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CASE STUDY

Peri-implantitis treatment with an open barrier double membrane technique (collagen + dense polytetrafluoroethylene)

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Abstract

Background: Reconstructive treatments of peri-implantitis are carried out with the principles of guided bone regeneration, with a non-submerged or with a submerged approach. The authors describe a new technique for the reconstruction of intra-bony vertical defects caused by peri-implantitis, which requires the removal of the prosthetic superstructure to have better access to the surgical site, in order to perform the defect debridement and the implant surface decontamination and detoxification, before placing the reconstructive biomaterials.

Methods: A 2 mm high cap screw was connected to the implant with the aim of not letting a cross-linked collagen membrane to collapse over the implant threads. This membrane covered the implant and the whole defect, filled with a porcine bone graft wet with hyaluronic acid. A second membrane, made of dense polytetrafluoroethylene (dPTFE), was placed over the previous one and left exposed, avoiding a second intervention for its removal, which occurred after a 5-week healing time by grasping the membrane with forceps and removing it with a gentle tug. After cap screw removal, it was possible to insert an healing abutment.

Results: The augmented bone remained stable 2.5 years after prosthetic superstructure re-insertion. Soft tissue architecture was maintained since the flaps were not repositioned coronally, the mucogingival line and the fornix were not distorted, and there was no reduction of keratinized mucosa.

Conclusions: The benefits of this technique include the reliable defect isolation and containment of graft particles, ease of membrane placement, simplified dPTFE membrane removal, and preservation of mucogingival architecture.

KEYWORDS
biocompatible materials, bone regeneration, bone replacement materials, guided tissue regeneration, periimplantitis

Key points

- The prosthetic superstructure removal provides better access to the surgical site in order to perform the defect debridement and the implant surface decontamination and detoxification, before placing the reconstructive biomaterials.
- The use of a 2 mm high closure cap or a short healing abutment prevents membrane collapse on the implant threads.
- Since the dense polytetrafluoroethylene membrane is not buried, but intentionally left exposed, its removal after a 5–6-week healing period doesn't require a second surgery. Furthermore, it is also possible to re-insert the prosthetic superstructure, reducing the overall treatment time generally respected

with the conventional submerged approach, which involves uncovering the implant after a healing period of 6–9 months.

Plain language summary

The authors describe a new technique for the reconstruction of intra-bony vertical defects caused by peri-implantitis, which requires the removal of the prosthetic superstructure to have better access to the surgical site, in order to perform the defect debridement and the implant surface decontamination and detoxification, before placing the reconstructive biomaterials. Two membranes are used: a collagen membrane that covers the whole defect filled with a xenograft, and a dense polytetrafluoroethylene membrane, applied over the collagen one, that is intentionally left exposed in order to easily remove it after a 5–6-week healing period without a second surgery. This cost-effective, predictable treatment protocol is indicated for the general practitioner who usually doesn't treat complex cases requiring advanced skills.

INTRODUCTION

Peri-implantitis is a plaque-associated pathological condition occurring in tissues around dental implants, characterized by inflammation in the peri-implant mucosa and subsequent progressive loss of supporting bone.[1] The treatment of peri-implantitis can be both non-surgical and surgical. If non-surgical therapy cannot provide a resolution, especially in the case of advanced lesions, then a surgical intervention must be considered. Different surgical approaches have been described:[2,3] non-reconstructive treatments (i.e., access flap surgery and resective techniques) primarily aim to resolve inflammation and arrest further disease progression, but are followed by significant postoperative peri-implant soft tissue recession. In esthetically demanding areas, reconstructive treatments have to be preferred, since they seek to limit the peri-implant soft-tissue recession, reduce the probing depth, regenerate the bony defect, and achieve re-osseointegration.[4,5]

Reconstructive treatments are carried out with the principles of guided bone regeneration (GBR), utilizing bone grafts covered by a barrier membrane,[6] and can be managed with a non-submerged or with a submerged approach.[7] The possibility of removing the prosthesis must be considered, since it allows not only better access to the surgical site but above all a submerged (two-stage) technique, rather than a transmucosal (single-stage) approach. Whenever it is possible to remove the prosthetic superstructure, the choice of a submerged healing allows better blood clot protection and a more predictable clinical outcome,[8] due to undisturbed healing and a reduced risk of infection, and may provide bone regeneration in both supra-bony and intra-bony components, while non-submerged approach can only provide bone regeneration limited to the intra-bony component.

In the non-submerged approach a collagen membrane (CM) is generally used, since it is resorbable and doesn't require a second intervention for its removal, while in the submerged approach a non-resorbable membrane made from dense polytetrafluoroethylene (d-PTFE), with or without titanium reinforcement, is often preferred to the resorbable membranes, because d-PTFE membranes allow to regenerate the supra-bony component of the bone defect. These membranes were originally developed for the open barrier ridge preservation technique after a tooth extraction[9] as their low porosity allowed the clinician to leave them intentionally exposed in the oral cavity, avoiding the passage of bacteria through the membrane into the bone graft, and making their removal easy after 3–4 weeks, without the need of a second intervention. This technique has been modified by the authors and adapted for the treatment of bone defects caused by peri-implantitis.

MATERIALS AND METHODS

Clinical presentation

A new technique for the treatment of peri-implantitis is described through the description of a clinical case. A healthy non-smoker 40-year-old woman, wearing a removable partial denture in the maxilla (Figure 1A–C), stabilized on two implants with Locator abutments (Figure 1D,E), presented to the private practice of one of the authors (Fabrizio Belleggia) for pain referred to the left implant (Figure 2A). Periapical radiograph (Figure 2B) revealed bone loss around the implant surface for approximately half of its length (about 5 mm). In the absence of previous examination data, the diagnosis of peri-implantitis was based on the presence of bleeding (BOP) and suppuration (SOP) on gentle probing, probing depth (PD) $\geq$ 6 mm, and bone levels $\geq$ 3 mm apical of the most coronal portion of the intraosseous part of the implant. PD measured as follows: 9 mm mesio-buccal (MB), 9 mm buccal (B), 8 mm disto-buccal (DB), 9 mm mesio-buccal (MP), 8 mm palatal (P), 8 mm disto-palatal (DP). BOP was present at all six sites, as was the presence of

