Rebuilding the Ridge: The Role of Block Bone Grafts in Implant Site Development

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Abstract: ***Adequate alveolar bone volume is essential for successful implant therapy, ensuring optimal implant placement, primary stability, and long-term functional and esthetic outcomes. However, significant horizontal and vertical ridge resorption commonly occurs following tooth extraction, often compromising implant placement. In cases of severe ridge deficiencies, block bone grafting has emerged as a predictable technique for three-dimensional alveolar ridge reconstruction. This review summarizes the biological principles, surgical protocols, graft materials, and clinical outcomes associated with block bone grafting. Autogenous block grafts remain the gold standard due to their osteogenic, osteoinductive, and osteoconductive properties, although donor-site morbidity has led to the development of alternatives such as allogenic, xenogenic, and synthetic grafts. Recent advancements including CAD/CAM-customized grafts, biologic adjuncts such as platelet-rich fibrin and bone morphogenetic proteins, and minimally invasive surgical techniques have further improved treatment outcomes. These developments highlight the evolving role of block bone grafting as a reliable approach for managing complex alveolar ridge defects and facilitating predictable implant rehabilitation.***

Keywords: Block bone grafting, Ridge augmentation, Guided bone regeneration, Implants

1. Introduction

Successful implant therapy is fundamentally dependent on the availability of adequate alveolar bone volume to ensure optimal implant positioning, primary stability, and long-term functional and esthetic outcomes. [1] However, following tooth extraction, the alveolar ridge undergoes significant dimensional alterations characterized by rapid horizontal and vertical resorption, particularly within the first year. [2],[3] Clinical and radiographic studies have demonstrated that up to 50% of ridge width reduction may occur during the initial healing phase, often resulting in compromised implant placement and prosthetic limitations. [2], [4]

When ridge deficiencies are mild to moderate, guided bone regeneration (GBR) using particulate grafts and barrier membranes has shown predictable outcomes. [5], [6]

However, in cases of severe horizontal or vertical bone loss, particulate grafting alone may lack adequate structural rigidity and space-maintaining capacity, especially in vertical augmentation procedures. [7] In such situations, block bone grafting has emerged as a predictable surgical modality for three-dimensional ridge reconstruction. [8]

Block bone grafting involves the transplantation of a cortical or corticocancellous bone segment to the deficient ridge, typically stabilized with rigid fixation to minimize micromotion and facilitate revascularization through creeping substitution.[9] Autogenous block grafts, harvested from intraoral sites such as the mandibular symphysis and ramus or extraoral sites such as the iliac crest, are traditionally regarded as the gold standard due to their osteogenic, osteoinductive, and osteoconductive properties.[10], [11] Nevertheless, donor-site morbidity, limited graft availability, and increased surgical complexity have prompted exploration of alternative materials, including allogenic and xenogenic block substitutes. [12], [13]

Clinical studies report high implant survival rates in sites augmented with autogenous block grafts, frequently exceeding 90% over long-term follow-up. [14],[15] However, graft resorption, wound dehiscence, and donor-site complications remain concerns, particularly in vertical augmentation procedures.[7],[16] Recent advancements-including CAD/CAM-customized allogenic blocks, piezosurgical harvesting techniques, and adjunctive biologics such as platelet-rich fibrin and bone morphogenetic proteins-have further expanded therapeutic possibilities while aiming to reduce morbidity and improve volumetric stability. [13], [17]

Given the continued clinical relevance of ridge augmentation and the evolving spectrum of biomaterials and surgical approaches, a comprehensive evaluation of block bone grafting is warranted. This article aims to review the biological principles, surgical protocols, clinical outcomes, and contemporary advancements associated with block bone grafts for alveolar ridge reconstruction.

Biological Principles of Block Bone Grafting

Block bone grafting for alveolar ridge reconstruction is based on fundamental biological mechanisms that govern bone regeneration and remodeling. Successful graft incorporation depends on three essential processes: osteogenesis, osteoinduction, and osteoconduction. Osteogenesis refers to the formation of new bone by viable osteogenic cells present within the graft, a property primarily associated with autogenous bone blocks.[10] Osteoinduction involves the recruitment and differentiation of host mesenchymal stem cells into osteoblasts under the influence of growth factors such as bone morphogenetic proteins.[17] Osteoconduction denotes the function of the graft as a three-dimensional

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scaffold that allows vascular and cellular ingrowth from the recipient site. [10, 17]

