Management of 80 Complications in Vertical and Horizontal Ridge Augmentation with Nonresorbable Membrane (d-PTFE): A Cross-Sectional Study

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Purpose: *Vertical and horizontal guided bone regeneration with nonresorbable membranes is a regenerative alternative for treating bone defects in edentulous zones. Its indication and good outcomes have been confirmed by different authors; however, this procedure remains highly technique sensitive and might lead to complications. The purpose of this study was to describe the management of complications such as exposures and infections following vertical and horizontal guided bone regeneration with titanium-reinforced high-density polytetrafluoroethylene (d-PTFE) nonresorbable membranes carried out using a new management protocol for complications related to this type of membrane.* ***Materials and Methods:*** *Complications in vertical and horizontal guided bone regeneration were evaluated by the same surgeon in a private practice between 2010 and 2017. They were classified and managed according to whether they were exposures and/or infections, and also according to their size, sagittal location, and coronal position of the alveolar ridge of the exposures. Descriptive analyses were conducted to evaluate the influence of age, sex, clinical characteristics of the complication, time of appearance, location, membrane size, anatomical and sagittal location, pink ceramic use, and definitive restoration, both before and after management protocol application.* ***Results:*** *Eighty complications were evaluated. The sextant with the highest number of complications was the anterior maxilla (35/80, 43.75%), followed by the mandibular left side area (16/80, 20.00%). The majority (56/80, 70.00%) of all complications appeared before 2 months. In relation to the sagittal location of exposures, 43.64% (24/55) were located coronal to the alveolar ridge. Statistically significant differences were found between exposures with or without purulent exudate, related to the coronal location of the exposure ($P < .05$).* ***Conclusion:*** *A new protocol for managing complications with titanium-reinforced high-density PTFE nonresorbable membranes is proposed based on the follow-up of 80 complications. These steps can help prevent total graft loss, allowing patients to reach final rehabilitation without multiple additional surgeries. Infections continue to be the most common cause of bone loss in guided bone regeneration. Long-term results and follow-up studies are necessary to assess the stability of soft and hard tissues in patients rehabilitated using this complication management protocol.* Int J Oral Maxillofac Implants 2019;34:927–935. doi: 10.11607/jomi.7214

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Soon after the introduction of guided tissue regeneration as a regenerative alternative for bone defects associated with teeth in the mid-1980s, the same concept was applied to bone ridges and dental implants and was termed guided bone regeneration, oriented to the use of barriers creating a space separating the cellular migration of soft tissue from the bone cells that participate in regeneration.[1]

One of the first studies of vertical bone regeneration with titanium-reinforced expanded polytetrafluoroethylene (e-PTFE) nonresorbable membranes in humans was published in 1994 and showed bone formation by using a blood clot and an e-PTFE barrier. Vertical bone regeneration occurred only 3 to 4 mm from the crest and was carried out with simultaneous implant placement.[2]

In 1996, Tinti and colleagues published an article that reported the use of the same surgical technique

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and membrane, along with autologous bone to simultaneously fill the vertical defect with an implant. Their results showed a bone formation area of 4.95 mm and concluded that vertical bone formation is possible as long as the following criteria are met: *(1)* the membrane should be completely covered during regeneration and sutured without tension; *(2)* horizontal mattress should be used as one of the suturing techniques; *(3)* regeneration time with the membrane should be at least 12 months; and *(4)* the graft material should be autologous bone.[3]

The indications for these types of procedures are vertical defects due to some kind of trauma or as a consequence of the loss of bone ridge that compromises the esthetic areas. Its indication and good results have been confirmed by different authors.[2–4] However, this procedure still appears to be highly technique sensitive and might lead to complications such as exposures and infections.[5,6]

