with ARP materials as the available studies are limited, and their findings are inconsistent due to potential bias and heterogeneity. Conducting further research is imperative as it has the potential to improve the results of ARP, thereby benefiting patient-related and implant treatment outcomes.

Keywords: alveolar ridge preservation; bone preservation; socket grafting

1. Introduction

Dental implants are gaining popularity among clinicians and patients as a method of tooth replacement. Many studies have explored the extent of prevention of bone resorption post-extraction and decreasing patient morbidity to avoid the need for future alveolar ridge augmentation. Normal physiological changes indicate that after dental extraction, the healing process involves remodelling of both hard and soft tissues[1–3]. A decrease in the alveolar ridge and narrowing of the keratinized mucosa with reduced soft tissue thickness often ensues post-extraction[1,2,4,5].

Dental clinicians must have a comprehensive understanding of the different graft materials and surgical techniques available for enhancing both hard and soft tissues, with the ultimate goal of mitigating resorption effects and facilitating healing with optimal alveolar ridges for implant placement or prosthodontic rehabilitation. This literature review evaluated the efficacy of current biomaterials employed in alveolar ridge preservation and explored the potential benefits of incorporating biologics to enhance regenerative outcomes for both hard and soft tissues.

2. Methods

A literature review was conducted using the PubMed database, which is a reputable resource for searching relevant publications. A search strategy was employed that included specific terms to

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identify appropriate studies: (tooth extraction OR teeth extraction OR extraction) AND (alveolar ridge preservation OR socket seal OR socket grafting OR bone preservation OR hard and soft tissue preservation); (alveolar ridge preservation) AND (biologics); (alveolar ridge preservation) AND (platelet-rich plasma); (alveolar ridge preservation) AND (platelet-rich fibrin); (alveolar ridge preservation) AND (recombinant human bone morphogenetic protein-2), (alveolar ridge preservation) AND (enamel matrix derivatives), and (alveolar ridge preservation) AND (Hyaluronic acid with polynucleotides);

To conduct this review, databases were searched extensively using Medical Subject Headings terms, keywords, and other relevant terms without language limitations. Boolean operators (OR, AND) were used to amalgamate the search results. The inclusion criteria were clinical trials, cohort studies, review articles, guidelines, animal research, and in vitro research. The year of publication of articles was not restricted, and databases were searched until May 2023. Additionally, manual searches of respected industry publications, *including Journal of Periodontology, Journal of Clinical Periodontology, and Periodontology 2000* were conducted. The articles were screened by a single reviewer who examined the titles and abstracts of each article.

A comprehensive search was conducted for relevant articles, including significant historical research. The reference lists of the primary articles related to this topic were thoroughly examined. Owing to significant variations in the studies, a meta-analysis was not conducted. In total, 63 articles were analyzed, including in vitro, animal, and human studies

3. Alveolar Ridge Preservation

Alveolar ridge preservation (ARP) aims to minimize ridge resorption post-extraction, preserve soft and hard tissue ridge contours, and promote the formation of new bone within the socket. Ultimately, the aim of ARP is to promote sufficient soft and hard tissue volumes to facilitate prosthetic reconstruction, permitting implant placement in a prosthetically ideal position to achieve optimal peri-implant health, function, and aesthetics without requiring further ridge augmentation[6]. While ARP attenuates post-extraction dimensional changes, there are clinical situations in which alveolar ridge augmentation (ARA) may be more suitable, especially when there is extensive alveolar bone damage. However, despite the use of ARP, implant site correction may still be required to improve implant site deficiencies in healed alveolar ridges.

Several factors should be considered when deciding whether to use ARP. First, it is important to consider the timing of implant placement and condition of the implant site. ARP may be more appropriate if the site is unsuitable for immediate type I implant placement[7,8]. Successful implant treatment outcomes require specific dimensions of both hard and soft tissues, which may not be present in cases of tissue deficiency. Second, it is necessary to determine whether optimization of soft or hard tissue or both is needed[7,9]. Other factors, such as patient age, overall health, and financial situation, should also be considered. Once these factors are considered, one or more graft materials can be selected to achieve the desired treatment outcome.

