AIMS Bioengineering, 9(1): 26–43.
DOI: 10.3934/bioeng.2022003
Received: 10 November 2021
Revised: 17 December 2021
Accepted: 24 December 2021
Published: 06 January 2022

http://www.aimspress.com/journal/Bioengineering

Research article

Hard and soft tissue augmentation of vertical ridge defects with the "hard top double membrane technique": introduction of a new technique and a case report

Fabrizio Belleggia*

DDS, Private practice, Rome, Italy

* **Correspondence:** Email: fabriziobelleggia@virgilio.it.

Abstract: Vertical ridge defects (VRD) of the jaws often require both bone and keratinized mucosa (KM) reconstruction. A new staged procedure is proposed to restore both hard and soft tissues in the VRD through a case report. A patient required the lower right second premolar and first molar rehabilitation. The first surgery aimed to restore the bone architecture through the use of a titanium reinforced dense-PTFE (TR-dPTFE) membrane, positioned and stabilized on top of tenting screws. This membrane didn't cover the whole defect, it just created an hard top that avoided the collapse of a collagen membrane that was placed over it. This resorbable membrane was stabilized with tacks and covered the whole defect, protecting a mixture of autogenous bone and porcine xenograft both lingually and buccally. The second surgery was performed after a 5 month healing time either to remove the tenting screws and the TR-dPTFE membrane, and to augment KM with a gingival graft harvested from the palate. Both regenerated hard and soft tissues were left to mature for 7 months before the third surgery. In this last stage implants insertion and healing abutments application were carried out in a straightforward way, since bone and KM had been previously restored. Two bone samples, harvested for histologic evaluation, stated a great amount of new bone formation. This new approach allowed inserting implants in matured and stable regenerated bone and augmented KM, avoiding the hard and soft tissue loss around implant neck that can affect the VRD treatments during healing.

Keywords: guided bone regeneration; vertical bone defect; bone graft; gingival graft; vertical bone augmentation

1. Introduction

Different surgical techniques to treat the vertical bone defects of the jaws have been described [1]. Among these, one of the most widely utilized is the guided bone regeneration (GBR) technique, since the use of a titanium-reinforced polytetrafluoroethylene (TR-PTFE) membrane allows space maintenance, that has been postulated to be one of the prerequisites for a successful GBR, and acts as a physical barrier when applied over bone defects, preventing the ingrowth of competing, non-osteogenic cells into the membrane protected space [2]. Infection of the regenerated site, with or without membrane exposure, and the need of a second invasive surgery for membrane removal, are considered the most important drawbacks of this technique.

Another disadvantage of these membranes lays in the fact that they exclude the periosteum from the regenerated area for all the time they are maintained, whose potential in the formation and regeneration of bone tissue has been widely demonstrated [3,4]. This often results in an immature regenerated bone, especially in areas far from the residual alveolar bone, from which neovascularization and new bone formation start. Immature bone could easily lead to bone resorption and marginal bone loss around implant neck, favoring the establishment of mucositis and peri-implantitis.

A drawback, common to all regenerative techniques, is the reduction of the band of keratinized mucosa (KM) due to the flap coronal advancement, in order to get primary closure and cover the increased bone volume. To restore a proper amount of KM, a free gingival graft (FGG) is widely considered the most reliable treatment option [5].

The author introduces the "Hard Top Double Membrane Technique" (HTDMT), a new staged procedure to restore both hard and soft tissues in the vertical ridge defects (VRD) of the jaws, and simultaneously reduce the overall treatment time and tissues resorption.

2. Materials and methods

A case report describes all the steps of the HTDMT. A 66-year-old non smoker and systemically healthy female patient presented to the author's private practice for for the failing of a prosthetic bridge in the lower right arch, due to the peri-implantitis of the distal implant (Figure 1a,b). Treatment options were discussed and the patient signed a consent form for the implant removal and the augmentation procedure to be scheduled as a staged approach for implant site development. After bridge sectioning and implant removal, a vertical bone defect was present at the premolar and molar area (Figure 2a–c). Three months after implant extraction, a mucoperiosteal flap was raised, a crestal incision connected the two vertical releasing incisions of the buccal flap, one on the mesial line angle of the canine, the other made at the level of the retromolar trigone. No vertical releasing incision was made on the lingual flap, that was extended mesially involving 3 teeth. After flap reflection, the vertical bone defect was clearly evident (Figure 3). Buccal flap was mobilized performing a continuous periosteal incision through the entire length of the flap between the 2 vertical releasing incisions. The cut through the periosteum gave access to the more flexible elastic fibers that could be expanded by the use of a blunt dissector or a blade, working in a brushing way. The lingual flap was coronalized separating the superior fibers of the mylohyoid muscle, that in the molar region is close to the crest, from the connective tissue of the lingual flap, applying a gentle pressure on the flap with a periosteal elevator. Cortical perforations were done with a small round bur in order to open the marrow cavities and

promote bleeding, giving vascular support to a bone graft consisting of particulate autogenous bone, harvested locally with a disposable scraper (Safescraper Twist, Meta, Reggio Emilia, Italy), mixed with a porcine xenograft (Zcore, Osteogenics Biomedical, Lubbock, TX) in a 1:1 ratio. Two self-drilling tenting screws (BOSS Screw, Cowellmedi, Seoul, Korea) were inserted in the vertical bone defect of the molar region (Figure 4a,b). A dense TR-PTFE membrane (Cytoplast Ti-250 PL, Osteogenics Biomedical) was cut so as to leave only the part with the titanium reinforcement (Figure 5a,b) and perforated to allow the passage of the tenting screws' cover screws with which was stabilized to the tenting screws (Figure 6a,b). This membrane was shaped so that it would not cover the whole defect but just the area above the tenting screws, with the aim of constituting a rigid roof, an hard top to define a space for vertical bone regeneration, helping the resorbable membrane not to collapse over the defect. A collagen membrane (Vitala 30 × 40, Osteogenics Biomedical) was stabilized with tacks on the lingual side (Figure 7a–c). Then the defect was filled with the composite graft, packing the particulate bone under the TR-PTFE membrane and laterally to it (Figure 8a,b). Then the collagen membrane was moved buccally to cover the graft and stabilized with tacks on the buccal side (Figure 9a–d). Flaps were closed (Figure 10) with horizontal mattress and single 4–0 PTFE sutures. Healing was uneventful and 2 weeks later the sutures were removed. After 5 months, the yet thin band of KM was reduced (Figure 11a), due to the coronal movement of the flaps, and the follow-up radiograph showed a still immature bone (Figure 11b). At this time point a split thickness buccal flap was raised (Figure 12a), with the aim of not exposing the bone graft below, the TR-PTFE membrane and the tenting screws were removed (Figure 12b). The regenerated bone was covered by a 1 mm thick soft tissue (Figure 13a) that was cut with a blade in order to promote bleeding (Figure 13b). A FGG was harvested from the palate (Figure 14a) and stabilized with sutures on the recipient site (Figure 14b) to augment the band of KM. Seven months after gingival augmentation, twelve months after GBR, a cone beam computed tomography (CBCT) was repeated to evaluate the amount of the regeneration (Figure 15a–c). The bone defect appeared completely filled by the regenerated tissue. Although a 30% gingival graft shrinkage happened, the amount of augmented KM was still adequate (Figure 16a). At this time point the site was reopened for implants and healing abutments application. A mucoperiosteal flap was raised with a similar design to that of the first stage but with less extension, especially on the lingual side (Figure 16b). No graft particle was noted to be entrapped within the width of the flap and the bone appeared to be mature and well mineralized. During implant bed preparation (Figure 17a), a bone sample was harvested from the premolar region (Figure 17b). This sample was fixed in buffered formalin, decalcified, embedded in paraffin, sectioned and stained with hematoxylin and eosin (Figure 17 c,d). Another bone sample was harvested from the molar area (Figure 18a,b), fixed, defatted in Xylene, infiltrated, embedded and polymerized in Technovit 9100. This specimen was cut in 60 μm sections and stained with toluidine blue and acid fuchsin (Figure 18c). Two implants (Inno Sub, Cowellmedi) were inserted 1 mm below the bone crest, as indicated by the manufacturer, and healing abutments were applied simultaneously (Figure 19a–c). Two screw-retained porcelain-fused-to-metal crowns were delivered 6 weeks later. The 1-year clinical and radiographic follow-up after prosthetic loading showed excellent hard and soft tissues maintenance (Figure 20a–c). The time elapsed between the implant removal and prosthetic loading was less than 17 months (Figure 21).