The first authors to describe the technique were also the first to report complications, namely, exposure with/without infection and abscesses without membrane exposure as a consequence of deficient bone regeneration.[5,7,8] In 2011, Fontana et al published the most complete classification of nonresorbable membrane complications to date and categorized them into the healing and surgical types. Healing complications were classified as small membrane exposure (≤ 3 mm) without purulent exudate (class I), large membrane exposure (> 3 mm) without purulent exudate (class II), membrane exposure with purulent exudate (class III), and abscess formation without membrane exposure (class IV). Surgical complications were classified as flap damage, neurologic complications, and vascular complications.[6] Location of the exposure and/or distance from the coronal alveolar ridge to the exposure were not mentioned as important elements that may determine the clinical result of these procedures. Moreover, this classification was only relevant to the use of e-PTFE membranes.[6]

Healing complication rates > 18% have been reported when using membrane and autologous, xenograft or allograft for vertical augmentation in areas surrounding the implant in humans.[9,10] When vertical ridge augmentation was performed with sinus elevation, up to 12.5% of membrane exposure was reported.[11] A systematic review reported a range of complications between 0.00% and 44.5% in vertical augmentations with nonresorbable membranes.[12]

Nevertheless, the last systematic review and meta-analysis that compared osteogenesis distraction, interpositioned graft, block graft, and guided bone regeneration with nonresorbable membranes for vertical augmentation in atrophic mandibles revealed that the technique associated with nonresorbable membranes has lower rates of complications and morbidity,[13] suggesting a need for long-term studies to evaluate biologic complication frequencies in these types of procedures. The objective of this cross-sectional study was to describe and propose a new management scheme for complications such as exposures and infections in procedures of vertical and horizontal guided bone regeneration with titanium-reinforced high-density PTFE (d-PTFE) membranes.

MATERIALS AND METHODS

This cross-sectional study evaluated all complications in vertical and horizontal bone regeneration with titanium-reinforced (d-PTFE) nonresorbable membranes (Cytoplast Ti-250 Titanium-Reinforced Membrane, Osteogenics Biomedical), by reviewing the clinical histories of patients seen in private consultations between 2010 and 2017.

Clinical histories of patients who presented with complications related to titanium-reinforced d-PTFE membranes were included. All complications were diagnosed and managed by the same surgeon (P.G.). The confirmation criteria of complications were based on the Fontana classification.[6] Complications were also classified according to anatomical and sagittal location, coronal position of the alveolar ridge of the exposures, numbers of surgeries, definitive restorations, and pink ceramic use. Time of the exposure and/or infection and time of membrane removal were recorded. Factors such as age, sex, and clinic attendance were noted from the clinical histories. Systemic alteration, many previous regeneration surgeries, and chronic medication use were contraindications for bone regeneration procedures.

Surgical Techniques

The complete surgical technique was previously described by different authors.[1,3,4,14–17] Briefly, the flap design was modified according to each surgical area where vertical regenerations were performed. In the maxilla, vertical incisions were made to one or two teeth of the defect. This was determined by the depth of the vertical defect, with deeper defects requiring more extensive flaps. A full-thickness, midcrestal incision into the keratinized gingiva was performed with a surgical scalpel. In the posterior mandible, the crestal incision extended 5 mm away from the bone defect. After incisions, periosteal elevators were used to create a full-thickness flap beyond the mucogingival junction and at least 5 mm beyond the bone defect. Corticotomies were performed in all cases. Autografts were harvested with a bone scraper and mixed with allograft or xenograft at a 50:50 proportion. The composite bone

graft was immobilized and covered with a titanium-reinforced membrane that was stabilized with titanium screws (Pro-Fix Tenting Screw, Osteogenics Biomedical). Once the membrane was completely secured and stable, the flap was mobilized to permit tension-free primary closure. Two suture lines were made. The first was horizontal mattresses 5 mm from the coronal edge of the flap, allowing direct contact with connective tissue. Then, simple sutures interrupted to finish the primary closure. All patients were prescribed pre- and postsurgical amoxicillin/clavulanic acid (875 + 125 mg) (Clavulin, GSK) starting 1 hour before surgery and continuing with one tablet every 12 hours for 7 days, and nimesulide (100 mg) (Scaflam, Eurofarma) was given twice a day (every 12 hours) for 5 days, complemented with chlorhexidine 0.12% mouthrinse (Clorhexol, Farpag) twice daily for 2 weeks. Sutures were removed between 15 and 30 days.