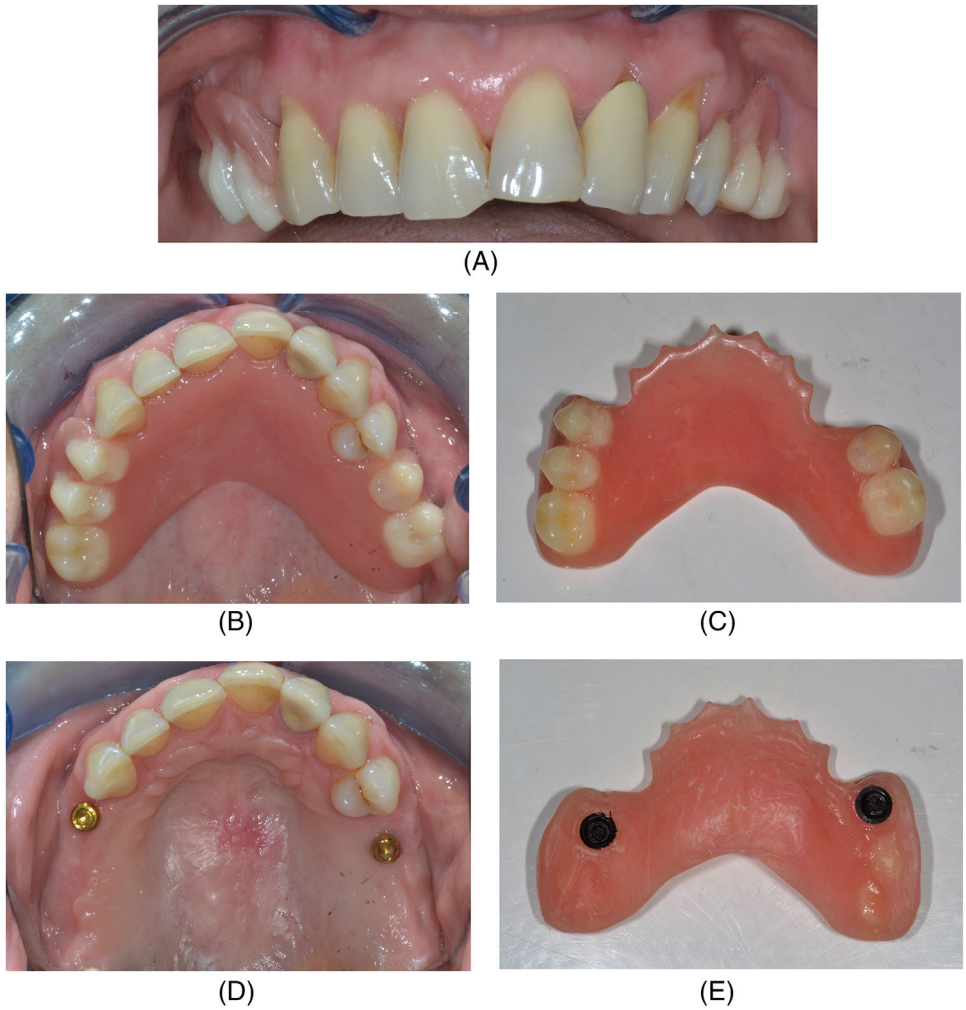

FIGURE 1 The patient had a removable partial denture in the maxilla (A–C) stabilized to Locator abutments on two implants in the premolar region (D, E).

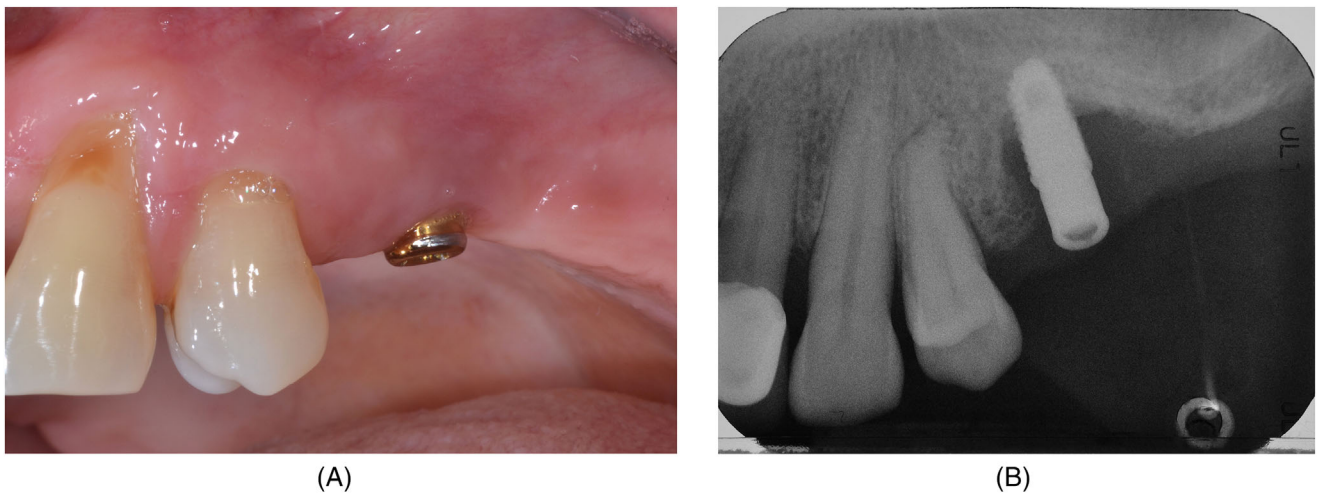

FIGURE 2 For the implant on the left (A), a diagnosis of peri-implantitis was based on the presence of bleeding and suppuration on gentle probing, and radiographic bone loss around the implant surface for approximately half of its length (B).

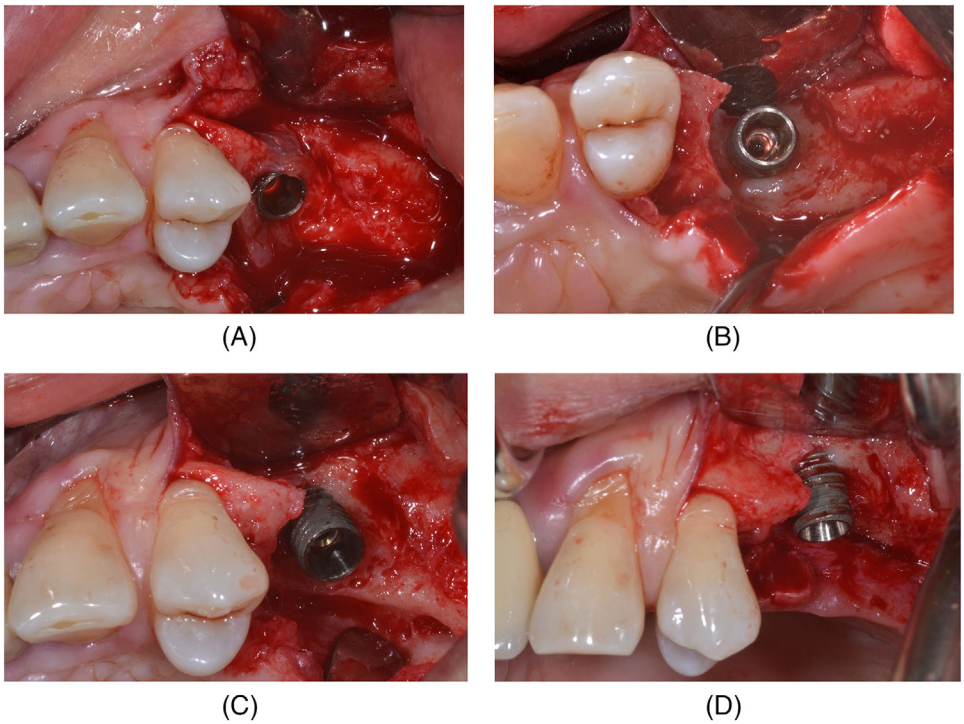

FIGURE 3 After prosthetic abutment removal, a small mucoperiosteal triangular flap, with one distal vertical releasing incision, was raised to expose the bone defect (A). Following peri-implant defect debridement, the three-dimensional morphology of the defect and the size of residual bony walls could be determined, with the loss of both the buccal and palatal walls (B–D).

