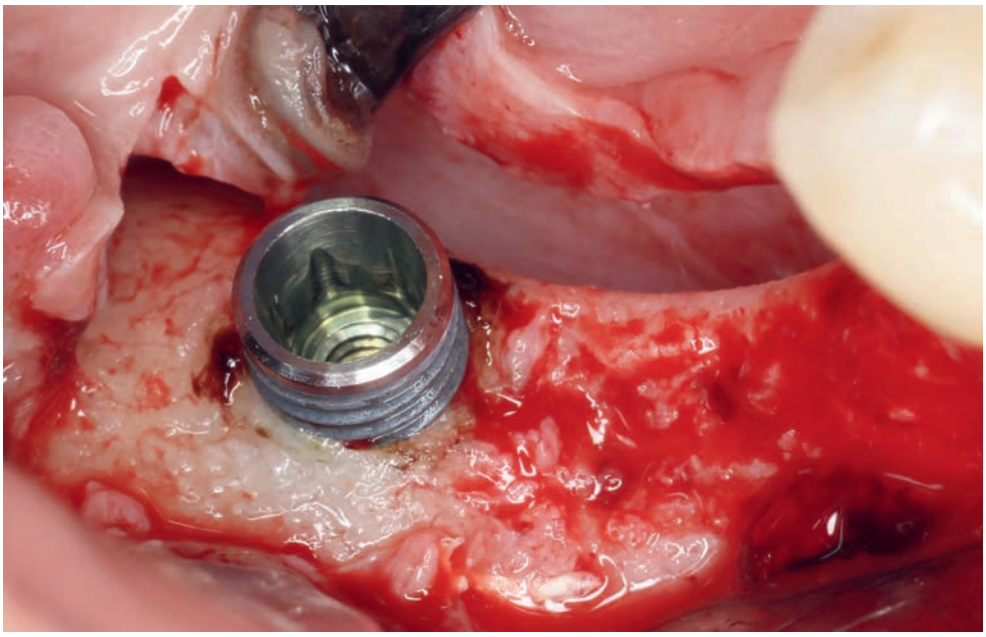

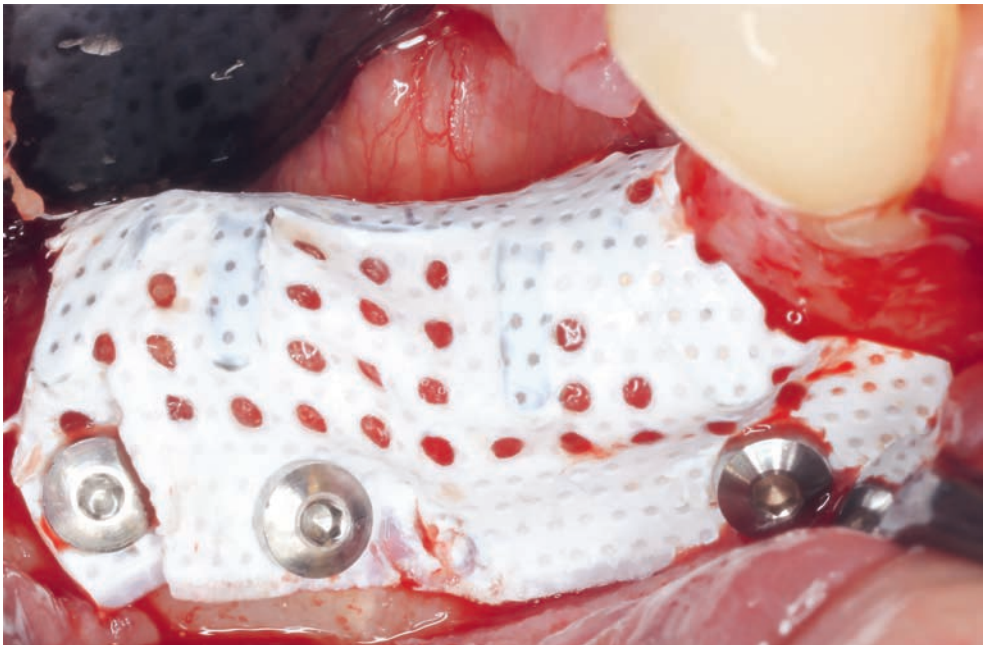

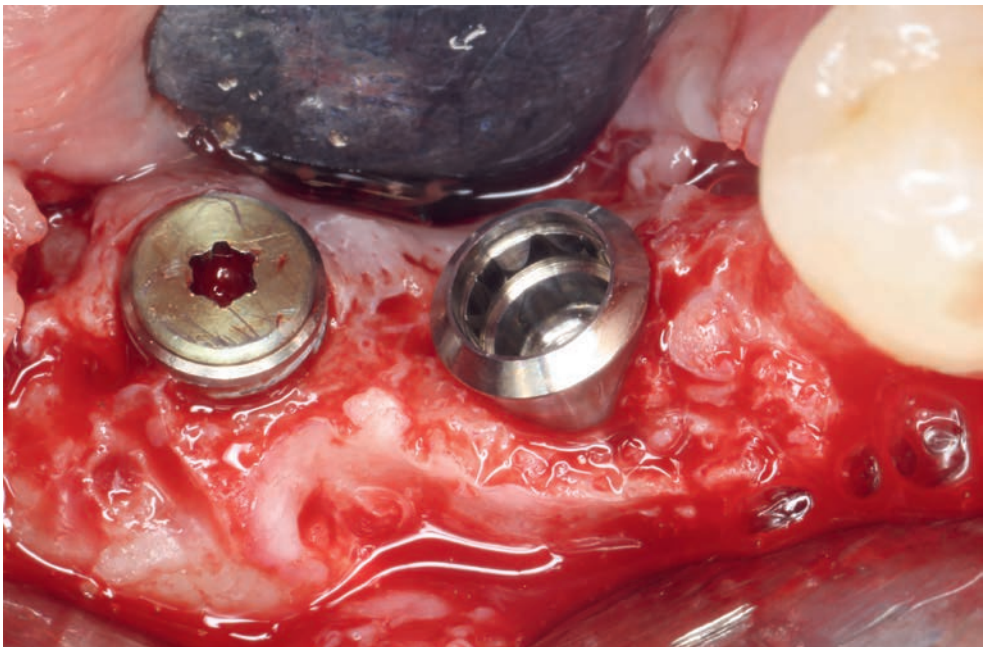

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Decision Tree for Reconstructive Treatment of Peri-implantitis Defects

Peri-implantitis is a common complication among patients receiving implant-supported restorative therapy, and it often requires surgical intervention for effective treatment. Understanding the specific configuration of the peri-implant bony defect and adjacent bone peaks is crucial for tailoring treatment strategies and improving outcomes. A decision tree for reconstructive peri-implantitis therapy has been developed based on the new classification of defect configurations (Classes I to V), guiding clinicians in selecting treatment options, including biomaterials, techniques, and healing approaches. Furthermore, clinicians are encouraged to consider various factors such as local predisposing factors (including soft tissue characteristics, prosthetic design, and implant position in a 3D perspective), clinical factors (surgeon skill and experience), and patient-related factors (such as local and systemic health, preferences, and cost) when evaluating reconstructive therapy options.
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Keywords: *bone regeneration, dental implants, peri-implant defect, peri-implantitis, reconstructive therapy*