All complications were registered and handled once a week with postoperative follow-up until the membrane was removed.

Complication Management

Once the patient arrived for postoperative follow-up with any complication(s), the type of complication was diagnosed according to the Fontana classification.[6] Cone beam computed tomography (CBCT) was performed in all cases to assess the condition of the graft under the exposed or infected membrane.

Management of Class I Healing Complications

Patients with a ≤ 3 mm exposure without purulent exudate were monitored weekly to clean the membrane with chlorhexidine 0.12%, and digital pressure was applied near the exposure borders to examine for the presence of purulent exudate. Postsurgical indications and care comprised gentle brushing to prevent the zone of membrane exposure from enlarging and applying chlorhexidine gel 0.12% twice a day. While chlorhexidine does not prevent infection, the local use twice a day reduces bacterial accumulation according to in vitro studies.[18]

If the exposure remained clean and ≤ 3 mm, weekly monitoring continued. If the exposure occurred within 10 days, it was considered as an exposure of immediate appearance, and the membrane would stay in place for 6 to 8 weeks before being removed. If the exposure appeared before 2 months, it was considered an exposure of medium appearance, and the membrane would remain in place for 6 to 8 weeks before being removed. If the exposure appeared after 2 months, it was considered an exposure of late appearance, and the membrane would remain for the longest time possible until the ninth month, as long as it was not infected.

Antibiotics were not used to prevent infection in any class I cases. If infection was present, it would be categorized as class III, and the membrane would be removed immediately. In CBCT follow-ups of class I exposure, it was evident that the grafts were in perfect condition and also in the original position. As a result, there was no graft loss in these exposures (Fig 1).

Management of Class II Healing Complications

Patients who showed exposure > 3 mm without purulent exudate were monitored using the same protocol employed for patients with class I complications. As long as they were not infected, the membrane would remain in the mouth for at least 6 to 8 weeks.

After 6 to 8 weeks, if the exposed membrane presented excess dental plaque, it was removed to prevent the patient from coming to the next follow-up visit with purulent exudate. This was, however, dependent on the patient's hygiene.

The postsurgical indications were to clean the exposed membrane with moistened gauze dipped in chlorhexidine three times a day. It has been proven that e-PTFE membranes (Goretex) with plaque after 4 weeks allow bacterial migration through the membrane and bone graft contraction by 2 to 3 mm.[19]

Despite this, all membranes used in the present study were d-PTFE with porosities < 0.3 μm, smaller than the < 8 μm porosities in e-PTFE.[20] Thus, it was speculated that bacterial filtration could last more than 4 weeks, although this hypothesis remains to be tested.

Only horizontal defects treated with d-PTFE membranes that had class II exposure were left in place 8 weeks before removal. The membrane was pulled for removal, without the need for surgery. Beneath it, a pseudo-periosteum covered all graft particles. The pseudo-periosteum showed epithelialization with time (months).[21] Implants were placed after 9 months of healing. Antibiotic therapy was not used in any of these patients while the membrane was exposed. No evidence of bone graft contraction was found under the membrane in CBCT follow-up (Fig 2).

Management of Class III Healing Complications

Patients who presented with membrane exposure with purulent exudate were immediately prescribed antibiotics (amoxicillin/clavulanic acid, 1 g every 12 hours for 7 days) and scheduled for immediate membrane removal. The clinical signs were pain and purulent exudation upon palpation, or fistula.

Graft contraction and replacement of soft tissue under the membrane were observed on the follow-up CBCT. In addition, all granulomatous tissues found between the membrane and bone graft were removed;

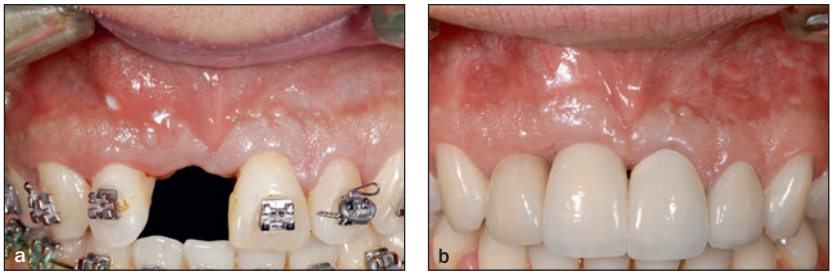

Fig 1 *(a)* Clinical case of class I healing complication. *(b)* 3-year follow-up.

