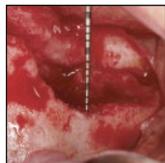


Decision Tree for Vertical Ridge Augmentation



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Vertical ridge augmentation (VRA) procedures before or during dental implant placement are technically challenging and often encounter procedure-related complications. To minimize complications and promote success, a literature search was conducted to validate procedures used for VRA. A decision tree based on the amount of additional ridge height needed (< 4, 4 to 6, or > 6 mm) was then developed to improve the procedure-selection process. At each junction, the clinician is urged to consider anatomical, clinical, and patient-related factors influencing treatment outcomes. This decision tree guides selection of the most appropriate treatment modality and sequence for safe, predictable management of the vertically deficient ridge in implant therapy. *Int J Periodontics Restorative Dent* 2018;38:269–275. doi: 10.11607/prd.3280

After extraction, the alveolar ridge undergoes significant resorption. The estimated 40% loss of ridge height presents a significant challenge to implant placement.^{1,2} Over the long term, the prevalence of peri-implantitis is high, affecting up to half of all implants.³ Both implant position and history of regeneration increase peri-implantitis risk, so careful treatment planning is key.⁴ Options include rebuilding height using vertical ridge augmentation (VRA) or placing a short implant. This article introduces a guide for successfully managing the vertically deficient ridge.

Vertical Ridge Augmentation Techniques

Strategies in this guideline for VRA include distraction osteogenesis (DO), onlay grafting (OG), and guided bone regeneration (GBR).

Distraction Osteogenesis

DO consists of surgical delineation of a bone segment followed by slow separation from basal bone, allowing new bone fill.⁵ DO is limited to vertical augmentation.⁶ Due to the complexity of DO, the authors do not recommend this procedure except for severe vertical deficiencies.

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Onlay Grafting

An onlay graft is a bone block. Complications include incision dehiscence, graft exposure, graft loss, and sensory changes.^{7,8} Due to these complications, short implants should be considered as an alternative.⁹ The greatest surgical challenge in OG is maintenance of soft tissue closure.⁶ Allogeneic and xenogenic block grafts are an alternative to autogenous blocks, but evidence is limited.^{10,11}

Guided Bone Regeneration

GBR has advantages over OG due to avoidance of a second surgical site and reduced complications. GBR uses barrier membranes for space maintenance and exclusion of non-bone-forming cells.¹² GBR can be applied at the time of implant placement or staged 4 to 9 months prior.¹ Adherence to the principles of primary closure, angiogenesis, stability, and space maintenance (PASS) maximizes GBR success.¹² Absorbable and nonresorbable barrier membranes are available. Collagen (CM) is a common absorbable membrane. Nonresorbable barriers include titanium (Ti) mesh (Ti-mesh), expanded and density polytetrafluoroethylene (PTFE), and Ti-reinforced PTFE (PTFE-TR). The most common complication for GBR is membrane exposure, which compromises the amount of regeneration.⁸

Survival is high for implants placed after vertical GBR (93.75% to 100%), and stability has been maintained over 4 to 5 years.^{6,8,13,14} The limited data on VRA, heterogeneity,

and small sample sizes hinders decision making.^{6,14-16} More data exists on nonresorbable versus resorbable membranes, but both types are comparable.¹⁵ A nonresorbable, Ti-reinforced membrane (PTFE-TR) may improve space maintenance and eliminate the need for tenting screws used with absorbable membranes.¹⁷⁻²¹ Extrapolating from the literature, GBR is a preferred technique because it allows for simultaneous horizontal augmentation (not possible with DO), and has fewer complications than OG.^{15,16} GBR with PTFE-TR can yield close to 100% success for VRA in all three (small, medium, and large) elevation height groups.^{17,18,20-22}

Short Implants

A short implant (< 8 mm) may be preferred over VRA due to their lower rates of complications and implant failures.^{16,23,24} Short implants show similar marginal bone levels and survival rates to ≥ 10 mm implants, but the peak failure rate occurred at an earlier point (4 to 6 versus 6 to 8 years).²⁵ Short implants decrease treatment time (by an average of 4 months), and patients prefer them 100% over grafting.^{26,27} This guide defines a short implant as < 8 mm. Short implants are an option for all stages of vertical deficiency if the remaining bone is sufficient.

