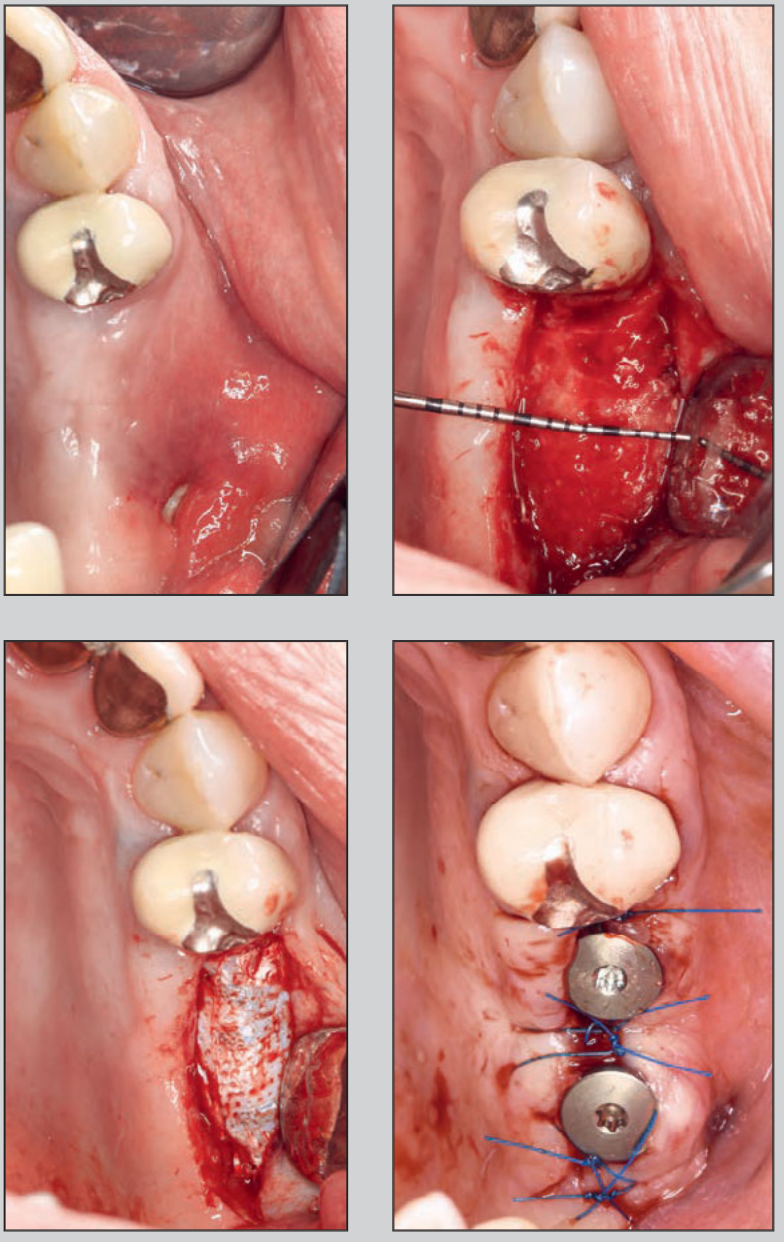
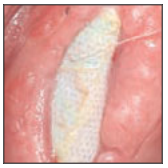


Clinical Classification of Healing Complications and Management in Guided Bone Regeneration Procedures with a Nonresorbable d-PTFE Membrane



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Since the introduction of guided bone regeneration (GBR) using nonresorbable membranes, membrane exposure has been categorized as one of the major complications associated with the procedure. Expanded polytetrafluoroethylene (e-PTFE) has a long history of use in GBR, and now the use of high-density PTFE (d-PTFE) is commonly reported in the literature. The major structural difference between these two materials is their permeability to bacteria: e-PTFE has an open-pore microstructure and is permeable to bacteria, while d-PTFE is not. Thus, there are fundamental differences in the two materials if premature exposure occurs. Protocols for classification and management of exposure specific to e-PTFE have been published and were well-received by clinicians, but these protocols do not necessarily apply to d-PTFE exposures. Because of the fundamental structural differences between these two PTFE materials, a protocol specific to the classification and management of d-PTFE membrane healing complications is required and is thus presented in this paper. Int J Periodontics Restorative Dent 2022;42:419–427. doi: 10.11607/prd.5590

