

REVIEW ARTICLE

The importance of soft tissue condition in bone regenerative procedures to ensure long-term peri-implant health

Mario Rocuzzo^{1,2,3} | Andrea Rocuzzo^{4,5,6}  | Crystal Marruganti^{7,8,9} | Stefan Fickl^{10,11}

¹Private Practice, Torino, Italy

²Division of Maxillo-Facial Surgery, University of Torino, Torino, Italy

³Department of Periodontics and Oral Medicine, University of Michigan, Ann Arbor, Michigan, USA

⁴Department of Periodontology, School of Dental Medicine, University of Bern, Bern, Switzerland

⁵Department of Oral and Maxillo-Facial Surgery, Copenhagen University Hospital (Rigshospitalet), Copenhagen, Denmark

⁶Department of Restorative, Pediatric and Preventive Dentistry, School of Dental Medicine, University of Bern, Bern, Switzerland

⁷Department of Surgical, Medical and Molecular Pathology and Critical Care Medicine, University of Pisa, Pisa, Italy

⁸Sub-Unit of Periodontology, Halitosis and Periodontal Medicine, University Hospital of Pisa, Pisa, Italy

⁹Unit of Periodontology, Endodontology and Restorative Dentistry, Department of Medical Biotechnologies, University of Siena, Siena, Italy

¹⁰Private Practice, Fürth, Germany

¹¹Department of Periodontology, Julius-Maximilians-University Würzburg, Würzburg, Germany

Correspondence

Andrea Rocuzzo, Department of Periodontology, School of Dental Medicine, University of Bern, Freiburgstrasse 7, CH-3010 Bern, Switzerland.

Email: andrea.rocuzzo@unibe.ch

1 | INTRODUCTION

High aesthetic satisfaction, improved quality of life, and near natural rehabilitation of functionality have made dental implants a successful long-term treatment option for missing teeth in both partially and fully edentulous patients.¹⁻⁶ Furthermore, dental implants are characterized by high 10-year survival rates of 96.4%,⁷ or 92.6% if assessed in a retrospective manner of up to 27 years.⁸

Prospective implant sites are often compromised due to horizontal or vertical bony defects and/or lack of soft tissue volume or quality. In order to prepare the surgical sites to achieve an optimal outcome before implantation, soft and/or hard tissue augmentation procedures are frequently conducted. There is a high variety of site preparation techniques with respect to bone regeneration reported in literature.⁹⁻¹¹ These procedures aim to create an ideal anatomical basis for future predictable implant placement and are mostly conducted in a staged manner.

Second, there are special circumstances, which indicate a need for soft and/or hard tissue augmentation that aim to improve clinical, biological, and patient related outcomes.¹²⁻¹⁴ Hard tissue

augmentation – including bony contour augmentation – aim to improve the emergence profile of the prosthetic restoration or to stabilize the soft tissue contour on a long-term basis. Lack of buccal bone surrounding dental implants has been reported to be associated with decrease of soft tissue height. Benic et al. have investigated the relevance of buccal bone on mucosal level surrounding immediately placed implants. The investigators have shown that sites with intact buccal bone – achieved with guided bone regeneration (GBR) reveal clinically philological mucosal levels, whereas sites with deficient buccal bone height led to a mucosal recession of 1 mm.¹⁵ Lateral ridge augmentation may also contribute to peri-implant health over a long-term period. A recent systematic review concludes that peri-implant soft and hard tissues have a bi-directional relationship showing that soft tissue augmentation is beneficial in terms of reducing mid-facial recession and brushing discomfort.¹⁶ Irrespective of the specific surgical technique, basic surgical principles should be respected to achieve optimal treatment outcomes. Wound healing in bone regenerative techniques is generally challenging due to the opposing avascular hard tissue structures such as autogenous bone blocks and demineralized bone mineral grafts. In bone regenerative

Mario Rocuzzo and Andrea Rocuzzo contributed equally to the manuscript and share first author position.

This is an open access article under the terms of the [Creative Commons Attribution](https://creativecommons.org/licenses/by/4.0/) License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

© 2023 The Authors. *Periodontology 2000* published by John Wiley & Sons Ltd.

techniques, the therapeutic outcome may depend on optimal blood supply as avascular grafting materials and barrier membranes are often utilized, which receive their nutrition by plasmatic diffusion from the flap and/or the underlying tissue.¹⁷

In a series of review articles on the biology of periodontal wound healing, it was pointed out that optimal bone regeneration depends on three major factors^{18–20}: space provision, that is, by means of a tissue barrier, wound stability (i.e., flap tension), and primary intention healing (i.e., blood supply of the flap). The same biologic principles could also be applied in bone regenerative procedures.

It is the aim of this narrative review article to elaborate on basic surgical principles of bone regenerative surgery (primary intention healing, wound stability) and to discuss the relevance of keratinized peri-implant mucosa and thickness of peri-implant mucosa.

2 | BASIC SURGICAL PRINCIPLES FOR BONE REGENERATIVE PROCEDURES

Various grafting methods have been employed for the treatment of bony defects including GBR-techniques and bone block/shell-techniques.⁹ In all of these techniques, the prerequisite for a successful regenerative result is a passive (tension-free) flap closure.²¹ Compared to horizontal bone augmentation, vertical GBR can be more challenging. The overall complication rate for vertical GBR is reported at 0%–45.4%, compared with 0%–24% for horizontal GBR.^{22,23}

More specifically, as reported by Donos et al.,²⁴ differences in flap dehiscence/membrane exposure were detected at 16.3% of the implants treated with a collagen membrane, while a wide range from 11.1% to²⁵ 24.4% was reported in cases where a e-PTFE membrane was used.²⁶ More recently, these findings have been further corroborated by other authors, who reported that the most commonly reported complication procedure was membrane exposure, ranging from 6.95% to 13.1%.^{27,28} This is mainly due to the difficulty in advancing the flap to achieve primary wound closure which needs to be maintained during the initial healing period.

If primary wound closure is retained, healing by primary intention will lead to an undisturbed microenvironment during the healing period. This can only be achieved, if an optimal blood supply of the flap and its underlying tissue can be maintained and a tension-free wound adaptation is facilitated.²⁹ However, wound dehiscence leading to healing by secondary intention and adverse events (i.e., post-operative wound infection, graft exposure to the oral cavity) during vertical and horizontal bone regenerative procedures are often reported.^{28,30} It has been documented, that in edentulous ridges, sites without membrane exposure achieved 74% more horizontal bone gain than sites with exposure.³¹

The first part of this narrative review will focus on the basic biological principles such as systemic factors affecting healing, flap preparation, flap mobilization, and suturing techniques during bone regenerative procedures, while the second part will summarize the current level of evidence on the importance of the peri-implant

keratinized peri-implant mucosa to ensure long-term peri-implant health.