Systemic and Local Factors

Prior to surgery, it is critical to ensure good oral and systemic health of the patient. A more conservative surgi-

cal approach such as short or tilted implants should be considered for medically compromised patients. A thorough clinical and radiographic examination should be performed to evaluate the local anatomical factors.

Important soft tissue-related factors include keratinized mucosa (KM) width and vestibular depth. If soft tissue is deficient, its augmentation should be performed after VRA to prevent scar tissue development, which can limit flap extension and passive primary closure.²¹ Soft tissue augmentation after VRA helps reestablish lost vestibular depth.²¹ A combination approach of an apically placed free gingival graft with coronally positioned free connective tissue graft can increase KM width while maximizing esthetics.²¹

The Decision Tree

This decision tree (Fig 1) is based on the amount of apicocoronal elevation needed for standard-length implant placement (≥ 8 mm). Strategies for small (< 4 mm), medium (4 to 6 mm), and large (> 6 mm) vertical ridge augmentation are proposed.

Small Apicocoronal Elevation (< 4 mm)

GBR may be used to predictably treat small vertical defects. Simultaneous implant placement and GBR can be considered for 3-mm mean vertical gain.⁸ Both resorbable and nonresorbable membranes may be used. CM performed similarly to PTFE membranes at buccal implant

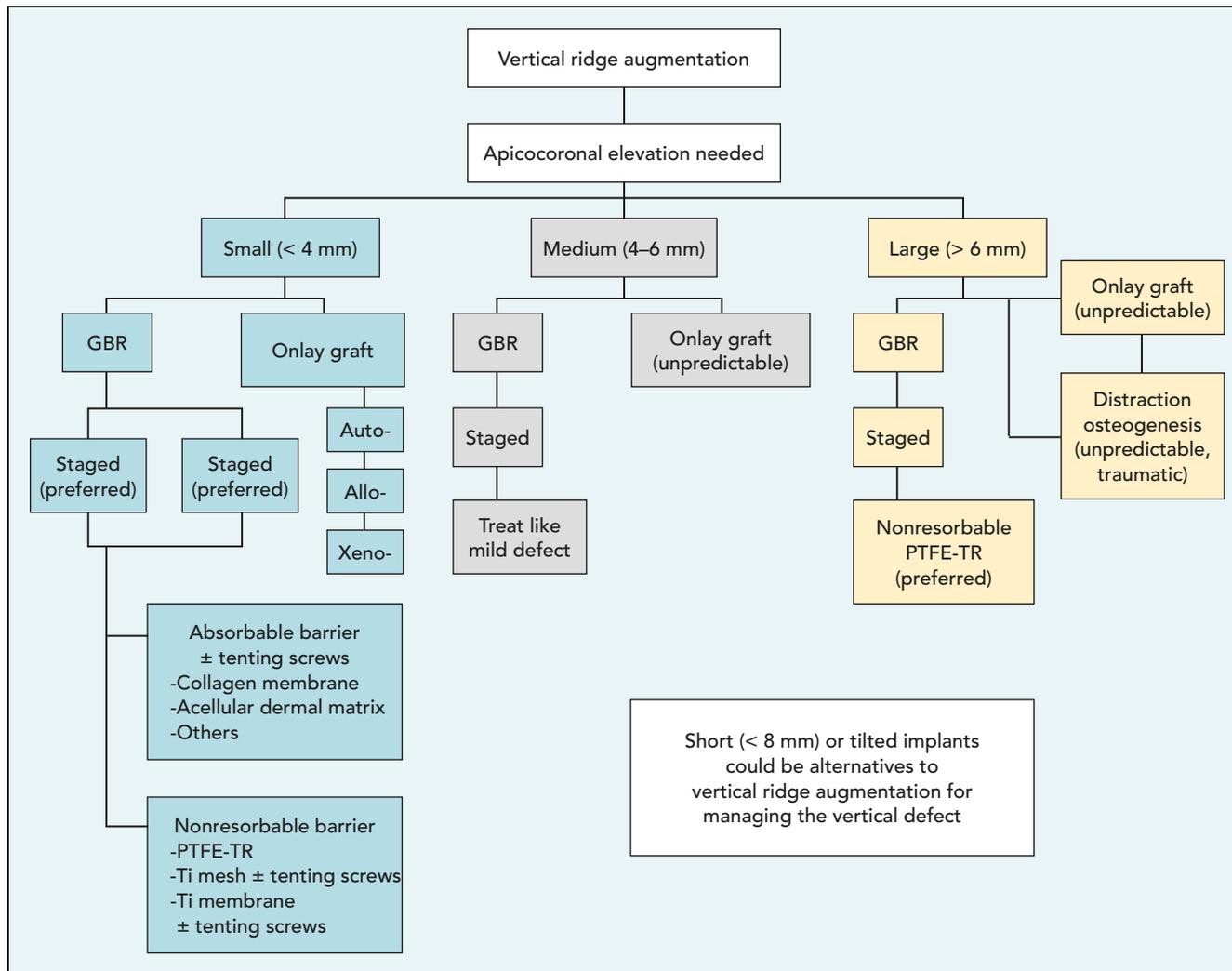


Fig 1 Decision tree for vertical ridge augmentation (VRA). The decision tree suggests procedures for managing the vertically deficient ridge based on amount of apicocoronal elevation needed for standard (≥ 8 mm) length implant placement. Strategies for small (< 4 mm), medium (4 to 6 mm), and large (> 6 mm) degrees of VRA are proposed. GBR = guided bone regeneration; PTFE-TR = titanium-reinforced polytetrafluoroethylene; Ti = titanium.)

dehiscence defects.^{28,29} A combination of autogenous and DBBM bone may be ideal for long-term graft stability due to autogenous graft shrinkage.^{30,31} When absorbable membranes are used, periosteal vertical mattress suturing with absorbable sutures are an alternative to fixation screws.²¹ Nonresorbable membranes have also shown success for VRA.^{17,18,20,21} Stable mem-

brane devices, such as PTFE-TR or Ti-mesh, provide enhanced stability and space. Figure 2 shows a small defect treated with GBR using a CM, tenting screws, and sandwich bone augmentation using a combination of autogenous and allogeneic grafting (enCore, Osteogenics Biomedical).

OG may be considered for an average 4.75-mm vertical height

gain; however, complication rates are higher than with GBR.^{8,32} While autogenous grafts are considered the gold standard, allogeneic blocks show high success rates in case series.¹⁰ This strategy is recommended for mild maxillary VRA to avoid a mandibular harvest site.¹¹ Xenogeneic grafts show promising early reports, but more evidence is needed to validate the findings.³³