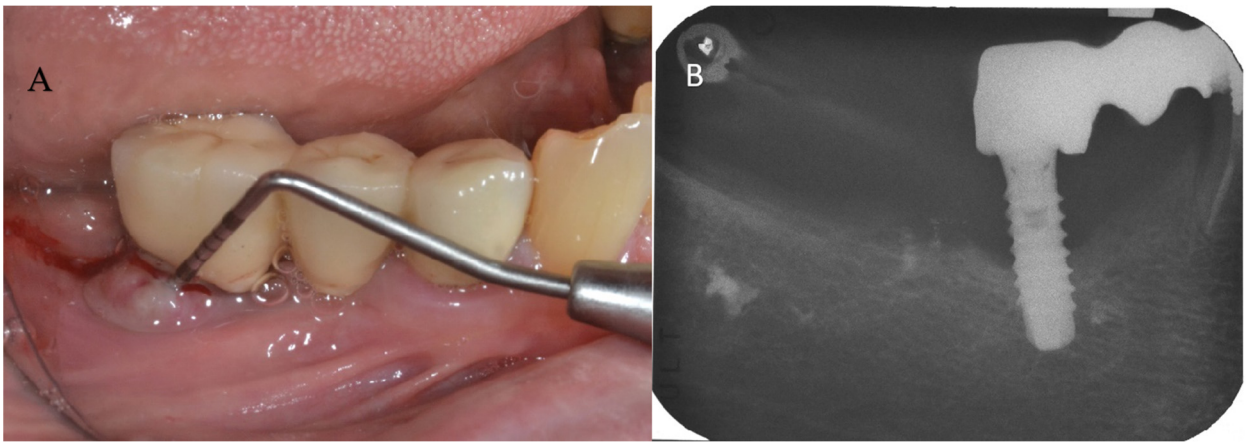

Figure 1. Peri-implantitis of the distal implant revealed by the probe (A) and the radiograph (B).

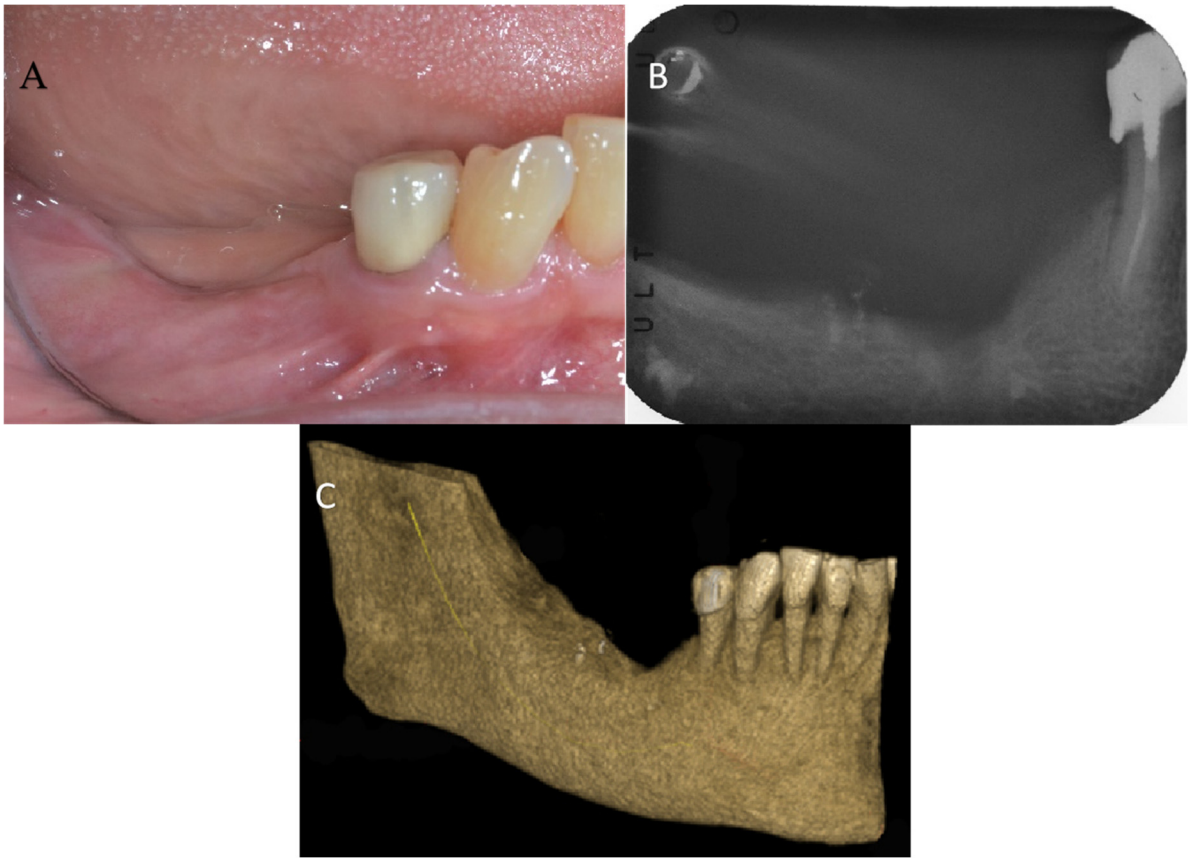

Figure 2. A vertical defect was evident after healing (A); Periapical radiograph (B) and cone beam computed tomography (C) revealed the amount of bone deficiency.

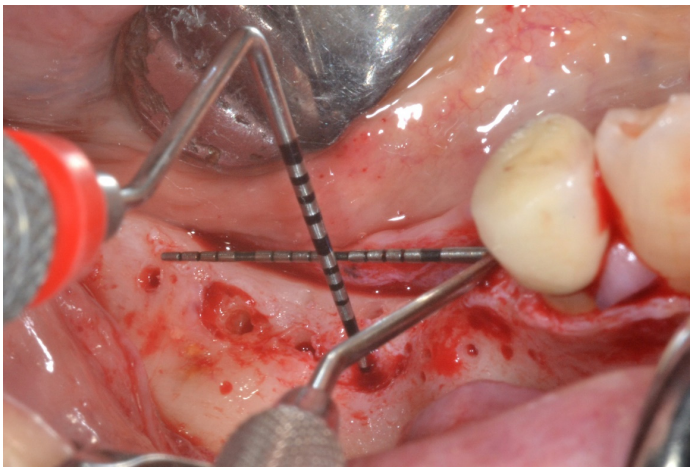

Figure 3. Measurement of the vertical bone defect.

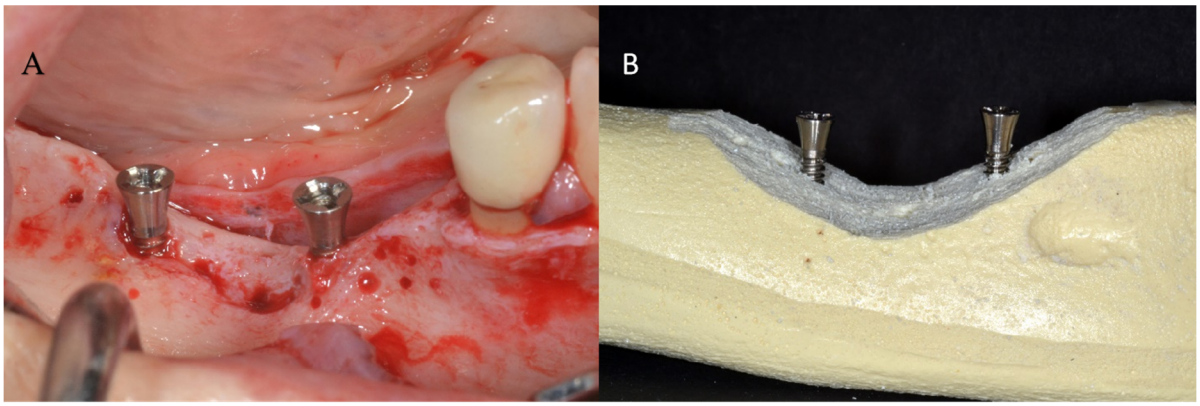

Figure 4. Insertion of two tenting screws (A clinical, B simulator).

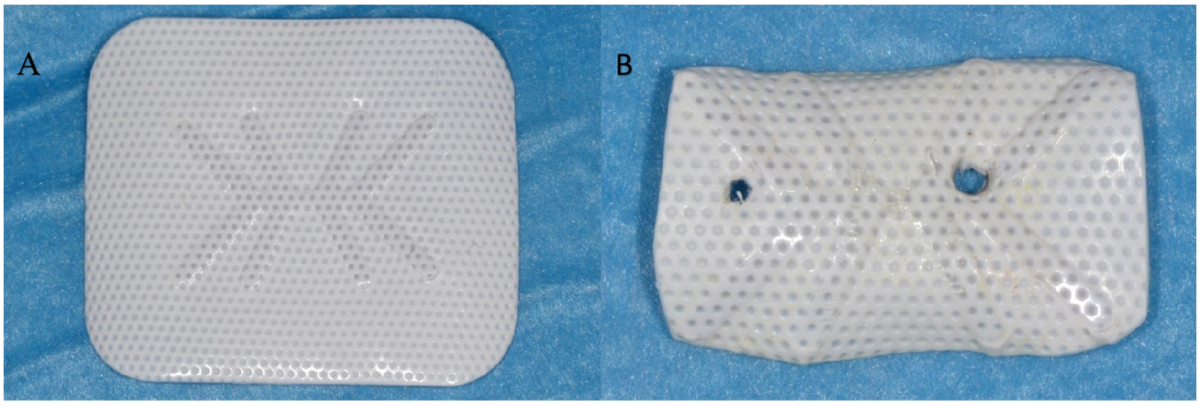

Figure 5. A TR-dPTFE membrane (A) was trimmed, so as to leave only the part with the titanium reinforcement, and perforated to allow the passage of the tenting screws' cover screws (B).