2.1 | Patient-related factors

Bone regenerative procedures are elective interventions. Therefore, adequate compliance of the patient in performing oral hygiene measures and therefore healthy and fibrous soft tissue structures may allow precise incision and suturing. Poor oral hygiene has been demonstrated to negatively affect treatment outcomes for example in regenerative periodontal surgeries.³² It must be assumed, particularly in cases with adjacent teeth, an adequate oral hygiene should be implemented before surgery and inflammation-free soft tissues have to be established. A second major factor jeopardizing optimal tissue healing is cigarette smoking. Cigarette smoking has been demonstrated to negatively influence treatment results in bone regenerative procedures.^{33–35} It is therefore strongly recommended – especially in elective surgeries – to ensure optimal patient oral hygiene and to seek for alternative restorative treatment in smokers.

2.2 | Flap preparation

The design of oral surgical flaps is substantively reliant on the vascularization of the oral mucosa. Contrary to soft and hard tissue grafts, which obtain their nutrition in the early wound healing phase by plasmatic diffusion,^{36–38} flaps are comprised of an established network of vessels. Thus, maintaining blood supply is the main concern, when planning different flap designs. First, recommendations for appropriate flap designs have been presented in a human cadaver study laying the anatomical foundation of incision planning.³⁸ Findings from these studies indicate that crestal incisions should be placed midline of the edentulous alveolar ridge which is covered by an avascular zone with no anastomosis crossing the alveolar ridge. Moreover, adequate width of the flap base (i.e., trapezoidal shape) should always be planned to limit the risk of flap necrosis during the healing phase.

Second, the releasing incisions – if/when necessary – should be divergent and placed one tooth away from the surgical site, while in cases of edentulous areas despite the lack of tooth-related landmarks, the described general principles should be kept in mind. This ensures that the borders of the bone graft used for the GBR procedure simultaneously performed with implant placement are completely embedded in the flap and tension and dislocation of the releasing incisions during flap closure are avoided.³⁹ Furthermore, as proved in a cadaver model, it was advocated that releasing incisions should be placed as short and medially as possible, as the main direction of supplying arteries is from posterior to anterior.³⁸

It has also been recommended, that the releasing incisions should be designed in a “hockey-stick” fashion, in order to establish broader flap margins and less tension when closing the releasing incisions.⁴⁰

Thirdly, flap thickness also seems to be an important factor for primary intention healing. A review article has pointed out that flaps thickness in plastic periodontal surgery of less than 0.7mm may negatively influence flap vascularity.⁴¹ Although only sparsely documented in literature for bone regenerative procedures, it may be speculated that a certain amount of flap thickness is important to maintain the blood supply of the flap and to achieve proper diffusion for the area covered by the underlying bone graft material. In addition, clinicians should be aware of the possible complications (e.g., fenestrations and/or incorrect handling of surgical instruments) and of the main challenge in performing flap mobilization due to thin soft tissue and presence of unfavorable anatomical conditions.

Finally, with respect to flap preparation, an adequate thickness of the flaps (i.e., 1mm), vertical releasing incisions placed as short and medially as possible, adequate width of the base of the flap, and strictly crestal incisions are advocated for an optimal nutrition of flaps and of the underlying graft materials (Figure 1).

2.3 | Flap mobilization

In order to minimize the risk of flap dehiscence, a tension-free wound closure is mandatory, in particular in cases with severe ridge defects. Depending on the location of the bone augmentation procedure, several surgical techniques have been developed to achieve primary closure of bone augmentation sites.

For the maxilla, different releasing strategies have been postulated for the buccal flap. A periosteal releasing incision connecting two vertical incisions is made to achieve elasticity of the flap. This releasing incision is further reinforced, until a completely tension-free wound closure was possible⁴² (Figure 2). In addition, coronally positioned palatal sliding flaps have been described to achieve a sufficient sliding position of the palatal tissue.⁴³

When regenerative procedures are performed in the mandible, coronally advanced lingual and buccal flaps have been widely postulated.⁴⁴⁻⁴⁸ In most of these techniques for the lingual flap, a full

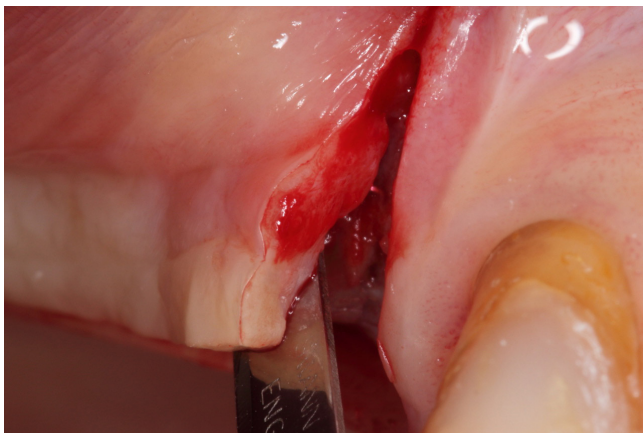


FIGURE 1 Clinical appearance of flap after incision revealing the importance of a minimal thickness of at least 1mm prior to guided bone regeneration procedure.

thickness preparation is executed to the mylohyoid line and then released by blunt detachment (i.e., with a Pritchard elevator) of the insertion of mylohyoid muscle from the inner part. On the buccal side, a full-thickness flap is raised, and then the buccal flap is released holding the flap in tension with an anatomical forceps and by releasing the periosteum to a depth of approximately 1mm apically to the muco-gingival junction and coronally to the vestibular fornix.

In short, with respect to flap mobilization, periosteal releasing incisions on the buccal and lingual flaps are recommended – in particular, on the lingual aspect a blunt preparation of the insertion of the mylohyoid muscle is recommended. Palatal sliding flaps might be used to increase tension-free wound closure in the anterior maxilla.

2.4 | Suturing technique

One of the basic premises of bone regenerative surgery is the attention to passive wound closure and, by this, wound stability over the first postoperative weeks. Wound stability primarily depends on the early formation and organization of the blood clot without any bacterial contamination and the establishment of an attachment of the clot resistant to mechanical forces. The tensile strength of the muco-gingival-flap to tooth-surface interface significantly increases from approximately 200g within days of wound closure to reach 340g at 7 days and can reach 1700g at 14 days in experimental periodontal defects.⁴⁹ During the early events of tissue healing, wound stability relies almost completely on sutures and on healing in a submerged environment.

Therefore, sutures aim to passively adapt wound margins and to maintain this wound stability over at least 2 weeks. In order to promote optimal wound stability and to withstand mechanical forces, a strategic placement of sutures should carefully be considered. Hogstrom et al. studied suture-holding strength in intestinal and laparotomy wounds and showed a decreased holding strength at 24- and 48-h post-incision.^{49,50} Aggregation of an inflammatory infiltrate extending up to 3mm from the incision line compromised the integrity of these sutures. Therefore, placement of holding sutures in the zone of inflammation may not be advisable.