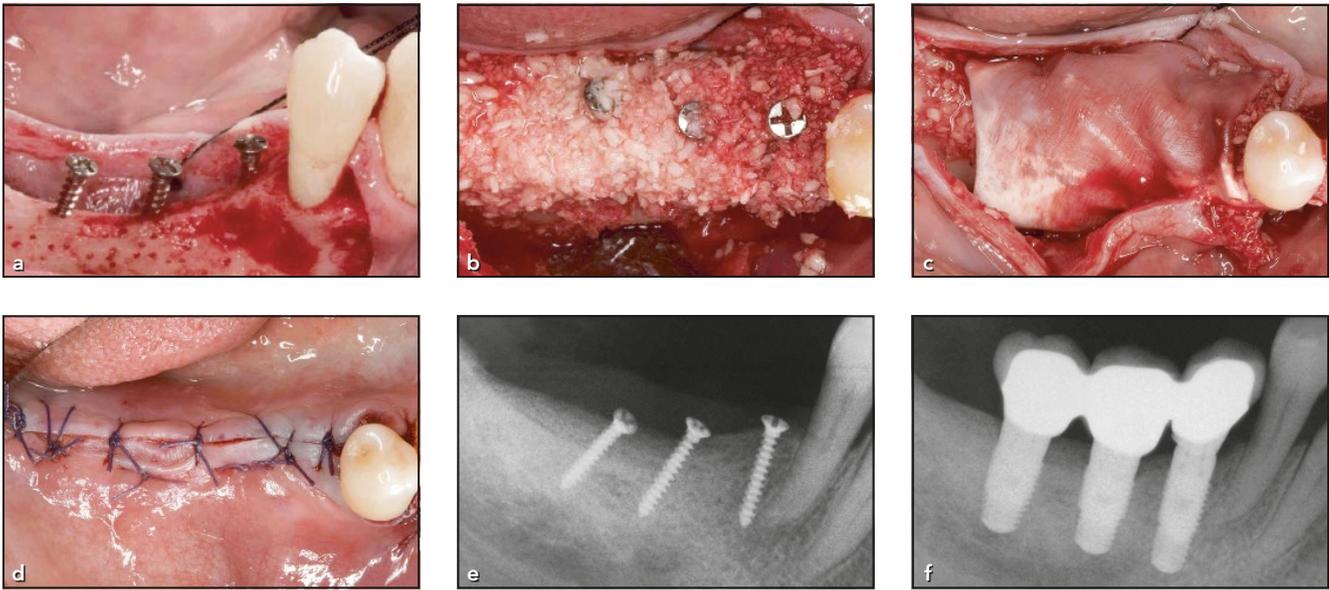


Fig 2 Sandwich guided bone regeneration for small vertical ridge augmentation. (a) Initial defect with intrabony marrow penetration. (b) Sandwich guided bone augmentation using cancellous and cortical particulate allograft (Puros Allograft Particulate, Zimmer/Biomet 3i) and tenting screws (Neo GBR kit, Neobiotech). (c) Pericardium membrane placement (CopiOs Pericardium Membrane, Zimmer Biomet). (d) Suturing with modified horizontal vertical mattress and simple interrupted sutures using 4-0 polyglactin 910 (Vicryl, Ethicon, Johnson & Johnson). (e) Radiograph after 5 months of healing. (f) Radiograph of final restoration 2 months after implant restoration (Zimmer TSV system, Zimmer/Biomet 3i).