Peri-implantitis is an inflammatory response occurring in tissues surrounding dental implants, characterized by signs of inflammation and progressive bone loss extending beyond the initial biologic bone remodeling.[1] Peri-implantitis has been reported to affect approximately 22% of individuals.[2] If left untreated, this condition follows a nonlinear accelerating pattern of bone loss, ultimately resulting in implant failure, which imposes a significant financial burden and affects overall patient well-being.[3,4]

The primary goal in treating peri-implantitis is to alleviate soft tissue inflammation and subsequently arrest further marginal bone loss. While nonsurgical therapy has shown limited effectiveness, surgical procedures have proven to be more successful by accessing and removing biofilm and related calculus from the implant

surface. Various surgical modalities are available, including access flap surgery, resective therapy, reconstructive therapy, and a combined approach.[5,6] Complementing the primary objective, the specific goal of reconstructive therapy is to regenerate the compromised bony architecture, facilitate reosseointegration, and minimize soft tissue recession, thereby providing what could be considered an ideal therapeutic outcome. Additionally, long-term stability should take into account the maintainability and cleansibility by both the patient and dental professionals. The literature supports the efficacy of reconstructive procedures; however, achieving complete reconstruction of lost tissues remains unpredictable. On average, there is a bone gain of approximately 2 mm and ~60% of defect fill.[7]

Challenges associated with reconstructing peri-implant tissues include ineffective surface treatment, unfavorable bone topography, inferior tissue perfusion, and unstable wound conditions.[8] In terms of surface treatment, none of the strategies (mechanical, chemical, implantoplasty, laser, and electrolysis) have been found to be superior to others. Complete decontamination cannot typically be achieved by single strategy, and a combination approach is frequently recommended and employed.[9] The wide variations observed in reported outcomes of reconstructive therapy may be attributed to numerous factors, including the heterogeneity in the configuration of peri-implant bone defects,[10–12] the selection of surgical techniques and biomaterials,[13] the skill level of surgeons, and the healing approach (submerged/nonsubmerged).[14,15]

Treatment Methods

Configuration of Peri-implant Bone Defect

Defect configuration has been shown to play a critical role in reconstructive outcomes.[10] In 2007, Schwarz et al[16] introduced a classification for peri-implant bone defects based on the pattern of bone loss observed around 40 implants. It was found that the most common peri-implant defect configuration is a combined defect (79%), comprising both a supracrestal defect (Class II) and an infraosseous component (Class I). The infraosseous defect was further categorized into five subclasses (Ia to Ie), depending on the presence or absence of buccal or lingual bony walls. Notably, a circumferential defect (Class Ie) was the most frequently observed (55.3%). Other defect types include buccal dehiscence defects with semicircular bone resorption extending to the middle of the implant body (Class Ib; 15.8%), and buccal dehiscence defects with a circular bone resorption with (Class Ic) or without (Class Id) the lingual component (13.3% and 10.2%, respectively). The least common category comprises conventional buccal dehiscence defects (Class Ia; 5.4%). Likewise, Serino et al[17] evaluated bone loss during open flap access and found that 66% of the defects were circumferential. García-García et al[18] observed that upon surgical entry, 32.6% of the defects presented a circumferential configuration (Class 1e), while 43.5% displayed a circumferential defect combined with a buccal dehiscence-type defect (Class Ic; 26.1%) and missing buccal/lingual (Class 1d; 17.4%). More recently, the peri-implant defect morphology has been further studied in a large clinical trial by Monje et al[19] and classified into three major defect categories: infraosseous (Class I), horizontal (Class II), and combined (Class III). These were then subclassified into dehiscence, 2- or 3-wall, and circumferential-type defect based on the number of remaining bony walls. Interestingly, the most prevalent defect morphology type identified in this study was 2- or 3-wall (68.9%). This has been consistently confirmed in clinical trials, showing that implants with peri-implantitis typically exhibit a combination of intrabony and buccal/oral dehiscence defects rather than purely circumferential defects.[11,20–22] In addition, a previously undescribed category of "Class Id with only one bone wall" was frequently observed (11.9%).[20]

Overall, compared to other defect types, circumferential defect was associated with greater probing pocket depth reduction and clinical attachment level gain,[10] as well as better bone fill after reconstructive therapy.[11,23] A positive correlation was found between bone gain and defect depth in infraosseous components.[11] Additionally, a baseline narrow defect angle (< 40 degrees) of peri-implantitis intrabony components was found

to result in better radiographic bone gain in reconstructive therapy.[12] The 15th European Workshop on Periodontology recommended indication criteria for reconstructive peri-implantitis therapy, specifically mentioning implant sites with a defect depth of ≥ 3 mm, ideally with intrabony 3- or 4-wall contained defects.[24]

Surgical Techniques and Biomaterials

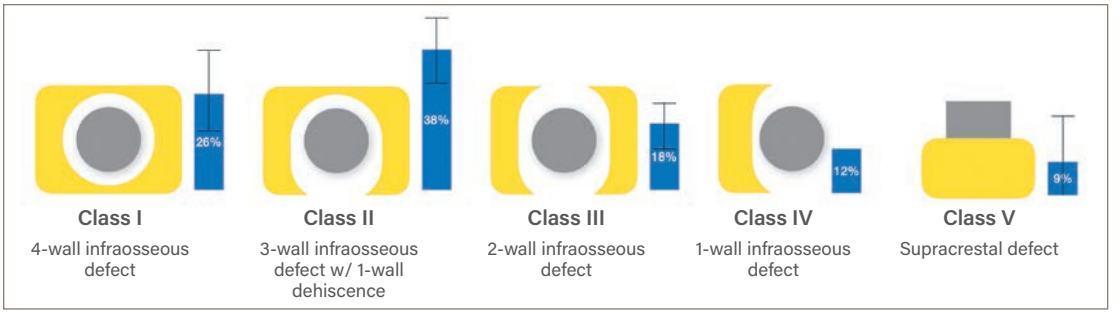
Treatment options and considerations for both horizontal[25] and vertical[26–28] bone augmentation in edentulous areas have been extensively documented, considering defect morphology and the required bone width/height. In the context of peri-implantitis defect reconstruction, guided bone regeneration (GBR) stands out as the most frequently reported technique. A variety of bone substitutes have been explored in this therapeutic approach, including autogenous bone, allograft, xenograft (either alone or combined with autogenous bone, collagen [10%], or biologic materials), as well as synthetic materials such as hydroxyapatite/tricalcium phosphate and porous titanium granules. Despite the numerous options available, significant heterogeneity exists concerning radiographic bone gain and disease resolution, making it challenging to determine the most suitable bone substitute.[13]