Single interrupted sutures only close the superficial layers of the wound without stabilizing the entire wound and consequently are more prone to wound dehiscence and exposure during the healing phase.⁵¹ Indeed, interrupted sutures apply pressure only in one point of the wound surface creating local ischemia.⁵²

Therefore, suturing may be manipulated to improve wound stability using holding sutures such as (modified) vertical and/or (modified) horizontal mattress sutures placed distant from the incision margin. Thus, pressure is eliminated from the wound margins and the wound can be protected against tensile forces. Following these holding sutures, primary wound closure is then completed by interrupted sutures approximating the incision lines. Additionally, by using holding or sling sutures the pressure and the ablative forces on a single interrupted suture over the flap margins are reduced and more equally distributed over the flap. As an example, most of the

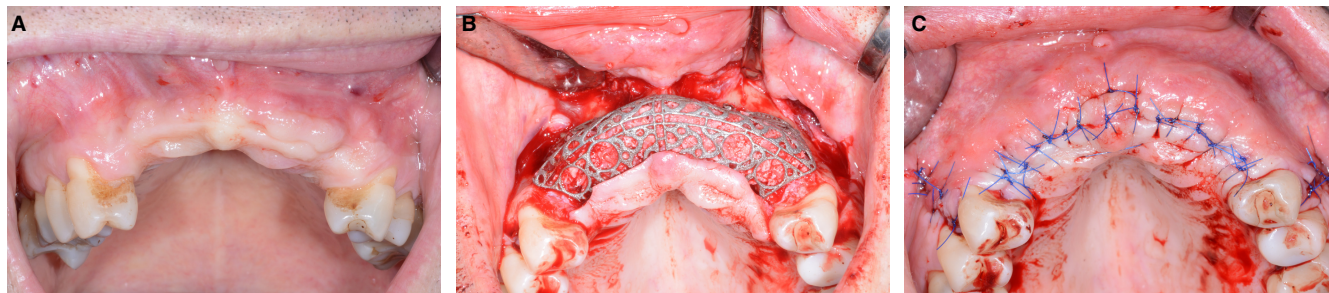


FIGURE 2 (A–C) Clinical appearance of the surgical area prior to surgery (A), after stabilization of a customized Ti-Mesh filled with demineralized bovine bone mineral and autogenous bone harvested from the ramus (B), and optimal tension-free submerged healing after performing deep releasing incisions on the buccal flap (C).

proposed techniques for vertical and horizontal bone regeneration advocated a combination of deep horizontal mattress sutures with U stitches as a first line of wound closure and a series of interrupted or double-interrupted sutures as a second line of wound closure (Figure 3). In addition, it has been described, that periosteal vertical mattress sutures using adsorbable suture material are able to firstly stabilize the barrier membrane and secondly add to a more passive wound closure using a combination of horizontal mattress sutures and superficial interrupted sutures.⁵³

When analyzing the healing patterns following suturing, it should be underlined that the sole act of applying a tensile force where the notch is placed initiated substantial and significant trauma⁵² and that consequently the microcirculation is severely affected, jeopardizing optimal wound healing. Clinically, this implies that sutures should be kept in situ “as short as necessary as long as needed”; more in detail, several local factors should be carefully considered during the first healing phase in order to avoid the risk of standardized suture removal after 7–10 days. Indeed, if after only 1 week, sutures applied on the vertical releasing incisions might be removed, the same process is not recommended where mid-crestal incisions are performed to limit the risk of early exposure of the grafted area.²¹

In conclusion, with respect to suturing techniques, a multi-layer wound closure using deep horizontal/vertical mattress sutures

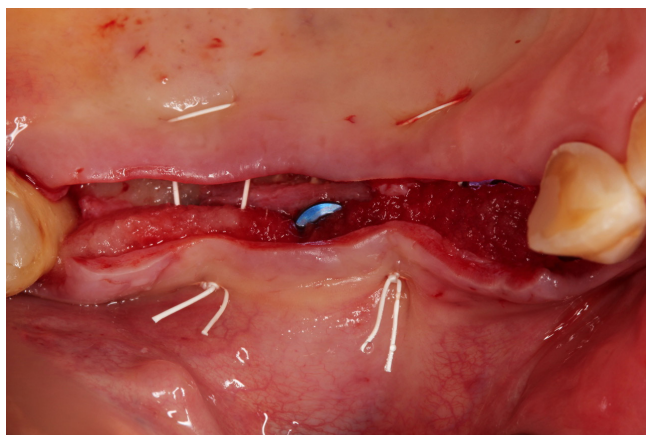


FIGURE 3 Ideal tension-free flap adaptation by means of horizontal mattress sutures at least 2mm away from the incision line.

at least 3mm distant from the wound margin combined with interrupted sutures to close the marginal flap areas are advocated (Figure 4).

3 | IMPORTANCE OF THE PERI-IMPLANT KERATINIZED MUCOSA FOR BONE REGENERATIVE PROCEDURES AND TO MAINTAIN PERI-IMPLANT HEALTH

It has been widely noted that tissue deficiencies such as horizontal and vertical bone defects are often associated to lack of soft tissue quality and quantity.¹⁵ Consequently, especially in challenging cases, both soft and hard tissue augmentation procedures are necessary to foster a proper site for prosthetically driven implant placement.

Soft tissue augmentation can be performed either to increase the keratinized mucosa width (KMW), in order to facilitate oral hygiene procedures, or to increase mucosal thickness (MT), in order to establish a proper peri-implant tissue volume.

The role of the soft tissues for the long-term maintenance of peri-implant health has been an important topic of discussion among the experts, for several decades. Part of it originated because of the confusion regarding the terminology used. Recently, Avila-Ortiz et al.⁵⁴ proposed a comprehensive description of the three soft-tissue components of the peri-implant phenotype (Figure 5):

The peri-implant KMW is the height of keratinized soft tissue that runs in an apico-coronal direction from the mucosal margin to the mucogingival junction.

Peri-implant MT is the horizontal dimension of the peri-implant soft tissue, which may or may not be keratinized.

The peri-implant supracrestal tissue height is the vertical dimension of the soft tissue that surrounds a dental implant from the mucosal margin to the crestal bone.

Historically, classic studies attributed minimal importance to the peri-implant soft tissue conditions. Heitz-Mayfield, in a systematic review for the Sixth European Workshop on Periodontology found “no association between the absence of keratinized peri-implant mucosa and peri-implant disease”.⁵⁵ Later, Esposito et al.⁵⁶ stated that there is “insufficient reliable evidence to provide recommendations whether techniques to increase the width of keratinized/