SOP. The patient signed an informed consent form for the reconstructive procedure. CARE reporting guidelines were used.[10]

Surgical case management

After Locator abutment removal, a small mucoperiosteal flap was raised to expose the bone defect. A 15 mm crestal incision was made distal to the implant to reach healthy bone for membrane stabilization, then a small vertical releasing incision was made, buccally and palatally. Mesially to the implant, only an intrasulcular incision was made to the zenith of the adjacent tooth. The extension of this flap, at least 5 mm beyond the sound bone margins on the palatal and the facial aspect of the implant site, provided full access and visibility to treat the peri-implant defect (Figure 3A). Following peri-implant defect debridement, with removal of the granulomatous soft tissue collar around the exposed implant threads, utilizing a titanium curette[*] and the Hirschfeld file[†], the three-dimensional morphology of the defect and the size of residual bony walls could be determined, with the loss of both the buccal and palatal walls (Figure 3B–D), that was classified as Class Id (buccal and palatal dehiscence + circular bone resorption) according to Schwarz et al.[11] Implant surface decontamination (Figure 4A), to remove biofilm and mineralized deposits from the implant surface, was carried out with a titanium brush[‡] and a titanium curette[*] applied in a circular direction around each exposed implant thread to remove or disrupt the biofilm and mineralized deposits on the implant surface. Implant surface detoxification was performed with the topical application of the powder of tetracycline hydrochloride[§] dissolved in physiologic solution (50 mg/mL) and rubbed on the implant surface with cotton pellets for 3 min, followed by rinsing with physiologic solution for 30 s.

A 2 mm high closure cap was connected to the implant in order to get a tenting effect and prevent membrane collapse on the implant threads (Figure 4B). Then, a 20×30 cross-linked CM (CLCM)[‖] was trimmed to fit the defect, placed on the palatal side (Figure 5A,B), and secured with a horizontal mattress suture utilizing a 6-0 monofilament resorbable material[¶] to the palatal flap. A highly porous particulate porcine xenograft[#], rehydrated with hyaluronic acid[**], was used to fill the defect (Figure 6A,B). Then the CLCM was moved toward the buccal side for a complete coverage of the implant and the bone graft (Figure 6C) and secured

[*] Langer 1/2 titanium implant scaler, Hu-Friedy, Frankfurt am Main, Germany
[†] Hirschfeld file 3/7, Hu-Friedy, Frankfurt am Main, Germany

[‡] I Brush II, Neo Biotech, Seoul, Korea
[§] Ambramicina 250, Sanofi Aventis, Paris, France
[‖] Cytoplast RTM, Osteogenics Biomedical, Lubbock, TX, USA
[¶] Flysorb Mono, Butterfly Italia, Cavenago di Brianza, Italy
[#] ZCore, Osteogenics Biomedical, Lubbock, TX, USA
[**] Hyamix 5, Italmed Srl, Firenze, Italy

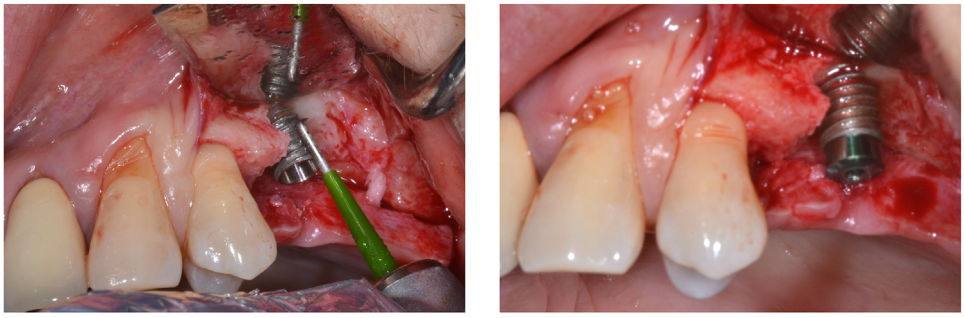

FIGURE 4 Implant surface decontamination was carried out with a titanium brush to remove biofilm and mineralized deposits from the implant surface (A). A 2 mm high closure cap was connected to the implant in order to create space and get a tenting effect to prevent membrane collapse on the implant threads (B).

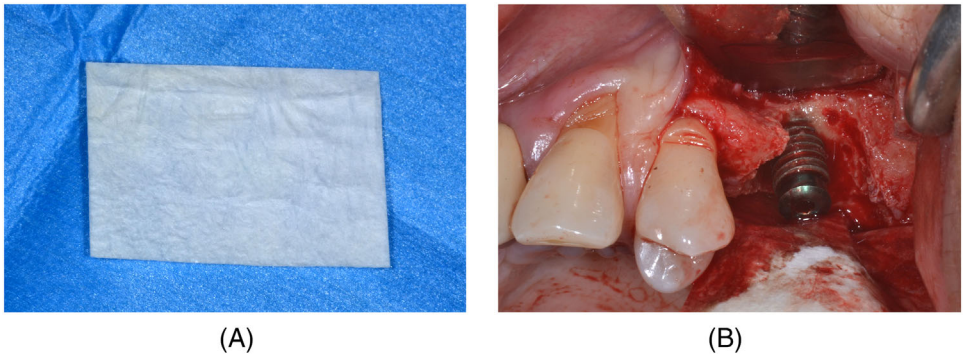

FIGURE 5 The structural characteristics of the cross-linked collagen membrane (A), which was placed on the palatal side and stabilized to the palatal flap with a horizontal mattress suture made of monofilament resorbable material (B).