Following placement, block grafts undergo a dynamic remodeling process termed creeping substitution, in which host blood vessels invade the graft, leading to gradual resorption of necrotic bone and replacement with newly formed vital bone.[9] Adequate revascularization is critical for graft survival and volumetric stability. Therefore, intimate adaptation of the graft to a well-prepared recipient bed and rigid fixation using titanium screws are essential to prevent micromotion, which may otherwise result in fibrous encapsulation rather than osseous integration.[8]

The structural characteristics of the graft influence its biological behavior. Cortical bone blocks provide superior mechanical strength and space maintenance, particularly advantageous in vertical augmentation, but demonstrate slower revascularization due to their dense architecture.[11] In contrast, corticocancellous grafts allow enhanced cellular infiltration and faster integration owing to their porous structure.[11]

Despite successful integration, graft resorption remains an inherent aspect of remodeling. Clinical studies evaluating autogenous block grafts report resorption rates ranging from 10–25% for horizontal augmentation, while vertical augmentation procedures may demonstrate volumetric reductions of up to 30–40% during early healing, depending on graft origin and recipient site vascularity. [7],[8] Intraoral membranous bone grafts have been shown to exhibit less resorption compared to extraoral endochondral grafts, contributing to improved long-term volumetric stability. [8] Collectively, these biological principles emphasize the importance of vascular access, mechanical stability, and controlled remodeling in achieving predictable outcomes with block bone grafts for ridge augmentation.

Surgical Protocol and Available Block Graft Options

Successful block bone grafting requires meticulous surgical planning and execution, as graft incorporation and volumetric stability are highly technique-sensitive.[7],[8] Preoperative assessment using cone-beam computed tomography (CBCT) and prosthetically driven implant planning are essential to determine defect morphology and the need for horizontal and/or vertical augmentation.[3]

Autogenous block grafts are considered the gold standard due to their osteogenic, osteoinductive, and osteoconductive properties.[8] Intraoral donor sites include the mandibular ramus and symphysis. Ramus grafts provide dense cortical bone with relatively low morbidity, whereas symphyseal grafts offer corticocancellous composition but may carry a higher risk of neurosensory disturbances.[7] Extraoral donor sites such as the iliac crest and calvarium are indicated for extensive defects requiring larger graft volumes, although they are associated with increased morbidity, including postoperative pain, hospitalization, and potential complications at the donor site.[8]

Allogenic block grafts, derived from human donor bone and processed as freeze-dried bone allografts (FDBA) or demineralized freeze-dried bone allografts (DFDBA), eliminate donor-site morbidity and reduce surgical time while providing an osteoconductive scaffold for bone regeneration.[18] Clinical and histomorphometric studies have demonstrated favorable implant survival rates in sites augmented with allogenic block grafts, although slightly higher resorption rates compared with autogenous grafts have been reported.[19]

Xenogenic block grafts, commonly bovine-derived, function primarily as osteoconductive matrices and exhibit slow resorption characteristics, which may contribute to improved contour stability and volume maintenance over time.[20]

Alloplastic or synthetic block grafts, including hydroxyapatite and β-tricalcium phosphate, offer advantages such as unlimited availability, absence of donor-site morbidity, and no risk of disease transmission; however, they lack intrinsic osteogenic and osteoinductive properties.[21] Recent advancements include CAD/CAM-customized allogenic block grafts, which enhance graft adaptation, improve stability, and reduce intraoperative manipulation and surgical time.[22] Additionally, the adjunctive use of biologic agents such as platelet-rich fibrin (PRF) and bone morphogenetic proteins (BMPs) has shown promising results in enhancing angiogenesis, accelerating healing, and improving graft integration.[23] Overall, graft selection should be individualized based on defect size, systemic and local patient factors, esthetic requirements, and clinician expertise to achieve predictable and stable ridge augmentation outcomes.

Recent advancement and future scope

Contemporary developments in block bone grafting are directed toward improving volumetric stability, minimizing donor-site morbidity, enhancing biologic integration, and increasing surgical precision. Advances in digital technology, biomaterial science, biologic modulation, and regenerative medicine have collectively expanded the therapeutic landscape of alveolar ridge reconstruction.

Digital Workflow and Customized Block Grafts

The integration of cone-beam computed tomography (CBCT), computer-aided design (CAD), and computer-aided manufacturing (CAM) has enabled the fabrication of patient-specific allogenic and xenogenic block grafts. These customized grafts are designed to precisely match defect morphology, thereby improving adaptation at the graft–recipient interface, reducing intraoperative manipulation, and shortening surgical time.[22],[24] Improved congruency enhances mechanical stability and may reduce early resorption associated with micro-movements or inadequate fixation.