4. Factors Influencing the Outcome of ARP

When considering ARP treatment, various factors must be considered to ensure optimal outcome. The outcome of ARP is affected by the surgical techniques employed, such as flap design and suture technique, and the type of socket grafting material used, including bone fillers and collagen membranes. It is also important to consider socket seal techniques and materials such as coronally advanced flaps, soft tissue grafts, and collagen sponges. Additionally, the patient's overall systemic health, smoking habits, and history of periodontal disease should be evaluated. Finally, local site factors, including the condition and thickness of the buccal bone wall[10], missing teeth, and previous trauma, may also influence the outcome of ARP [11,12].

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5. Graft Materials

Current ARP methods employ a diverse range of materials and techniques, each tailored to enhance the properties of hard and soft tissues. Clinical trials and systematic reviews have provided a range of preclinical and clinical studies using a variety of biomaterials within the extraction socket[13–15]. As material choice is vital to ARP treatment, clinicians should consider specific treatment goals when it comes to material selection; individual materials may be utilized to specifically optimize hard tissue, soft tissue, or a combination. Additionally, patient and site factors play a role in determining the best material for an ideal outcome. A review conducted by Avila et al. revealed that a favorable approach for preserving the horizontal ridge is through the application of xenograft or allograft materials, which are subsequently secured using an absorbable collagen membrane or collagen sponge[16]. Regardless of the materials and techniques, ARP's main objective remains to promote healing of the soft and hard tissues within the extraction socket, eliminate or limit post-extraction ridge alterations, and facilitate the placement of dental implants in a prosthetically ideal position with minimal or no need for additional augmentative procedures[9].

6. Soft Tissue Graft Materials

ARP focuses on attenuating the ridge dimensions after extraction. However, a recent study showed increased interest in soft tissue regeneration and enhancement, mainly when tissue deficiency precedes and follows tooth extraction[17]. Available materials include autogenous subepithelial connective tissue grafts or free gingival grafts harvested from the palate, collagen membranes (cross-linked and non-cross-linked), and soft tissue substitutes (acellular dermal matrix and collagen matrix)[9,18,19].

A recent systematic review evaluated and compared the impact of various ARP methods and materials on soft-tissue dimensions[11]. It was proposed that grafting materials, different alveolar ridge preservation methods, and patient and local site factors may influence keratinized mucosal thickness, vertical soft tissue height and 3-dimensional contour[11].

Proper management of soft tissue is essential for maintaining keratinized mucosal tissue, which is critical for achieving optimal implant placement, facilitating easy access to oral hygiene, and ensuring excellent aesthetics[20,21]. Most ARP research has primarily focused on the changes in hard tissue dimensions following dental extraction, neglecting the impact of soft tissue healing and dimensional changes at post-extraction sites. The limited literature available focusing on soft tissue outcomes after ARP found that unassisted healing sites had increased soft tissue thickness compared to groups that received ARP treatment[17,22–24]. Chappuis et al. explained that this could be due to a compensatory effect as the soft tissue thickness increases when there is a more pronounced contraction of the bone[10].

In their systematic review, Canullo et al. found that cross-linked collagen membranes and autogenous soft tissue grafts in ARP were the most effective socket sealing materials for minimizing soft tissue contraction after tooth extraction. However, the study had limitations such as a small sample size, shorter follow-up duration, and inconsistencies in the measurement methodology. Furthermore, other factors, such as the condition of the buccal walls, type of bone fillers used, and smoking status, have impacted the outcomes[11].

7. Hard Tissue Graft Materials

Hard tissue graft materials pack the bony socket to the alveolar crest after extraction. Several systematic reviews and studies have compared the results of autografts, allografts, xenografts, alloplasts, and a combination of two or more. Despite numerous studies and reviews agreeing that no grafting material is superior to others, studies have agreed that using ARP biomaterials reduces alveolar ridge resorption and shrinkage after extraction[13,25]. For example, Canellas et al.[15] found no distinction in the formation percentage of new bone between bone substitute biomaterials (Allograft, Xenograft, and Alloplast).