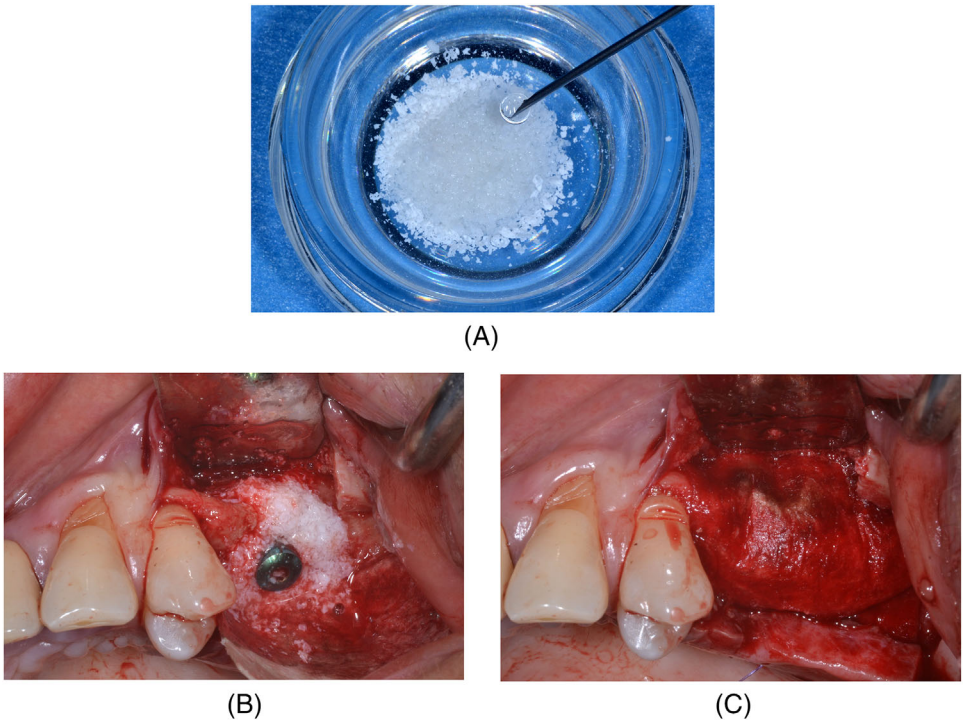

FIGURE 6 A highly porous particulate porcine xenograft, wet with hyaluronic acid in a 1cc/1 mL ratio (A), was used to fill the defect (B). Then the collagen membrane was moved toward the buccal side for a complete coverage of the implant and the bone graft and secured with a monofilament resorbable stitch to the buccal flap (C).

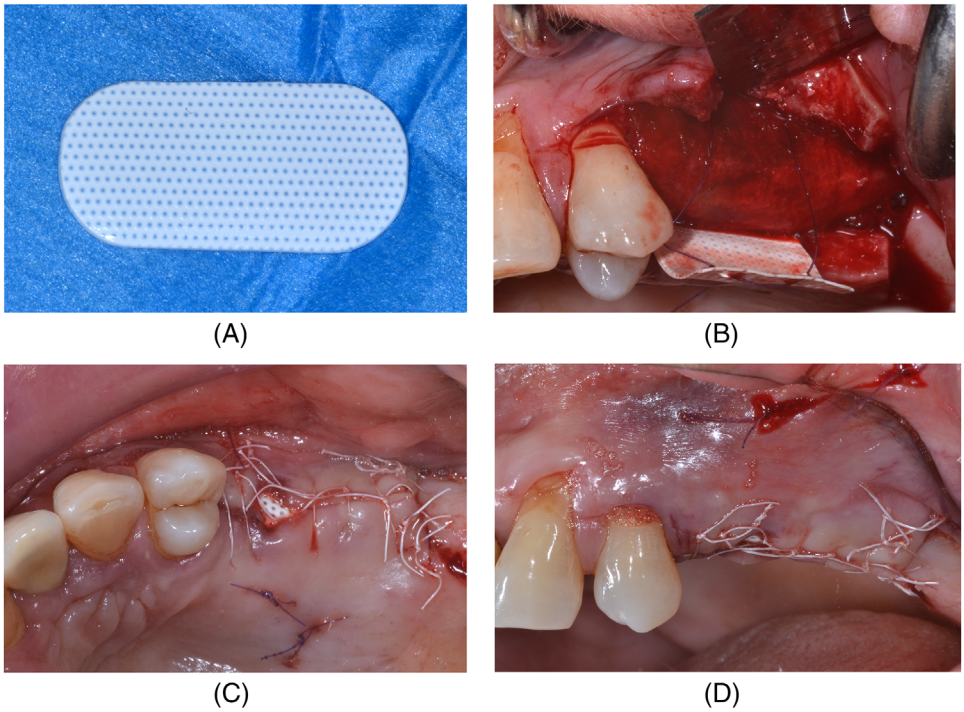

FIGURE 7 A dense polytetrafluoroethylene membrane (A), with a textured surface designed to increase the surface area available for cellular attachment, thereby assisting in stabilization of the PTFE membrane and prevention of soft tissue retraction, was placed over the collagen membrane in the same way, stabilized to the buccal and palatal flap with the use of horizontal mattress monofilament resorbable sutures (B). Flaps were closed with 4-0 dense polytetrafluoroethylene sutures without any attempt to get primary closure, but leaving the dense polytetrafluoroethylene membrane intentionally exposed (C, D).

with a monofilament resorbable horizontal mattress suture to the buccal flap. A 12×24 dPTFE membrane[††] was placed over the CLCM in the same way (Figure 7A,B), stabilized to the buccal and palatal flap with the use of horizontal mattress resorbable sutures[¶]. The mesio-distal extension of this second membrane was more limited than the collagen one, since its removal had to occur without the elevation of a flap. Flaps were closed with 4-0 dPTFE sutures[‡‡] without any attempt to get primary closure, but leaving the dPTFE membrane intentionally exposed (Figure 7C,D), as in a case of open barrier ridge preservation technique after a tooth extraction. The patient was prescribed to take amoxicillin 1 g, two times daily for 6 days and ibuprofen 600 mg as needed, rinse with 0.2% chlorhexidine mouthwash two times daily for 15 days, apply 1% chlorhexidine gel to the membrane 3 times daily and clean the wound with a cotton swab soaked in 3% hydrogen peroxide for 5 weeks. The bone defect filling was checked with a post-operative peri-apical radiograph (Figure 8), and two weeks later, sutures were removed (Figure 9A,B). After a 5-week uneventful healing (Figure 10A), a radiograph was taken to have time 0 to evaluate volume, contraction, and maturation of the bone graft over time (Figure 10B). The dPTFE membrane was grasped with tissue forceps and removed with a gentle tug. This procedure was well tolerated by the patient, did not require a second surgery, nor the administration of local anesthetic. Soft tissue, a dense vascular connective tissue matrix according to a histologic human study performed at dPTFE membrane removal,[12] covered the bone graft (Figure 10C) and surrounded the head of the 2 mm high cover cap, which was replaced with a wider healing abutment (Figure 10D) for transmucosal healing.

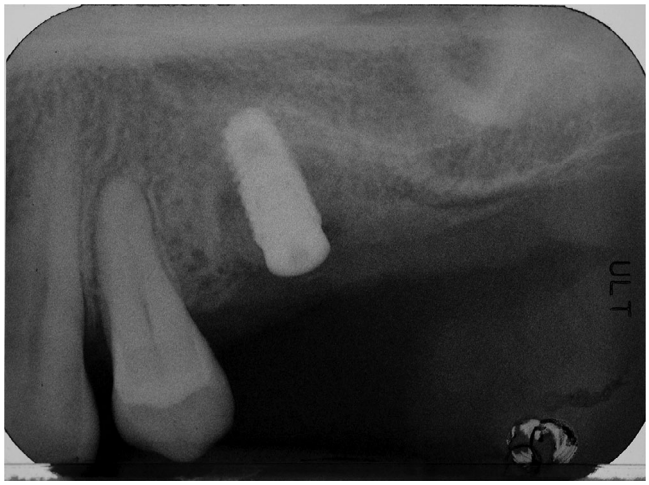

FIGURE 8 Post-operative peri-apical radiograph showing the bone defect filling.