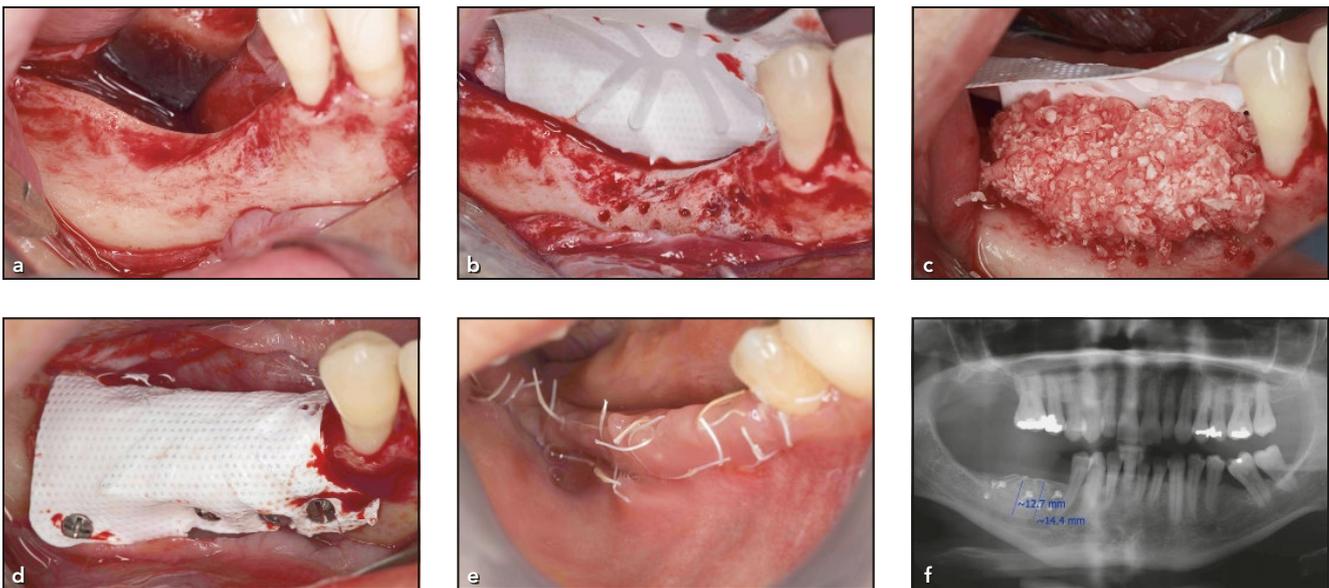


Fig 3 Guided bone regeneration using nonresorbable fixed membrane for medium vertical ridge augmentation (VRA). (a) Initial defect. (b) Intrabony marrow penetration and placement of titanium-reinforced polytetrafluoroethylene (PTFE-TR) membrane (Cytoplast Ti-250 Titanium-Reinforced, Osteogenics Biomedical) on the lingual aspect, secured with fixation screws (Profix, Osteogenics Biomedical). (c) Grafting with combination of autogenous bone and deproteinized bovine bone mineral (DBBM) (Geistlich). (d) Fixation of PTFE-TR membrane on buccal aspect (Profix Osteogenics Biomedical). (e) Suturing with horizontal mattress and simple interrupted 3-0 and 4-0 PTFE sutures (Osteogenics Biomedical). (f) Radiographic bone gain at 9 months. Approximately 5 mm VRA was achieved.