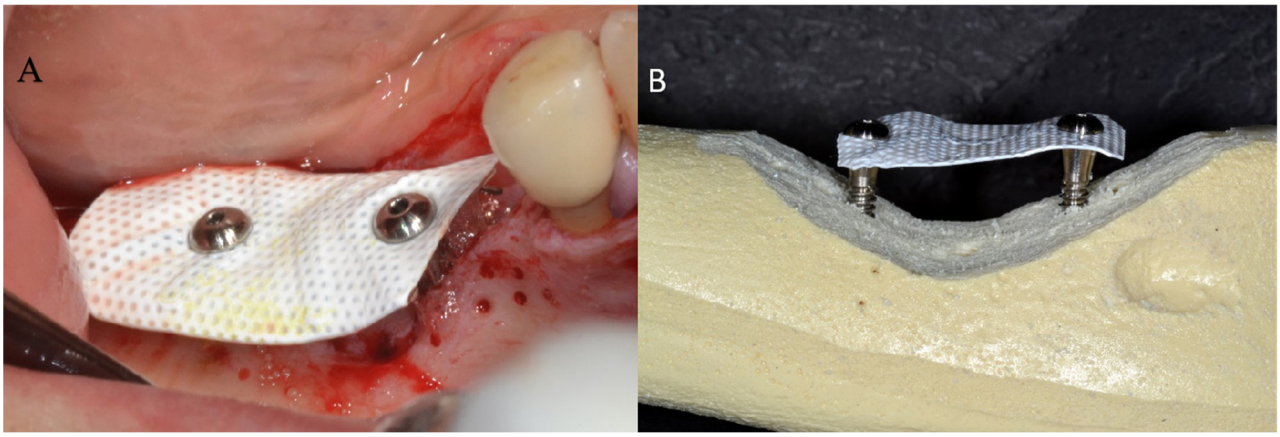

Figure 6. The TR-dPTFE membrane was fixed to the tenting screws with the use of their cover screws (A clinical, B simulator).

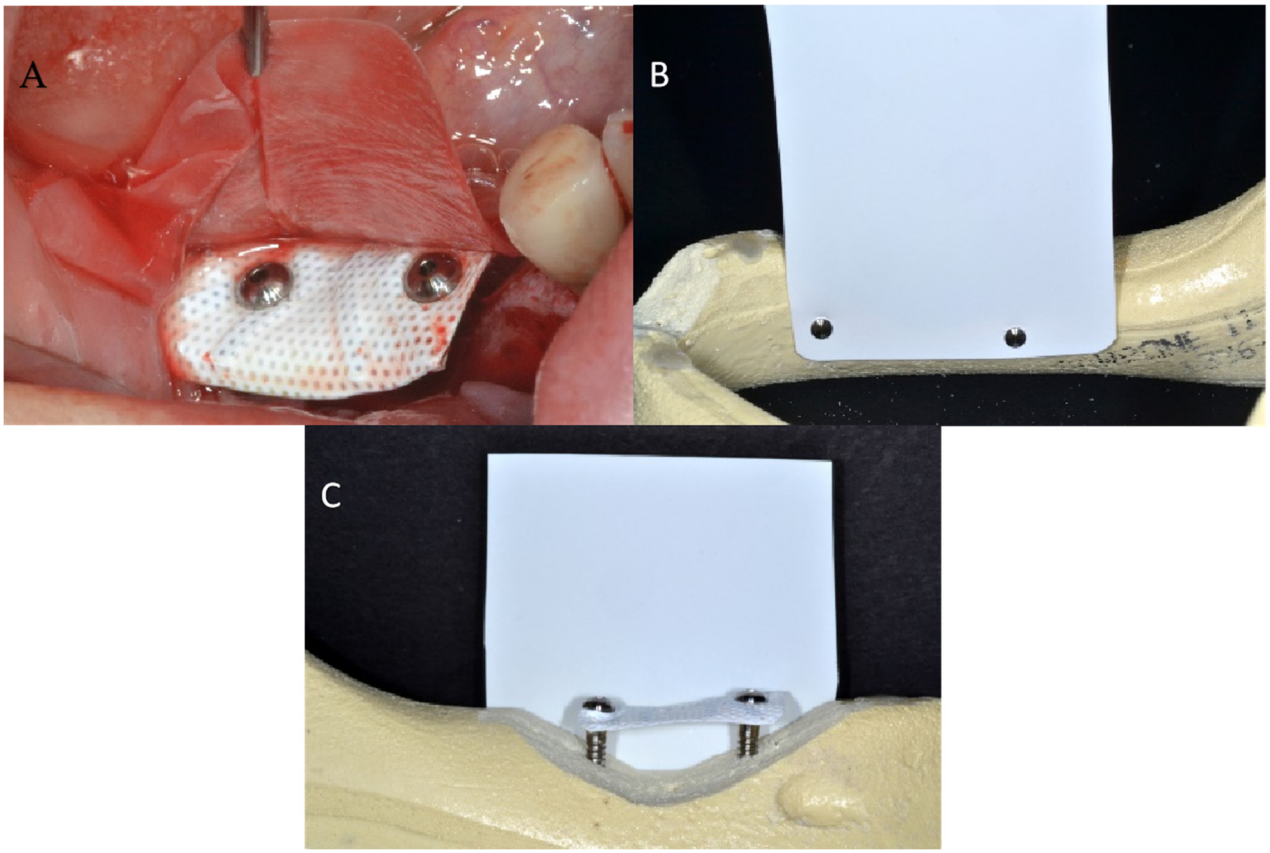

Figure 7. A collagen membrane was stabilized with tacks on the lingual side (A clinical, B-C simulator).

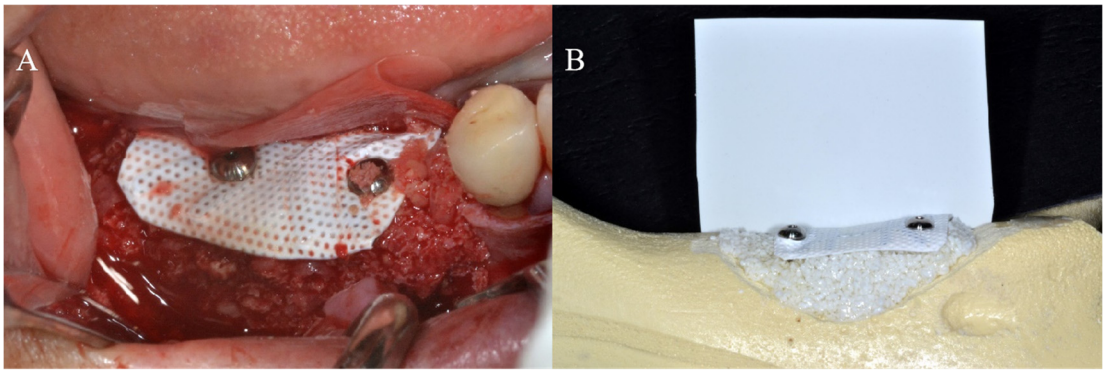

Figure 8. A mixture of particulate autogenous bone and porcine xenograft was introduced from the buccal side to fill the defect, while the collagen membrane on the lingual side served as a matrix to contain the graft (A clinical, B simulator).

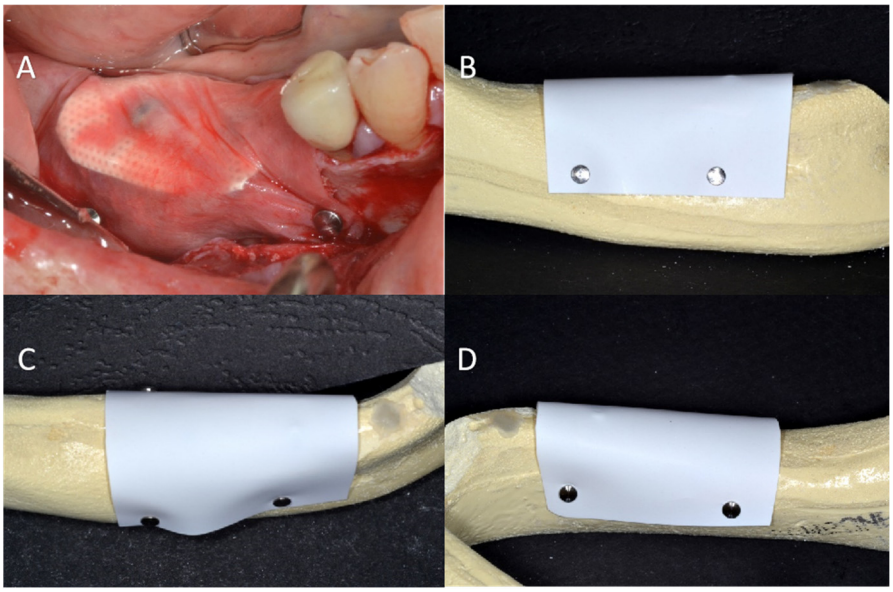

Figure 9. The collagen membrane was moved buccally to cover the graft and stabilized with tacks (A clinical, B–D simulator).