[††] Cytoplast TXT, Osteogenics Biomedical
[‡‡] Cytoplast PTFE Suture, Osteogenics Biomedical

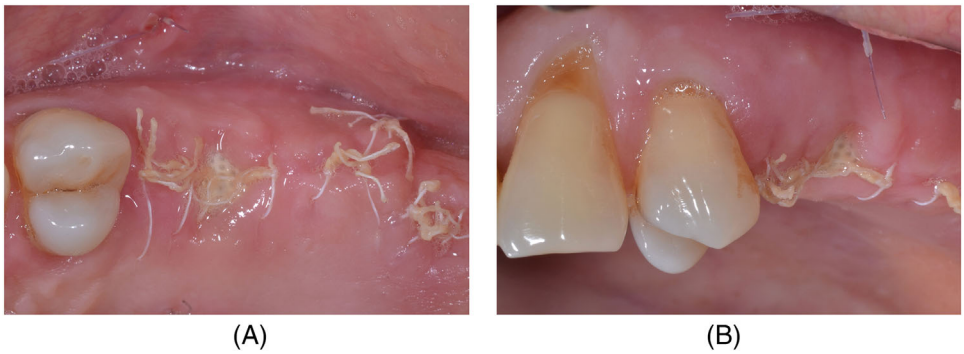

FIGURE 9 Sutures were removed after 2 weeks (A, B).

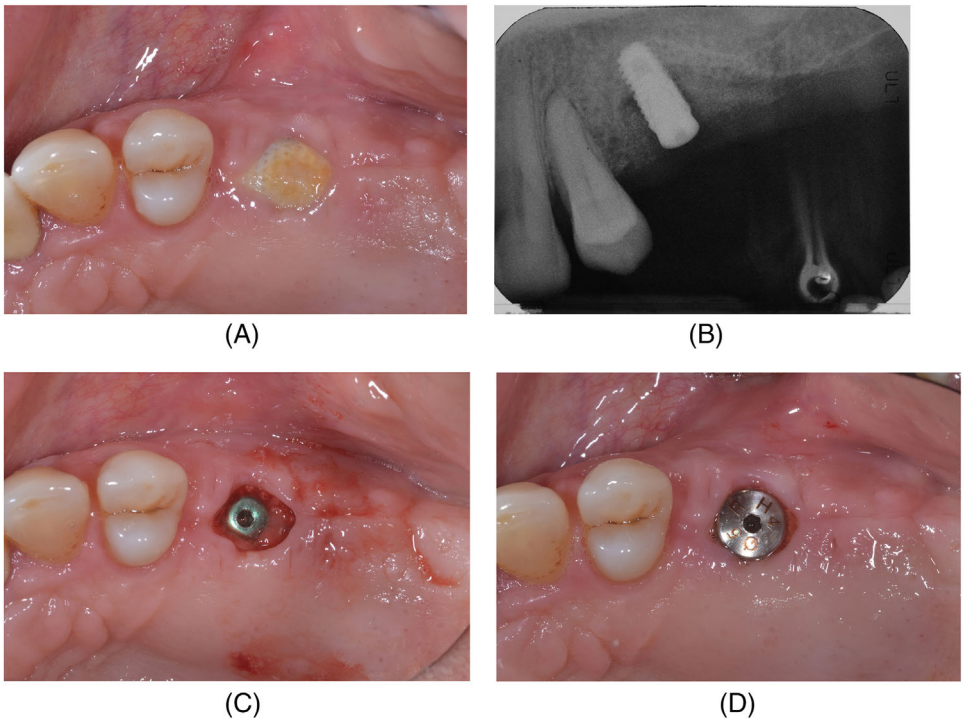

FIGURE 10 Clinical (A) and radiographic (B) follow-up after 5 weeks. The dense polytetrafluoroethylene membrane was grasped with a tissue forcep and removed with a gentle tug. A dense, vascular connective tissue matrix covered the bone graft and surrounded the head of the 2 mm high cover cap (C), which was replaced with a wider healing abutment for transmucosal healing (D).

RESULTS

At the 3-month follow-up, soft tissues remodeled around the healing abutment (Figure 11A,B) and the bone graft improved mineralization (Figure 11C), so that the following month the healing abutment was removed (Figure 12A–C) and the former Locator abutment was re-inserted (Figure 12D–F). Supportive peri-implant care was provided every 3 months for the first 12 months, and then every 6 months. At the 6-week follow-up after prosthetic abutment re-insertion, the peri-implant site was characterized by the absence of erythema, bleeding on probing, swelling, and suppuration (Figure 13A) and a stable radiographic bone filling (Figure 13B). The same conditions were also maintained 1 year after Locator abutment was re-inserted (Figure 14A–C), without clinical signs of inflammation or radiographic bone loss, and at the 2.5-year clinical and radiographic follow-up (Figure 15A–C), when PD values measured as follows: 4 mm MB, 3 mm B, 4 mm DB, 4 mm MP, 4 mm P, 4 mm DP, with no BOP or SOP.

DISCUSSION

The choice to manage peri-implant bone loss with a non-submerged or with a submerged approach depends on several factors, first of all, the defect type.[7] The possibility of removing the prosthetic superstructure is mandatory to

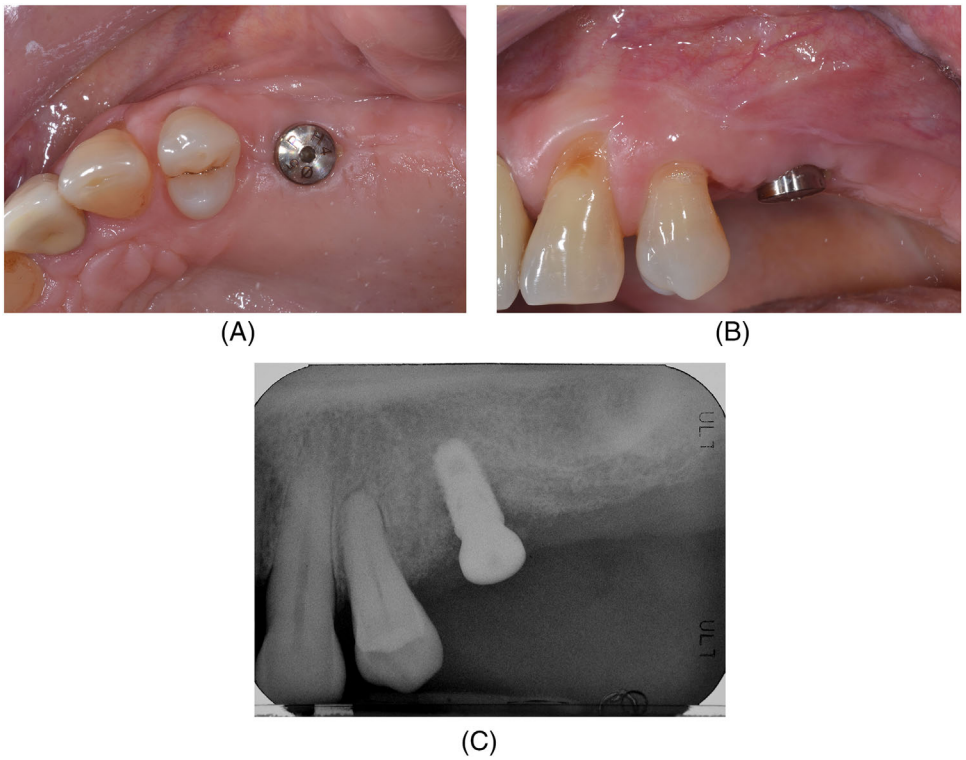

FIGURE 11 Re-epithelialization of the underlying tissue occurred over the next 7 to 10 days after membrane removal and, at the 3-month follow-up, soft tissues remodeled around the healing abutment (A, B) and the bone graft improved mineralization (C).

