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ALVEOLAR RIDGE AUGMENTATION

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Abstract: Alveolar ridge augmentation is a central reconstructive procedure in contemporary implant dentistry because loss of teeth, periodontal disease, trauma, infection, and prolonged edentulism may produce horizontal or vertical bone deficiency that prevents prosthetically driven implant placement. The purpose of this review was to summarize current principles of ridge augmentation, compare commonly used surgical techniques and biomaterials, and identify factors associated with predictable regeneration and complications. A structured literature review was performed using PubMed/MEDLINE and accessible regional scholarly repositories, with priority given to systematic reviews, consensus statements, comparative clinical studies, and publications from Uzbekistan. Evidence indicates that guided bone regeneration, ridge-split procedures, autogenous block grafting, and selected staged reconstructive approaches can provide clinically useful bone gain when case selection, vascularity, space maintenance, wound stability, and tension-free closure are respected. Autogenous bone remains biologically valuable because of its osteogenic and osteoinductive potential, whereas xenografts and allografts are frequently used to reduce donor-site morbidity and maintain volume. Horizontal defects are generally more predictable than major vertical defects. Vertical augmentation can achieve substantial bone gain, but complication rates increase with surgical complexity. Recent evidence also supports careful use of platelet-rich fibrin and composite grafting, although these adjuncts should not replace sound surgical principles. Uzbek clinical research has similarly emphasized individualized defect assessment, soft-tissue management, and combined grafting strategies. Alveolar ridge augmentation should therefore be planned as part of a prosthetically oriented, biologically controlled treatment sequence rather than as an isolated bone-grafting procedure.

Keywords: alveolar ridge augmentation, bone grafting, guided bone regeneration, dental implants, autogenous bone, biomaterials, ridge split, vertical augmentation

Introduction

The alveolar process is a tooth-dependent anatomical structure. After extraction, the socket undergoes a physiologic remodeling process characterized by bundle-bone resorption, reduction of ridge width, and variable loss of height. The most pronounced dimensional change generally occurs during the early healing period, although remodeling continues thereafter. These alterations may compromise the future implant site by moving the residual ridge away from the ideal prosthetic envelope and by reducing the volume of mineralized tissue available for stable implant placement. The clinical problem becomes more complex when tooth loss is accompanied by advanced periodontitis, endodontic infection, traumatic extraction, congenital deficiency, long-standing edentulism, or previous surgical procedures (Tan et al., 2012; Jepsen et al., 2019).

Alveolar ridge augmentation encompasses surgical procedures intended to increase the quantity and configuration of alveolar bone before or during implant placement. The objective is not simply to create more radiographic bone. Successful augmentation must generate a three-dimensional ridge that supports an implant in a prosthetically correct position, provides adequate

facial and lingual bone thickness, allows stable peri-implant soft tissues, and can be maintained under functional loading. Accordingly, treatment planning requires integration of restorative objectives, defect morphology, soft-tissue quality, systemic and local risk factors, and the regenerative potential of the site.

A broad range of techniques has been proposed. Guided bone regeneration (GBR) uses a barrier membrane to exclude rapidly proliferating soft-tissue cells and maintain a secluded space for bone formation. Autogenous block grafting transfers cortical or corticocancellous bone from an intraoral or extraoral donor site. Ridge splitting and expansion mobilize the cortical plates to create additional width in selected narrow ridges. Vertical reconstruction may employ non-resorbable membranes, titanium-reinforced barriers, titanium mesh, block grafts, or distraction osteogenesis. Sinus floor elevation addresses posterior maxillary height deficiency, while ridge preservation aims to limit post-extraction collapse before a major defect develops. These methods share common biological requirements but differ in technical sensitivity, morbidity, healing time, and complication profile (Jepsen et al., 2019; Urban et al., 2019).

Biomaterial selection is equally important. Autogenous bone has traditionally been considered the reference graft because it provides living cells, growth factors, and a mineralized scaffold. However, its quantity is limited and donor-site morbidity is unavoidable. Allografts, xenografts, and alloplastic materials are therefore used alone or in combination with autogenous chips to extend graft volume and improve dimensional stability. Contemporary practice increasingly favors composite strategies in which rapidly remodeling autogenous bone is combined with a slower-resorbing scaffold and protected by a stable membrane. Adjuncts such as platelet-rich fibrin (PRF) have also been investigated for their potential influence on wound healing and graft maturation (Sanz-Sánchez et al., 2019; Nulty et al., 2024).