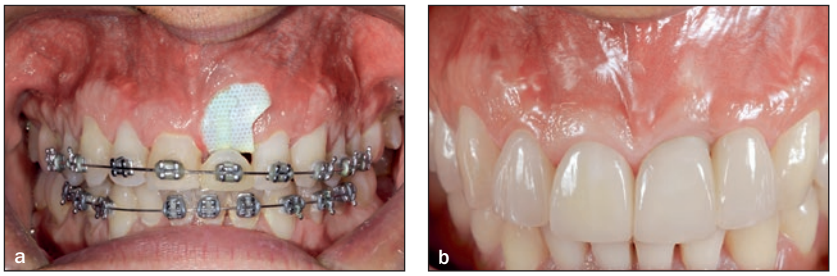

Fig 2 *(a)* Clinical case of class II healing complication. *(b)* 5-year follow-up.

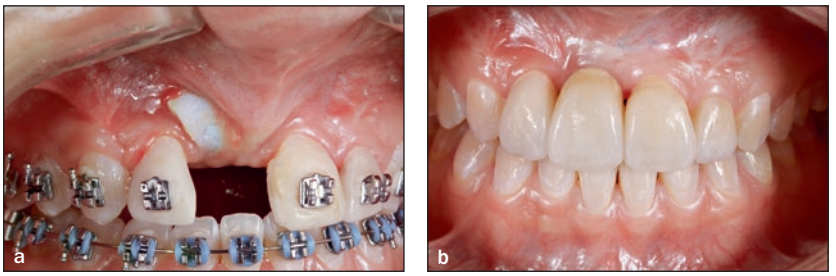

Fig 3 *(a)* Clinical case of class III healing complication. *(b)* 4-year follow-up.

only the hard, integrated graft was retained in place. Graft loss depended on the time of appearance of the infection, meaning that patients who showed purulent exudate exposure within the first 2 months lost most of the graft, whereas those who presented with the same situation after 3 months were able to preserve some of the graft under the granulomatous tissue, which upon removal was washed with tetracycline and a collagenous membrane placed in situ. Three months later, the case was evaluated to determine the surgical course of action, ie, whether to be regenerated again or wait 9 months to be rehabilitated with short implants and pink ceramic. The first secondary regeneration option was particle bone graft and collagenous membrane, although if the defect continued to be considerably vertical, it was regenerated with a d-PTFE membrane (Fig 3).

Management of Class IV Healing Complications

Patients who showed abscess without exposure had the same symptoms as class III: pain and purulent exudate either in the fistula or in the gingival sulcus around the adjacent teeth near the membrane. Patients with this complication presented with inflammation and swelling of the infected area. All patients who presented with inflammation and pain after 15 days were considered to have an infection.

The protocol used for class IV was immediate removal of the membrane, soft tissue, and mobile graft particles and placement of a collagenous membrane. Immediate regeneration was not performed in any of these cases, and after 3 months, it was reconsidered to be new treatment. If the membrane is not removed immediately or the infection is too aggressive, the graft can be compromised and there may be basal bone resorption.[6] Therefore, the membrane was immediately removed with ongoing antibiotic treatment starting before the surgery and continuing 7 days after the surgery (amoxicillin/clavulanic acid, 1 g every 12 hours). None of the patients were allergic to these medications (Fig 4).

Management of Surgical Complications According to the Fontana Classifications

All patients who presented with flap damage after graft and membrane fixation to the defect had tissues sutured over the d-PTFE membrane and achieved primary closure. Despite this, all patients presented to the first follow-up with exposure, class I, or class II complications and were treated with the appropriate protocol.