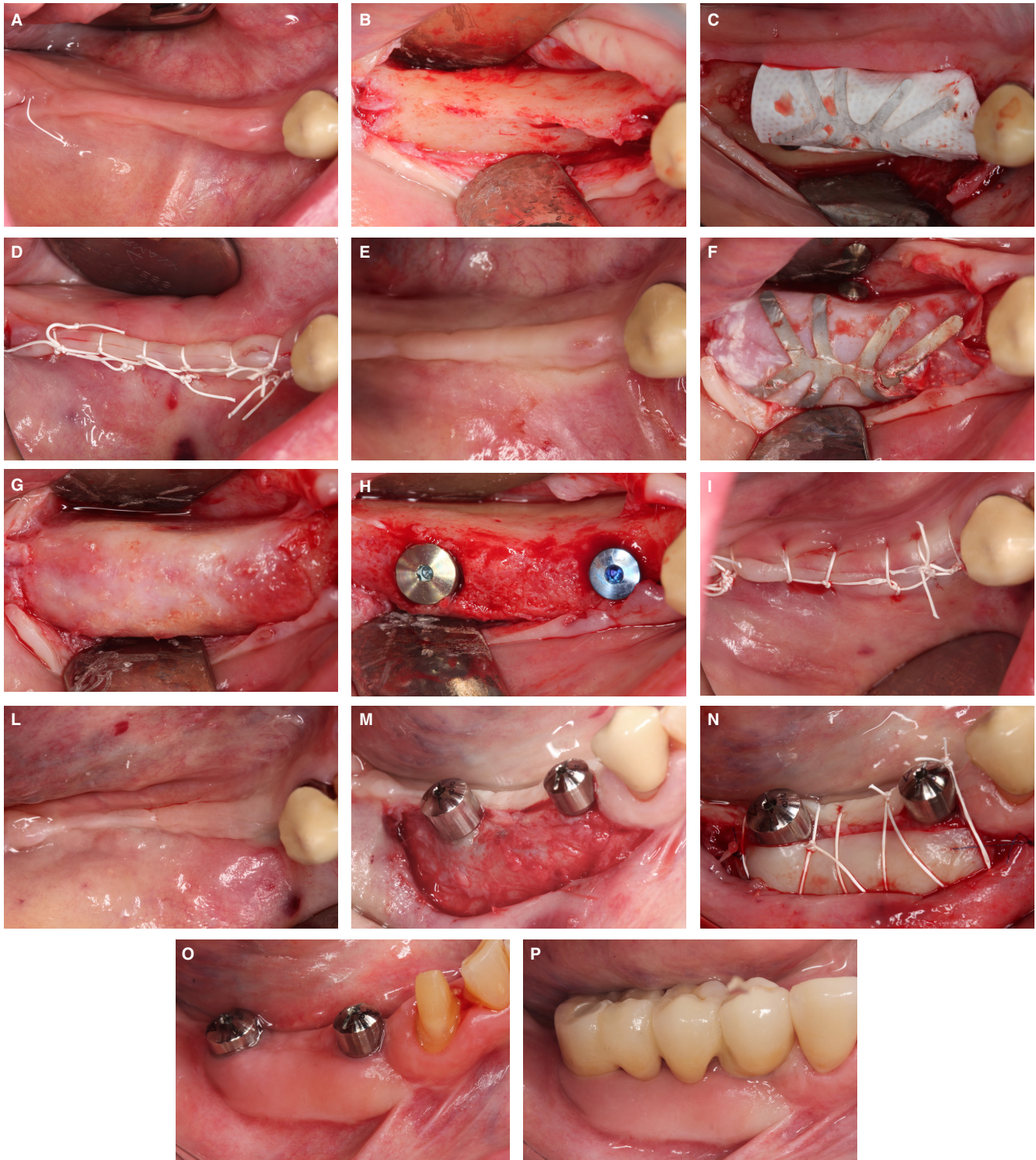


FIGURE 4 (A–P) exemplifies this approach in the posterior mandible. Pre-operative clinical situation showing a minimal amount of keratinized mucosa (A). Intra-operative scenario revealing the need for horizontal bone augmentation to allow an ideal implant placement (B), the application of an e-PTFE membrane fixed with pins to stabilize the bone graft (C), and clinical appearance immediately after suturing (D). At 6 months follow-up, optimal soft-tissue (E) and hard tissue healing (F and G) allows prosthetically-driven implant placement in region 44–46 (H) followed by a submerged healing (I). After an additional 3 months healing period (L), a split thickness flap was performed (M) to allow the placement of a free gingival graft on the buccal aspect (N) to increase the quantity and quality of keratinized mucosa. Clinical appearance after 3 months of healing (O) at the time of delivery of the final screw-retained metal-ceramic restoration (P).

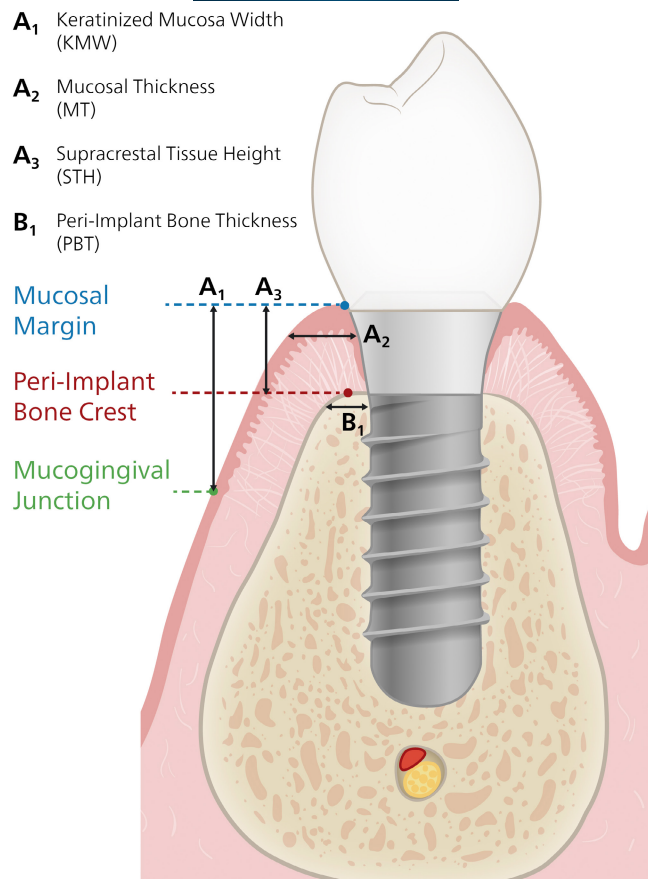


FIGURE 5 Illustration of the different components of the peri-implant phenotype according to Avila-Ortiz et al.⁵⁴

attached mucosa are beneficial to patients or not". In the same period, Wennstrom and Derks⁵⁷ during the third EAO Consensus Conference found out that the evidence in support of the need for keratinized tissues around implants to maintain health and tissue stability is limited.

In more recent years, the attention of the scientific community over the importance of soft tissues has dramatically increased as demonstrated by the great number of systematic reviews published in a short period of time: in particular, Gobbato et al.⁵⁸ found out that reduced KMW around implants appears to be associated with clinical parameters indicative of inflammation and poor oral hygiene, suggesting the need of a certain amount of KT to guarantee peri-implant health. In the same years, similar conclusions were drawn by Lin et al.⁵⁹ and Brito et al.⁶⁰ who found that lack of adequate KM around endosseous dental implants is associated with more plaque accumulation, tissue inflammation, mucosa recession, and attachment loss.

During the 2017 World Workshop, Hammerle and Tarnow⁶¹ reported that a significant amount of controlled prospective studies with medium-sized patient samples indicated that thin soft tissue around implants leads to increased peri-implant marginal bone loss compared to thick soft tissue. Most of the data, however, were published by one group of researchers.