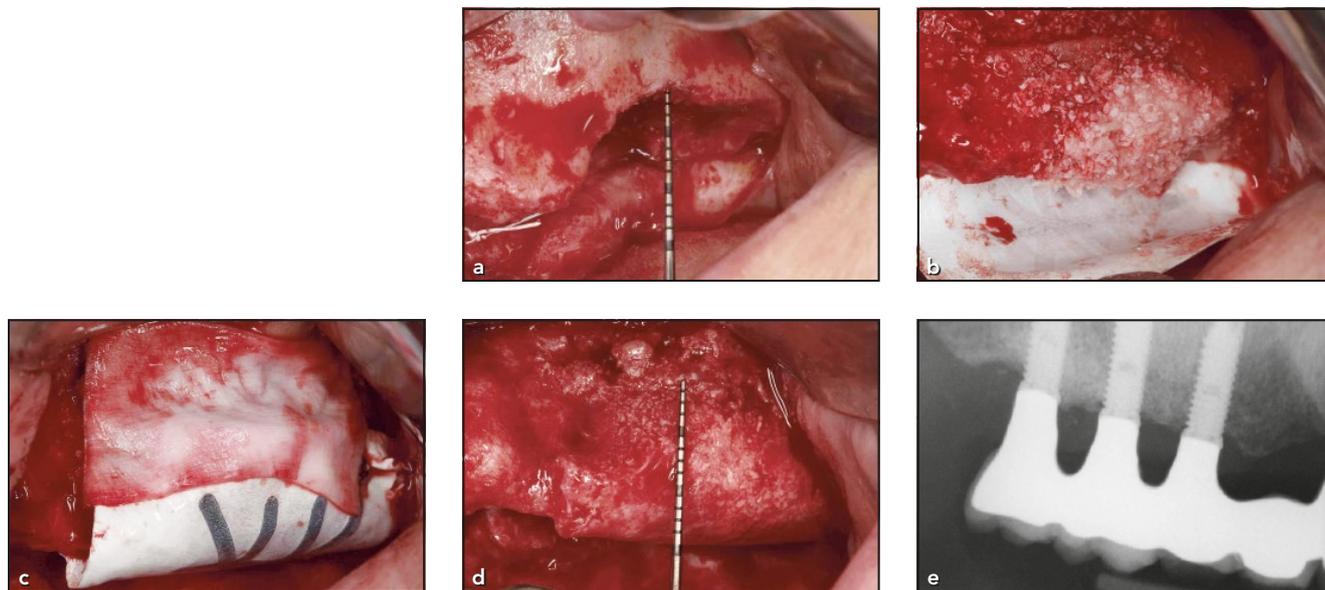


Fig 4 Guided bone regeneration (GBR) for large vertical ridge augmentation (VRA). (a) Initial defect exceeds 10 mm. (b) Grafting with combination of autogenous graft and deproteinized bovine bone mineral (DBBM) (Geistlich). (c) Fixed (Master-Pin-Control Bone Management System, Meisinger) nonresorbable high density titanium-reinforced polytetrafluoroethylene (PTFE-TR) membrane (Cytoplast Ti-250 Titanium-Reinforced, Osteogenics Biomedical) overlaid by collagen membrane to improve tissue tolerance of fixation screws. (d) Vertical ridge height gain > 10 mm 24 months after VRA. (e) Radiograph at 8 years after final implant-supported restoration (Brånemark System, Nobel Biocare).