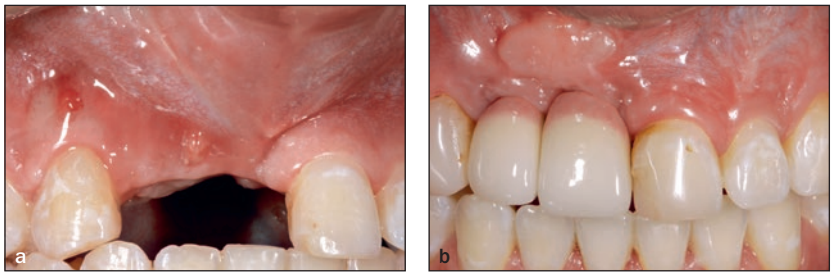

Fig 4 *(a)* Clinical case of class IV healing complication. *(b)* 3-year follow-up.

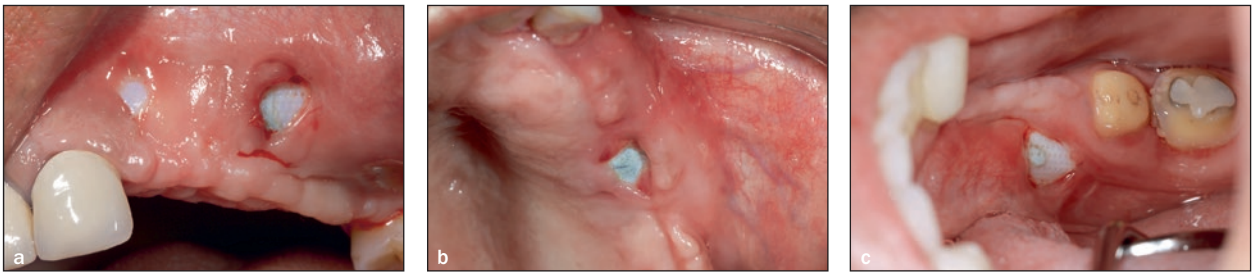

Fig 5 Classification of membrane exposure according to sagittal location: *(a)* vestibular, *(b)* crestal, and *(c)* lingual/palatine.

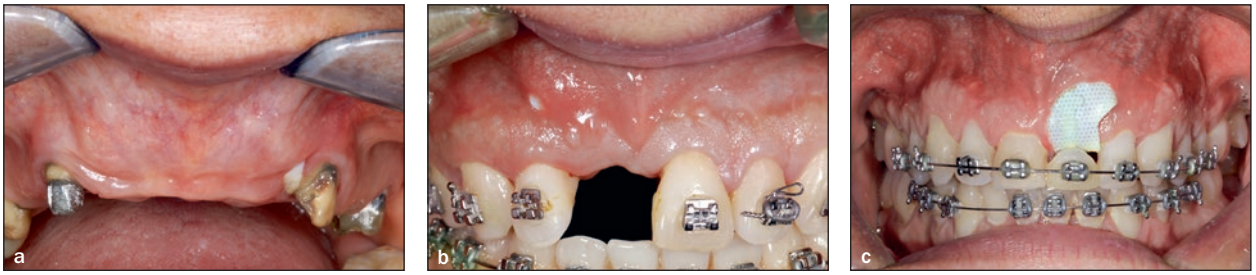

Fig 6 Classification of membrane exposure according to distance from the coronal part of the alveolar ridge: *(a)* < 3 mm from the coronal bone crest, *(b)* > 3 mm from the coronal bone crest, and *(c)* combined.

All neurologic complications (transitory paresthesia of the mental nerve) were treated with daily intramuscular injections of vitamins B1 + B6 + B12 (Neurobion Merck) for 4 days. Symptoms improved following this treatment.

Classification of the Exposure According to Sagittal Location

Exposures were divided at the time of appearance according to the sagittal location, taking into consideration the sagittal view of the alveolar ridge: vestibular, crestal, and lingual/palatine (Fig 5).

Classification of the Exposure According to Coronal Distance from the Alveolar Ridge

The distance between the exposure and the most coronal part of the alveolar ridge (CAR) was documented, and exposures were classified in the following manner: exposure of the membrane ≤ 3 mm relative to the CAR; exposure of the membrane > 3 mm relative to the CAR; or combined, which implies that an exposure begins in the CAR and exceeds the mucogingival line. This measurement was also applied in complications with or without purulent exudate (Fig 6).