Utilizing a barrier membrane in constructive peri-implantitis therapy remains a topic of debate due to variations in defect configurations, types of bone grafting materials used, and implant positioning.[13] However, based on current evidence regarding edentulous sites, collagen membranes may be suitable for gains up to 3 mm.[28] The application and fixation of a membrane may prove beneficial,[29h] with the sausage technique demonstrating particularly favorable outcomes, achieving horizontal bone gain up to 5 mm.[30] In cases where augmentation requirements approach 5 mm, especially in the vertical dimension, a nonresorbable membrane, such as titanium-reinforced dense polytetrafluoroethylene (Ti-reinforced d-PTFE), may be preferred.[30] Extensive research has been conducted on the application of biologic materials in the fields of periodontal and implantology[31]; however, the literature on peri-implantitis therapy is limited to platelet-rich fibrin, enamel matrix derivative, and human recombinant bone morphogenetic protein type-2 (rhBMP-2). A recent systematic review on 21 animal studies suggested that the application of BMP-2 in peri-implant defects is associated with improved histometric outcomes, an increased percentage of defect fill, and greater vertical bone regeneration compared to untreated defects.[32] Although preliminary cases treated with rhBMP-2 by the present research team have yielded promising outcomes, there is a pressing need for comprehensive clinical trials to broadly assess its efficacy and potential benefits in the treatment of peri-implantitis. This will allow for a more conclusive understanding of the role of rhBMP-2 in the reconstructive therapy of these conditions. It should also be noted that BMP-2 is not universally available worldwide.

Healing Approach (Submerged vs Nonsubmerged)

In reconstructive therapy, two primary healing approaches are commonly utilized: submerged and nonsubmerged protocols. In the nonsubmerged protocol, either the implant crowns or healing abutments are kept in place during treatment and healing. This method offers advantages such as the potential avoidance of a new crown and shorter treatment duration. However, challenges include difficulty achieving primary closure and a higher risk of membrane exposure. Additionally, bulky crowns may impede disinfection and instrumentation during surgery. Favorable outcomes have been reported when applying nonsubmerged healing in circumferential defects, while in other defect types, such as noncontained defects with openings at the buccal and/or lingual aspect, less improvement was noted.[10,11] In one randomized clinical trial, reconstructive therapy with nonsubmerged healing showed outcomes similar to those of access flap alone.[22]

In contrast, the submerged approach aims to facilitate access for debridement and detoxification procedures, achieving aseptic healing. Following the example set by guided tissue/bone regeneration, submerged healing is a crucial step for stabilizing the blood clot, improving graft stability, and maximizing the regenerative potential. Drawbacks of submerged healing include the need for



▲ **Fig 1** Classification and frequency distribution of the defect configuration.

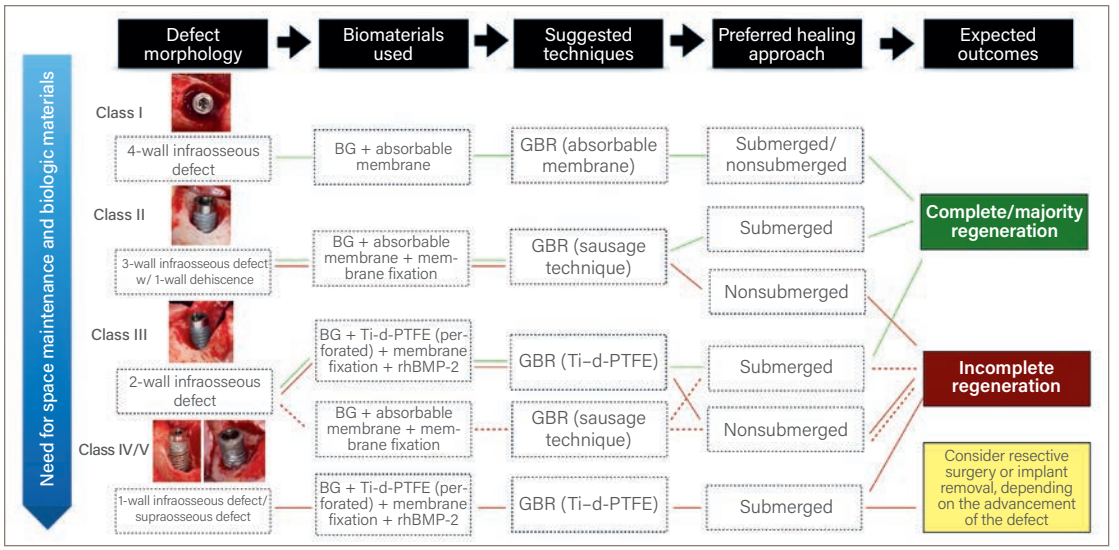
prosthesis retrieval, increased postsurgical discomfort and swelling due to the efforts to release the flap, greater overall complexity, and a longer duration required for full restoration of function. In a case series, Roos-Jansåker et al[33] demonstrated that submerged healing for 6 months reduced the probing pocket depth by 4.2 mm and achieved a mean defect fill of 2.3 mm, whereas nonsubmerged healing applied by the same group yielded significantly less optimal outcomes.[34] Monje et al reported the benefits of submerged guided bone regeneration for managing 2- or 3-wall infraosseous and combined peri-implantitis bone defects, utilizing a combination of 1:1 autogenous bone/Bio-Oss (Geistlich) and collagen membranes, stabilized with tacks when possible.[14] Wen et al conducted two prospective studies[35,36] evaluating nonsubmerged and submerged approaches for treating infraosseous peri-implant defects, with the submerged group showing superior clinical outcomes.[15] In their submerged protocol, a composite bone graft and a nonresorbable membrane (d-PTFE) were used, reporting a clinical bone gain of approximately 3.5 mm at reentry at 8 months.

Understanding the specific configuration of the bony defect is crucial for tailoring treatment methods and improving outcomes. Osseous regeneration predominantly stems from the surrounding bone walls. Therefore, the morphology of the peri-implant bone defect and adjacent bone peaks should guide selection of biomaterials and techniques. An unfavorable morphology presents greater challenges to regeneration, often necessitating space maintenance and the use of biologic materials. Although prognostic systems and management strategies for failing implants have been proposed, techniques in reconstructive therapy have not been adequately addressed.[37,38] Given the role that defect morphology plays upon decision-making in peri-implantitis treatment, the present article aimed to propose a new decision tree for reconstructive peri-implantitis therapy based on different bone defect morphology.