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Future research conducted with a consistent approach in the methods used to evaluate ridge dimensions after ridge preservation would allow for reduced evaluation bias and easier comparison of results and materials. This inconsistency may have contributed to the inability to establish an ideal ARP grafting material for soft and hard tissue preservation or for individual tissues.

With no consensus on the ideal graft materials, clinicians performing alveolar ridge preservation should understand the biomaterials they are handling, in addition to patient and local site factors that could interact with the chosen graft materials.

8. Current Conclusion of ARP Materials

Currently, many methods and biomaterials are available for the treatment of ARP, and no individual material has been demonstrated to be superior. However, ARP has demonstrated the ability to limit ridge profile resorption in horizontal and vertical dimensions following dental extraction. Most grafting materials are effective, with only slight distinctions between them[26]. Nonetheless, additional research is required to determine whether ARP mitigates the need for further bone augmentation prior to implant placement. The current literature supports the use of ARP to preserve ridge volume and possibly simplify treatment procedures prior to ridge augmentation or implant site augmentation; however, the current literature has been unable to confirm the additional clinical benefits of implant-related outcomes[12,27–30].

9. Novel Biologics Currently Available in the Market

There has been growing interest in biologics in recent years. Biologics are a class of therapeutic agents that play crucial roles in promoting tissue regeneration by facilitating a series of cellular events in wound healing[31]. These agents exert their effects through various mechanisms such as DNA synthesis, chemotaxis, cellular differentiation, mitogenesis, and matrix biosynthesis [32]. In addition to their regenerative properties, biologics also possess anti-inflammatory and analgesic properties that can help alleviate postoperative pain and inflammation[33,34]. Furthermore, emerging literature has shown that using biologics in conjunction with ARP biomaterials can positively affect post-tooth extraction healing[31]. This may result in faster recovery times and a potential decrease in the amount of hard and soft tissue volume changes [31–34].

The biologics covered in this literature review were not exhaustive. The ones included are commonly used as monotherapy or as an enhancing agent for existing ARP graft materials. The biologics included are growth factors (platelet-rich plasma (PRP), platelet-rich fibrin (PRF), recombinant human bone morphogenetic protein-2 (rhBMP-2), enamel matrix derivatives (EMD), and hyaluronic acid with polynucleotides. Growth factors can be added to existing ARP materials to convert them from osteoconductive to osteoinductive by stimulating undifferentiated mesenchymal cells to differentiated osteoblasts, which form de novo bone [35–37].

10. Autologous Blood Product Derived Products

Platelet-rich plasma (PRP) promotes hemostasis and healing of the extraction sockets with an anti-inflammatory effect[38]. Evidence suggests that PRP may have an impact on the dimensional changes of the alveolar ridge following tooth extraction. However, inconsistent results have confirmed the effectiveness[39–41]. PRP is prepared from autologous blood, which is then activated by thrombin or collagen [35]. Activation causes platelets to release granules containing platelet-derived growth factor (PDGF), transforming growth factor-β (TGF-β1), fibrinogen, vascular endothelial growth factor, fibronectin, and von Willebrand factor, resulting in initiation of the coagulation cascade.

Platelet-rich fibrin (PRF) is a new generation of platelet concentrate for PRP and was first introduced by Choukroun et al[42]. PRF has “an autologous leukocyte-platelet-rich fibrin matrix”[43] which contains cytokines, platelets, and stem cells, acting as a biodegradable scaffold allowing for vascularization and epithelial cell migration. In addition, PRF may be a vehicle for cells involved in

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tissue regeneration, with the release of growth factors continuing for 1-4 weeks. Some of the advantages of PRF are the fibrin clot's ability to stabilize and maintain the graft, and the incorporation of a fibrin mesh network in the regeneration site enables migration of cells, allowing for angiogenesis, resulting in increased graft survival potential. Throughout the wound healing process, several platelet cytokines, including platelet-derived growth factor (PDGF), transforming growth factor-beta (TGF-β), and IGF-1, are released to promote healing. Moreover, leukocytes and cytokines present in the fibrin network serve to regulate inflammation and protect against infection during grafting procedures[42,43].