Statistical Analysis

All information related to complications evaluated was registered in a database and analyzed through the software IBM-SPSS-V20 (IBM) and STATA-V12 (StataCorp).

A descriptive analysis was conducted to evaluate the influences of age, sex, clinical characteristics of the complication, times of appearance, location, membrane size, anatomical and sagittal locations, pink ceramic use, and definitive restoration.

Similarly, the variables with *t* tests and χ^2 tests were evaluated to compare distributions according to presence and absence of the final rehabilitation, Fontana classification, and bone crest distance. The measurement of prevalence reason and intervals of trust were used to establish the relationship of each variable with the final rehabilitation outcome. All tests were performed with a 5% level of significance ($P < .05$).

RESULTS

Eighty complications were evaluated, with the majority (51/80, 63.75%) affecting female patients. The mean age was 49 ± 11 years. All patients received bone

ridge augmentation and were in general good health. Seventy-three implants were placed to restore partially edentulous zones. The sextant with the highest number of complications was the anterior maxilla (35/80, 43.75%), followed by the left mandible (16/80, 20.00%). The rest of the posterior areas were between 8/80 (10.00%) and 9/80 (11.00%). Fewer complications were indicated (4/80, 5.00%) for the mandibular anterior area.

In terms of time of manifestation, 70% (56/80) of complications appeared before 2 months, 13.75% (11/80) appeared between 2 and 4 months, and 16.25% (13/80) appeared between 4 and 12 months.

Regarding defect size, edentulous zones corresponding to three or more teeth that used a 30 × 40-mm membrane had a 38.75% (31/80) complication rate. Membranes measuring 25 × 30 mm used in edentulous zones with less than three teeth reported the second-highest complication rate of 37.50% (30/80). In edentulous zones corresponding to one tooth, 7/80 (8.75%) were reported.

It was found that 20% (16/80) of complications were in areas of regeneration with simultaneous implant placement, 7.5% (6/80) with peri-implantitis, and 6.25% (5/80) with sinus elevation.

According to Fontana classification, 22.50% (18/80), 22.50% (18/80), 23.75% (19/80), and 31.25% (25/80) corresponded to class I, II, III, and IV complications, respectively. Among the 80 complications, 55 were membrane exposures. Surgical complications in relation to flap damage and neurologic complications were 3.75% (3/80) for each one, while only 1.25% (1/80) of patients presented with vascular complications. The mean exposure size was 4.73 ± 4.18 mm.

Membrane location in relation to the coronal part of the alveolar ridge was observed in greater proportion, ≤ 3 mm near the CAR in 65.45% (36/80) of cases, > 3 mm distant from the CAR in 20% (11/80), and as combined location in 14.55% (8/80) of cases.

Regarding the sagittal location of exposures, 43.64% (24/55) were in the coronal part of the alveolar ridge, 43.64% (24/55) in the vestibular area, 10.91% (6/55) in the lingual area, and only 1.82% (1/55) in the palatal area. In accordance with final restorations, 64.29% (36/56) were rehabilitated with definitive prostheses, 12.50% (7/56) could not be rehabilitated after the first surgery and required a second regeneration procedure, and 23.21% (13/56) of patients elected to discontinue treatment. Twenty-four patients are currently in treatment. Patients with pink ceramic restorations accounted for 13.00% (5/36).

In the exploratory analyses according to the Fontana classification, there were no statistically significant differences between sex, type of defect, anatomical or sagittal location, need for a second regeneration, final rehabilitation, or pink ceramic use (Table 1).

In relation to sagittal location, exposures on the coronal part of the alveolar ridge showed a greater percentage of abscess formation, and patients who ceased to continue with implantology treatment were more likely to develop abscesses with exposure as complications (Table 1).

The analysis of distance of exposure from the membrane did not show significant statistical differences with respect to sex, type of defect, anatomical or sagittal location, need for second regeneration, final rehabilitation, or pink ceramic use. All complications that required pink ceramic showed exposure ≤ 3 mm from the coronal part of the alveolar ridge, prevalence reason 2.1, 95% CI (1.34 to 3.28) (Table 1).