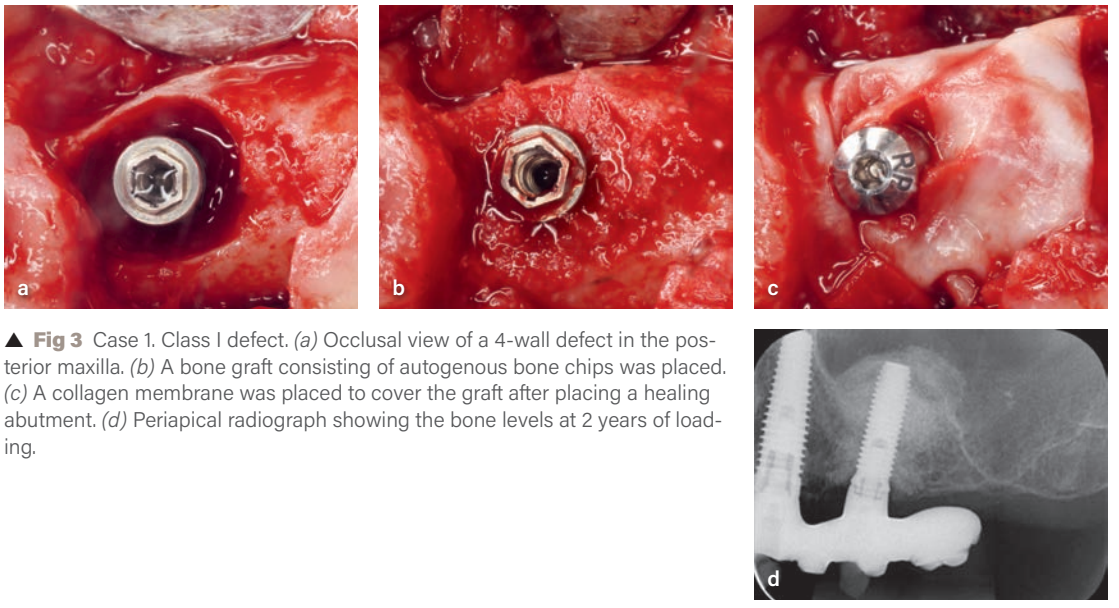
Proposed Decision Tree for Reconstructive Peri-implantitis Therapy

The decision-making process starts with identifying the defect morphology. The current defect classification, stratified into Classes I to V (Fig 1), is a modification of a previously published work by one of the present authors (H.L.W.).[19] It includes Class I (4-wall infraosseous defect), Class II (3-wall infraosseous defect with a 1-wall dehiscence), Class III (2-wall infraosseous defect), Class IV (1-wall infraosseous defect), and Class V (supracrestal defect). Their prevalence rates were further calculated from the existing literature[11,16–22] using a random effects model and Stata software (version 16.0, StataCorp).

Recommended treatment options (biomaterials, technique, and healing approach) are provided for each defect type (Fig 2). This decision tree is recommended for situations where the implant is centrally placed within the ridge. If the implant is positioned too far buccally or lingually/palatally from the ideal position, or if it is not feasible to achieve a 1.5-mm bone thickness[39] due to it being out of bony housing, other treatment options such as a combined approach (resective/



▲ **Fig 2** Flowchart demonstrating the decision-making process for reconstructive peri-implantitis therapy. BG = bone graft; GBR = guided bone regeneration; Ti–d-PTFE = titanium-reinforced dense polytetrafluoroethylene; rhBMP-2 = human recombinant bone morphogenetic protein 2.

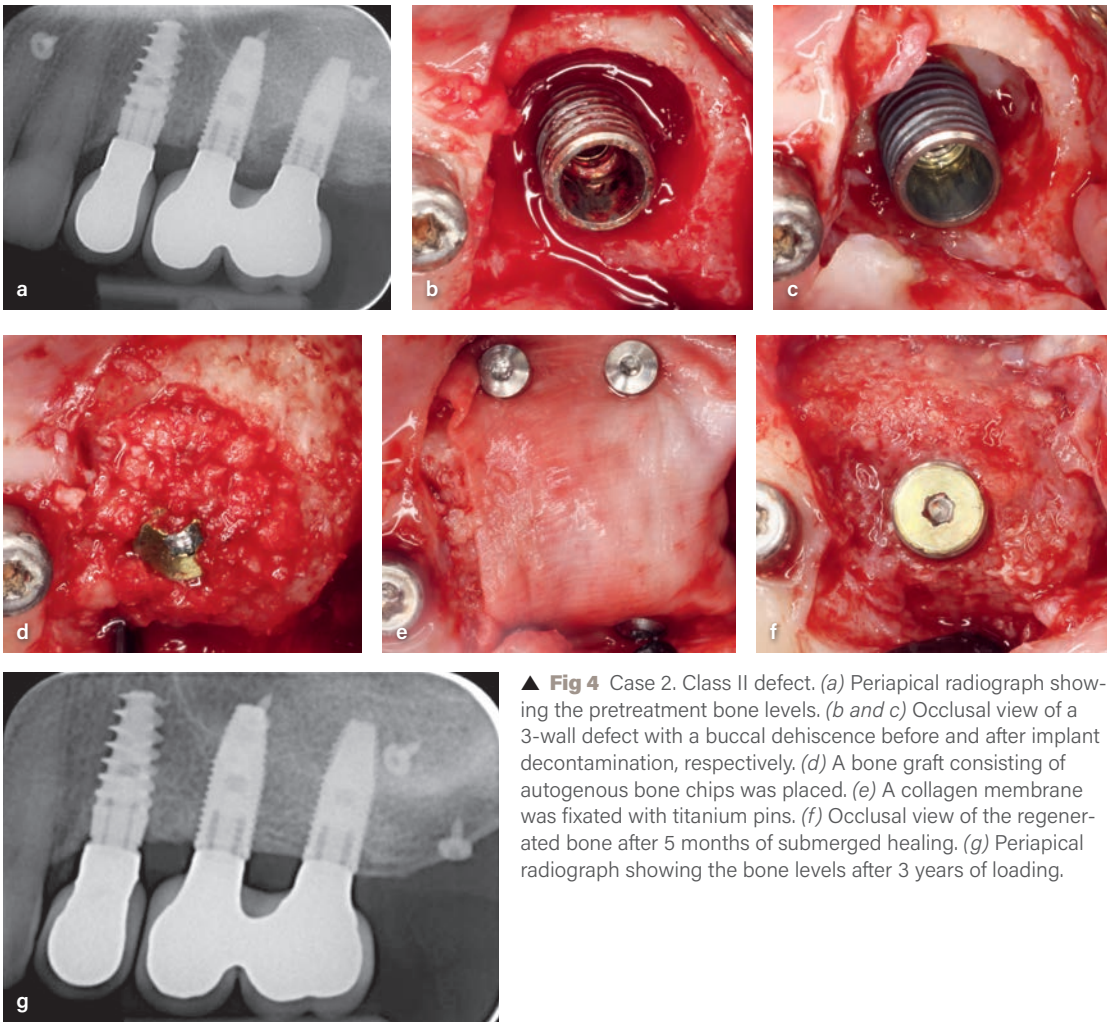


▲ **Fig 3** Case 1. Class I defect. *(a)* Occlusal view of a 4-wall defect in the posterior maxilla. *(b)* A bone graft consisting of autogenous bone chips was placed. *(c)* A collagen membrane was placed to cover the graft after placing a healing abutment. *(d)* Periapical radiograph showing the bone levels at 2 years of loading.

reconstructive) or implant removal should be considered.[38]

Class I: 4-Wall Infraosseous Defect

This defect corresponds to Class Ie in Schwarz's classification, characterized by circular bone resorption while maintaining the integrity of the buccal and oral compacta. Its prevalence rate is ~26% (95% CI: 14% to 39%) based on current evidence.[11,16–22] In this defect type, when thorough debridement is performed, the presence of an existing implant creates a clinical scenario similar to immediate implant placement in an intact socket. The circumferential defect has been demonstrated to be the most favorable defect type for regeneration.[10,11] GBR treatment with a bone graft and absorbable membrane is suggested (Fig 3). Complete bone regeneration up to the implant level can be achieved with either submerged or nonsubmerged healing.