The aim of this article was to review the biological basis, indications, principal techniques, graft materials, clinical outcomes, and complications of alveolar ridge augmentation, with attention to evidence relevant to implant rehabilitation and to publications from Uzbekistan.

Materials and Methods

A structured narrative review was performed to synthesize clinically relevant evidence on alveolar ridge augmentation. Literature was identified through PubMed/MEDLINE and accessible regional scholarly repositories, including Uzbek medical journal platforms and inlibrary.uz. The search was completed in August 2026. Search terms included combinations of “alveolar ridge augmentation,” “guided bone regeneration,” “horizontal ridge augmentation,” “vertical ridge augmentation,” “bone graft,” “ridge split,” “dental implant,” “atrophic alveolar ridge,” and corresponding Russian or Uzbek terminology. Priority was given to systematic reviews, meta-analyses, consensus reports, randomized or comparative clinical studies, and regional publications that described surgical management of alveolar bone deficiency.

Studies were considered relevant when they addressed augmentation of deficient alveolar ridges for implant-supported rehabilitation, evaluated clinical or radiographic bone gain, implant feasibility or survival, graft behavior, soft-tissue management, or postoperative complications. Reports focused exclusively on oncologic reconstruction or major craniofacial defects were not emphasized because their biological and reconstructive requirements differ from routine

dentoalveolar implant therapy. Findings were organized into four domains: defect assessment and indications, surgical techniques, graft materials and biologic adjuncts, and clinical outcomes including complications. Because the included literature was heterogeneous in defect classification, measurement methods, and follow-up, the present article uses qualitative synthesis rather than pooled statistical analysis.

Results

The reviewed evidence confirms that alveolar ridge augmentation is effective when the regenerative strategy is matched to defect morphology. Horizontal deficiencies are generally more predictable than extensive vertical deficiencies because the recipient bed offers a broader vascular interface and because space maintenance is easier to achieve. Consensus evidence supports staged lateral augmentation before implant placement as a reliable method for increasing ridge width, while vertical augmentation is also effective but associated with a higher frequency of wound dehiscence, membrane exposure, graft infection, and partial graft loss (Jepsen et al., 2019).

Guided bone regeneration is one of the most widely used techniques. Its success depends on exclusion of non-osteogenic tissues, maintenance of a stable regenerative compartment, vascular access from the recipient bed, immobilization of the graft, and primary wound closure. Resorbable collagen membranes simplify treatment by avoiding a second operation for membrane removal and are commonly used for small and moderate horizontal defects. In larger three-dimensional or vertical defects, stronger space-maintaining devices such as titanium-reinforced membranes or titanium mesh may be required. A consensus report on GBR emphasized patient selection, defect analysis, flap passivation, membrane fixation, delayed implant placement in demanding defects, and meticulous soft-tissue management as decisive elements of predictable treatment (Urban et al., 2019).

Autogenous block grafting remains useful when the ridge is severely deficient or when rigid structural support is required. Intraoral donor sites include the mandibular ramus and symphysis. Cortical blocks are adapted and rigidly fixed to the recipient ridge, while particulate graft can fill peripheral gaps. The advantages are biological activity and structural stability, but resorption, neurosensory disturbance, donor-site pain, limited graft volume, and an additional surgical field must be considered. In many cases, particulate autogenous bone combined with a xenograft and protected by a membrane provides a compromise between biologic activity and long-term volume maintenance.

Ridge splitting is primarily indicated for narrow ridges that retain sufficient vertical height and a cancellous component between buccal and lingual plates. By creating and progressively expanding a crestal osteotomy, the clinician can increase ridge width and sometimes place implants simultaneously. A 2023 systematic review and meta-analysis concluded that alveolar ridge split procedures can produce clinically useful horizontal expansion with favorable implant survival, but case selection and control of buccal plate fracture are important (Al Haydar et al., 2023). A later meta-analysis comparing ridge expansion, GBR, and ridge-split approaches also found that all three methods can increase horizontal width, supporting selection according to initial ridge anatomy and the amount of expansion required (Vorovenci et al., 2024).

