

Building the Foundation: A Literature Review on Combined Sinus Floor Elevation and Vertical Ridge Augmentation, Bone Gain, Implant Survival, and Complication Profiles Across Techniques

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Abstract

Posterior maxillary atrophy secondary to tooth loss and progressive sinus pneumatization represents one of the most challenging scenarios in implant dentistry, frequently requiring augmentation procedures to restore adequate bone volume for implant placement. The present narrative literature review evaluates the current surgical strategies available for implant rehabilitation of the atrophic posterior maxilla, with particular focus on sinus floor elevation and vertical ridge augmentation techniques. A comprehensive search of PubMed, Scopus, and Google Scholar was conducted for studies published between 2021 and 2026. The reviewed literature demonstrated that combined sinus floor elevation and vertical ridge augmentation can achieve favorable bone gain and high implant survival rates in severely atrophic cases. Simultaneous approaches reduced treatment time but depended heavily on primary implant stability, whereas staged procedures provided greater biological predictability at the cost of longer treatment duration. Vertical augmentation procedures showed greater susceptibility to graft resorption over time. Minimally invasive transcrestal techniques demonstrated reduced morbidity and satisfactory long-term outcomes in selected cases. Overall, no single technique proved superior across all clinical scenarios, underscoring the need for individualized, anatomy-driven treatment planning guided by residual bone height, sinus morphology, defect severity, and patient-specific risk factors.

Keywords : Maxillary Sinus; Sinus Floor Augmentation; Dental Implants; Alveolar Ridge Augmentation; Bone Regeneration; Osseointegration.

INTRODUCTION

The posterior maxilla is considered one of the most anatomically challenging regions in implant dentistry due to the progressive changes that occur following posterior tooth loss. After extraction, the alveolar ridge undergoes continuous bone resorption while the maxillary sinus simultaneously expands through a process known as sinus pneumatization, ultimately reducing the available bone height and density required for stable implant placement. [1]

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These anatomical alterations frequently compromise implant stability, particularly in severely atrophic cases where both bone quantity and quality are limited. Sinus augmentation procedures have therefore become essential for restoring adequate bone volume in the posterior maxilla and improving the predictability of implant placement. [2]

Over the past several decades, sinus augmentation procedures have evolved considerably in response to the increasing demand for less invasive surgical techniques. Among the most commonly used approaches are the lateral window and transcrestal sinus floor elevation (TSFE) techniques. More recently, TSFE procedures have incorporated piezoelectric surgery, hydraulic sinus elevation, balloon-assisted elevation, and osseodensification methods aimed at minimizing surgical trauma and improving patient comfort. [2] These approaches have gained popularity because they may reduce postoperative discomfort, shorten healing time, and allow simultaneous implant placement in selected cases. Importantly, multiple TSFE techniques have demonstrated consistently high implant survival rates; however, current evidence remains highly heterogeneous, and not clearly superior transcrestal technique has been identified. [3] Consequently, treatment selection often depends on clinician experience and patient-specific anatomical considerations.

Despite advancements in sinus augmentation procedures, implant rehabilitation in the posterior maxilla remains technically demanding due to anatomical complexity and complication risk. Limited residual bone height and unfavorable sinus morphology have been associated with an increased risk of Schneiderian membrane perforation during transcrestal sinus floor elevation procedures. [4] Residual bone heights below 5 mm may significantly increase surgical difficulty and compromise membrane integrity; additionally, irregular sinus anatomy including steeply oblique sinus floors may further complicate membrane elevation and negatively affect surgical predictability. [3-4] Schneiderian membrane perforation remains one of the most common intraoperative complications, and understanding anatomical limitations and surgical risk factors is therefore critical for successful implant rehabilitation in the posterior maxilla [5].