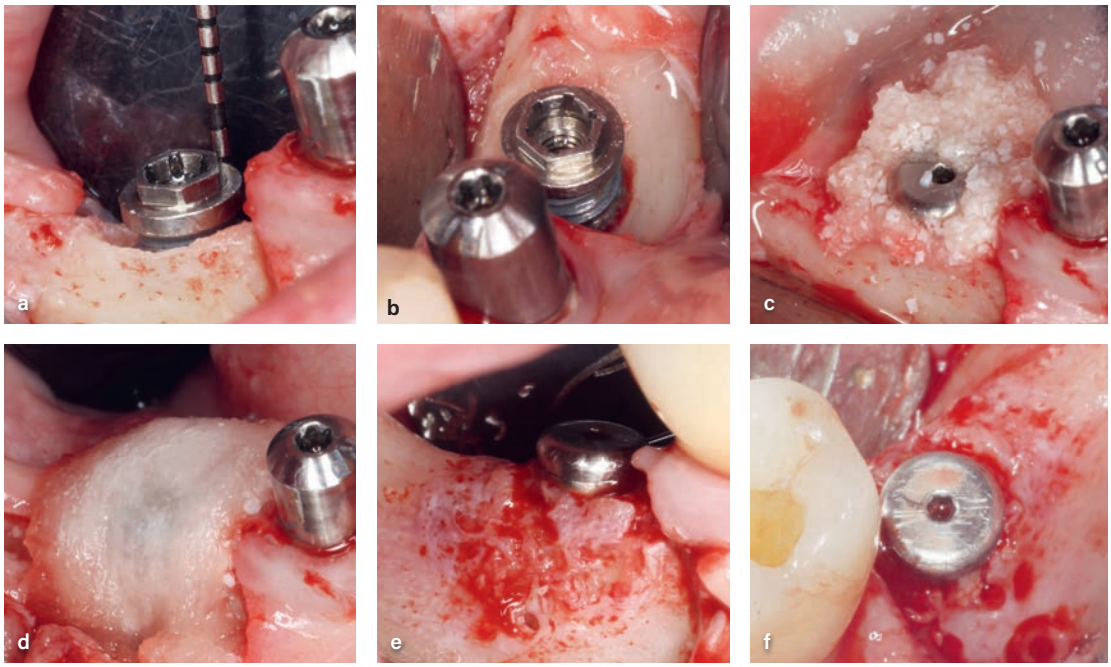
▲ **Fig 4** Case 2. Class II defect. *(a)* Periapical radiograph showing the pretreatment bone levels. *(b and c)* Occlusal view of a 3-wall defect with a buccal dehiscence before and after implant decontamination, respectively. *(d)* A bone graft consisting of autogenous bone chips was placed. *(e)* A collagen membrane was fixated with titanium pins. *(f)* Occlusal view of the regenerated bone after 5 months of submerged healing. *(g)* Periapical radiograph showing the bone levels after 3 years of loading.

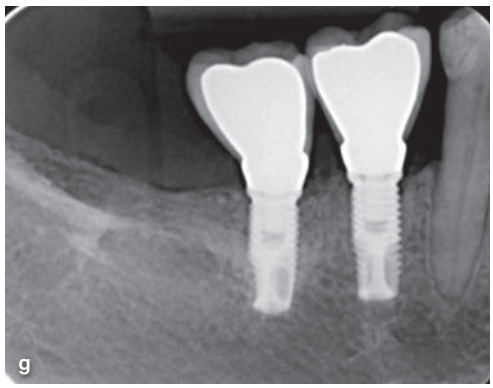
Class II: 3-Wall Infraosseous Defect with a 1-Wall Dehiscence

This type of defect is categorized as a partially contained defect with a buccal or lingual "opening." It can be regarded as a 2- or 3-wall defect in Monje's classification and a combination of Classes 1b and 1c in Schwarz's classification. The prevalence rate for this defect is 38% (95% CI: 27% to 49%) based on six studies.[11,16,18–21] With thorough debridement performed, the presence of an existing implant creates a clinical scenario that mimics simultaneous implant placement with bone regeneration or immediate implant placement in type 2 sockets. Studies have reported less favorable outcomes when using a collagen membrane without fixation and nonsubmerged healing in this defect type.[10,11,22] However, benefits have been seen when the membrane was tacked and a submerged approach healing was used.[14] The sausage technique, which immobilizes the native collagen membrane with a titanium pin and pushes the bone graft material crestally to create a balloon effect, is recommended in conjunction with submerged healing for this defect type (Figs 4 and 5).

Class III: 2-Wall Infraosseous Defect

This defect type comprises buccal dehiscence defects with circular bone resorption, resulting in the loss of lingual compacta (same as Schwarz Class 1d). It exhibits two walls on the mesial and distal aspects, and the estimated prevalence rate is 18% (95% CI: 12% to 24%).[16,18,20,21] Its challenging morphology necessitates extensive space