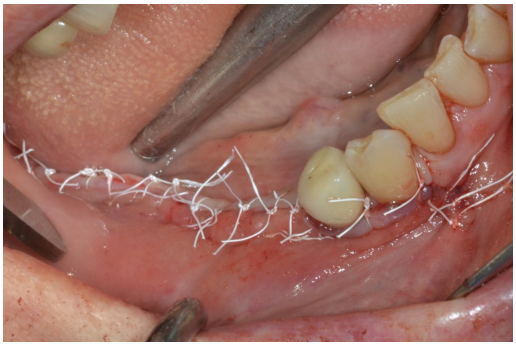

Figure 10. Flaps were closed with horizontal mattress and single 4-0 PTFE sutures.

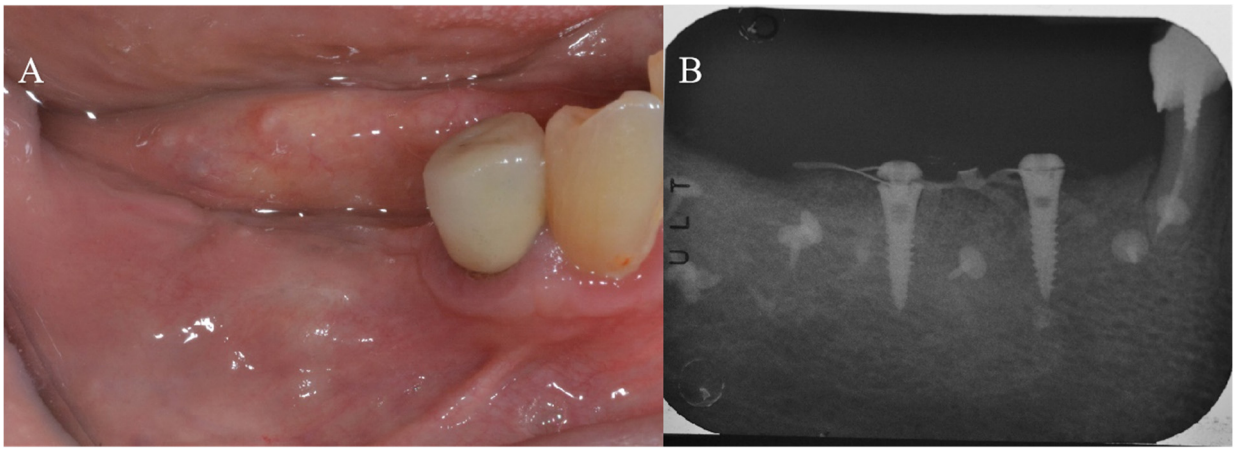

Figure 11. The yet thin band of keratinized mucosa was reduced (A), due to the coronal movement of the flaps, and the follow-up radiograph showed a still immature bone (B).

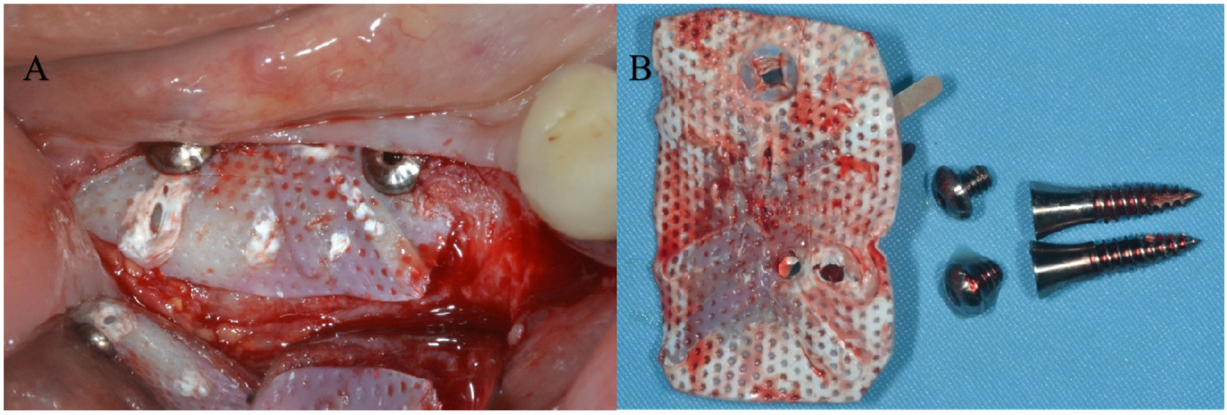

Figure 12. A split thickness buccal flap was raised (A) with the aim of not exposing the bone graft below, and the TR-dPTFE membrane was removed together with the tenting screws (B).

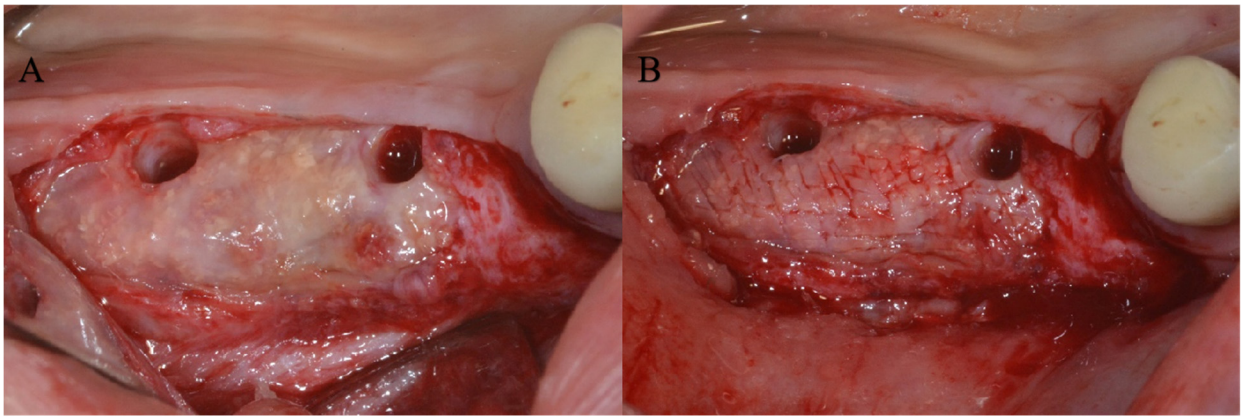

Figure 13. The bone graft below the TR-dPTFE membrane was covered by a 1 mm thick soft tissue (A) that was cut with a blade in order to promote bleeding (B).

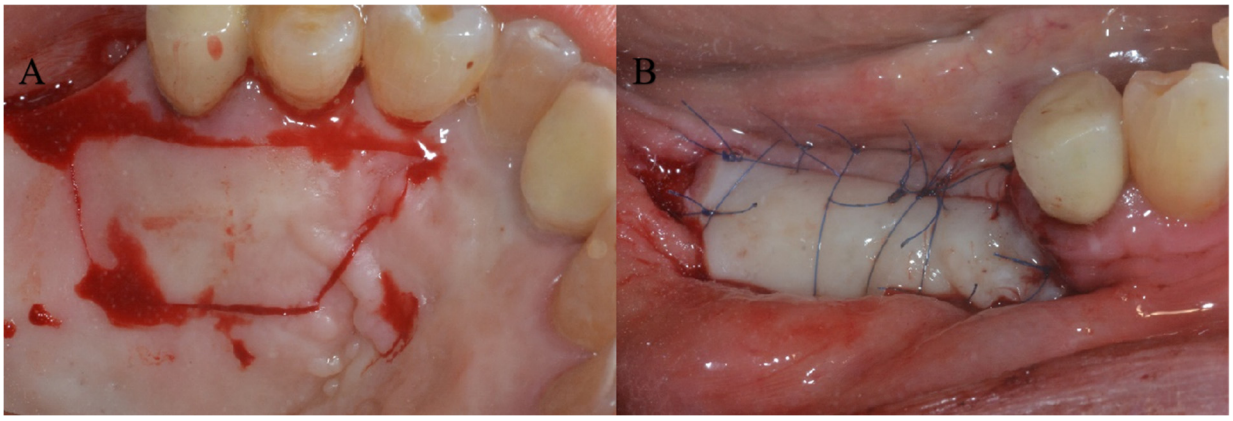

Figure 14. A free gingival graft was harvested from the palate (A) and stabilized with sutures on the recipient site to augment the band of keratinized mucosa (B).