Statistically significant differences were found between exposures with or without purulent exudate, relative to the coronal location of the exposure (Table 2).

DISCUSSION

The use of nonresorbable membrane as an alternative for vertical and horizontal bone regeneration continues to be presented as a sensible technique. Managing complications according to the protocol allowed a high number of patients to complete their original rehabilitation. Some patients continued treatment because they required a second intervention; unfortunately, a considerable number of patients did not want to continue with the treatment due to negative experiences with their complications and formation of abscess without exposure associated with pain, inflammation, purulent exudate, and loss of bone graft and/or loss of basal bone.

Some of the complications described in this study indicate that the anterior maxillary area is more likely to develop exposure on the membrane. The authors consider that this could be due to challenges associated with performing a primary closure dependent on coronal advancement of the buccal flap, as the palate is immobile.

Given the number of complications that appeared within 2 months of placement, it is important to consider postsurgical follow-up for all surgeries with nonresorbable membranes: once a week for the first 2 months; every 2 weeks in months 3 to 4; and monthly from months 4 to 9. In the present study, the complication rate considerably decreased after the second month.

It is very important to understand that the success of these protocols depends on postsurgical follow-up. Regenerations with nonresorbable membranes initially require weekly follow-up so that complications can be diagnosed and treated in a timely fashion. It is very

Table 1 Clinical Characteristics of Complications According to Fontana Healing Classification

	Membrane exposure ≤ 3 mm without purulent exudate		Membrane exposure > 3 mm without purulent exudate		Membrane exposure with purulent exudate		Abscess formation without exposure		*P* value
	n	%	n	%	n	%	n	%	
Sex									
Female	13	25.49	10	19.61	13	25.49	15	29.41	.702
Male	5	17.24	8	27.59	6	20.69	10	34.48	
Type of defect									
Horizontal	1	7.14	3	21.43	5	35.71	5	35.71	.380
Vertical	17	26.15	15	21.54	14	21.54	20	30.77	
Location									
Anterior mandible	1	25.00	2	50.00	0	0.00	1	25.00	.141
Anterior maxilla	9	25.71	9	25.71	10	28.57	7	20.00	
Right posterior maxilla	4	44.44	0	0.00	0	0.00	5	55.56	
Left posterior maxilla	2	25.00	2	25.00	3	37.50	1	12.50	
Left posterior mandible	1	6.25	2	12.50	4	25.00	9	56.25	
Right posterior mandible	1	12.50	3	37.50	2	25.00	2	25.00	
Sagittal location of exposure									
Palatine	0	0.00	1	100.00	0	0.00	0	0.00	.780
Vestibular	8	33.33	9	37.50	7	29.17	0	0.00	
Crest	8	33.33	6	25.00	10	41.67	0	0.00	
Lingual	2	33.33	2	33.33	2	33.33	0	0.00	
Second regeneration									
No	14	21.54	18	27.69	13	20.00	20	30.77	.176
Yes	4	28.57	0	0.00	6	42.86	4	28.57	
Final restorations									
No	1	14.29	0	0.00	4	57.14	2	28.57	.058
Yes	8	24.24	8	24.24	6	18.18	11	33.33	
Quit treatment	1	7.69	2	15.38	2	15.38	8	61.54	
Restorations without implants	0	0.00	0	0.00	1	100.00	0	0.00	
Restorations with previous implants	0	0.00	2	100.00	0	0.00	0	0.00	
Pink ceramic									
No	7	23.33	9	30.00	5	16.67	9	30.00	.685
Yes	1	20.00	1	20.00	2	40.00	1	20.00	

Chi-square/Fisher test and Student *t* test; significant difference, $P < .05$.

useful to communicate with the patient, who should know that spontaneous inflammation, acute pain, and purulent exudate are not normal after the first week. The clinician is responsible for explaining which symptoms indicate a complication.