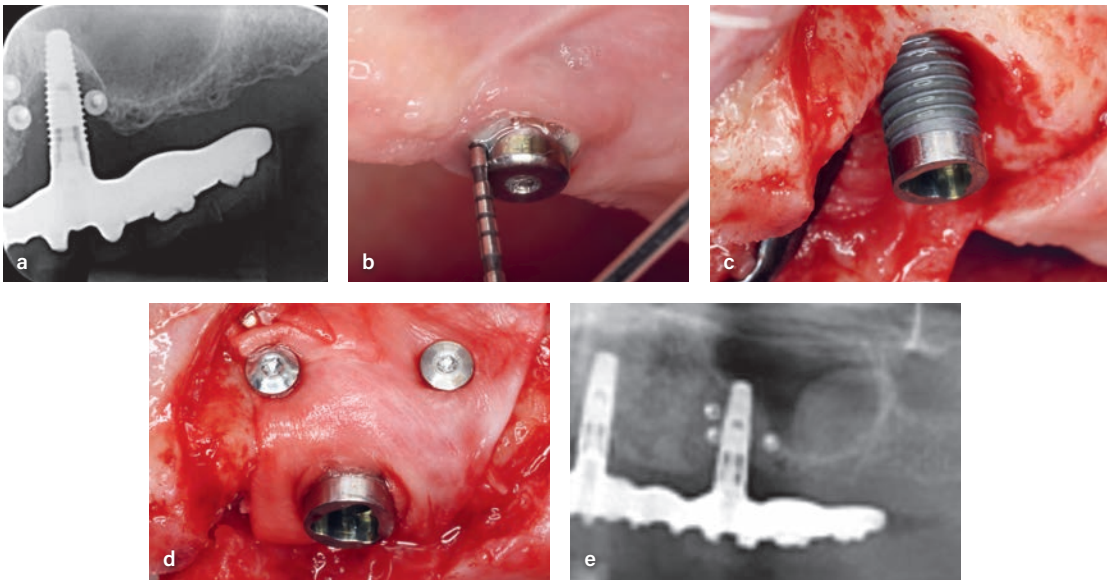


▲ **Fig 5** Case 3. Class II defect. *(a and b)* Labial and lingual views, respectively, of a 3-wall defect with a lingual dehiscence. *(c)* A bone graft consisting of 90% anorganic bovine bone mineral and 10% porcine collagen (Bio-Oss, Geistlich) was placed. *(d)* The graft was covered with a collagen matrix infiltrated with 0.5 mg of rhBMP-2 (Infuse, Medtronic). The matrix was fixated with titanium pins. *(e and f)* Labial and lingual views, respectively, of the regenerated bone at 6 months of submerged healing. *(g)* Periapical radiograph showing the complete bone fill after 6 months of loading.

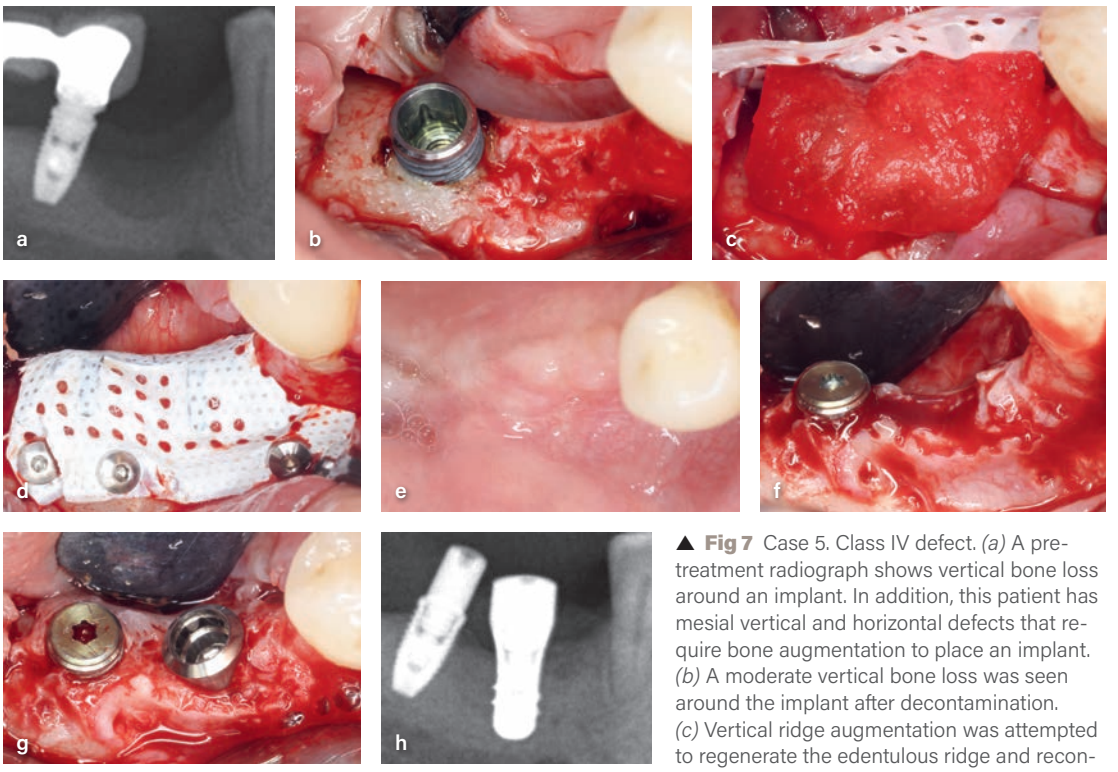
maintenance and the potential use of biologic materials. While the sausage technique could still be employed in this category, achieving complete regeneration may be less predictable (Fig 6). For large vertical bone augmentations, GBR using a nonresorbable membrane with a titanium (Ti)-reinforced framework may be preferred.[35,40]

Class IV: 1-Wall Infraosseous Defect & Class V: Supracrestal Defect

Generally, Class IV defects fulfill the criteria of Class III defects, but they lack either the mesial or distal bone wall. Class V defects correspond to Schwarz and Monje's Class II, indicating horizontal bone loss. Class IV was reported in only one study,[20] comprising 12% of the defects. The reported prevalence rate for pure supracrestal defects is around 9%. In cases with a moderate defect (< 4 mm), the sausage technique using a well-fixated resorbable membrane and submerged healing could achieve favorable results. In advanced peri-implantitis cases with noncontained defects and a vertical component, combining the strategic application of advanced barrier membranes with long-term stability (such as Ti-reinforced d-PTFE), bone grafts possessing higher osteoconductive and intrinsic osteoinductive potential, and rhBMP-2[41–43] or other biologic materials might significantly augment the site's reconstructive potential (Fig 7). Based on the present authors' clinical experience, using perforated Ti-reinforced



▲ **Fig 6** Case 4. Class III defect. *(a)* Periapical radiograph showing the pretreatment bone levels. *(b)* The site showed purulent exudate and a deep probing depth. *(c)* Labial view of a 2-wall defect with a dehiscence on the labial and lingual sides. *(d)* A collagen membrane was fixated over the graft with titanium pins. The graft consisted of autogenous bone chips directly on the implant surface and anorganic bovine bone mineral layered on the autograft. *(e)* A follow-up radiograph showing partial bone fill, which makes the future of this therapy questionable. Submerged healing and the use of a Ti-reinforced membrane would have made this regeneration more predictable. This is the least favorable result among the present examples.



▲ **Fig 7** Case 5. Class IV defect. *(a)* A pretreatment radiograph shows vertical bone loss around an implant. In addition, this patient has mesial vertical and horizontal defects that require bone augmentation to place an implant. *(b)* A moderate vertical bone loss was seen around the implant after decontamination. *(c)* Vertical ridge augmentation was attempted to regenerate the edentulous ridge and reconstruct the defect around the implant. *(d)* A perforated d-PTFE membrane was used, covering a collagen matrix infiltrated with 0.5 mg of BMP-2. No other bone graft material was utilized. *(e)* Occlusal view of the submerged healing. *(f)* The regenerated bone. *(g)* Bone gain was seen covering the implant as well as reconstructing the edentulous area, allowing implant placement. *(h)* A follow-up radiograph shows the bone gain around the implant.