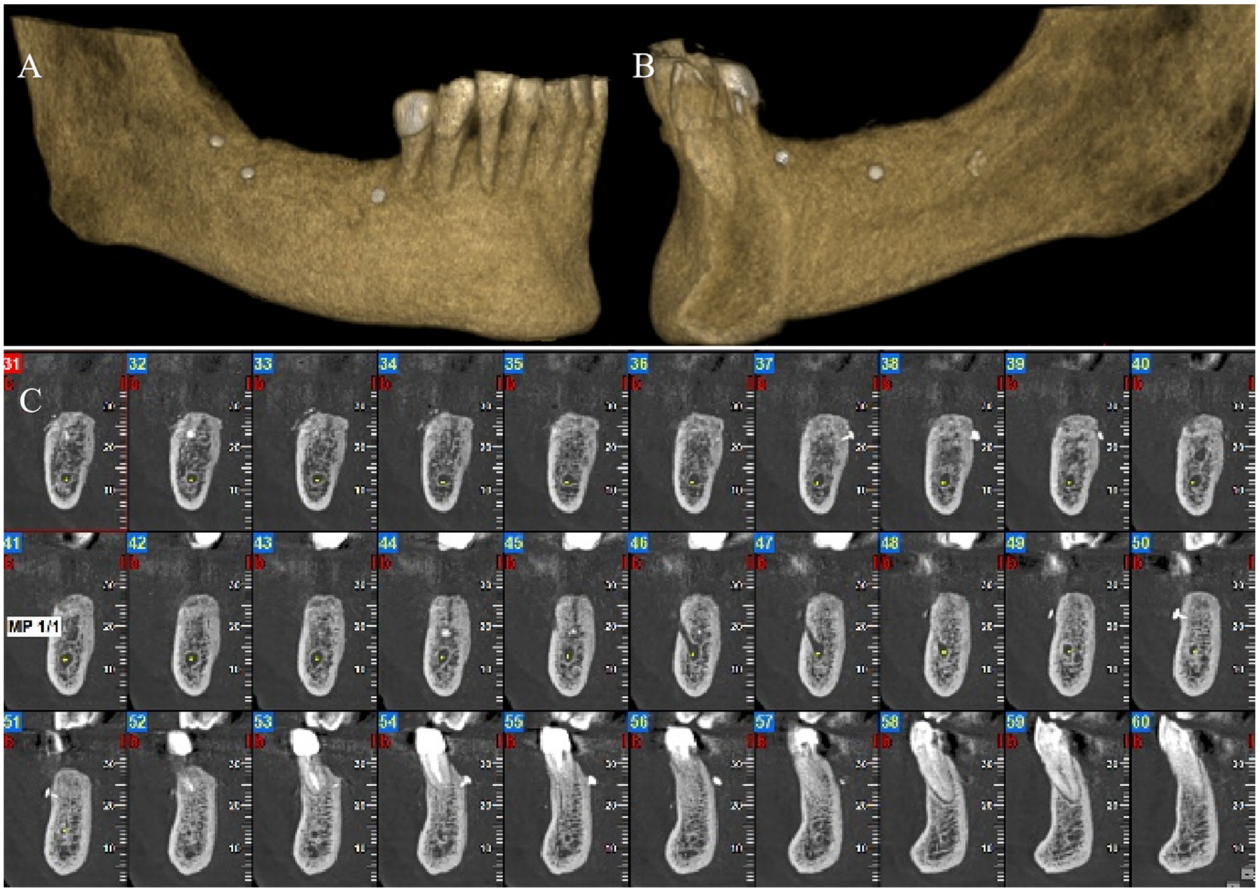

Figure 15. Twelve months after GBR a cone beam computed tomography was repeated: the tacks stabilizing the collagen membrane on the buccal (A) and lingual (B) side are still present. The scans show the resolution of the vertical bone defect (C).

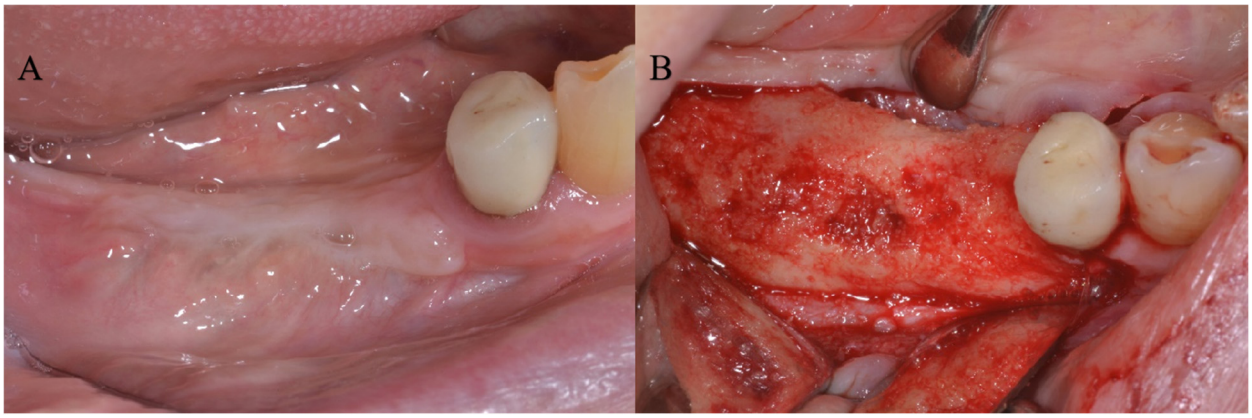

Figure 16. Although a gingival graft shrinkage happened, the amount of augmented keratinized mucosa was still adequate (A). A mucoperiosteal flap was raised and the bone appeared to be mature and well mineralized (B).

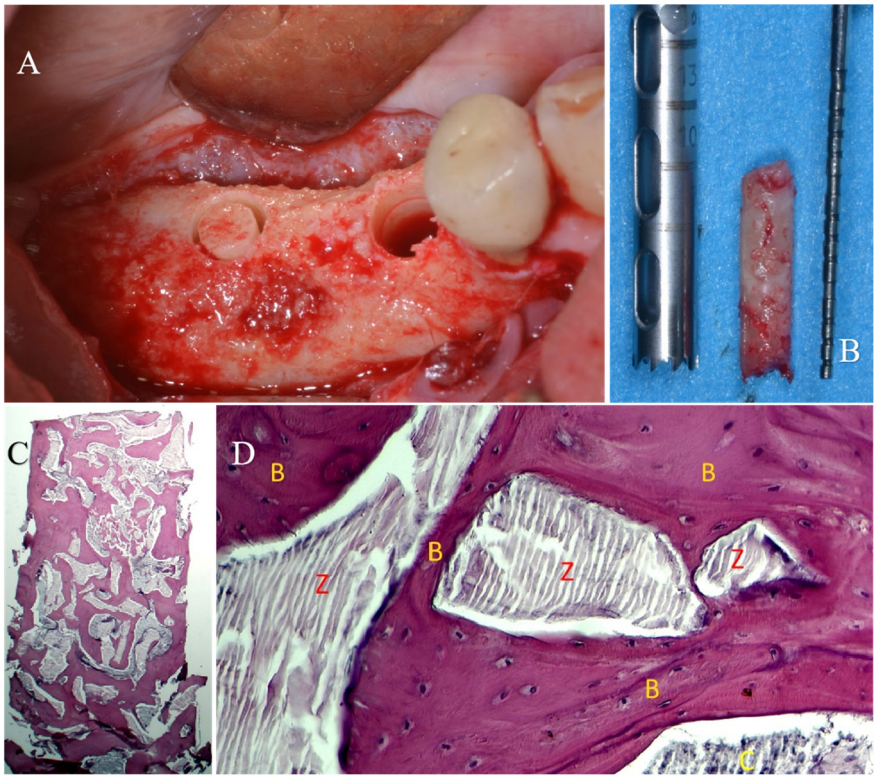

Figure 17. During implant bed preparation (A), a bone sample was harvested from the premolar region (B); the decalcified specimen was stained with hematoxylin and eosin, original magnification 25X (C) and 200X (D): new bone formation [B] occurred not only around the porcine xenograft particle [Z] but also within its cavities. Connective tissue [C] showed no sign of inflammation.