The addition of PRF has shown inconsistent results, with some studies demonstrating less bone resorption and higher bone formation, whereas others showed no differences compared to sites with unassisted healing. For instance, Castro et al. found no differences in resorption between the control and test sites, whereas Canellas et al. found lower bone resorption in the test group than in the unassisted healing group[44,45]. Similarly, PRGF also showed conflicting results, with some studies showing an increase in bone fill and mature bone, whereas others showed no enhancement in early bone deposition (Table 1 for the different studies). For example, studies completed by Anitua et al. in 1999 and subsequently in 2015 found that extraction socks treated with PRGF had more bone fill and mature bone than unassisted sites. However, a study conducted by Farina et al. found that PRGF did not enhance bone deposition.

The systematic review by Siawasch et al.[46] highlighted variability in outcomes with autologous blood products. Most of the 25 RCTs on L-PRF showed reduced alveolar bone resorption, greater socket fill, improved bone quality, faster soft tissue healing, and less postoperative pain; however, a few studies found no significant benefits.[46] PRGF results were more modest and inconsistent. Meta-analyses confirmed that L-PRF significantly reduced bone loss and improved vertical buccal height.[46] Despite these findings, heterogeneity in protocols and study quality limits firm conclusions on the efficacy of PRF and PRGF in alveolar ridge preservation.[46]

Table 1. Studies evaluating ARP and Platelet Rich Fibrin and Plasma Rich Growth Factor.

Author	Year	Groups Compared RCT Design	Healing Times (months)	Clinical/Radiographic / Histomorphometric Outcomes
Canellas et al.[45]	2020	L-PRF vs UH RCT	3	L-PRF had the higher bone formation and lower bone resorption compared to UH radiographically
Ibrahim[47]	2022	CPS vs CPS + PRF vs UH RCT	6	Increased horizontal bone dimensional changes in CPS and CPS + PRF groups.
Castro et al.[44]	2021	L-PRF vs A-PRF+ vs None Split-mouth RCT (Multiple adjacent teeth extracted) - small sample group (only 5 participants had their bone biopsied)	3	All groups did not attenuate dimensional ridge changes. Bone resorption for L-PRF and A-PRF+, and UH groups had similar bone resorption. However, both PRF matrices showed radiographically superiority for socket fills with histological analysis reporting more newly formed bone.
Wang et al.[48]	2022	L-PRF vs UH Split-mouth RCT	5	The L-PRF group had increased GF concentration than UH. However, the increased concentration did not provide clinical benefits in early wound healing or decreased bone resorption.

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Anitua[40]	1999	PRGF vs PRGF + autologous bone vs UH RCT	2	Greater buccolingual/palatal width was found in the PRGF + autologous bone group. Biopsies of defects treated with PRGF showed more mature bone and better organised trabeculae with more significant bone regeneration.
Anitua et al.[38]	2015	PRGF vs UH RCT	2.5	PRGF group had more bone filling compared to the UH group radiographically. Bone biopsy showed more new bone formation in the PRGF group. Less post-operative pain was reported in the PRGF group.
Farina et al.[49]	2013	PRGF vs UH RCT	2	PRGF did not show any enhancement in early bone deposition

A-PRF: Advanced Platelet Rich Fibrin; CPS: Calcium Phosphosilicate; FDBA: Freeze-Dried Bone Allograft; PRF: Platelet Rich Fibrin; PRGF: Plasma Rich Growth Factor; RCT: Randomised Controlled Trial; UH: Unassisted healing.