select the submerged approach[8] which, on the one hand, allows the reconstruction of not only intra-bony defects but also supra-bony ones, and allows for better surgical access for decontamination and detoxification of the infected implant surface, but on the other hand, deprives the patient of the prosthesis for a very long period of time, up to 9 months, with the associated functional, phonetic, and esthetic issues. In case of a non-submerged treatment, bone reconstruction is limited to the intra-bony component, and decontamination of the implant surface may be hampered by the presence of the prosthetic restoration in difficult-to-access areas.[7] Furthermore, the transmucosal healing model poses the risk of site infection starting from the peri-implant sulcus.[8]

The evaluation to use the same prosthesis after healing, with a significant financial saving to the patient, or provide a new one, can influence this choice.[7] A prosthesis with problems with the ceramic veneer or a poorly made prosthesis, which could itself be the cause of the peri-implantitis, can direct the clinician towards the submerged approach with the remaking of the prosthesis.

Regenerative outcomes are more predictable when a submerged approach is performed due to undisturbed healing and a reduced risk of infection.[8] The submerged environment creates more predictable clinical outcomes based on vertical GBR principles:[13]

- to create sufficient space for blood clot stabilization and bone regeneration;
- to exclude soft tissue ingrowth into the bony defect;
- to obtain predictable primary soft tissue closure for an uneventful healing.

This technique is considered highly technique-sensitive and dependent on the operator's skills, whose clinical experience should influence treatment options. The coronal mobilization of the flap, the frequent need to augment the keratinized mucosa (KM), previously reduced by the GBR procedure, the need to apically reposition the fornix and the muco-gingival line, distorted by the bone augmentation procedure, make this technique more suitable for use by a specialist and less by a general practitioner.

The scientific rationale of the technique reported in this article is to take the positive aspects of both approaches. As with the submerged approach, the removal of the prosthetic component facilitates surgical access, decontamination of the implant surface, and reconstructive procedures. At the same time, leaving the externally positioned dPTFE membrane exposed, the need for a second surgical intervention for its removal is avoided, as in the non-submerged approach. The choice to use a CLCM was made for its good handling, the high tensile strength, which allowed its positioning and stabilization through the sutures, and the long-lasting resorption rate, which allows maintaining the barrier effect under the flaps for many weeks after dPTFE membrane removal. Studies comparing the biodegradation and vascularization of different CLCMs were made in rats, and reported the delayed vascularization of these

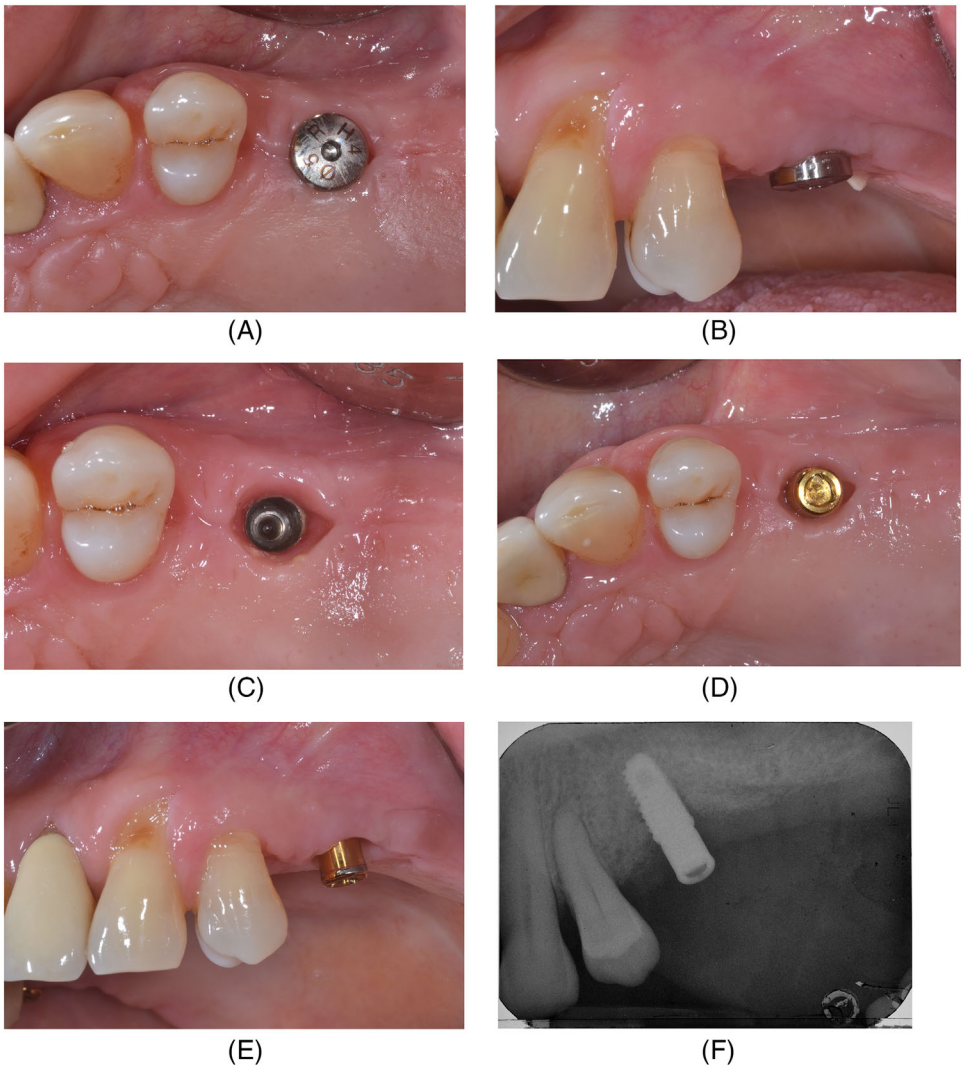

FIGURE 12 At the 4-month follow-up after surgery (A, B), the healing abutment was removed (C) and the former prosthetic abutment was re-inserted (D, E). A periapical radiograph was taken to assess the bone levels (F).

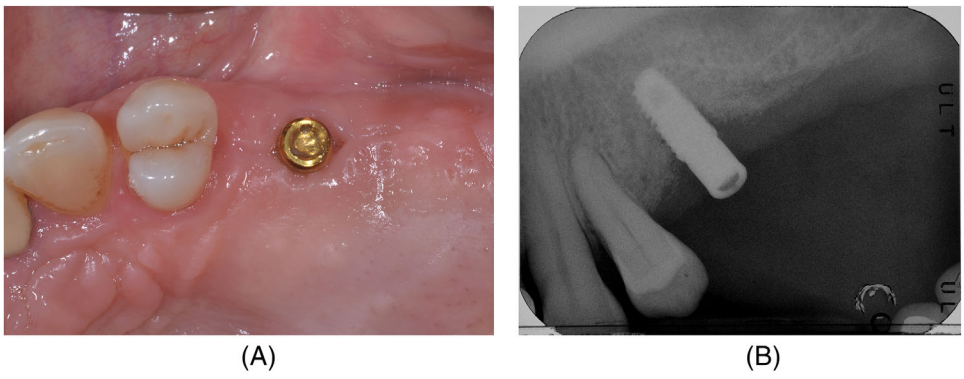

FIGURE 13 At the 6-week follow-up after abutment re-insertion, the peri-implant site was characterized by absence of erythema, bleeding on probing, swelling, and suppuration (A) and a stable radiographic bone filling (B).