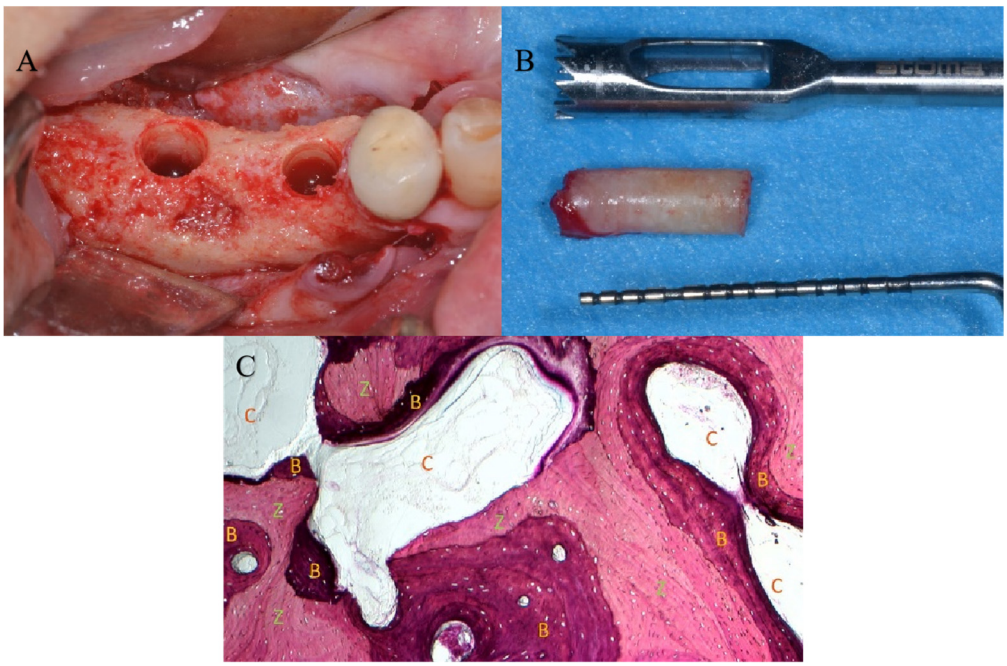

Figure 18. Another bone sample was harvested from the molar area (A). This specimen (B) was not decalcified but embedded in Technovit 9100, sectioned and stained with toluidine blue and acid fuchsin (C), original magnification 100X: porcine xenograft particles [Z] with apposition of newly formed bone [B] and well vascularized connective tissue [C].

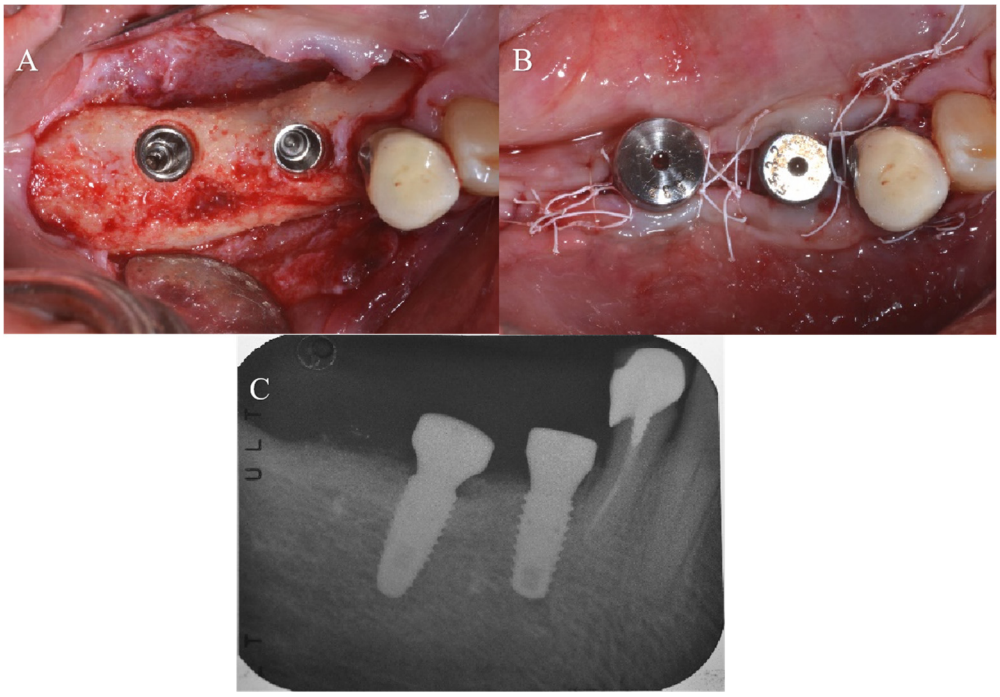

Figure 19. Two implants were inserted in the premolar/molar region 1 mm below the bone crest (A), and healing abutments were applied simultaneously (B). The control periapical radiograph (C).

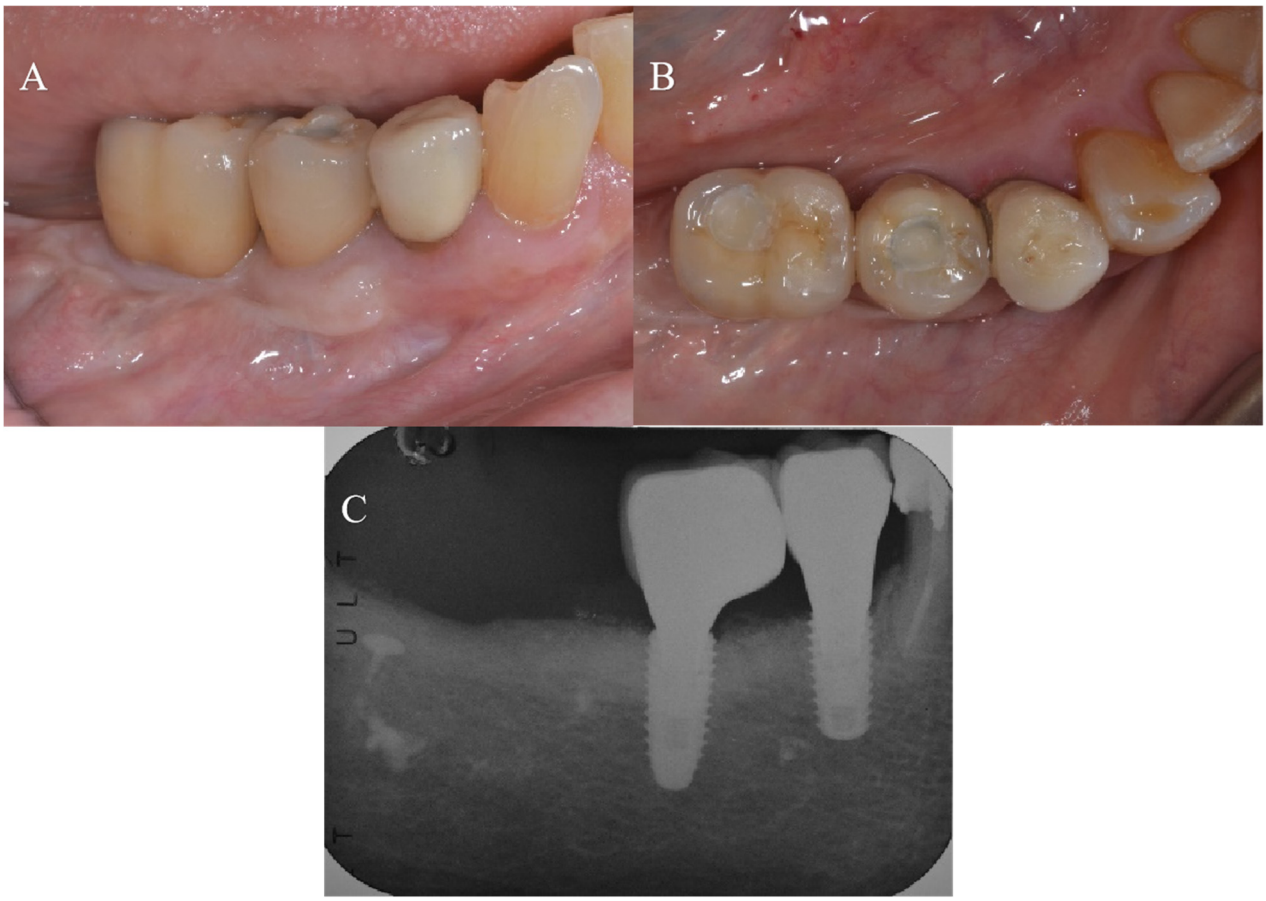

Figure 20. The 1 year clinical (A, B) and radiographic (C) follow-up after prosthetic loading showed excellent hard and soft tissues maintenance of the screw-retained porcelain-fused-to-metal crowns.