11. Enamel Matrix Derivatives (EMD)

Enamel Matrix proteins (EMD) are growth factors extracted from a piglet's tooth bud and placed into a polyglycerol gel medium. EMD comprises 95% amelogenin, with the remaining 5% being enamelin and other proteins[35]. These derivatives have been claimed to promote wound healing and bone growth in intrabony and recession defects, in addition to reduce post-operative pain[35,50].

EMD has been used to treat peri-implantitis and in periodontal regenerative procedures[51]. The mechanism and evidence supporting the use of EMD still requires further research, with limited research available detailing the effects of combining EMD and ARP grafting materials (Table 2). Research has demonstrated that socket sites treated with EMD tend to exhibit more new bone formation[34,52]. However, Alkan et al. found contradictory results with similar bone formation in both the control (Bio-oss) and test (EMD) groups[53]. It is important to note that this was a small pilot study with a moderate to high risk of bias, and neither the clinician nor examiner was blinded. The available literature fails to present improvements in the horizontal and vertical dimensions of the alveolar ridge with the use of EMD, irrespective of the presence or absence of new bone formation[34,50,54]. Nevertheless, extraction socket sites treated with EMD exhibited a shorter extent of postoperative discomfort and inflammation[52].

Table 2. Studies evaluating ARP and Enamel Matrix Derivatives.

Author	Year	Groups Compared Study Design	Healing Times (months)	Clinical/Radiographic / Histomorphometric Outcomes
Alkan, Parlar, Yildrim, & Senguven[53]	2013	Pilot study: Risk of bias: moderate-high. No blinding. RCT	3	Histomorphometric analysis: New bone formation was similar between EMD and Bio-oss Collagen sites with no significant differences between groups.
Lee, Kim, & Jeong [54]	2020	DBBM-C + EMD + non-crosslinked resorbable collagen membrane (test) vs DBBM-C + non-crosslinked resorbable collagen membrane (control)	5	There were no discernible differences in either horizontal or vertical bone dimension changes or soft tissue wound healing outcomes among the tested groups. Yet, the groups that underwent EMD treatments reported less post-operative pain and swelling.

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		RCT		
Lee & Jeong[50]	2020	DBBM-C + EMD + Non-crosslinked resorbable collagen membrane (test group 1) vs DBBM-C + Non-crosslinked resorbable collagen membrane (test group 2) Vs UH RCT	5	UH showed more significant horizontal bone width resorption compared to the test groups. No significant difference between all three groups for vertical height changes.
Mercado, Vaquette, Hamlet, Ivanovski[34]	2021	DBBM-C (control) vs DBBM-C +EMD (test) RCT	4	Both groups lost alveolar ridge width but no buccal or palatal bone height change. The addition of EMD to DBBM-C resulted in more new bone formation in the test group.
Bonta et al.[52]	2022	Alloplast (test 1) vs Alloplast + EMD (test 2) vs UH (control) RCT	6	Histomorphometric analysis revealed a significant increase in new bone tissue formation in test group 2 compared to test group 1 and UH.

DBBM-C: Deproteinized Bovine Bone Mineral with 10% collagen; EMD: Enamel Matrix Derivatives; RCT: Randomised Controlled Trial; UH: Unassisted Healing.

12. Bone Morphogenetics Proteins

Recombinant human bone morphogenetic protein-2 (rhBMP-2) is a bone morphogenetic protein. Through the migration and proliferation of stem cells, rhBMP-2 may induce angiogenesis and osteoblastic differentiation. There have been reports of successful bone formation and implant placement using rhBMP-2 and collagen sponge[55]. The carriers available for rhBMP-2 are collagen sponge, synthetic polymer, β-tricalcium phosphate (β-TCP), and hydroxyapatite. Collagen sponges lack strength and have a rapid resorption time of 2 weeks. Therefore, hydroxyapatite may be a better carrier for rhBMP-2, as it is more resistant to mechanical forces and has a high affinity for rhBMP-2[56].

Table 3 presents the literature that used a collagen sponge as a carrier for rhBMP-2 and yielded promising outcomes. Although most studies have demonstrated that rhBMP-2 promotes the growth of new bone, there are variations among them, rendering it challenging to reach a conclusive evaluation regarding the effectiveness of rhBMP-2 in preserving the alveolar ridge.