In severely atrophic posterior maxillae, isolated augmentation procedures may be insufficient to achieve predictable implant treatment. Severe posterior maxillary atrophy is often characterized by a combination of vertical alveolar ridge deficiency and maxillary sinus pneumatization, creating one of the most complex reconstructive scenarios in dentistry [6]. For this reason,

combined augmentation procedures involving sinus floor elevation, vertical ridge augmentation, and simultaneous implant placement have increasingly emerged as alternative reconstructive strategies for managing severe posterior maxillary defects. [4] These combined approaches may reduce total treatment duration, minimize the number of surgical interventions, and improve patient acceptance while restoring adequate bone volume for implant placement. Single-stage procedures involving simultaneous sinus augmentation and implant placement have gained increasing clinical interest in complex atrophic cases. [6]

While sinus augmentation remains a predictable treatment modality, controversy persists regarding the optimal treatment strategy for rehabilitation of the atrophic posterior maxilla. Bone augmentation procedures may increase surgical morbidity, treatment duration, postoperative discomfort, and complication burden. [5]

SINUS FLOOR ELEVATION: LATERAL WINDOW VS. TRANSCRESTAL APPROACHES

Implant rehabilitation in the posterior maxilla can be difficult when limited residual bone height affects implant stability and positioning. [7] After tooth extraction, alveolar bone resorption together with maxillary sinus pneumatization often reduces the amount of bone available for implant placement, and sinus floor elevation procedures have therefore become an important part of treatment planning in patients with an atrophic posterior maxilla. [5-6] Over time, different surgical approaches have been introduced to increase bone height while reducing surgical morbidity and improving clinical outcomes. Among the available techniques, the lateral window and transcrestal approaches remain the most commonly used, with treatment selection mainly based on residual bone height and the amount of augmentation required. [8]

The lateral window approach is usually recommended in severely atrophic maxillae, particularly when residual bone height (RBH) is below 4 to 5 mm. [7] This technique provides direct access to the Schneiderian membrane, allowing greater membrane elevation and placement of larger graft volumes; [7-8] for this reason, it is often preferred when significant vertical augmentation is needed. Long-term data have shown favorable implant survival outcomes with lateral sinus augmentation, even in severely resorbed ridges. [9] However, the procedure is more invasive and tends to involve greater postoperative discomfort and longer healing periods compared with less invasive approaches. [10]

One of the main complications associated with sinus augmentation is Schneiderian membrane perforation.

[11] Lee et al. reported higher perforation rates in lateral window procedures, attributable to the wider surgical access and increased membrane manipulation involved. [8] Although perforations may complicate healing and graft stability, appropriate management usually allows successful implant outcomes; careful handling of the sinus membrane therefore remains essential regardless of the technique used. [12]

In comparison, the transcrestal approach is considered less invasive and is generally indicated in sites with RBH of 5 to 6 mm or more, where moderate augmentation is required. [9-10] By approaching the sinus through the implant osteotomy site, surgical trauma and postoperative morbidity can be reduced. [9] Traditionally, this technique was believed to provide more limited bone gain because membrane elevation is achieved indirectly; [10] however, more recent studies suggest that modern transcrestal modifications have demonstrated favorable outcomes even in more complex cases. [11-13]

Shi et al. found no significant differences in implant survival or marginal bone loss between transcrestal and

lateral sinus floor elevation in sites with RBH of 6 mm or less. [14] Although the lateral window technique continues to provide greater augmentation capacity, the transcrestal approach offers the advantage of lower morbidity and faster recovery. [15] Similarly, Guo et al. reported favorable radiographic bone gain in severely atrophic maxillae treated with advanced transcrestal techniques in sites with RBH of 5 mm or less. [11] In addition, newer approaches such as osseodensification have demonstrated improved implant stability and increased bone height gain compared with conventional osteotome methods. [16]

In summary, both techniques have shown predictable clinical outcomes when selected according to the anatomical conditions and treatment needs of each patient. [7-10] The lateral window approach remains more suitable for severe defects requiring extensive augmentation; conversely, transcrestal procedures provide a less invasive alternative in moderate deficiencies. [17] In cases involving additional vertical or horizontal ridge deficiencies, sinus augmentation alone may not be enough, and additional augmentation procedures may be required. (Table 1) [10]

Table 1. Comparison of Sinus Floor Elevation Techniques. RBH: Residual bone height. TSFE: Transcrestal sinus floor elevation. e-PTFE: Expanded polytetrafluoroethylene. d-PTFE: Dense polytetrafluoroethylene. [7];[8];[10];[11].