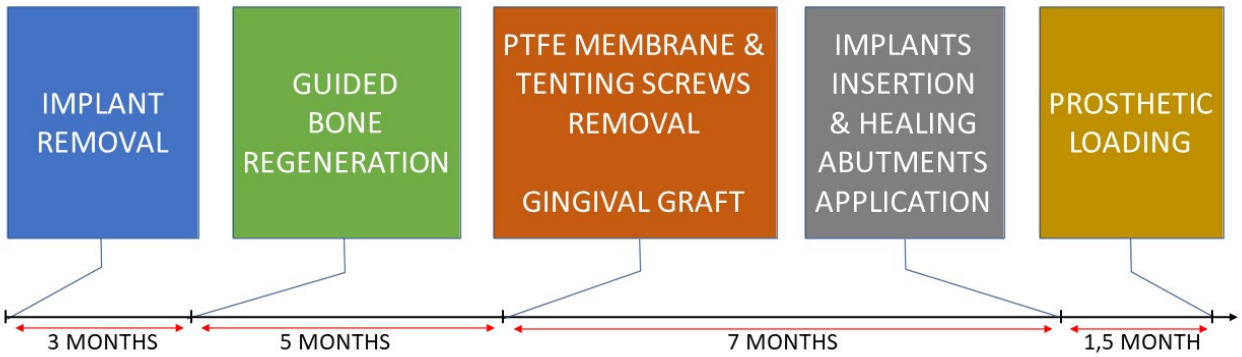

Figure 21. Global diagram summarizing the overall process and the time elapsed between the various procedures.

3. Results

This bone augmentation procedure was effective for the reconstruction of the alveolar ridge defect and the reestablishment of a proper band of KM. No additional ridge augmentation was required for implant placement. Although a 30% contraction of the gingival graft happened, the increased KM was equally divided by the lingual and buccal flap in adequate quantities. The regenerated bone had a "stone-like" quality and the implants reached primary stability very easily. Histologic evaluation revealed porcine xenograft particles integrated in newly formed bone or in well vascularized, uninflamed, loose connective tissue. One year later, clinical and radiographic follow-up showed well-maintained augmented hard and soft tissues. No bone loss happened in this first year of functional prosthetic loading.

4. Discussion

Some procedures are demanding and bear a higher risk for post-operative complications. GBR with non resorbable membranes, aimed to achieve vertical ridge augmentation, is a highly technique sensitive surgical intervention, and the most frequently reported related complications are wound dehiscences, membrane exposure, graft exposure, loss of graft material, and infection [1].

Bone augmentation can be performed simultaneously with or prior to dental implant placement. The staged approach offers several advantages compared with the simultaneous application of implants and barrier membrane [6]:

- it provides a larger bone surface to contribute to new bone formation, since no implant is inserted in the defect area. With a simultaneous implant placement, the implant reduces the exposed bone surface and its marrow space as a source of angiogenic and osteogenic cells, and an incomplete bone regeneration could be experienced in the most coronal part of the implant;
- it is easier to prepare the recipient site and obtain a better primary stability for the implant;
- the implant positioning can be optimized (especially important for esthetic indications);
- it offers the possibility to harvest a bone specimen for histologic evaluation;
- a better success rate in case of complications;
- it offers advantages with respect to bone maturation, since new bone formation is activated twice by the local release of growth factors. The first activation occurs during membrane surgery, when the cortical layer is perforated prior to graft placement to open the marrow cavity. The second activation occurs during implant placement, when the implant recipient site is prepared into the newly regenerated alveolar crest;
- a better bone apposition to the titanium surface can be achieved, since the "travel distance" for osteogenic elements from the exposed marrow cavity to the implant surface is much shorter.

In the technique proposed, as well as in the case reported, a staged approach was chosen. In the first stage, a resorbable collagen membrane was used to augment bone both vertically and horizontally. This membrane was sustained by a TR-dPTFE membrane, stabilized only with the tenting screws in the most coronal part of the vertical defect. These supporting devices helped the collagen membrane not to collapse over the defect and were removed after a primary bone graft remodeling happened. At this second stage, five months after GBR, the bone graft was still immature to receive implants, so the opportunity was taken to correct the soft tissues at this stage, augmenting the band of KM, previously reduced by flap coronal advancement, and deepening the vestibule. Implants were placed during the

third and last stage, 7 months after gingival graft/12 months after GBR, during which both bone and gingival graft had the time to get matured. This intervention was originally scheduled 3 months after gingival graft but was postponed because of Covid 19 pandemic restrictions. At this final stage healing abutments were applied too, since a thick and wide band of KM had been previously restored, avoiding a subsequent uncovering surgery.

Although the need of having a proper band of KM around the implants is still a controversial issue, the majority of the studies are in favor of having a band of KM to not only improve esthetic appearance but also to facilitate oral hygiene for better implant long-term stability, [1,7–9], and it was shown to be related to a better peri-implant-tissue health [10]. The presence of KM results in a more stable seal around the implant neck that facilitates the ability of the patients to clean the reconstructions and to limit bacterial infiltration [11]. Implant sites with less than 2 mm of KM were more prone to brushing discomfort, plaque accumulation, and peri-implant soft tissue inflammation compared to implant sites with ≥2 mm of KM [12]. A lack of adequate KM around endosseous dental implants is associated with more plaque accumulation, tissue inflammation, mucosal recession, and attachment loss [9,13].

FGG has been shown to be the most reliable way to increase the amount of KM and vestibular deepening. This was further confirmed by a systematic review, which reported that FGG remains the best documented and the most successful approach to increase KM width [5]. KM band augmentation surgeries can also be performed at different time points during implant treatment, prior to implant placement, during the phase of tissue integration, or after final restoration. However, 4–6 weeks before healing abutment connection was regarded as an optimal time point for this procedure. On the contrary, soft tissue augmentation after final restoration could be less predictable because of highly required skills [5,14]. A recent review revealed that the stability of soft tissue, in terms of KT width, can be obtained 3 months after surgery [15].

New bone formation into the grafted area may come either from the residual bone and from the periosteum. Periosteum is accepted to be the essential source for the repair of the bone tissue [3,4]. The osteogenic activity of the periosteal tissues has a great importance regarding the purposes of reconstruction. Ortak et al. [16] found that periosteal flaps had a very fast and stable reconstructive capacity of osteogenesis.

Bone resorption after vertical ridge augmentation with TR-PTFE membranes was attributed to the poor quality of the regenerated bone [17]. The difficulty to preserve the regenerated crestal bone and the rational to perform a secondary particulate graft, composed by 30% autogenous bone and 70% xenograft, covered by a collagen membrane, in order to prevent any bone resorption after implant placement, were described by these authors. Bone fragility and fracture of the newly formed ridge during implant placement were reported as well.

Some studies found that barrier membranes limited the amount of new bone formation in the portion of the graft closer to the periosteum. Simion et al. [18] evaluated the outcome of vertical ridge augmentation in a standardized dog model by combining purified recombinant platelet-derived growth factor and a block of deproteinized cancellous bovine bone, with or without the coverage by a resorbable barrier membrane. They found a larger amount of newly formed bone, and a larger amount of bone-to-implant contact in the group treated without placement of a barrier membrane than the group where the collagen membrane was used. They concluded that the results seemed to point to the importance of the periosteum as a source of osteoprogenitor cells in growth factor-mediated regenerative procedures.

This is consistent with the study of another group of researchers, who found a significantly greater bone formation closer to the residual bone (29%) compared with the portion of the graft closer to the periosteum (16%) in laterally augmented defects treated with the use of a resorbable membrane [19]. The authors explained that these results were influenced by the fact that the use of a membrane obstructed the mesenchymal cells of the cambium layer of the periosteum.

The use of a novel perforated resorbable barrier membrane (PRBM) was firstly described to enhance guided tissue regeneration (GTR) of periodontal defects [20], and then for a lateral bone augmentation of an horizontal maxillary defect for implant site development [21].The concept of PRBM consists of mechanically perforating a barrier membrane to allow the contribution of progenitor cells and growth factors from the periosteum and gingival connective tissues (CTs) into both intrabony osseous and periodontal defects.

GBR protocol consists of using barrier membranes to create a secluded space to allow the ingrowth of angiogenic and osteogenic cells to populate and regenerate these defects with bone, and simultaneously prevent the ingrowth of more rapidly proliferating soft tissues, such as periosteum and CTs, in which mesenchymal stem cells have been identified [22,23].

Those studies demonstrated enhanced clinical outcomes when using novel PRBMs compared to occlusive membranes in GTR procedures [20], and 38,1% new vital bone regeneration in the horizontal GBR procedure [21]. These results may be affected by the penetration of gingival CT contained stem cells and periosteal cells and their differentiation into components of the attachment apparatus and the regenerated bone.

Another clinical investigation, comparing vertical ridge augmentation with the use of either TR-PTFE membranes or a resorbable membrane sustained by a titanium mesh with the same bone graft, found that titanium-mesh group exhibited a slightly larger bony tissue area and lower soft tissue area than those of the TR-PTFE group [24]. The authors explained these results with the fact that the use of a resorbable membrane offers a better revascularization and mineralization of the bone graft compared to a PTFE membrane whose cellular occlusive effect was more lasting.