Table 3. Studies evaluating ARP and Recombinant Human Bone Morphoprotein-2.

Author	Year	Groups Compared Study Design	Healing Times (months)	Clinical/Radiographic/ Histomorphometric Outcomes
Shim et al.	**2018**	rhBMP-2+HAX synthetic bone (test) vs DBBM (control) RCT- Parallel	3	The alveolar ridge was clinically and histologically preserved in both groups, but the test group had increased new bone formation than the control group.
Jo et al.	**2019**	rhBMP-2-soaked absorbable collagen	3	Both delivery methods of rhBMP were equally effective in

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		sponge + collagen membrane (test) vs β-tricalcium phosphate and hydroxyapatite particles immersed in rhBMP-2 and collagen membrane (control group) RCT- Parallel		preserving the Alveolar Ridge, and there were no negative effects observed
Fiorellini et al.	**2005**	rhBMP-2 (0.75mg/ml) + bioabsorbable collagen sponge (test 1) vs rhBMP-2 (1.50mg/ml) + bioabsorbable collagen sponge (test 2) vs Bioabsorbable sponge (test 3) Vs No Treatment RCT	4	Test group 2 performed the best bone augmentation compared to other groups. Additionally, this group had fewer patients requiring secondary augmentation before implant placement.

DBBM: Deproteinized Bovine Bone Mineral; HAX: Hydroxyapatite; RCT: Randomised Controlled Trial; rhBMP-2: Recombinant Human Bone Morphogenetic Protein-2.

13. Hyaluronic Acid and Polynucleotides

Hyaluronic acid (HA) is a "naturally occurring non-sulphated glycosaminoglycan[57]", that plays an essential role in the extracellular matrix of periodontal tissues[58]. HA has been found to enhance bone formation by stimulating osteocalcin[59,60]. This, in turn, affects the mineralization process of the bone matrix[57,58]. The desirable properties of HA include bacteriostatic and anti-inflammatory effects, which make it useful for treating infected sockets[59]. The studies listed in Table 4 show that the addition of hyaluronic acid during the extraction socket process results in notable improvements in bone mineralization and density[56,57,59]. However, no significant differences were observed in ridge measurements between the groups that received HA treatment with hyaluronic acid and those that did not. Additional research is required to confirm the effectiveness of HA in enhancing ARP materials.

Polynucleotides are natural in origin and are "highly purified DNA polymers derived from trout gonads"[61]. Due to their hydrophilic properties, they can bind molecules, have viscoelastic properties, and form a 3-D viscoelastic gel[62]. Recently, PN was co-formulated with HA in an in vitro study that investigated the effectiveness of PN with and without HA in a gingival fibroblast model[63]. It has been demonstrated that while PN alone can stimulate the growth of gingival fibroblasts, the addition of HA was more effective in encouraging wound healing by synergistically stimulating cell growth and migration with the synthesis of the collagen's extracellular matrix[63]. Additionally, integrating HA and PN within a viscoelastic gel has proven to be a valuable adjunctive therapy in periodontal regeneration treatment for addressing periodontitis. Studies have shown a reduction in inflammation and an increased wound healing capacity[61,64,65]. Currently, there is limited research investigating the effectiveness of viscoelastic gels containing HA and PN in extraction sockets. Further exploration of this combination would provide valuable insights for enhancing current ARP biomaterials.

Table 4. Studies evaluating ARP and Hyaluronic Acid.