In addition, the second Consensus Meeting of the Osteology Foundation was devoted to the maintenance of peri-implant soft tissues; indeed, the systematic review presented by Thoma et al.⁶² concluded that soft tissue grafting procedures resulted in a more favorable peri-implant health: (i) in order to gain keratinized mucosa using autogenous grafts with a greater improvement of bleeding indices and higher marginal bone levels; (ii) in order to increase MT using autogenous grafts with significantly less marginal bone loss. From a clinical point of view, it has to be mentioned that, even though the application of a FGG to gain KM in posterior area is still considered the standard of care, this procedure does present some disadvantages such as a relative high patient's morbidity and that the harvested tissue undergoes significant shrinkage during the first healing phase.

More recently, Tavelli et al.⁶³ found out that apically positioned flap in combination with soft tissue graft was associated with reduction of probing depths, soft tissue dehiscence, and plaque compared to non-augmented sites. The evidence regarding the effect of peri-implant soft tissue phenotype modification on peri-implant bone level preservation is inconclusive.

In 2021, the EAO organized the sixth Consensus Conference. Fickl et al. investigated the influence of soft tissue augmentation procedures around dental implants on marginal bone level changes and found out that soft tissue augmentation either for augmentation of keratinized mucosa or soft tissue volume inconsistently influenced marginal bone level changes when compared to no soft tissue augmentation, but consistently improved secondary outcomes such as bleeding indices, mucosal inflammation, and peri-implant pocket depth. The combination of soft and hard tissue augmentation showed no statistically significant difference in terms of marginal bone level changes when compared to hard tissue augmentation alone but resulted in less marginal soft tissue.^{16,64} Similar results have been published in the same period following the 2022 DGI, Osteology Foundation, and SEPA by Ramanauskaite et al.⁶⁵ who stated that, based on the observation that significantly less bone loss occurs around implants placed in thick tissue phenotypes compared to thin phenotypes, clinicians may be encouraged to augment thin, soft tissue before or during implant placement to enhance crestal bone stability.

One of the remaining open questions is whether specific clinical thresholds in soft tissue thickness should be used to distinguish between peri-implant health and disease: as reported by Ravida et al.⁶⁶ the presence of KM is not essential to achieve peri-implant health, but the quality of evidence supporting KM as a risk factor for peri-implant disease and the 2-mm cutoff point used in the literature is low at best. Very recently, Tavelli et al. reported that implant sites characterized by the presence of KM were associated with a high stability of the peri-implant soft tissue margin.⁶⁷

Two factors may have influenced the results of this literature research. First of all, different thresholds were used by different researchers to define an adequate width of KM to maintain peri-implant health. From a clinical perspective, the presence of a soft tissue seal around the collar of the implant, regardless of the

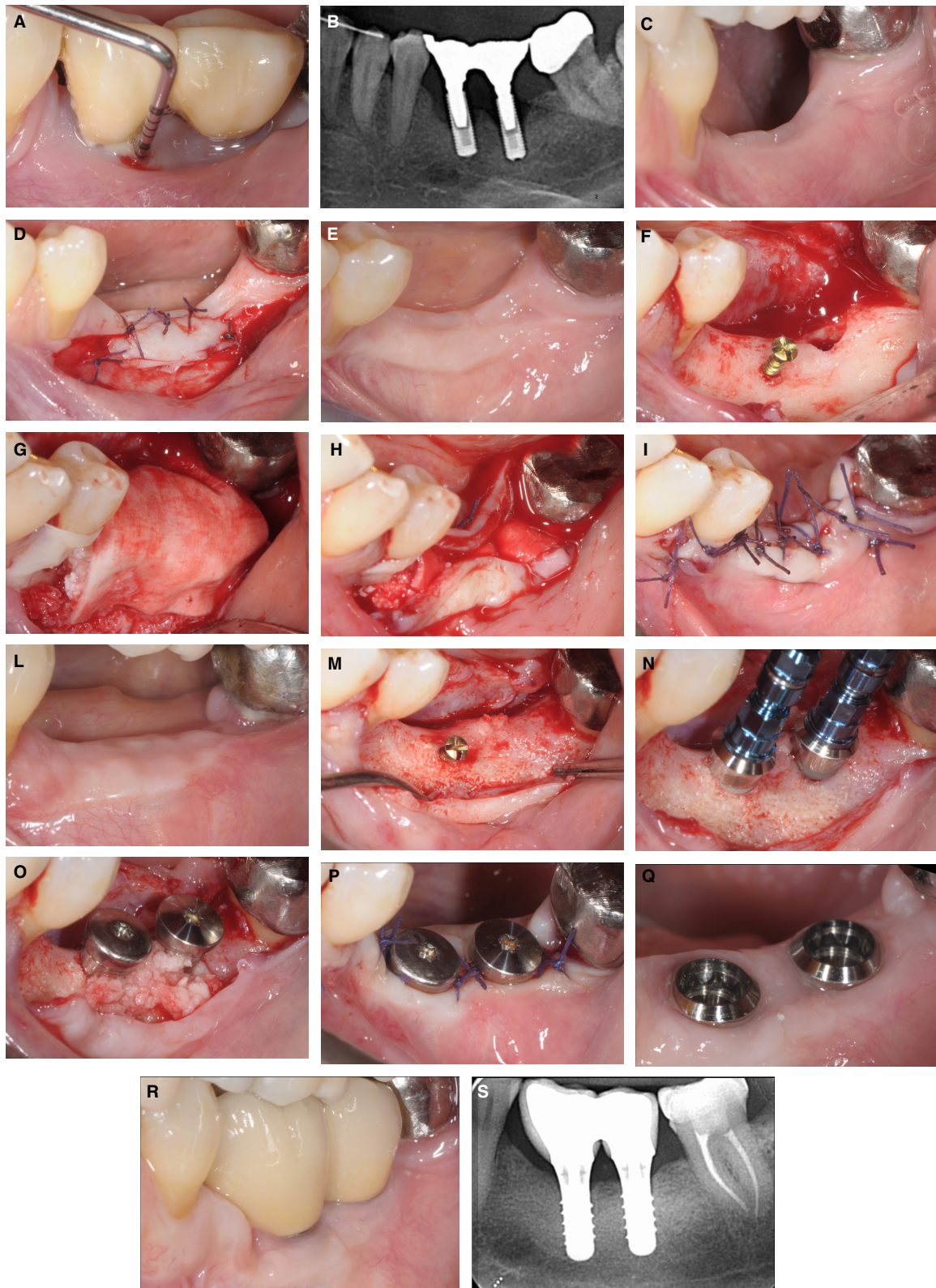


FIGURE 6 (A–S) exemplifies this approach in the mandible of a 45-year-old female patient. She had previously received implants at sites 35 and 36, which presented severe peri-implantitis. After surgical removal of the implants, bone augmentation was required, as the bone was not sufficient to places in a correct position. The clinical examination revealed thin phenotype and minimal keratinized mucosa width. To reduce the risk of soft-tissue dehiscence and of exposure or infection of the area following guided bone regeneration, the patient was advised that preliminary soft-tissue augmentation would be beneficial prior to any attempt at bone regeneration.