Medium Apicocoronary Elevation

GBR may be used predictably for medium defects (4 to 6 mm) with adherence to the PASS principles.¹² Implant placement should be staged after 6 to 9 months to allow graft maturation.^{19–22} Nonresorbable stable membrane devices are preferred. The combination of PTFE-TR, DBBM, and particulate autogenous graft was used for a mean vertical gain of 5.45 mm with no complications.¹⁸

Cases with a thin gingival biotype may consider use of an absorbable CM alone or layered over a nonresorbable barrier to improve tissue tolerance. Since CM are non-rigid, tenting screws may enhance space maintenance. However, screws can create pressure spots, leading to

flap or screw exposure, so it may be preferable to use PTFE-TR (Fig 3). For absorbable and nonresorbable barriers, rigid fixation maximizes stability. While VRA requires significant flap advancement to obtain passive closure, free soft tissue grafting after VRA may be used to reestablish vestibular depth and KM width.²¹

Autogenous OG is another option for medium VRA. Overall, OG has a high complication rate, second to DO (8.1%), although the average implant survival rate is high (96.32%).⁸ Clinician skill is key when considering this technique.

Large Apicocoronary Elevation

VRA in large (> 6 mm) cases may require extensive soft and hard tissue

augmentation procedures over 1 to 2 years, so short implants should be considered.²¹

GBR using a nonresorbable membrane with a Ti-reinforced framework (Fig 4) may be the preferred choice for large VRA.^{17,18,20–22} A challenging area for primary closure is the maxillary anterior. A classification based on amount of VRA, presence of horizontal ridge deficiency, history of regeneration performed, periosteum status (native versus scarred), and vestibular depth guides flap management to maximize success of GBR.²⁰

DO is another option for severe defects, with the largest height gain (mean 7.08 mm) but the highest complication rate (22.4%).^{8,13} Complications include fracture,

mechanical problems, hypoesthesia, and implant failure.⁸ Despite these challenges, the implant survival rate is high and there may be less resorption than OG. This procedure should be reserved for the most severe cases.

Finally, OG may be considered for large VRA.³⁴ Due to donor site morbidity, short implants should be considered.³⁵ Long-term implant survival after OG was 93.4% over a mean of 39.9 months.³⁶ Based on the drawbacks associated with OG, GBR is a preferred choice in managing this specific clinical situation.

Conclusions

Limited evidence is present regarding vertical ridge augmentation.

When considering vertical ridge augmentation, the authors urge the clinician to evaluate pertinent anatomical (KM width, tissue thickness, anatomical structures), clinical (surgeon skill and experience), and patient-related (local and systemic health, preferences) factors. GBR is generally preferred due to its high predictability and low incidence of complications. OG should be reserved for patients resistant to allogeneic and xenogenic graft sources. Due to its high complication rate, DO should only be used in cases of extreme vertical ridge deficiency and with high operator experience and skill.

This guideline offers an approach based on available evidence and the authors' clinical experience to achieve safe, predictable management of vertically deficient ridg-

es. This approach is case-specific: in addition to anatomical factors, clinicians must consider their own experience and skill level and patient preferences and health concerns. This guideline allows judicious selection of vertical augmentation techniques for successful outcomes.