The technique described in this report lets the periosteum being in contact with the bone graft for a long period before implant placement. The use of a collagen membrane ensures that, when this is reabsorbed, the periosteum can vascularize and supply osteoprogenitor cells to the graft. Even in the most coronal part, once tenting screws and TR-dPTFE membrane have been removed, the periosteum will improve the quality of the regenerated tissue that, after a period of 12 months of maturation, that is considered to be an optimal healing time for vertical GBR [24], was found to be of the highest quality, well remodeled and mineralized, allowing the implant to achieve a high primary stability.

The handling of TR-dPTFE membrane was very easy, since it was not extended to cover the entire area of the defect, but was just limited in dimension to the most coronal part of the defect, defining the roof of the area to be regenerated. Belleggia & Gargari utilized a titanium mesh for the same purpose [25]. This mesh has a tendency to get exposed more easily than a TR-dPTFE membrane due to its higher stiffness. In addition, the texture of the dPTFE membrane seems to be more delicate with the thin thickness of the flaps since it's designed to increase the surface area available for cellular attachment, thereby assisting in stabilization of the membrane and prevention of soft tissue retraction.

Finally, in case of wound dehiscence and membrane exposure, the risk of complications is low, and its management would be very easy, since the TR-dPTFE membrane is fixed only by the tenting screws which are easy to access and remove. This kind of membrane was originally developed for the

open barrier technique utilized for socket preservation [26], since it doesn't require any primary soft tissue coverage and can be left exposed for some weeks without bacteria entering the grafted site below.

5. Conclusions

The "Hard Top Double Membrane Technique" is a procedure that allows the increase of hard and soft tissues, a reduction of the overall treatment time and the complication rate, and an improved bone graft quality and maturation with respect to non-resorbable membranes. The contribution of the periosteum improved the quality of the regenerated bone and allowed a straightforward implant insertion in a well remodeled mineralized bone and augmented KM, tissues that remained stable 1 year after prosthetic loading. The clinical outcome from this case report is encouraging: further clinical studies are needed to validate the advantages that this technique offers for vertical augmentation of the alveolar crest.

Acknowledgments

The author wishes to thank Mr. Ezio Bassotti from Catholic University of Sacred Heart, Rome, Italy, for bone biopsies' processing and staining.

Conflict of interest

The author declares no conflicts of interest in this paper.

References

1. Jepsen S, Schwarz F, Cordaro L, et al. (2019) Regeneration of alveolar ridge defects. Consensus report of group 4 of the 15th European Workshop on Periodontology on Bone Regeneration. *J Clin Periodontol* 46: 277–286. https://doi.org/10.1111/jcpe.13121
2. Dahlin C, Linde A, Gottlow J, et al. (1988) Healing of bone defects by guided tissue regeneration. *Plast Reconstr Surg* 81: 672–676. https://doi.org/10.1097/00006534-198805000-00004
3. Cohen J and Lacroix P (1955) Bone and cartilage formation by periosteum; assay of experimental autogenous grafts. *J Bone Joint Surg* 37: 717–730. https://doi.org/10.2106/00004623-195537040-00005
4. Melcher AH and Accursi GE (1971) Osteogenic capacity of periosteal and osteoperiosteal flaps elevated from the parietal bone of the rat. *Arch Oral Biol* 16: 573–580. https://doi.org/10.1016/0003-9969(71)90060-4
5. Thoma D, Buranawat B, Hammerle C, et al. (2014) Efficacy of soft tissue augmentation around dental implants and in partially edentulous areas: A systematic review. *J Clin Periodontol* 41: S77–S91. https://doi.org/10.1111/jcpe.12220
6. Buser D, Dula K, Hirt HP, et al. (1996) Lateral ridge augmentation using autografts and barrier membranes: a clinical study with 40 partially edentulous patients. *J Oral Maxillofac Surg* 54: 420–432. https://doi.org/10.1016/S0278-2391(96)90113-5
7. Bouri A, Bissada N, Al-Zahrani MS, et al. (2008) Width of keratinized gingiva and the health status of the supporting tissues around dental implants. *Int J Oral Maxillofac Implants* 23: 323–326.

8. Chung DM, Oh TJ, Shotwell JL, et al. Significance of keratinized mucosa in maintenance of dental implants with different surfaces. *J Periodontol* 77: 1410–1420. https://doi.org/10.1902/jop.2006.050393
9. Lin GH, Chan HL, Wang HL (2014) Effects of currently available surgical and restorative interventions on reducing midfacial mucosal recession of immediately placed single-tooth implants: A systematic review. *J Periodontol* 85: 92–102. https://doi.org/10.1902/jop.2013.130064
10. Brito C, Tenenbaum HC, Wong BK, et al. (2014) Is keratinized mucosa indispensable to maintain peri-implant health? A systematic review of the literature. *J Biomed Mater Res B Appl Biomater* 102: 643–650. https://doi.org/10.1002/jbm.b.33042
11. Thoma DS, Naenni N, Figuero E, et al. (2018) Effects of soft tissue augmentation procedures on peri-implant health or disease: A systematic reviewand meta-analysis. *Clin Oral Impl Res* 29: 32–49. https://doi.org/10.1111/clr.13114
12. Souza AB, Tormena M, Matarazzo F, et al. (2016) The influence of peri-implant keratinized mucosa on brushing discomfort and peri-implant tissue health. *Clin Oral Implants Res* 27: 650–655. https://doi.org/10.1111/clr.12703
13. Warrer K, Buser D, Lang NP, et al. (1995) Plaque-induced peri-implantitis in the presence or absence of keratinized mucosa. An experimental study in monkeys. *Clin Oral Implants Res* 6: 131–138. https://doi.org/10.1034/j.1600-0501.1995.060301.x
14. Thoma DS, Mühlemann S, Jung RE (2014) Critical soft-tissue dimensions with dental implants and treatment concepts. *Periodontol 2000* 66: 106–118. https://doi.org/10.1111/prd.12045
15. Lin CY, Chen Z, Pan WL, et al. (2018) Impact of timing on soft tissue augmentation during implant treatment: A systematic review and meta-analysis. *Clin Oral Impl Res* 29: 508–521. https://doi.org/10.1111/clr.13148
16. Ortak T, Ozdemir R, Uysal A, et al. (2005) Osteogenic capacities of periost grafts, periost flaps and prefabricated periosteal flaps: experimental study. *J Craniofac Surg* 16: 594–600. https://doi.org/10.1097/01.scs.0000168773.71356.62
17. Urban IA, Monje A, Wang HL (2015) Vertical ridge augmentation and soft tissue reconstruction of the anterior atrophic maxillae: a case series. *Int J Periodontics Restorative Dent* 35: 613–623. https://doi.org/10.11607/prd.2481
18. Simion M, Rocchietta I, Kim D, et al. (2006) Vertical ridge augmentation by means of deproteinized bovine bone block and recombinant human platelet-derived growth factor-BB: a histologic study in a dog model. *Int J Periodontics Restorative Dent* 26: 415–423.
19. Mordenfeld A, Johansson CB, Albrektsson T, et al. (2014) A randomized and controlled clinical trial of two different compositions of deproteinized bovine bone and autogenous bone used for lateral ridge augmentation. *Clin Oral Impl Res* 25: 310–320. https://doi.org/10.1111/clr.12143
20. Gamal AY and Iacono VJ (2013) Enhancing guided tissue regeneration of periodontal defects by using a novel perforated barrier membrane. *J Periodontol* 84: 905–913. https://doi.org/10.1902/jop.2012.120301
21. Carrion JA, Wang HH, Masselli J, et al. (2017) Enhanced lateral bone augmentation with a perforated resorbable barrier membrane. *Clin Adv Periodontics* 7: 152–158. https://doi.org/10.1902/cap.2017.160080

22. Ferretti C, Borsari V, Falconi M, et al. (2012) Human periosteum-derived stem cells for tissue engineering applications: The role of VEGF. *Stem Cell Rev* 8: 882–890. https://doi.org/10.1007/s12015-012-9374-7
23. Mitrano TI, Grob MS, Carrion F, et al. (2010) Culture and characterization of mesenchymal stem cells from human gingival tissue. *J Periodontol* 81: 917–925. https://doi.org/10.1902/jop.2010.090566
24. Cucchi A, Sartori M, Parrilli A, et al. (2019) Histological and histomorphometric analysis of bone tissue after guided bone regeneration with non-resorbable membranes vs resorbable membranes and titanium mesh. *Clin Implant Dent Relat Res* 21: 693–701. https://doi.org/10.1111/cid.12814
25. Belleggia F and Gargari M (2019) The "Umbrella Technique": a new procedure for hard and soft tissue augmentation in the vertical defects of the jaws. *Oral Implantol (Rome)* 12: 180–193.
26. Bartee BK (2001) Extraction site reconstruction for alveolar ridge preservation. Part 2: membrane-assisted surgical technique. *J Oral Implantol* 27: 194–197. https://doi.org/10.1563/1548-1336(2001)027<0194:ESRFAR>2.3.CO;2

AIMS Press