dimensions, works as an effective barrier, capable of biologically protecting the peri-implant structures still seems of paramount importance. In this regard, it may be reasonable to suggest that an absence of KM and the presence of a thin (0–2 mm) band of keratinized tissue should be considered to represent two different clinical conditions, even though they were included in the same group, in several studies. The other important factor that could explain the lack of association between paucity of KM and peri-implantitis, is that the incidence of peri-implantitis increases with time. Therefore, in order to demonstrate a possible association, we would need several long-term studies, when instead the vast majority of the research on this topic is limited to a few years of follow-up.^{68–70}

Several studies have demonstrated the use of various techniques for vertical ridge augmentation in cases of severe alveolar ridge atrophy, with the use of non-resorbable or resorbable membranes supported by a space-making device, or by the use of a titanium mesh.^{71–73} These studies have also shown though that the use of a barrier device is a technique-sensitive procedure that is subject to surgical complications.⁷⁴ Recently, to overcome these problems, the use of customized Ti-Meshes have been proposed and validated: more specifically, based on the CBCT files gathered from the 3-D radiographic evaluation, the Ti-Mesh is created based on the bone defect morphology taking in the consideration the final position of the implant-supported restoration according to the concept of prosthetically driven bone augmentation procedure.⁷⁵ This procedure does present several advantages, such as the pre-surgical evaluation of the 3D design of the mesh and an intraoperative optimal adaption to the alveolar ridge defect. Finally, and most importantly, even in cases of post-operative wound dehiscence with partial mesh exposure to the oral cavity, signs of graft infection were rare and do not preclude from implant placement.⁷²

One of the main reasons for GBR failure is related to exposure of the barrier device which leads to bacterial contamination of the surgical area and infection, which compromises the outcome of bone regeneration.

Even though there are no specific studies on this matter, it is reasonable to assume that membrane exposure, particularly during the first 4 postoperative weeks, may be higher in patients who present a very thin mucosa, and/or no keratinization and/or scar tissues. In specific circumstances, it may be indicated to optimize the quantity and the quality of the soft tissues, before hard tissue regenerative procedures are carried out.

Consequently, from a clinical point of view, it would be reasonable to advise surgical interventions aimed at re-creating ideal soft-tissue conditions whether prior to bone regenerative procedures or prior to final prosthesis delivery (Figure 5).

The importance of the soft-tissue thickness flap during GBR procedures has been recently underling in a 3-year randomized controlled trial where it was found that implant sites that underwent horizontal GBR experienced more soft-tissue recession than those treated with a connective tissue graft.⁷⁶ This finding should be taken into consideration by clinicians during the decision-making process, especially in aesthetically demanding cases (Figure 6).

4 | CONCLUSIONS

Based on the present level of evidence the following conclusions can be drawn:

- Horizontal and vertical bone regenerative procedures are effective interventions in terms of bone formation around dental implants but are not free from post-operative complications which may have a negative impact on the clinical outcomes and on patients' morbidity.
- One of the most common complications, particularly in case of soft tissue deficiencies, is flap dehiscence with subsequent membrane or mesh exposure.
- Several surgical aspects such as flap design, tension, mobilization, and suture techniques must be taken into consideration prior to and during surgery to obtain an optimal healing.
- The presence of an adequate quantity and quality of soft-tissues play an important role in the long-term maintenance of peri-implant health.

ACKNOWLEDGMENTS

Open access funding provided by Universitat Bern.

CONFLICT OF INTEREST STATEMENT

The authors declare no potential conflict of interests with respect to this study.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

ORCID

Andrea Rocuzzo  <https://orcid.org/0000-0002-8079-0860>

REFERENCES

1. Duong HY, Rocuzzo A, Stahli A, Salvi GE, Lang NP, Sculean A. Oral health-related quality of life of patients rehabilitated with fixed and removable implant-supported dental prostheses. *Periodontol* 2000. 2022;88(1):201–237.
2. Rocuzzo M, Bonino L, Dalmaso P, Aglietta M. Long-term results of a three arms prospective cohort study on implants in periodontally compromised patients: 10-year data around sandblasted and acid-etched (SLA) surface. *Clin Oral Implants Res*. 2014;25(10):1105–1112.
3. Schmid E, Rocuzzo A, Morandini M, Ramseier CA, Sculean A, Salvi GE. Clinical and radiographic evaluation of implant-supported single-unit crowns with cantilever extension in posterior areas: a retrospective study with a follow-up of at least 10 years. *Clin Implant Dent Relat Res*. 2021;23(2):189–196.
4. Schmid E, Morandini M, Rocuzzo A, Ramseier CA, Sculean A, Salvi GE. Clinical and radiographic outcomes of implant-supported fixed dental prostheses with cantilever extension. A retrospective cohort study with a follow-up of at least 10 years. *Clin Oral Implants Res*. 2020;31(12):1243–1252.
5. Rocuzzo A, Imber JC, Marruganti C, Salvi GE, Ramieri G, Rocuzzo M. Clinical outcomes of dental implants in patients with and without history of periodontitis: a 20-year prospective study. *J Clin Periodontol*. 2022;49(12):1346–1356.