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References

1. Fu JH, Wang HL. Horizontal bone augmentation: The decision tree. *Int J Periodontics Restorative Dent* 2011;31:429–436.
2. Araújo MG, Lindhe J. Dimensional ridge alterations following tooth extraction. An experimental study in the dog. *J Clin Periodontol* 2005;32:212–218.
3. Daubert DM, Weinstein BF, Bordin S, Leroux BG, Flemming TF. Prevalence and predictive factors for peri-implant disease and implant failure: A cross-sectional analysis. *J Periodontol* 2015;86:337–347.
4. Monje A, Galindo-Moreno P, Tözüm TF, Suárez-López del Amo F, Wang HL. Into the paradigm of local factors as contributors for peri-implant disease: Short communication. *Int J Oral Maxillofac Implants* 2016;31:288–292.
5. Ilizarov GA. Basic principles of transosseous compression and distraction osteosynthesis [in Russian]. *Ortop Travmatol Protez* 1971;32:7–15.
6. Keestra JA, Barry O, Jong L, Wahl G. Long-term effects of vertical bone augmentation: A systematic review. *J Appl Oral Sci* 2016;24:3–17.
7. Misch CM. Comparison of intraoral donor sites for onlay grafting prior to implant placement. *Int J Oral Maxillofac Implants* 1997;12:767–776.
8. Milinkovic I, Cordaro L. Are there specific indications for the different alveolar bone augmentation procedures for implant placement? A systematic review. *Int J Oral Maxillofac Surg* 2014;43:606–625.
9. Aloy-Prósper A, Peñarrocha-Oltra D, Peñarrocha-Diago M, Peñarrocha-Diago M. The outcome of intraoral onlay block bone grafts on alveolar ridge augmentations: A systematic review. *Med Oral Patol Oral Cir Bucal* 2015;20:e251–e258.
10. Waasdorp J, Reynolds MA. Allogeneic bone onlay grafts for alveolar ridge augmentation: A systematic review. *Int J Oral Maxillofac Implants* 2010;25:525–531.
11. Monje A, Pikos MA, Chan HL, et al. On the feasibility of utilizing allogeneic bone blocks for atrophic maxillary augmentation. *Biomed Res Int* 2014;2014:814578.
12. Wang HL, Boyapati L. "PASS" principles for predictable bone regeneration. *Implant Dent* 2006;15:8–17.
13. Fiorellini JP, Nevins ML. Localized ridge augmentation/preservation. A systematic review. *Ann Periodontol* 2003;8:321–327.
14. Clementini M, Morlupi A, Canullo L, Agrestini C, Barlattani A. Success rate of dental implants inserted in horizontal and vertical guided bone regenerated areas: A systematic review. *Int J Oral Maxillofac Surg* 2012;41:847–852.
15. Jensen SS, Terheyden H. Bone augmentation procedures in localized defects in the alveolar ridge: Clinical results with different bone grafts and bone-substitute materials. *Int J Oral Maxillofac Implants* 2009;24(suppl):s218–s236.
16. Esposito M, Grusovin MG, Felice P, Karatzopoulos G, Worthington HV, Coulthard P. The efficacy of horizontal and vertical bone augmentation procedures for dental implants—A Cochrane systematic review. *Eur J Oral Implantol* 2009;2:167–184.
17. Urban IA, Jovanovic SA, Lozada JL. Vertical ridge augmentation using guided bone regeneration (GBR) in three clinical scenarios prior to implant placement: A retrospective study of 35 patients 12 to 72 months after loading. *Int J Oral Maxillofac Implants* 2009;24:502–510.