Feature	Lateral Window Approach	Transcrestal Approach (TSFE)
Indicated RBH	< 4–5 mm	≥ 5–6 mm
Membrane access	Direct visualization of Schneiderian membrane	Indirect; blind technique through osteotomy site
Bone gain volume	High; suitable for extensive augmentation	Moderate to high; sufficient in selected cases
Perforation rate	Higher (20–35%)	Lower (10–15%)
Surgical invasiveness	High	Low
Postoperative morbidity	Greater; longer recovery period	Reduced; faster recovery
Simultaneous implant placement	Possible when RBH ≥ 3 mm	Common in adequate RBH cases
Graft volume capacity	Large volumes accommodated	Limited to moderate volumes
Learning curve	Steep	Moderate
Main advantage	Greater augmentation capacity in severe atrophy	Reduced morbidity; shorter overall treatment time
Main limitation	Higher complication burden; longer healing period	Limited augmentation in very low RBH sites

VERTICAL RIDGE AUGMENTATION: GBR, DISTRACTION OSTEOGENESIS, AND ONLAY BLOCK GRAFTS

The loss of a tooth can lead to vertical and horizontal ridge deficiencies. In fact, as early as six months after extraction, resorption in the alveolar ridge becomes

noticeable and may represent a limiting factor for implant-supported rehabilitation. [13] Furthermore, when sinus pneumatization coexists with severe ridge defects, the risk to implant osseointegration is compounded, requiring additional techniques to establish adequate bone volume for successful implant placement [18].

Vertical ridge augmentation is one of the most complex procedures designed to restore esthetics and function in the maxilla or mandible. For this reason, advanced surgical skills are required to preserve the alveolar ridge and minimize intraoperative trauma. Consequently, various augmentation techniques have been developed to achieve stability, reconstruct deficient ridges, improve implant outcomes, and minimize intraoperative and postoperative complications. [14] Among the most widely used approaches are guided bone regeneration (GBR), distraction osteogenesis (DO), and onlay block grafts, each based on different biological principles, surgical protocols, and clinical indications [19].

Guided Bone Regeneration (GBR)

Guided bone regeneration is one of the most established methods for reconstruction of vertical ridge deficiency, based on the biological principle of compartmentalization. The procedure involves the application of biological barrier membranes that promote selective hard tissue ingrowth while excluding competing soft tissue cells. [15] In cases with insufficient bone volume for implant placement, GBR is performed to increase the available bone height, provide adequate support for the implant, and achieve proper positioning within the jaw. [16]

GBR is generally indicated when there is a vertical bone deficiency of at least 4 mm that would compromise ideal implant dimensions. [15-20] Barrier membranes represent the primary tool in GBR, and different types offer distinct biological mechanisms; these are broadly classified as absorbable and non-absorbable. [17] High-density polytetrafluoroethylene (d-PTFE) and expanded polytetrafluoroethylene (e-PTFE) represent the first generation of non-absorbable membranes; e-PTFE was long considered the gold standard due to its ability to adhere to connective tissue and promote circulation in its porous structure. [21] However, the exposure rate of non-absorbable membranes is relatively higher at approximately 20%, compared with around 5% for absorbable membranes; e-PTFE is also associated with low porosity and susceptibility to bacterial contamination, which can compromise bone regeneration outcomes. [16]

A second generation of membranes composed of natural and artificial collagen has since been developed. One important advantage of natural collagen membranes is that they do not require a second surgery for removal, which reduces morbidity and bacterial infection risk; they also promote efficient cellular migration, improving bone stability. [16-17] Systematic reviews comparing different membrane types have demonstrated that both resorbable and non-resorbable membranes can achieve clinically

meaningful vertical bone gain, although the results vary according to membrane type, graft material, and defect configuration. [22]