PTFE covered by collagen soaked with low-dose rhBMP-2 has shown a favorable outcome (see Fig 6). Future studies are warranted to evaluate the effect of this treatment in the long-term.

Discussion

In addition to the defect morphology, it has been well-documented that disease severity impacts the peri-implantitis resolution, particularly for the resective approach.[44–48] Studies suggest a significantly lower success rate for surgically managing peri-implantitis when the defect extends to 5 mm or is more than a third of the implant length.[44,45] Additionally, baseline advanced bone loss (> 50% of the implant length) is strongly linked to therapeutic failure, with an odds ratio of 20 compared to bone loss < 25% of implant length.[47] In cases with advanced bone loss (> 50% relative to the implant length), the possibility of reconstruction remains, yet it largely depends on the lesion's nature. If the deficit is primarily intrabony and deemed capable of effectively containing the grafting material, reconstructive approaches are considered viable.[38,49] Utilizing a d-PTFE membrane may indeed improve wound stability and maintain the requisite space for regeneration. It is important to note, however, that d-PTFE application demands a high degree of surgical expertise due to its sensitive technique requirements and the heightened risk of membrane exposure if the procedure is not executed with precision. Careful consideration of patient-specific factors, including the potential for increased morbidity and an assessment of overall cost-effectiveness, is essential in determining the suitability of this intervention.

Conversely, in situations where a significant portion of the bone loss is supracrestal, particularly in Class IV or V cases, alternative strategies may be more suitable. These can include a resective approach tailored to the individual case or, if justified by the circumstances, implant removal. Choosing between these options should be informed by comprehensive evaluations encompassing the defect location, degree of bone loss, technical skillset of the surgeon, and anticipated impact on esthetic and phonetic outcomes. The present revised decision tree aims to provide more specific and strategically sound recommendations, ensuring that treatment choices are grounded in detailed clinical assessments and the unique needs of the patient.

With respect to soft tissue management, a narrow width of keratinized tissue has been associated with detrimental outcomes, including increased biofilm accumulation, soft tissue inflammation, heightened patient discomfort during oral hygiene procedures, mucosal recession, and a consequent increased incidence of peri-implantitis and marginal bone loss.[50] In cases where such conditions coexist with pathologic changes in the peri-implant mucosa, surgical intervention may be warranted to increase the keratinized tissue dimensions. The standard of care for augmenting the keratinized tissue width typically involves the use of apically positioned flaps in conjunction with autogenous soft-tissue grafts. This procedure is ideally performed after the bone regeneration healing period, as undertaking free gingival grafting beforehand could compromise flap elasticity and may impede the ability to attain tension-free primary wound closure.

Conclusions

Limited evidence exists regarding reconstructive peri-implantitis therapy. The proposed decision tree was developed based on available evidence and the authors' clinical experience, serving as a guide for selecting clinical procedures based on defect configuration. When considering reconstructive therapy, the authors urge the clinician to evaluate local predisposing (soft tissue characteristics, prosthetic design, 3D implant position), clinical (surgeon skill and experience), and patient-related (local and systemic health, preferences, cost) factors.

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References

1. Schwarz F, Derks J, Monje A, Wang HL. Peri-implantitis. J Clin Periodontol 2018;45(suppl 20):s246–s266.
2. Derks J, Tomasi C. Peri-implant health and disease. A systematic review of current epidemiology. J Clin Periodontol 2015;42(suppl 16):s158–s171.
3. Derks J, Schaller D, Håkansson J, Wennström JL, Tomasi C, Berglundh T. Effectiveness of implant therapy analyzed in a Swedish population: Prevalence of peri-implantitis. J Dent Res 2016;95:43–49.
4. Abrahamsson KH, Wennström JL, Berglundh T, Abrahamsson I. Altered expectations on dental implant therapy; views of patients referred for treatment of peri-implantitis. Clin Oral Implants Res 2017;28:437–442.
5. Schwarz F, Jepsen S, Obreja K, Galarraga-Vinueza ME, Ramanauskaite A. Surgical therapy of peri-implantitis. Periodontol 2000 2022;88:145–181.
6. Ramanauskaite A, Cafferata EA, Begic A, Schwarz F. Surgical interventions for the treatment of peri-implantitis. Clin Implant Dent Relat Res 2023;25:682–695.
7. Tomasi C, Regidor E, Ortiz-Vigón A, Derks J. Efficacy of reconstructive surgical therapy at peri-implantitis-related bone defects. A systematic review and meta-analysis. J Clin Periodontol 2019;46(suppl 21):340–356.
8. Chan HL, Rodriguez Betancourt A, Liu CC, Chiang YC, Schmidlin PR. A conceptual review on reconstructive peri-implantitis therapy: Challenges and opportunities. Clin Exp Dent Res 2023;9:735–745.
9. Monje A, Amerio E, Cha JK, et al. Strategies for implant surface decontamination in peri-implantitis therapy. Int J Oral Implantol (Berl) 2022;15:213–248.
10. Schwarz F, Sahm N, Schwarz K, Becker J. Impact of defect configuration on the clinical outcome following surgical regenerative therapy of peri-implantitis. J Clin Periodontol 2010;37:449–455.
11. Aghazadeh A, Persson RG, Renvert S. Impact of bone defect morphology on the outcome of reconstructive treatment of peri-implantitis. Int J Implant Dent 2020;6:33.
12. Monje A, Pons R, Sculean A, Nart J, Wang HL. Defect angle as prognostic indicator in the reconstructive therapy of peri-implantitis. Clin Implant Dent Relat Res 2023;25:992–999.
13. Monje A, Pons R, Nart J, Miron RJ, Schwarz F, Sculean A. Selecting biomaterials in the reconstructive therapy of peri-implantitis. Periodontol 2000 2024;94:192–212.
14. Monje A, Pons R, Roccuzzo A, Salvi GE, Nart J. Reconstructive therapy for the management of peri-implantitis via submerged guided bone regeneration: A prospective case series. Clin Implant Dent Relat Res 2020;22:342–350.
15. Wen SC, Sabri H, Dastouri E. Submerged vs non-submerged reconstructive approach for surgical treatment of peri-implantitis: Re-analysis of two prospective clinical studies. Int J Oral Maxillofac Implants 2024;39:526–536.
16. Schwarz F, Herten M, Sager M, Bieling K, Sculean A, Becker J. Comparison of naturally occurring and ligature-induced peri-implantitis bone defects in humans and dogs. Clin Oral Implants Res 2007;18:161–170.
17. Serino G, Turri A, Lang NP. Probing at implants with peri-implantitis and its relation to clinical peri-implant bone loss. Clin Oral Implants Res 2013;24:91–95.
18. García-García M, Mir-Mari J, Benic GI, Figueiredo R, Valmaseda-Castellón E. Accuracy of periapical radiography in assessing bone level in implants affected by peri-implantitis: A cross-sectional study. J Clin Periodontol 2016;43:85–91.
19. Monje A, Pons R, Insua A, Nart J, Wang HL, Schwarz F. Morphology and severity of peri-implantitis bone defects. Clin Implant Dent Relat Res 2019;21:635–643.
20. Wehner C, Bertl K, Durstberger G, Arnhart C, Rausch-Fan X, Stavropoulos A. Characteristics and frequency distribution of bone defect configurations in peri-implantitis lesions—A series of 193 cases. Clin Implant Dent Relat Res 2021;23:178–188.
21. Roccuzzo M, Mirra D, Pittoni D, Ramieri G, Roccuzzo A. Reconstructive treatment of peri-implantitis infrabony defects of various configurations: 5-year survival and success. Clin Oral Implants Res 2021;32:1209–1217.
22. Derks J, Ortiz-Vigón A, Guerrero A, et al. Reconstructive surgical therapy of peri-implantitis: A multicenter randomized controlled clinical trial. Clin Oral Implants Res 2022;33:921–944.
23. Schlee M, Rathe F, Brodbeck U, Ratka C, Weigl P, Zipprich H. Treatment of peri-implantitis-electrolytic cleaning versus mechanical and electrolytic cleaning—A randomized controlled clinical trial–Six-month results. J Clin Med 2019;8:1909.
24. Jepsen S, Schwarz F, Cordaro L, et al. Regeneration of alveolar ridge defects. Consensus report of group 4 of the 15th European Workshop on Periodontology on Bone Regeneration. J Clin Periodontol 2019;46(suppl 21):277–286.
25. Yu SH, Saleh MHA, Wang HL. Simultaneous or staged lateral ridge augmentation: A clinical guideline on the decision-making process. Periodontol 2000 2023;93:107–128.
26. Plonka AB, Urban IA, Wang HL. Decision tree for vertical ridge augmentation. Int J Periodontics Restorative Dent 2018;38:269–275.
27. Misch CM, Basma H, Misch-Haring MA, Wang HL. An updated decision tree for vertical bone augmentation. Int J Periodontics Restorative Dent 2021;41:11-21.
28. Urban I, Sanz-Sánchez I, Monje A, Montero E. Complications and treatment errors in peri-implant hard tissue management. Periodontol 2000 2023;92:278–298.
29. Wessing B, Lettner S, Zechner W. Guided bone regeneration with collagen membranes and particulate graft materials: A systematic review and meta-analysis. Int J Oral Maxillofac Implants 2018;33:87–100.
30. 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.
31. Avila-Ortiz G, Ambruster J, Barootchi S, et al. American Academy of Periodontology best evidence consensus statement on the use of biologics in clinical practice. J Periodontol 2022;93:1763–1770.
32. Lee E, Moy A, Nguyen T, Kao R, Lin GH. The effect of bone morphogenetic protein-2 (BMP-2) on volumetric and histometric outcomes for peri-implant defects in the animal model: A systematic review and meta-analysis. Int J Oral Maxillofac Implants 2023;38:651–666.
33. Roos-Jansåker AM, Renvert H, Lindahl C, Renvert S. Submerged healing following surgical treatment of peri-implantitis: A case series. J Clin Periodontol. 2007;34:723–727.