Biologic Modulation and Growth Factors

Adjunctive biologic agents have been increasingly incorporated to enhance osteogenesis and angiogenesis. Autologous platelet concentrates, including platelet-rich fibrin (PRF) and platelet-rich plasma (PRP), provide a reservoir of growth factors such as PDGF, TGF-β, and VEGF, promoting early vascularization and soft-tissue healing.[25] Recombinant human bone morphogenetic proteins (rhBMP-2 and rhBMP-7) demonstrate potent osteoinductive properties and have shown favorable outcomes in complex ridge defects, although considerations related to cost, dosage control, and regulatory approval remain limiting factors.[26],[27]

Minimally Invasive Harvesting Techniques
Piezosurgical devices have improved the safety profile of intraoral block harvesting by enabling micrometric, selective cutting of mineralized tissue while preserving adjacent soft tissues and neurovascular structures. This technology reduces intraoperative trauma, enhances graft precision, and decreases donor-site complications compared to conventional rotary instrumentation. [28]

Biomimetic and Composite Block Substitutes
Material innovations have led to the development of composite block grafts combining hydroxyapatite (HA), β-tricalcium phosphate (β-TCP), and bioactive glass. These scaffolds aim to replicate the hierarchical architecture of native bone while allowing controlled resorption and replacement by host tissue.[29] Such biomimetic constructs seek to balance structural rigidity with favorable biologic remodeling, particularly in vertical augmentation procedures where mechanical stability is critical.

Stem Cell–Based and Tissue Engineering Approaches
Regenerative strategies incorporating mesenchymal stem cells (MSCs) seeded onto three-dimensional scaffolds represent a promising frontier. Early clinical reports have demonstrated the feasibility of engineering vascularized bone constructs for large craniofacial defects.[30],[31] These approaches aim to create biologically active grafts capable of accelerated integration and enhanced regenerative potential.

Three-Dimensional Bioprinting and Smart Scaffolds
Emerging 3D bioprinting technologies allow spatial control over scaffold architecture and bioactive molecule distribution. Smart scaffolds capable of delivering growth factors in a controlled temporal manner may optimize bone regeneration while reducing adverse effects associated with supraphysiologic dosing.[32]

2. Future Scope

Future directions in block bone grafting will likely focus on:

- Long-term comparative studies evaluating volumetric stability of customized versus autogenous blocks.
- Integration of artificial intelligence in surgical planning and graft design.
- Development of bioactive, resorption-controlled synthetic blocks that eliminate donor-site morbidity.
- Standardization of stem cell–based regenerative protocols.
- Cost-effectiveness analyses to facilitate broader clinical adoption.

As digital planning, biologic enhancement, and tissue engineering converge, block bone grafting is evolving from a predominantly surgical reconstructive technique toward a biologically driven, patient-specific regenerative therapy. Continued high-quality randomized clinical trials and long-term outcome data are essential to validate these emerging modalities and define evidence-based clinical protocols.

References

[1] Buser D, Sennerby L, De Bruyn H. Modern implant dentistry based on osseointegration: 50 years of progress. Clin Implant Dent Relat Res. 2017;19(1):7-16.
[2] Schropp L, Wenzel A, Kostopoulos L, Karring T. Bone healing and soft tissue contour changes following single-tooth extraction: a clinical and radiographic 12-month prospective study. Int J Periodontics Restorative Dent. 2003;23(4):313-323.
[3] Araújo MG, Lindhe J. Dimensional ridge alterations following tooth extraction. An experimental study in the dog. J Clin Periodontol. 2005;32(2):212-218.
[4] Tan WL, Wong TL, Wong MC, Lang NP. A systematic review of post-extractional alveolar hard and soft tissue dimensional changes in humans. Clin Oral Implants Res. 2012;23(Suppl 5):1-21.
[5] Dahlin C, Linde A, Gottlow J, Nyman S. Healing of bone defects by guided tissue regeneration. Plast Reconstr Surg. 1988;81(5):672-676.
[6] Urban IA, Monje A, Wang HL. Vertical ridge augmentation and soft tissue reconstruction of the anterior atrophic maxillae: a case series. Int J Periodontics Restorative Dent. 2015;35(5):613-623.
[7] Urban IA, Montero E, Monje A, Sanz M. Effectiveness of vertical ridge augmentation interventions: a systematic review and meta-analysis. J Clin Periodontol. 2019; 46 (Suppl 21):319-339.
[8] Chiapasco M, Casentini P, Zaniboni M. Bone augmentation procedures in implant dentistry. Int J Oral Maxillofac Implants. 2009;24(Suppl):237-259.
[9] Cordaro L, Amadé DS, Cordaro M. Clinical results of alveolar ridge augmentation with mandibular block bone grafts in partially edentulous patients prior to implant placement. Clin Oral Implants Res. 2002;13(1):103-111.
[10] Misch CM. Autogenous bone grafts: is it still the gold standard? Implant Dent. 2010;19(5):361-362.
[11] Nkenke E, Neukam FW. Autogenous bone harvesting and grafting in advanced jaw resorption: morbidity, resorption and implant survival. Eur J Oral Implantol. 2014;7(Suppl 2): S203-S217.
[12] Nissan J, Marilena V, Gross O, Mardinger O, Chaushu G. Histomorphometric analysis following augmentation of the anterior atrophic maxilla with cancellous bone block allograft. Int J Oral Maxillofac Implants. 2012;27(1):84-89.
[13] Sanz-Sánchez I, Ortiz-Vigón A, Sanz-Martín I, Figuero E, Sanz M. Effectiveness of lateral bone augmentation procedures using block grafts versus particulate grafts: a systematic review and meta-analysis. Clin Oral Investig. 2015;19(3):673-687.
[14] Buser D, Dula K, Hess D, Hirt HP, Belser UC. Localized ridge augmentation with autografts and barrier membranes. Int J Periodontics Restorative Dent. 1996;16(4):311-325.
[15] Chiapasco M, Zaniboni M, Boisco M. Augmentation procedures for the rehabilitation of deficient edentulous ridges with oral implants. Clin Oral Implants Res. 2006;17(Suppl 2):136-159.
[16] Nkenke E, Schultze-Mosgau S, Radespiel-Tröger M, Kloss F, Neukam FW. Morbidity of harvesting of