Author	Year	Groups Compared Study Design	Healing Times (months)	Clinical/Radiographic/ Histomorphometric Outcomes

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Lee et al.	**2021**	ACS (group 1) Vs ACS + 1% HA gel (group 2) Vs DBBM-C + Collagen membrane (group 3) Vs DBBM-C + Collagen membrane + 1% HA gel (group 4) Animal study	3	Ridge width remained higher in groups 3 and 4. Groups 2 and 4 had the highest proportion of mineralised bone and bone volume density compared with other groups.
Shim et al.	**2018**	rhBMP-2+HA synthetic bone (test) vs Deproteinised Bovine Bone Mineral (control) RCT- Parallel	3	In both groups, the clinical and histological preservation of the alveolar ridge was observed. However, the test group demonstrated a higher level of new bone formation compared to the control group.
Kim et al.	**2016**	1% HA gel Vs UH RCT	3	The sockets of the test group had denser mineralised bone compared to the control group. Clinical measurements of dimensional changes were not provided in this study.

ACS: Absorbable Collagen Sponge; DBBM-C: Deproteinized Bovine Bone Mineral with 10% collagen; HA: Hyaluronic Acid; rhBMP-2: Recombinant Human Bone Morphogenetic Protein-2; UH: Unassisted Healing; RCT: Randomised Controlled Trial.

14. Conclusions

In conclusion, ARP has been shown to be impactful in attenuating ridge resorption. However, studies and systematic reviews have not conclusively provided sufficient evidence that ARP improves implant outcomes and reduces the likelihood of requiring future ridge augmentation or reconstruction before implant placement[13]. Additional research and clinical trials are still required to demonstrate the effectiveness of biologics and whether they enhance current ARP materials used[31]. While ARP still requires more research, biologics that enhance ARP materials show potential and could provide ARP with improved treatment outcomes. Most studies investigated by systematic reviews have shown heterogeneity between them. In addition, research often investigates novel techniques; thus, few studies have repeatedly employed similar techniques or materials, making it difficult for systematic reviews to compare methods and materials directly. Current research has demonstrated that the incorporation of biologics into bone graft materials leads to better histomorphometric results and accelerates wound healing compared to the control groups. Therefore, for future research, conducting additional studies on various biologics would be valuable for improving the current ARP materials and maximizing their benefits.

Conflicts of Interest: None.

Funding: Self.

Appendix

Table 5. PICO - Inclusion and Exclusion Criteria.

Criterion	Inclusion/Exclusion Criteria
Study and Information types	Inclusion • Peer-reviewed literature • Historic papers until May 2023 • Study types include systematic and literature reviews, meta-analyses, randomised controlled trials, clinical trials, and case reports/series.

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	Exclusion • Non-peer reviewed publications • Publications not in the English language • Commentaries and editorials
Population	Inclusion: • Healthy individuals with no age limit undergoing ARP following permanent tooth extraction. Studies including smokers and history of periodontal disease.
Intervention	Inclusion: • Graft and socket seal materials are used in extraction sockets post-extraction. • Biologics: platelet-rich plasma (PRP), platelet-rich fibrin (PRF), recombinant human bone morphogenetic protein-2 (rhBMP-2), enamel matrix derivatives (EMD), and hyaluronic acid with polynucleotides Exclusion • Literature that does not include a graft material
Comparison	Inclusion: • Literature that compares grafting and socket materials with unassisted socket healing • Literature that compares grafting materials with the addition of biologics that could enhance the socket graft and seal material
Outcome	Inclusion: • Reporting clinical and radiographic measurements for soft and hard tissue • Reporting of soft tissue characteristics, including increased or decreased healing rate, the risk for infection

Table 6. Summary of Literature Analysed.

Area of Interest of included articles	Alveolar Ridge Preservation Materials	Number of articles
Alveolar Ridge Preservation	Hard Tissue Grafts (Autograft, allograft, xenograft) Soft Tissue Grafts (Autograft, Xenograft, Collagen membrane, Collagen plug))	29
Biologics	rhBMP-2, PRGF, PRF, EMD, Hyaluronic Acid and Polynucleotides	30
Study Design	**Number of Articles**	
Systematic Review / Meta-analysis	12	
Randomised Controlled Trials	29	
Pilot Study	1	
Case Report	1	
Animal research study	1	
In-vitro laboratory study	1	
Literature review	11	
Expert Opinions and Consensus statement	3	

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