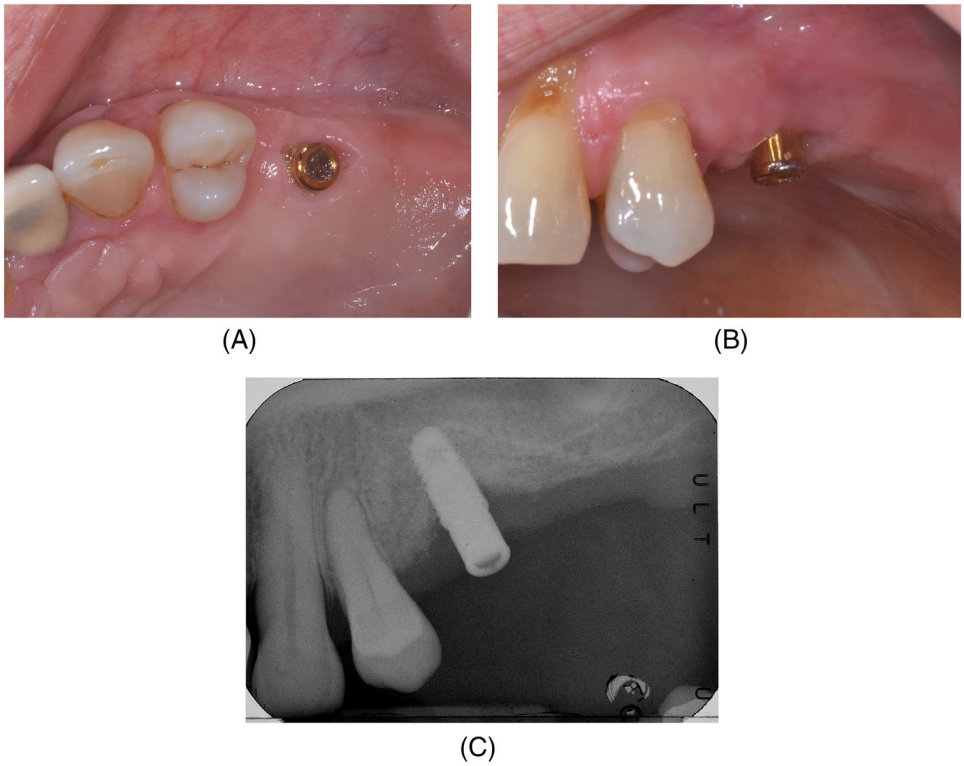

FIGURE 14 Clinical (A, B) and radiographic (C) 1-year follow-up after prosthetic abutment was re-inserted, without clinical signs of inflammation or radiographic bone loss.

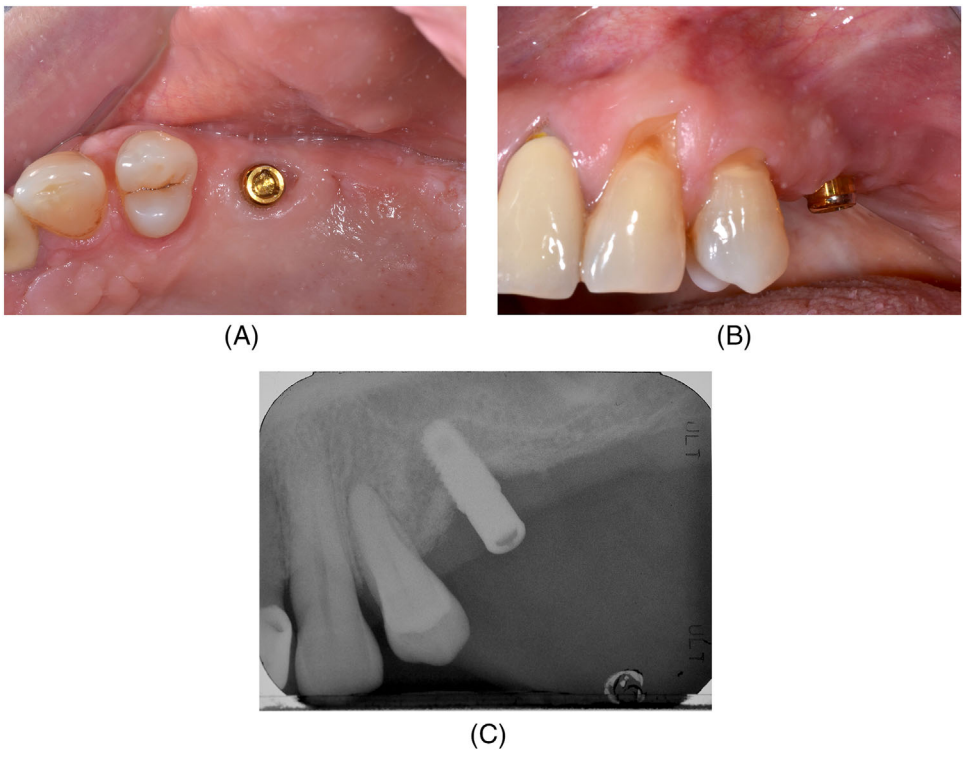

FIGURE 15 At the 2.5-year clinical (A, B) and radiographic (C) follow-up after prosthetic abutment re-insertion, both hard and soft tissue remained stable.

membranes compared to native CMs.[14,15] If on one hand the vascularization of the membranes leads to a new angiogenesis of the graft and the formation of new bone, on the other hand vascularization may also contribute to early membrane degradation, because the monocytes penetrating through the blood vessel wall may differentiate into macrophages, and the loss of the barrier function.[15] This can represent a problem in large defects, and this was the reason why a slow-reabsorbing membrane was chosen.

The removal of the dPTFE membrane is accomplished after 5–6 weeks by grasping the exposed membrane with forceps and gently lifting it from the wound without anesthesia or trauma to the adjacent tissues. As with alveolar ridge preservation (ARP) procedures with the open barrier technique,[9] soft tissue architecture is maintained since primary closure is not required, the flaps are not mobilized and repositioned coronally, the mucogingival line and the fornix are not distorted and there is no reduction in KM, but rather an increase is possible with this technique.[16] Due to the low porosity (0.2 μm), the dPTFE membrane resists the incorporation of bacteria into its structure[17] and can be left exposed in the mouth with a low risk of infection and subsequent graft loss. Exposure of the membrane does not compromise the underlying bone graft. No bacterial contamination was observed in the newly formed matrix at dPTFE membrane removal 4 weeks after socket preservation.[12] In a report of 420 cases utilizing this technique in ARP, no postoperative wound infection was observed.[18]

The characteristic property of this membrane to remain exposed also reduces the need to perform large flaps and vertical incisions to achieve primary closure, making the technique considered minimally invasive. A 2–5 mm vertical ridge augmentation around previously placed dental implants, with the use of a d-PTFE membrane left exposed to heal in a secondary intention, to correct two previously failed GBRs, was reported.[19] Soldatos et al. used Eiji Funakoshi's technique, a GBR with Open Barrier Membrane Technique, which, unlike classical GBR, does not require primary closure of the flaps. In that case study, the authors placed 4 tenting screws to allow the membrane not to collapse onto the exposed implants threads.[19]

The insertion of a 2 mm high closure cap or a low healing abutment is key to success with the technique here reported. It will not only prevent the collapse of the membranes on the implant threads, but will also allow bone reconstruction, not limited to the intra-osseous component, but also to a lesser extent to the supra-osseous component.