Vertical ridge augmentation is more technically demanding. A systematic review and meta-analysis reported mean vertical gains of approximately 4.18 mm for GBR, 3.46 mm for block grafting, and 8.04 mm for distraction osteogenesis, while complication rates varied substantially and were highest with distraction osteogenesis in the included evidence (Urban et al., 2019a). More recent network meta-analysis indicates that techniques capable of greater vertical bone gain may also carry greater healing risk, while non-resorbable membrane-based GBR can provide a favorable balance between efficacy and complications in appropriately selected cases (Tavelli et al., 2023). These findings reinforce the principle that the largest possible bone gain is not necessarily the best clinical endpoint; predictable prosthetic rehabilitation with acceptable morbidity is the more relevant objective.

The principal graft materials can be classified as autografts, allografts, xenografts, and alloplasts. Autogenous bone provides osteogenic cells and osteoinductive proteins, but tends to remodel relatively quickly. Xenografts, particularly bovine-derived mineral matrices, are highly osteoconductive and may maintain space for long periods. Allografts provide a human-derived mineral or demineralized scaffold without a second surgical site, although processing influences biologic properties. Alloplastic substitutes include calcium phosphates, bioactive ceramics, and other synthetic matrices. Current reviews suggest that no single material is universally superior; outcomes depend strongly on defect morphology, graft stability, barrier function, vascularity, and surgical execution (Al-Maawi et al., 2025).

Regional evidence from Uzbekistan is consistent with these principles. Shomurodov and Mirkhusanova (2023) evaluated soft-tissue expansion before GBR in 76 patients with alveolar bone atrophy and examined different graft combinations, highlighting the importance of soft-tissue volume and closure in atrophic ridges. Isayev (2024) reviewed post-extraction preservation of alveolar bone and emphasized that early management of extraction sockets can reduce later reconstructive demand. Uzbek research summarized by the national attestation system has also described individualized algorithms for augmentation of atrophic alveolar processes and combined grafting approaches before implant placement. Collectively, these publications demonstrate increasing regional attention to biologically based augmentation and pre-implant reconstructive planning.

Table 1. Clinical comparison of principal alveolar ridge augmentation techniques

Technique	Typical indication	Main advantage	Main limitation	Implant timing
GBR	Horizontal and selected vertical defects	Flexible; avoids block harvest; strong evidence base	Membrane exposure and loss of space if fixation is inadequate	Simultaneous in moderate defects; staged in major defects
Autogenous block graft	Non-contained horizontal or combined defects	Structural support and high biologic activity	Donor-site morbidity and graft resorption	Usually staged
Ridge split/expansion	Narrow ridge with adequate height	Horizontal gain with limited graft	Risk of cortical fracture; anatomy	Often simultaneous

		volume; possible simultaneous implant	dependent	
Vertical GBR / titanium mesh	Severe vertical deficiency	Can create clinically meaningful vertical height	Technique sensitive; higher wound complication risk	Usually staged
Composite particulate graft	Moderate defects requiring volume maintenance	Balances autogenous biology with scaffold stability	Requires reliable containment and vascularization	Simultaneous or staged

Source: synthesized from Jepsen et al. (2019), Urban et al. (2019), Al Haydar et al. (2023), Tavelli et al. (2023), and Vorovenci et al. (2024).

Discussion

The central finding of the reviewed literature is that successful ridge augmentation depends less on a single "best" graft material than on the interaction among defect anatomy, biological environment, mechanical stability, and soft-tissue management. The PASS principles often applied to regenerative surgery—primary closure, angiogenesis, space maintenance, and stability—remain clinically relevant. A technically sophisticated graft can fail if the flap closes under tension or if micromotion disrupts revascularization. Conversely, modest biomaterials can perform well when the defect is favorable and the regenerative compartment is stable.

Defect morphology should therefore guide technique selection. A contained horizontal defect may respond predictably to particulate grafting under a collagen membrane. A non-contained horizontal defect often needs additional fixation, tenting screws, a more stable membrane, or a rigid block. A narrow but tall ridge with elastic cortical plates may be suitable for ridge splitting. Extensive vertical deficiency generally requires staged reconstruction with rigid space maintenance. Cone-beam computed tomography is essential for evaluating residual width and height, cortical configuration, proximity to the mandibular canal or maxillary sinus, and available donor anatomy. However, CBCT findings must be integrated with clinical examination of keratinized mucosa, scar tissue, vestibular depth, and flap mobility.

The timing of implant placement is another major decision. Simultaneous implantation reduces treatment time and may help stabilize certain horizontal grafts when primary implant stability can be obtained in native bone. Nevertheless, staged implantation is preferable when the residual ridge cannot provide stable three-dimensional implant positioning or when extensive augmentation is required. Attempting simultaneous placement in a severely deficient ridge may force the implant into a prosthetically unfavorable position. Staging allows the surgeon to optimize bone volume first, then place the implant according to restorative needs after graft consolidation.