34. Roos-Jansåker AM, Lindahl C, Persson GR, Renvert S. Long-term stability of surgical bone regenerative procedures of peri-implantitis lesions in a prospective case-control study over 3 years. J Clin Periodontol 2011;38:590–597.
35. Wen SC, Barootchi S, Huang WX, Wang HL. Surgical reconstructive treatment for infraosseous peri-implantitis defects with a submerged healing approach: A prospective controlled study. J Periodontol 2022;93:195–207.
36. Wen SC, Barootchi S, Wang HL, Huang WX. Non-submerged reconstructive approach for peri-implantitis osseous defect with removal of implant crowns: One-year outcomes of a prospective case series study. J Periodontol 2022;93:1250–1261.
37. Sinjab K, Garaicoa-Pazmino C, Wang HL. Decision making for management of peri-implant diseases. Implant Dent 2018;27:276–281.
38. Rosen PS, Froum SJ, Sarmiento H, Wadhawani CP. A revised peri-implantitis classification scheme: Adding three-dimensional considerations to facilitate prognosis and treatment planning. Int J Periodontics Restorative Dent 2022;42:291–299.
39. Monje A, Chappuis V, Monje F, et al. The critical peri-implant buccal bone wall thickness revisited: An experimental study in the beagle dog. Int J Oral Maxillofac Implants 2019;34:1328–1336.
40. Wen SC, Huang WX, Wang HL. Regeneration of peri-implantitis infrabony defects: Report on three cases. Int J Periodontics Restorative Dent 2019;39:615–621.
41. Hanisch O, Tatakis DN, Boskovic MM, Rohrer MD, Wikesjö UM. Bone formation and reosseointegration in peri-implantitis defects following surgical implantation of rhBMP-2. Int J Oral Maxillofac Implants 1997;12:604–610.
42. Schwarz F, Sahm N, Mihatovic I, Golubovic V, Becker J. Surgical therapy of advanced ligature-induced peri-implantitis defects: Cone-beam computed tomographic and histological analysis. J Clin Periodontol 2011;38):939–949.
43. Park SY, Kim KH, Gwak EH, et al. Ex vivo bone morphogenetic protein 2 gene delivery using periodontal ligament stem cells for enhanced re-osseointegration in the regenerative treatment of peri-implantitis. J Biomed Mater Res A 2015;103:38–47.
44. Lagervall M, Jansson LE. Treatment outcome in patients with peri-implantitis in a periodontal clinic: A retrospective study. J Periodontol 2013;84:1365–1373.
45. de Waal YCM, Raghoebar GM, Meijer HJA, Winkel EG, van Winkelhoff AJ. Prognostic indicators for surgical peri-implantitis treatment. Clin Oral Implants Res 2016;27: 1485–1491.
46. Koldsland OC, Wohlfahrt JC, Aass AM. Surgical treatment of peri-implantitis: Prognostic indicators of short-term results. J Clin Periodontol 2018;45:100–113.
47. Ravidà A, Siqueira R, Di Gianfilippo R, et al. Prognostic factors associated with implant loss, disease progression or favorable outcomes after peri-implantitis surgical therapy. Clin Implant Dent Relat Res 2022;24:222–232.
48. Romandini M, Bougas K, Alibegovic L, et al. Long-term outcomes and prognostic factors of surgical treatment of peri-implantitis—A retrospective study. Clin Oral Implants Res 2024;35:321–329.
49. Froum SJ, Froum SH, Rosen PS. A regenerative approach to the successful treatment of peri-implantitis: A consecutive series of 170 implants in 100 patients with 2- to 10-year follow-up. Int J Periodontics Restorative Dent 2015;35: 857–863.
50. Sanz M, Schwarz F, Herrera D, et al. Importance of keratinized mucosa around dental implants: Consensus report of group 1 of the DGI/SEPA/Osteology Workshop. Clin Oral Implants Res 2022;33(suppl 23):47–55.

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