6. Howe MS, Keys W, Richards D. Long-term (10-year) dental implant survival: a systematic review and sensitivity meta-analysis. *J Dent.* 2019;84:9-21.
7. Fischer K, Stenberg T. Prospective 10-year cohort study based on a randomized controlled trial (RCT) on implant-supported full-arch maxillary prostheses. Part 1: sandblasted and acid-etched implants and mucosal tissue. *Clin Implant Dent Relat Res.* 2012;14(6):808-815.
8. Balshi TJ, Wolfinger GJ, Stein BE, Balshi SF. A long-term retrospective analysis of survival rates of implants in the mandible. *Int J Oral Maxillofac Implants.* 2015;30(6):1348-1354.
9. Benic GI, Hammerle CH. Horizontal bone augmentation by means of guided bone regeneration. *Periodontol 2000.* 2014;66(1):13-40.
10. Troeltzsch M, Troeltzsch M, Kauffmann P, et al. Clinical efficacy of grafting materials in alveolar ridge augmentation: a systematic review. *J Craniomaxillofac Surg.* 2016;44(10):1618-1629.
11. Naenni N, Lim HC, Papageorgiou SN, Hammerle CHF. Efficacy of lateral bone augmentation prior to implant placement: a systematic review and meta-analysis. *J Clin Periodontol.* 2019;46(Suppl 21):287-306.
12. Mancini L, Barootchi S, Thoma DS, et al. The peri-implant mucosa color: a systematic appraisal of methods for its assessment and clinical significance. *Clin Implant Dent Relat Res.* 2023;25:224-240.
13. Thoma DS, Strauss FJ, Mancini L, Gasser TJW, Jung RE. Minimal invasiveness in soft tissue augmentation at dental implants: a systematic review and meta-analysis of patient-reported outcome measures. *Periodontol 2000.* 2022;91:182-198.
14. Tavelli L, Barootchi S, Stefanini M, Zucchelli G, Giannobile WV, Wang HL. Wound healing dynamics, morbidity, and complications of palatal soft-tissue harvesting. *Periodontol 2000.* 2022. doi:10.1111/prd.12466
15. Benic GI, Mokti M, Chen CJ, Weber HP, Hammerle CH, Gallucci GO. Dimensions of buccal bone and mucosa at immediately placed implants after 7 years: a clinical and cone beam computed tomography study. *Clin Oral Implants Res.* 2012;23(5):560-566.
16. Fickl S, Therese Kroger A, Dietrich T, Kerschull M. Influence of soft tissue augmentation procedures around dental implants on marginal bone level changes—a systematic review. *Clin Oral Implants Res.* 2021;32(Suppl 21):108-137.
17. Burkhardt R, Lang NP. Fundamental principles in periodontal plastic surgery and mucosal augmentation – a narrative review. *J Clin Periodontol.* 2014;41(Suppl 15):S98-S107.
18. Susin C, Fiorini T, Lee J, De Stefano JA, Dickinson DP, Wikesjo UM. Wound healing following surgical and regenerative periodontal therapy. *Periodontol 2000.* 2015;68(1):83-98.
19. Polimeni G, Xiropaidis AV, Wikesjo UM. Biology and principles of periodontal wound healing/regeneration. *Periodontol 2000.* 2006;41:30-47.
20. Susin C, Wikesjo UM. Regenerative periodontal therapy: 30 years of lessons learned and unlearned. *Periodontol 2000.* 2013;62(1):232-242.
21. Burkhardt R, Lang NP. Influence of suturing on wound healing. *Periodontol 2000.* 2015;68(1):270-281.
22. 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(5):606-625.
23. Rocchietta I, Fontana F, Simion M. Clinical outcomes of vertical bone augmentation to enable dental implant placement: a systematic review. *J Clin Periodontol.* 2008;35(8 Suppl):203-215.
24. Donos N, Mardas N, Chadha V. Clinical outcomes of implants following lateral bone augmentation: systematic assessment of available options (barrier membranes, bone grafts, split osteotomy). *J Clin Periodontol.* 2008;35(8 Suppl):173-202.
25. Blanco J, Alonso A, Sanz M. Long-term results and survival rate of implants treated with guided bone regeneration: a 5-year case series prospective study. *Clin Oral Implants Res.* 2005;16(3):294-301.
26. Zitzmann NU, Naef R, Schärer P. Resorbable versus nonresorbable membranes in combination with bio-Oss for guided bone regeneration. *Int J Oral Maxillofac Implants.* 1997;12(6):844-852.
27. Lim G, Lin GH, Monje A, Chan HL, Wang HL. Wound healing complications following guided bone regeneration for ridge augmentation: a systematic review and meta-analysis. *Int J Oral Maxillofac Implants.* 2018;33(1):41-50.
28. Rocchietta I, Ferrantino L, Simion M. Vertical ridge augmentation in the esthetic zone. *Periodontol 2000.* 2018;77(1):241-255.
29. Burkhardt R, Lang NP. Role of flap tension in primary wound closure of mucoperiosteal flaps: a prospective cohort study. *Clin Oral Implants Res.* 2010;21(1):50-54.
30. Roccuazzo M, Ramieri G, Spada MC, Bianchi SD, Berrone S. Vertical alveolar ridge augmentation by means of a titanium mesh and autogenous bone grafts. *Clin Oral Implants Res.* 2004;15(1):73-81.
31. Garcia J, Dodge A, Luepke P, Wang HL, Kapila Y, Lin GH. Effect of membrane exposure on guided bone regeneration: a systematic review and meta-analysis. *Clin Oral Implants Res.* 2018;29(3):328-338.
32. Tonetti MS, Prato GP, Cortellini P. Factors affecting the healing response of intrabony defects following guided tissue regeneration and access flap surgery. *J Clin Periodontol.* 1996;23(6):548-556.
33. Barbato L, Baldi N, Gonnelli A, Duvina M, Nieri M, Tonelli P. Association of smoking habits and height of residual bone on implant survival and success rate in lateral sinus lift: a retrospective study. *J Oral Implantol.* 2018;44(6):432-438.
34. Sakkas A, Schramm A, Winter K, Wilde F. Risk factors for post-operative complications after procedures for autologous bone augmentation from different donor sites. *J Craniomaxillofac Surg.* 2018;46(2):312-322.
35. Jäger DHJ, Maarse F, Klausch T, et al. Wound dehiscences following pre-implant bone augmentation with autogenous iliac crest bone grafts: a retrospective cohort study. *Int J Oral Implantol (Berl).* 2019;12(2):227-236.
36. Oliver RC, Loe H, Karring T. Microscopic evaluation of the healing and revascularization of free gingival grafts. *J Periodontol Res.* 1968;3(2):84-95.
37. De Marco AC, Jardini MA, Lima LP. Revascularization of autogenous block grafts with or without an e-PTFE membrane. *Int J Oral Maxillofac Implants.* 2005;20(6):867-874.
38. Kleinheinz J, Buchter A, Kruse-Losler B, Weingart D, Joos U. Incision design in implant dentistry based on vascularization of the mucosa. *Clin Oral Implants Res.* 2005;16(5):518-523.
39. Urban IA, Monje A, Lozada J, Wang HL. Principles for vertical ridge augmentation in the atrophic posterior mandible: a technical review. *Int J Periodontics Restorative Dent.* 2017;37(5):639-645.
40. Tinti C, Parma-Benfenati S. Vertical ridge augmentation: surgical protocol and retrospective evaluation of 48 consecutively inserted implants. *Int J Periodontics Restorative Dent.* 1998;18(5):434-443.
41. Hwang D, Wang HL. Flap thickness as a predictor of root coverage: a systematic review. *J Periodontol.* 2006;77(10):1625-1634.
42. Urban IA, Monje A, Wang HL. Vertical ridge augmentation and soft tissue reconstruction of the anterior atrophic maxillae: a case series. *Int J Periodontics Restorative Dent.* 2015;35(5):613-623.
43. Tinti C, Parma-Benfenati S. Coronally positioned palatal sliding flap. *Int J Periodontics Restorative Dent.* 1995;15(3):298-310.
44. Park JC, Kim CS, Choi SH, Cho KS, Chai JK, Jung UW. Flap extension attained by vertical and periosteal-releasing incisions: a prospective cohort study. *Clin Oral Implants Res.* 2012;23(8):993-998.
45. Ogata Y, Griffin TJ, Ko AC, Hur Y. Comparison of double-flap incision to periosteal releasing incision for flap advancement: a prospective clinical trial. *Int J Oral Maxillofac Implants.* 2013;28(2):597-604.
46. Greenstein G, Greenstein B, Cavallaro J, Elian N, Tarnow D. Flap advancement: practical techniques to attain tension-free primary closure. *J Periodontol.* 2009;80(1):4-15.
47. Urban IA, Monje A, Wang HL, Lozada J, Gerber G, Baksa G. Mandibular regional anatomical landmarks and clinical