Autogenous bone remains biologically attractive, yet its limitations explain the widespread use of mixed grafts. Combining autogenous chips with a slowly resorbing xenograft can provide early biologic activity while preserving contour during remodeling. The ratio of components should not be treated as a rigid formula; it should reflect defect size, recipient vascularity, need for long-term

space maintenance, and available donor bone. In vertical or non-contained defects, mechanical containment becomes particularly important. Titanium mesh or reinforced membranes may preserve the intended volume, but exposure remains a clinically significant risk. The literature consistently links wound stability and soft-tissue management with treatment success.

The role of biologic adjuncts is promising but should be interpreted cautiously. PRF provides a fibrin matrix rich in platelets and growth factors and may improve handling, early healing, and patient comfort. A 2024 systematic review and meta-analysis found that PRF used with ridge reconstruction or GBR was associated with increased horizontal ridge width and reduced graft resorption, but the evidence base was limited and the risk of bias was not uniformly low (Nulty et al., 2024). Therefore, PRF should be considered an adjunct to, rather than a substitute for, stable graft fixation, adequate vascularity, and tension-free closure.

Complications should be discussed with patients before surgery. Membrane exposure, wound dehiscence, infection, graft resorption, sensory disturbance at donor sites, sinus complications, and need for re-augmentation can prolong treatment. Smoking, uncontrolled periodontal disease, poor oral hygiene, uncontrolled diabetes, parafunction, thin soft tissues, and previous scarring can increase risk. The clinician should eliminate active infection, establish plaque control, and optimize systemic conditions before grafting. Antibiotic protocols vary and should follow local antimicrobial stewardship principles rather than being viewed as a substitute for aseptic surgery and wound control.

The outcome measures used in augmentation studies also deserve attention. Traditional reports emphasize linear bone gain and implant survival, but these variables do not fully capture treatment quality. Recent systematic work has highlighted inconsistent reporting of patient-reported outcomes, esthetic outcomes, complications, and long-term volumetric stability (Saleh et al., 2026). Future studies should therefore combine three-dimensional imaging, implant-centered bone thickness, need for additional grafting, patient morbidity, soft-tissue stability, and long-term prosthetic success. Standardized outcome reporting would also make comparison among techniques more clinically meaningful.

Evidence from Uzbekistan adds practical relevance for regional clinical settings. The study by Shomurodov and Mirkhusanova (2023) is particularly notable because it addressed soft-tissue expansion before GBR rather than focusing only on the graft itself. This approach reflects a broader contemporary understanding: the soft-tissue envelope can determine whether a large augmentation is feasible and whether primary closure can be achieved without excessive tension. Similarly, Isayev (2024) emphasized ridge preservation after extraction, which is important because prevention of severe resorption can reduce the need for later complex augmentation. These concepts can be integrated into staged care pathways in local implant practice.

Several limitations apply to the present review. The literature is heterogeneous regarding defect definitions, membrane types, graft combinations, implant timing, radiographic measurements, and follow-up periods. Direct comparison among techniques is therefore difficult. In addition, some regional publications are not indexed in major international databases, which limits visibility and standardized appraisal. Nevertheless, convergence among consensus statements, systematic reviews, recent meta-analyses, and regional studies supports a consistent clinical message: augmentation should be defect-specific, prosthetically driven, and biologically disciplined.

Conclusion

Alveolar ridge augmentation is an effective component of implant rehabilitation when residual bone volume is insufficient for prosthetically correct implant placement. Guided bone regeneration, autogenous block grafting, ridge splitting, and vertical reconstructive procedures each have valid indications, but they differ in predictability, morbidity, technical sensitivity, and complication risk. Horizontal reconstruction is generally more predictable, whereas major vertical augmentation requires stronger space maintenance and more demanding soft-tissue control. Autogenous bone remains biologically valuable, while xenografts, allografts, and alloplastic materials can reduce donor morbidity and improve volume stability when used appropriately. PRF and other biologic adjuncts may enhance selected outcomes but do not replace core regenerative principles. Careful defect assessment, tension-free closure, graft stability, vascular access, staged implant placement when necessary, and maintenance of periodontal health are decisive for long-term success. Regional evidence from Uzbekistan supports the same individualized and biologically based approach.

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