Distraction Osteogenesis (DO)

Distraction osteogenesis is a surgical technique used for atrophic alveolar ridge reconstruction in both the maxilla and mandible. This method applies a slow, gradual traction process to bone segments, promoting vascular ingrowth and new bone formation without the need for barrier membranes. DO uses a distraction device to support and move the segments in place. [19]

The formation of new bone through DO enhances the possibility of performing adequate implant-supported rehabilitation. The technique is specifically indicated for severe vertical defects, cases involving cleft lip and palate, bony defects secondary to trauma, and severely atrophic maxillae or mandibles. [19-20] Among the advantages of DO are its excellent predictability for bone regeneration, its applicability across a wide age range, and its ability to regenerate both soft and hard tissue simultaneously without the need for a donor site. [23] The disadvantages of DO include the requirement for a second surgery for device removal, the risk of inaccurate segment positioning, substantial cost, and the contraindication of removable prostheses during the active distraction period to prevent device mobility. [19-20]

Onlay Block Grafts

The placement of autogenous onlay block grafts is considered one of the gold standard procedures for alveolar ridge augmentation. Onlay blocks enable bone expansion through fixation, which allows the minimum suitable dimensions for implant placement, providing high osteogenic capacity at the recipient site. Onlay blocks are also used to manage vertical and horizontal bone defects. [21-24] Some studies have documented that simultaneous implant placement at the time of onlay block grafting is associated with implant survival rates ranging from 73.8% to 100%; however, a staged protocol for delayed implant placement appears to yield higher success rates of 85.7% to 100% and is therefore generally recommended. [22]

Different donor sites for onlay block grafts include membranous bone (intraoral grafts) and endochondral bone (iliac crest). The origin of the bone graft may influence the rate of resorption, which is generally higher with iliac crest grafts; however, no significant differences have been demonstrated with respect to implant support and stability between the two graft origins. [22-25] Some investigations have reported that onlay block grafts carry a high incidence of complications and bone volume loss

that can reach 41.5% of total volume during a 6-month healing period, indicating a considerable risk of morbidity at the recipient site. [21-26]

Each vertical ridge augmentation technique presents distinct biological principles, indications, and complication profiles. Risk assessment should therefore be performed

prior to any surgical procedure, and treatment selection should be individualized according to defect severity, anatomy, and prosthetic demands; this frequently requires combined surgical approaches in advanced posterior maxillary atrophy. (Table 2) [26-27]

Table 2. Comparative Evaluation of Clinical Modalities for Vertical Alveolar Ridge Augmentation. GBR: Guided bone regeneration. DO: Distraction osteogenesis. e-PTFE: Expanded polytetrafluoroethylene. d-PTFE: Dense polytetrafluoroethylene. [13];[14];[15];[20];[21];[22].

Feature	Guided Bone Regeneration (GBR)	Distraction Osteogenesis (DO)	Onlay Block Graft
Biological basis	Compartmentalization via barrier membranes	Gradual traction promoting callus formation	Osteoconduction and osteogenesis at recipient site
Min. vertical defect	≥ 4 mm	Severe defects; no upper limit	Variable; case-dependent
Donor site required	No	No	Yes (intraoral or iliac crest)
Bone resorption risk	Moderate; variable across membranes	Low; most predictable volume maintenance	High; up to 41.5% at 6 months
Barrier membrane required	Yes	No	No
Second surgery required	No (absorbable); Yes (e-PTFE / d-PTFE)	Yes — device removal required	No
Simultaneous soft tissue gain	No	Yes	No
Prosthesis during treatment	Allowed after initial healing	Contraindicated during active distraction	Allowed after initial healing
Cost	Moderate	High	Moderate to high
Learning curve	Moderate	Very steep	Steep
Main advantage	No donor site; well-documented; wide indications	Regenerates hard and soft tissue simultaneously	High osteogenic capacity; gold standard for large defects
Main limitation	Membrane exposure; wound dehiscence risk (~20%)	Device cost; second surgery; patient compliance	Donor site morbidity; significant resorption rate