18. Urban IA, Lozada JL, Jovanovic SA, Nagursky H, Nagy K. Vertical ridge augmentation with titanium-reinforced, dense-PTFE membranes and a combination of particulated autogenous bone and anorganic bovine bone-derived mineral: A prospective case series in 19 patients. *Int J Oral Maxillofac Implants* 2014;29:185–193.
19. Urban IA, Monje A, Lozada JL, Wang HL. Long-term evaluation of peri-implant bone level after reconstruction of severely atrophic edentulous maxilla via vertical and horizontal guided bone regeneration in combination with sinus augmentation: A case series with 1 to 15 years of loading. *Clin Implant Dent Relat Res* 2017;19:46–55.
20. Urban IA, Monje A, Nevins M, Nevins ML, Lozada JL, Wang HL. Surgical management of significant maxillary anterior vertical ridge defects. *Int J Periodontics Restorative Dent* 2016;36:329–337.
21. 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;35:613–623.
22. Urban IA, Lozada JL, Wessing B, Suárez-López del Amo F, Wang HL. Vertical bone grafting and periosteal vertical mattress suture for the fixation of resorbable membranes and stabilization of particulate grafts in horizontal guided bone regeneration to achieve more predictable results: A technical report. *Int J Periodontics Restorative Dent* 2016;36:153–159.
23. Monje A, Chan HL, Fu JH, Suarez F, Galindo-Moreno P, Wang HL. Are short dental implants (<10 mm) effective? A meta-analysis on prospective clinical trials. *J Periodontol* 2013;84:895–904.
24. Esposito M, Grusovin MG, Felice P, Karatzopoulos G, Worthington HV, Coulthard P. Interventions for replacing missing teeth: Horizontal and vertical bone augmentation techniques for dental implant treatment. *Cochrane Database Syst Rev* 2009;(4):CD003607.
25. Monje A, Suarez F, Galindo-Moreno P, García-Nogales A, Fu JH, Wang HL. A systematic review on marginal bone loss around short dental implants (<10 mm) for implant-supported fixed prostheses. *Clin Oral Implants Res* 2014; 25:1119–1124.
26. Nisand D, Picard N, Rocchietta I. Short implants compared to implants in vertically augmented bone: A systematic review. *Clin Oral Implants Res* 2015;26(suppl):s170–s179.
27. Pistilli R, Felice P, Cannizzaro G, et al. Posterior atrophic jaws rehabilitated with prostheses supported by 6 mm long 4 mm wide implants or by longer implants in augmented bone. One-year post-loading results from a pilot randomized controlled trial. *Eur J Oral Implantol* 2013;6:359–372.
28. Jung RE, Herzog M, Wolleb K, Ramel CF, Thoma DS, Hämmerle CH. A randomized controlled clinical trial comparing small buccal dehiscence defects around dental implants treated with guided bone regeneration or left for spontaneous healing. *Clin Oral Implants Res* 2017;28:348–354.
29. Moses O, Pitaru S, Artzi Z, Nemcovsky CE. Healing of dehiscence-type defects in implants placed together with different barrier membranes: A comparative clinical study. *Clin Oral Implants Res* 2005; 16:210–219.
30. Llambés F, Silvestre FJ, Caffesse R. Vertical guided bone regeneration with bio-absorbable barriers. *J Periodontol* 2007; 78:2036–2042.
31. Jung RE, Benic GI, Scherrer D, Hämmerle CH. Cone beam computed tomography evaluation of regenerated buccal bone 5 years after simultaneous implant placement and guided bone regeneration procedures—A randomized, controlled clinical trial. *Clin Oral Implants Res* 2015;26:28–34.
32. Rocchietta I, Simion M, Hoffmann M, Trisciuglio D, Benigni M, Dahlin C. Vertical bone augmentation with an autogenous block or particles in combination with guided bone regeneration: A clinical and histological preliminary study in humans. *Clin Implant Dent Relat Res* 2016; 18:19–29.
33. Simion M, Rocchietta I, Dellavia C. Three-dimensional ridge augmentation with xenograft and recombinant human platelet-derived growth factor-BB in humans: Report of two cases. *Int J Periodontics Restorative Dent* 2007;27: 109–115.
34. Chiapasco M, Casentini P, Zaniboni M. Implants in reconstructed bone: A comparative study on the outcome of Straumann tissue level and bone level implants placed in vertically deficient alveolar ridges treated by means of autogenous onlay bone grafts. *Clin Implant Dent Relat Res* 2014;16:32–50.
35. Peñarrocha-Oltra D, Aloy-Prósper A, Cervera-Ballester J, Peñarrocha-Diago M, Canullo L, Peñarrocha-Diago M. Implant treatment in atrophic posterior mandibles: Vertical regeneration with block bone grafts versus implants with 5.5-mm intrabony length. *Int J Oral Maxillofac Implants* 2014;29:659–666.
36. Schwartz-Arad D, Ofec R, Eliyahu G, Ruban A, Sterer N. Long term follow-up of dental implants placed in autologous onlay bone graft. *Clin Implant Dent Relat Res* 2016;18:449–461.