retromolar bone grafts. Clin Oral Implants Res. 2002;13(5):514-521.

[17] Al-Nawas B, Schiegnitz E. Augmentation procedures using bone substitute materials or autogenous bone – a systematic review and meta-analysis. Eur J Oral Implantol. 2014;7(Suppl 2):S219-S234.

[18] Nevins M, Mellonig JT. Enhancement of the damaged edentulous ridge using allogenic bone grafts. Int J Periodontics Restorative Dent. 1992;12(3):206-219.

[19] Nissan J, Marilena V, Gross O, Mardinger O, Chaushu G. Histomorphometric analysis of allogenic bone block grafts for alveolar ridge augmentation. Clin Implant Dent Relat Res. 2011;13(4):301-309.

[20] Jensen SS, Terheyden H. Bone augmentation procedures in localized defects in the alveolar ridge: clinical results. Clin Oral Implants Res. 2009;20(Suppl 4):218-236.

[21] LeGeros RZ. Properties of osteoconductive biomaterials: calcium phosphates. Clin Orthop Relat Res. 2002;(395):81-98.

[22] Draenert FG, Huetzen D, Neff A, Mueller WE. Vertical bone augmentation using customized CAD/CAM allogenic bone blocks. J Craniomaxillofac Surg. 2014;42(7): e346-e355.

[23] Jung RE, Windisch SI, Eggenschwiler AM, Thoma DS, Weber FE, Hämmerle CHF. A randomized controlled clinical trial evaluating BMP-2 in bone regeneration. Clin Oral Implants Res. 2009;20(Suppl 4):66-74.

[24] Urban IA, Lozada JL. Digital planning and customized grafting techniques in alveolar augmentation. Int J Periodontics Restorative Dent. 2019; 39: 713-721.

[25] Miron RJ, Fujioka-Kobayashi M, Bishara M, Zhang Y, Hernandez M, Choukroun J. Platelet-rich fibrin in regenerative dentistry. Clin Oral Investig. 2017;21(6):1913-1927.

[26] Boyne PJ, Marx RE. Application of rhBMP-2 in oral and maxillofacial surgery. Oral Maxillofac Surg Clin North Am. 2015;27(1):105-119.

[27] James AW. Signaling pathways in MSC differentiation for bone regeneration. Bone. 2013;55(2):523-529.

[28] Vercellotti T. Piezosurgery in oral and maxillofacial surgery. Periodontol 2000. 2008; 47: 151-159.

[29] Rasmusson L, Sennerby L, Lundgren S, Nyman S. Guided bone regeneration with biphasic calcium phosphate blocks. Clin Oral Implants Res. 2011;22(9):915-923.

[30] Warnke PH, Springer IN, Wiltfang J, et al. Growth and transplantation of a custom vascularized bone graft in a man. Tissue Eng. 2004;10(9-10):1326-1334.

[31] Quarto R, Mastrogiacomo M, Cancedda R, et al. Repair of large bone defects using autologous bone marrow stromal cells. N Engl J Med. 2001;344(5):385-386.

[32] Murphy SV, Atala A. 3D bioprinting of tissues and organs. Nat Biotechnol. 2014;32(8):773-785.