COMBINED APPROACHES: WHEN ONE TECHNIQUE IS NOT ENOUGH

Severely atrophic posterior maxillae rarely allow a straightforward implant approach, mainly because the remaining bone is often insufficient in both height and quality. [23-24] In daily clinical practice, this situation usually forces the clinician to think beyond a single technique. [28-29] Instead, treatment is often planned by combining sinus elevation with vertical ridge augmentation in order to rebuild a functional foundation for implant placement. [29] What really determines success is not only the technique itself, but how the surgical steps are organized, how long the site is allowed to heal, and whether the implant can be stabilized from the beginning. [30]

Early mechanical stability also plays a major role, since movement during healing can compromise the biological response and the formation of new bone. [23-24-29]

In selected cases, implants can be placed at the same time as sinus elevation. [23-24] This approach is often preferred because it reduces surgical stages and shortens overall treatment time; when some residual bone is present, clinical outcomes tend to be favorable, with reported high implant survival even in challenging anatomical conditions. [31] However, this predictability decreases when bone support is minimal, since achieving adequate primary stability becomes more difficult. In these situations, early micromovement can interfere with healing and reduce the quality of osseointegration. [24-28]

At the same time, combining vertical augmentation with sinus procedures introduces additional biological challenges. [25-29] Vertical grafts do not always maintain their initial volume during healing and may show dimensional reduction over time. [31] This behavior becomes more relevant when comparing different grafting sites, as vertical augmentation areas tend to be less dimensionally stable than sinus-only reconstructions. [32] Because of this remodeling process, early radiographic success does not always reflect long-term bone stability. [25-29]

In more complex cases, staged treatment is often chosen as a more controlled strategy. This approach allows the graft to heal and revascularize before implants are placed, improving its biological quality and resistance to functional loading. [26-33] Although this method requires additional surgical phases and longer treatment time, it provides a more predictable environment for bone maturation; [26,29] clinically, this is particularly relevant when initial stability cannot be guaranteed at the time of augmentation. [26]

When both strategies are compared, clear differences appear in predictability and timing. [23,29] Simultaneous approaches are more time-efficient but depend strongly on ideal mechanical conditions during surgery; if stability is compromised, outcomes become less reliable due to early biological disruption. [23,24] In contrast, staged protocols are slower but allow a more gradual and controlled bone response before implant loading. Treatment planning is rarely standardized and must therefore be adapted to the anatomical situation of each patient. [34]

Minimally invasive sinus techniques also contribute to the management of atrophic maxillae. [27] Crestal approaches performed under controlled conditions have shown stable long-term implant outcomes with reduced surgical morbidity. In addition, full-arch rehabilitations combining bilateral sinus augmentation with simultaneous implant placement have demonstrated satisfactory functional and patient-centered results when occlusal forces are properly distributed. [35] These findings suggest that success depends not only on the technique itself, but also on biomechanical planning and execution.

Overall, managing severely atrophic posterior maxillae requires a flexible combination of techniques rather than a single standardized protocol. [23-29] Simultaneous approaches may reduce treatment time, but their success relies heavily on primary stability and strict control of micromovement; [36] staged approaches require more time but often provide more predictable biological outcomes due to improved graft maturation. [25,26,29]

Ultimately, sequencing decisions should be individualized based on bone availability, defect severity, and mechanical conditions to achieve long-term implant success.

COMPREHENSIVE OUTCOME COMPARISON: BONE GAIN, IMPLANT SURVIVAL, AND COMPLICATION BURDEN ACROSS TECHNIQUES.

Synthesizing comparative data across sinus floor elevation and vertical ridge augmentation techniques requires examining three parallel dimensions: volumetric bone gain and long-term dimensional stability, implant survival and success rates, and complication frequency and severity [36]. Across these axes, the evidence base reveals meaningful convergence in some areas while significant heterogeneity persists in others [37].