The use of the two membranes is particularly indicated when the buccal and palatal/lingual bony walls are missing. It was first reported in a clinical study,[20] and subsequently in a dog study.[21] ARP treated with 2 membranes (collagen + dPTFE) achieved more bone volume, vertical bone height, and alveolar ridge width as compared to when the single dPTFE membrane was used.[21] These authors used the same 2 membranes used in the present study, and hypothesized that placement of a dPTFE membrane over collagen further stabilized the graft at the defect site thereby increasing new bone formation, coupling the microbe-free environment, provided by the dPTFE membrane, with the cell adhesive properties and soft tissue response of the collagen.[21]

Actually, there is no universally accepted method for implant surface decontamination and detoxification. To remove biofilm and mineralized deposits from the implant surface, the authors prefer the use of a titanium curette and a titanium brush mounted on a contra-angle to reach the deepest parts of the defect. A number of other methods for decontamination, such as the use of lasers or abrasive devices, ultrasonic instruments with specific inserts, and implantoplasty of the exposed implant threads, have been suggested as adjuncts to surgical resective or regenerative surgery, but the clinical improvements reported are limited.[22–24]

The detoxification was carried out with the topical application of tetracycline powder dissolved in physiologic solution and rubbed on the implant surface with cotton pellets. This antibiotic has a prolonged antibacterial, acidifying, and anticollagenolytic effect. Although many other substances have been proposed, such as citric acid, hydrogen peroxide, sodium chloride, chloramines, chlorhexidine gluconate, and ethylenediaminetetraacetic acid (EDTA), from the evidence available, no single method has been proven to be superior.[25,26] Another method for implant surface detoxification is with the airborne particle–abrasion systems, with specific plastic inserts that allow delivery of antiseptic and slightly abrasive substances, such as glycine, erythritol powder, or sodium bicarbonate in extremely narrow areas. However, the use of these devices could develop subcutaneous air emphysema.[27]

As the only bone graft material, a highly porous porcine bone was used, an osteo-conductive biomaterial that promotes new bone formation not only around its particles but even inside its cavities.[28] The xenograft particles were wet with hyaluronic acid (HA), a biologic agent that accelerates bone formation through its migratory and proliferative properties,[29] and acts as a natural bacteriostatic shield.[30] HA attracts the growth factors naturally present in the blood and promotes vascularization with the support, for example, of porous porcine bone substitutes. The synergy between HA and porcine bone graft contributes to accelerating bone healing while showing balanced bone volume remodeling, since bone cell adherence and proliferation are facilitated with the porcine bone substitute's rough surfaces.[31] In a prospective randomized trial on lateral GBR, the combination of xenograft and HA improved the quality and quantity of bone formed with the xenograft alone.[32] The synergistic effect of HA with highly porous porcine graft gave an excellent and long-lasting clinical result in this case study. However, further studies are needed to understand the real efficacy of the treatment of peri-implantitis.

No intraoral autogenous bone was harvested in order to reduce invasiveness. Allograft and other biologic agents,

such as commercial products containing platelet-derived growth factors or bone morphogenetic proteins, are not allowed for clinical use by the local legislation.

The Locator abutment was reinserted 4 months after surgery. It could have been inserted at the time of removal of the dPTFE membrane, once the 2 mm high cap screw had been removed, but it was preferred to insert a rather wide healing abutment in order to close the space and protect the highly vascular osteoid matrix that had formed under the membrane, and which would undergo re-epithelialization within 7–10 days. If instead of a Locator abutment it had been a screw-retained prosthetic crown, it would have been repositioned immediately, as it would have covered the whole underlying tissue. The implant already has its own stability due to the previous process of osseointegration. Therefore, it is not necessary to wait further time to prosthetically load the implant.

The most important limitation of this article is that it reports the treatment of a single clinical case. Further validation is needed for this open membrane approach to achieve predictable results in the treatment of implants with peri-implantitis.

Implications from this case study should prompt clinicians to consider a reconstructive approach with intentionally exposed membranes. Although primary closure was described as one of the PASS principles of the GBR,[33] that article was written in 2006, when expanded PTFE (ePTFE) membranes or resorbable CMs were predominantly used. Those membranes needed to be buried under the flaps, because membrane exposure would have led to infection of the graft material due to passage of bacteria through the ePTFE membrane in the first case, and to resorption of the CM and loss of the graft material in the second. For this open membrane reconstructive approach, the principle of primary closure no longer needs to be satisfied, and the membrane exposure does not need to be considered as a complication that could lead to infection and failure of the bone defect augmentation. Since ePTFE membranes were withdrawn from the market in 2011, dPTFE membranes have been increasingly used for horizontal and vertical GBR, and the experience gained in managing exposure of this membrane has led to different guidelines being codified[34,35] than those recommended for managing exposure of ePTFE membranes.[36] Nowadays, an exposed dPTFE membrane can be left in place for several weeks before being removed,[34,35] which was unthinkable with previous ePTFE membranes, which had to be removed as soon as possible,[36] otherwise bacteria could pass through the membrane and cause infection.[36,37]

Future research should be directed on the one hand to clarify the histological healing model with in vivo studies, to evaluate whether a re-osseointegration process can occur, and on the other hand to evaluate whether it would be possible to obtain the same good results using only the dPTFE membrane, eliminating the use of the CLCM and further reducing the costs of the procedure.

CONCLUSION

This user-friendly handling of grafting material and membranes for a cost-effective treatment protocol is indicated for the general practitioner who usually doesn't treat complex cases requiring advanced skills for the regenerative therapies. The benefits of this technique include optimal access to the surgical site, in order to perform the defect debridement and the implant surface decontamination and detoxification, the reliable defect isolation and containment of graft particles, ease of membrane placement, simplified dPTFE membrane removal, and preservation of mucogingival architecture. Although promising, the results obtained in this case study need to be confirmed by prospective controlled clinical studies.

AUTHOR CONTRIBUTIONS

Fabrizio Belleggia: Conceptualization (lead); Writing – Original Draft Preparation (equal); Writing – review and editing (equal). **Luca Signorini**: Writing – Original Draft Preparation (equal); Writing – review and editing (equal). **Mirko Martelli**: Conceptualization (supporting); Writing – review and editing (equal). **Marco Gargari**: Writing – Original Draft Preparation (equal); Writing – review and editing (equal). All listed authors have agreed to the final submitted version.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.

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