The results of the present study suggest that the greatest challenge of this surgical technique is achieving a primary closure without tension that promotes optimal soft tissue healing, as many exposures were ≤ 3 mm from the CAR. This is the most coronal area of the vertical defect, where tissues have more tension, so it is essential to suture these tissues in two planes: first along the horizontal mattress 5 mm to the edge of the flap, and then with a coronal complement with simple interrupted sutures.[17,22]

The greater proportion of complications appearing as abscess formation without exposure means that despite achieving primary closure without exposure, there is always a risk of complications due to a possible infection in the graft at the time of placement, membrane contamination during long periods of manipulation, or incomplete suture removal.[6] Even prophylactic antibiotic treatment does not eliminate the risk of infection.

On follow-up CBCT, all patients with this complication presented with partial or total reabsorption of the bone graft. It is therefore necessary for the operator to understand and know a priori the sagittal location of the exposure, as a location in the crest could lead to major abscess formation due to dental plaque

Table 2 Clinical Characteristics of Complications According to Coronal Position of the Alveolar Ridge

	Distance of the exposure from the alveolar ridge						
	≤ 3 mm		> 3 mm		Combined		
	n	%	n	%	n	%	*P* value
Sex							
Female	25	69.44	8	22.22	3	8.33	.194
Male	11	57.89	3	15.79	5	26.32	
Type of defects							
Horizontal	6	66.67	2	22.22	1	11.11	.956
Vertical	30	64.44	9	20.00	7	15.56	
Location							
Anterior mandible	1	33.33	2	66.67	0	0.00	.204
Anterior maxilla	19	67.86	6	21.43	3	10.71	
Right posterior maxilla	3	75.00	1	25.00	0	0.00	
Left posterior maxilla	5	71.43	1	14.29	1	14.29	
Left posterior mandible	6	85.71	0	0.00	1	14.29	
Right posterior mandible	2	33.33	1	16.67	3	50.00	
Second regeneration							
No	30	66.67	9	20.00	6	13.33	.858
Yes	6	60.00	2	20.00	2	20.00	
Definitive restorations							
No	4	80.00	1	20.00	0	0.00	.145
Yes	13	59.09	6	27.27	3	13.64	
Quit treatment	2	40.00	1	20.00	2	40.00	
Restorations with implants	1	100.00	0	0.00	0	0.00	
Restorations with previous implants	0	0.00	0	0.00	2	100.00	
Pink ceramic							
No	10	47.62	6	28.57	5	23.81	.05
Yes	4	100.00	0	0.00	0	0.00	
Healing complications							
Membrane exposure ≤ 3 mm without purulent exudate	12	66.67	6	33.33	0	0.00	.046
Membrane exposure > 3 mm without purulent exudate	9	50.00	4	22.22	5	27.78	
Membrane exposure with purulent exudate	15	78.95	1	5.26	3	15.79	

Chi-square/Fisher test and Student *t* test; significant difference, $P < .05$.

accumulation causing bone crest loss or as a consequence of pink ceramic use. These events increase the risk of losing the entire bone graft.

Although the main objective of this study was not to identify causes of complications, many may have developed due to inadequate soft tissue management, poor membrane positioning and fixation, an incomplete suture technique, and poor postoperative management. Given the limitations of the present study design, it is not possible to determine which factors led to complications.

Therefore, it is very important to have a learning curve, with the initial focus on learning to manage complications. In addition, patients must be prepared before surgery, have excellent periodontal health, and eliminate all retentive factors of the dentobacterial plaque. Appropriate patient selection is essential to avoid complications.

CONCLUSIONS

Despite the limitations of this cross-sectional study, a new protocol for managing complications in patients with titanium-reinforced high-density PTFE nonresorbable membranes is proposed. Such protocols can be effective in preventing total graft loss and can help patients reach final rehabilitation without additional

surgeries. Infections continue to be the major cause of bone loss in guided bone regeneration. As the location of membrane exposure is crucial for achieving better results, a new classification based on distance from the coronal part of the alveolar ridge should be considered. Long-term results and follow-up studies are necessary to assess the stability of soft and hard tissues in patients rehabilitated using this complication management protocol.

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