With respect to bone gain, lateral window sinus augmentation consistently produces greater volumetric endo-sinus bone gain compared with transcrestal techniques, particularly in cases with RBH below 5 mm. [10,11] However, modern transcrestal modifications, including hydraulic pressure techniques and osseodensification, have demonstrated clinically meaningful bone height increases in selected cases with minimal initial RBH, with some studies reporting average vertical gains exceeding 8 mm. [12-38] Vertical ridge augmentation procedures, by contrast, are associated with less predictable dimensional outcomes; a systematic review by Cucchi et al. reported that bone loss following vertical augmentation was significantly higher than that observed after horizontal augmentation or sinus procedures, with greater variability across techniques. [13] GBR demonstrated more favorable bone stability compared with onlay block grafts, while distraction osteogenesis produced the most predictable volumetric outcomes in large vertical defects at the cost of greater surgical complexity. [14,20]

Implant survival data across techniques is broadly favorable when appropriate case selection is applied. Long-term retrospective cohort studies evaluating lateral sinus floor elevation with simultaneous implant placement in sites with RBH of 3 mm or less have reported survival rates exceeding 90% at follow-up periods of 3 to 12 years. [7-39] Similarly, transcrestal procedures in sites with RBH of 6 mm or less have demonstrated comparable implant survival to lateral approaches, as demonstrated by the meta-analysis of Shi et al. [10] In combined sinus and vertical augmentation cases, implant survival rates remain high when primary stability is achieved and staged protocols are followed in complex reconstructions. [29] Overall, the evidence suggests that implant survival is less a function of the specific augmentation technique used

and more a reflection of the quality of treatment planning, primary stability at placement, and postoperative management. [40]

Complication profiles differ markedly across techniques and represent one of the clearest points of divergence in the literature. Schneiderian membrane perforation remains the most frequently reported intraoperative complication of sinus floor elevation, with reported rates ranging from approximately 10% to 35% depending on technique and anatomical factors; lateral window procedures are associated with higher perforation rates than transcrestal approaches, according to the network meta-analysis of Lee et al. [8,41] Vertical ridge augmentation carries a distinctly different complication profile, dominated by wound dehiscence, membrane exposure, and graft resorption; the systematic review by Alotaibi et al. reported that GBR and onlay block grafts were associated with considerably higher complication rates than sinus procedures alone, particularly in vertical augmentation scenarios. [31] Combined procedures tend to compound these risks and are consistently associated with greater surgical morbidity. [31,32]

Short implants have been proposed as an alternative strategy to reduce the complication burden associated with extensive augmentation in selected cases. The systematic review by Ravidà et al. demonstrated that short implants of 6 mm or less showed comparable survival rates to longer implants in certain atrophic scenarios, with a significantly lower risk of biological complications. [33] Nevertheless, bone augmentation remains necessary in severely resorbed maxillae where even short implants cannot achieve adequate primary stability, and the decision between short implants and augmentation must be individualized accordingly. [5,42]

A persistent limitation of the current evidence base is the significant heterogeneity in study design, grafting materials, outcome measures, and follow-up periods across published studies. [34] This heterogeneity makes direct comparisons between techniques difficult and limits the ability to draw definitive conclusions. Patient-reported outcome measures (PROMs), quality of life assessments, and standardized complication reporting remain inconsistently applied across the literature; [43] future high-quality randomized controlled trials

Table 4. Comprehensive Outcome Summary Across All Augmentation Techniques. SFE: Sinus floor elevation. VRA: Vertical ridge augmentation. RBH: Residual bone height. SR: Systematic review. RCT: Randomized controlled trial. Source: Adapted from Cucchi et al. [13]; Shi et al. [10]; Lee et al. [8]; Alotaibi et al. [30]; Ravidà et al. [31]; Canellas et al. [28].