- implications for ridge augmentation. *Int J Periodontics Restorative Dent.* 2017;37(3):347-353.
48. Ronda M, Stacchi C. A novel approach for the coronal advancement of the buccal flap. *Int J Periodontics Restorative Dent.* 2015;35(6):795-801.
 49. Hogstrom H, Haglund U, Zederfeldt B. Suture technique and early breaking strength of intestinal anastomoses and laparotomy wounds. *Acta Chir Scand.* 1985;151(5):441-443.
 50. Hogstrom H, Haglund U. Postoperative decrease in suture holding capacity in laparotomy wounds and anastomoses. *Acta Chir Scand.* 1985;151(6):533-535.
 51. Nobuto T, Imai H, Suwa F, et al. Microvascular response in the periodontal ligament following mucoperiosteal flap surgery. *J Periodontol.* 2003;74(4):521-528.
 52. McLean TN, Smith BA, Morrison EC, Nasjleti CE, Caffesse RG. Vascular changes following mucoperiosteal flap surgery: a fluorescein angiography study in dogs. *J Periodontol.* 1995;66(3):205-210.
 53. Urban IA, Lozada JL, Wessing B, Suarez-Lopez 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(2):153-159.
 54. Avila-Ortiz G, Gonzalez-Martin O, Couso-Queiruga E, Wang HL. The peri-implant phenotype. *J Periodontol.* 2020;91(3):283-288.
 55. Heitz-Mayfield LJ. Peri-implant diseases: diagnosis and risk indicators. *J Clin Periodontol.* 2008;35(8 Suppl):292-304.
 56. Esposito M, Grusovin MG, Maghazeh H, Worthington HV. Interventions for replacing missing teeth: different times for loading dental implants. *Cochrane Database Syst Rev.* 2013;2013(3):CD003878.
 57. Wennstrom JL, Derks J. Is there a need for keratinized mucosa around implants to maintain health and tissue stability? *Clin Oral Implants Res.* 2012;23(Suppl 6):136-146.
 58. Gobbato L, Avila-Ortiz G, Sohrabi K, Wang CW, Karimbux N. The effect of keratinized mucosa width on peri-implant health: a systematic review. *Int J Oral Maxillofac Implants.* 2013;28(6):1536-1545.
 59. Lin GH, Chan HL, Wang HL. The significance of keratinized mucosa on implant health: a systematic review. *J Periodontol.* 2013;84(12):1755-1767.
 60. Brito C, Tenenbaum HC, Wong BK, Schmitt C, Nogueira-Filho G. Is keratinized mucosa indispensable to maintain peri-implant health? A systematic review of the literature. *J Biomed Mater Res B Appl Biomater.* 2014;102(3):643-650.
 61. Hammerle CHF, Tarnow D. The etiology of hard- and soft-tissue deficiencies at dental implants: a narrative review. *J Clin Periodontol.* 2018;45(Suppl 20):S267-S277.
 62. Thoma DS, Naenni N, Figuero E, et al. Effects of soft tissue augmentation procedures on peri-implant health or disease: a systematic review and meta-analysis. *Clin Oral Implants Res.* 2018;29(Suppl 15):32-49.
 63. Tavelli L, Barootchi S, Avila-Ortiz G, Urban IA, Giannobile WV, Wang HL. Peri-implant soft tissue phenotype modification and its impact on peri-implant health: a systematic review and network meta-analysis. *J Periodontol.* 2021;92(1):21-44.
 64. Bienz SP, Carrera ER, Hüslér J, Rocuzzo A, Jung RE, Thoma DS. Soft tissue contour changes at implant sites with or without soft tissue grafting in the esthetic zone: a retrospective case-control study with a 12-year follow-up. *Clin Oral Implants Res.* 2023;34(5):521-530.
 65. Ramanauskaite A, Schwarz F, Sader R. Influence of width of keratinized tissue on the prevalence of peri-implant diseases: a systematic review and meta-analysis. *Clin Oral Implants Res.* 2022;33(Suppl 23):8-31.
 66. Ravida A, Arena C, Tattan M, et al. The role of keratinized mucosa width as a risk factor for peri-implant disease: a systematic review, meta-analysis, and trial sequential analysis. *Clin Implant Dent Relat Res.* 2022;24(3):287-300.
 67. Tavelli L, Barootchi S, Majzoub J, et al. Prevalence and risk indicators of midfacial peri-implant soft tissue dehiscence at single site in the esthetic zone: a cross-sectional clinical and ultrasonographic study. *J Periodontol.* 2022;93(6):857-866.
 68. Trombelli L, Pramstraller M, Severi M, Simonelli A, Farina R. Peri-implant tissue conditions at implants treated with sub-periosteal peri-implant augmented layer technique: a retrospective case series. *Clin Oral Implants Res.* 2020;31(10):992-1001.
 69. Linkevicius T, Puisys A, Linkeviciene L, Peculiene V, Schlee M. Crestal bone stability around implants with horizontally matching connection after soft tissue thickening: a prospective clinical trial. *Clin Implant Dent Relat Res.* 2015;17(3):497-508.
 70. Rocuzzo A, Imber JC, Salvi GE, Rocuzzo M. Peri-implantitis as the consequence of errors in implant therapy. *Periodontol 2000.* 2023. doi:10.1111/prd.12482
 71. Urban IA, Montero E, Monje A, Sanz-Sanchez I. Effectiveness of vertical ridge augmentation interventions: a systematic review and meta-analysis. *J Clin Periodontol.* 2019;46(Suppl 21):319-339.
 72. Chiapasco M, Casentini P, Tommasato G, Dellavia C, Del Fabbro M. Customized CAD/CAM titanium meshes for the guided bone regeneration of severe alveolar ridge defects: preliminary results of a retrospective clinical study in humans. *Clin Oral Implants Res.* 2021;32(4):498-510.
 73. Rocuzzo M, Savoini M, Dalmaso P, Ramieri G. Long-term outcomes of implants placed after vertical alveolar ridge augmentation in partially edentulous patients: a 10-year prospective clinical study. *Clin Oral Implants Res.* 2017;28(1210):1204-1210.
 74. 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.
 75. Chiapasco M, Casentini P. Horizontal bone-augmentation procedures in implant dentistry: prosthetically guided regeneration. *Periodontol 2000.* 2018;77(1):213-240.
 76. Bouckaert E, De Bruyckere T, Eghbali A, Younes F, Wessels R, Cosyn J. A randomized controlled trial comparing guided bone regeneration to connective tissue graft to re-establish buccal convexity at dental implant sites: three-year results. *Clin Oral Implants Res.* 2022;33(5):461-471.

How to cite this article: Rocuzzo M, Rocuzzo A, Marruganti C, Fickl S. The importance of soft tissue condition in bone regenerative procedures to ensure long-term peri-implant health. *Periodontol 2000.* 2023;00:1-10. doi:10.1111/prd.12496