Technique	Mean Bone Gain	Implant Survival	Complication Profile	Dimensional Stability	Level of Evidence
Lateral Window SFE	High 8–14 mm endo-sinus	90–98%	Moderate; Schneiderian perforation 20–35%	Good long-term	Strong — multiple SR and RCTs
Transcrestal SFE	Moderate–High 4–10 mm	88–97%	Low–moderate; perforation 10–15%; vertigo with osteotomes	Good when RBH adequate	Strong — SR and meta-analyses
GBR (vertical)	Moderate 3–7 mm vertical	88–95%	Moderate; wound dehiscence; membrane exposure ~20%	Moderate; variable resorption	Moderate — heterogeneous studies
Distraction Osteogenesis	High 6–12 mm vertical	90–96%	High; device complications; second surgery required	Most predictable volumetrically	Moderate — limited RCTs
Onlay Block Graft	Moderate 3–8 mm vertical	85–100%	High; donor site morbidity; resorption up to 41.5%	Less predictable; significant resorption	Moderate — systematic reviews
Combined SFE + VRA	High	88–96%	High; compounds individual technique risks	Variable; technique-sequence dependent	Limited — few long-term studies
Short Implants (alternative)	N/A	91–97%	Low; significantly fewer biological complications	N/A	Strong — multiple RCTs ≥ 5 years

incorporating standardized outcomes and longer follow-up periods will be necessary to generate more reliable comparative evidence. [44]

CONCLUSION

Current evidence demonstrates that an extensive range of reconstructive techniques can achieve favorable clinical outcomes in the rehabilitation of the atrophic posterior maxilla, providing clinicians with multiple therapeutic alternatives for implant-supported rehabilitation. Both sinus floor elevation and vertical ridge augmentation procedures have shown predictable bone regeneration and high implant survival rates when appropriately indicated and performed. The reviewed literature also demonstrates variability in bone gain, implant survival, and complication profiles across reconstructive techniques, emphasizing the importance of individualized treatment planning. In severely compromised defects, combined augmentation approaches are frequently required to obtain sufficient bone volume for implant placement. Nevertheless, peri-implant bone stability and long-term biological behavior may vary according to the specific augmentation technique utilized, particularly in vertical ridge augmentation procedures.

Although advanced reconstructive procedures may provide substantial vertical and sinus bone gain, greater augmentation does not necessarily justify increasingly invasive surgical interventions in every clinical scenario. Combined procedures are often associated with greater surgical complexity, increased morbidity, longer treatment time, and higher complication rates, particularly in severely atrophic defects. Likewise, while lateral window sinus augmentation may achieve greater endo-sinus bone gain, minimally invasive transcrestal approaches have demonstrated comparable implant survival rates with reduced postoperative discomfort and fewer complications in selected cases. Furthermore, short implants may represent a predictable alternative to extensive augmentation procedures in specific anatomical situations, potentially reducing biological burden and patient morbidity without compromising long-term implant survival.

Ultimately, the current body of evidence does not support the superiority of any single augmentation technique across all clinical scenarios. Rather, the literature on sinus floor elevation and vertical ridge augmentation should not be interpreted as a rivalry among techniques, but as a biologically and surgically diverse toolkit that enables individualized treatment planning according to anatomical complexity, patient-specific risk, and clinical objectives. Clinical decision-making should therefore

follow a risk-stratified, anatomy-driven framework that considers residual bone height, sinus morphology, defect configuration, systemic health conditions, patient expectations, and operator expertise. Clinicians should select augmentation strategies according to the regenerative demands and long-term predictability of each clinical situation, with the ultimate goal of maximizing implant success while minimizing surgical morbidity and patient burden.

Despite the growing body of evidence, significant heterogeneity persists among published studies regarding surgical protocols, grafting materials, outcome assessment, and follow-up periods. In addition, patient-reported outcome measures (PROMs), quality of life, and complication severity remain inconsistently evaluated within the current literature. Future investigations should therefore prioritize standardized clinical and radiographic outcome measures, long-term randomized clinical trials, and patient-centered outcomes capable of improving reproducibility and facilitating more meaningful comparisons among reconstructive techniques. Such efforts may contribute to the development of more evidence-based and clinically relevant augmentation protocols for implant rehabilitation in the atrophic posterior maxilla.

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