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Since the introduction of expanded-polytetrafluoroethylene (e-PTFE) membranes in implant dentistry, several studies have reported the efficacy of this material in guided bone regeneration (GBR) procedures.[1–3] However, a major disadvantage is the occurrence of complications in case of an exposure.[4,5] Simion et al[6] reported that exposure around e-PTFE membranes should be regarded as a complication, as it reduces or hinders the effect of GBR. Several studies have reported that in cases of an exposure, anywhere from 0% to 73% of the treated defect's bone fill will result in suboptimal bone fill or complete failure.[6–8] In addition to exposures, complications include abscess formation or the presence of a fistula. In 2011, Fontana et al[9] proposed a classification of complications in GBR with nonresorbable membranes (e-PTFE) for easier identification and management. This classification also provides guidelines on how to address the complications, such as cutting away the exposed part of the membrane in case of a small exposure (≤ 3 mm), or immediate membrane removal for large exposures (> 3 mm). The major limitation of the aforementioned article is that all guidelines were based on e-PTFE membranes, which are not widely used today.

The evolution in PTFE membrane technology led to the introduction of dense-PTFE (d-PTFE) membranes.[10] In contrast to e-PTFE, the lack of tensile forces applied to the PTFE during the manufacturing process results in d-PTFE. Thus, d-PTFE has a lower porosity (< 0.3 µm) than e-PTFE. As a result, d-PTFE has been shown to be nonpermeable to bacteria,[11,12] creating a distinct difference in the clinical handling of exposures around d-PTFE membranes.

Management of d-PTFE exposures specifically in the context of GBR have been proposed by Fontana et al,[13] Urban,[14] and Gallo and Díaz-Báez.[15] In 2016, Fontana et al[13] described a management technique that resulted in a minor modification of the original 2011 classification, related to the location of abscess formation (under or above the PTFE membrane). All previously mentioned classifications or guidelines did not take into account membrane exposure with or without exposure of the membrane edges. However, the presence of an exposed edge is of clinical significance, as it facilitates a bacterial entry (under the membrane) that can negatively influence the final amount of regeneration. Thus, the aim of the present study was to propose a complete clinical classification solely comprising the healing complications and management of GBR with titanium-reinforced, nonresorbable d-PTFE membranes (nonperforated) in augmentation procedures.

Owing to the lack of studies and published data on how to manage such complications, the present proposed classification and treatment recommendations are based purely on *(1)* the authors' past clinical experience with, and published data on, e-PTFE healing complications[5–7,9]; *(2)* significant documented clinical experience with d-PTFE membranes[12,16]; and *(3)* existing published data concerning d-PTFE healing complications.[13–15,17] Details of the proposed classification are shown in Fig 1.

- Class I: a = Membrane exposures without purulent exudate; b = Edges of the membrane covered by tissue (E+) or not (E–); c = Time of exposure (T), measured in number of days postoperation.
- Class II: a = Membrane exposure with purulent exudate; b = Time of exposure (T), measured in number of days postoperation.
- Class III: a = No membrane exposure but presence of an abscess and/or fistula; b = Time of presence of an abscess and/or fistula (T), measured in number of days postoperation.

Treatment Modalities to Control Healing Complications

Class I

A Class I complication includes membrane exposures without purulent exudate, with the modifiers being whether the edges of the membrane are covered by tissue (E+) or not (E–) and the time of exposure (T), measured in number of days postoperation. If T is < 28 days, this is defined as an early membrane exposure, while a late exposure shows a T of ≥ 28 days. No purulent exudate is visible nor becomes visible when light pressure is applied on the membrane. For this class, the patient is instructed to rinse with chlorhexidine once a day, and weekly checks are scheduled to monitor the exposure and membrane integrity. If the exposure is larger than 3 to 4 mm, the patient can also be instructed to gently clean the exposed part of the membrane with a cotton swab to keep it free of bacterial plaque. During these checks, one has to evaluate whether the initially diagnosed complication class and E+ or E– presence have remained the same or changed into another class.

The membrane is removed after 6–12 weeks depending on the T value. The aim is to postpone membrane removal as long as possible to enhance bone regeneration. If graft particles are visible at the time of membrane exposure, loose particles should be gently removed, as they can be considered contaminated. Placement of a collagen membrane and primary closure can be considered. Primary closure ensures continued protection of the immature osteoid matrix. If the exposure is < 3 mm, primary closure after membrane removal is easy to achieve because the wound edges are flexible due to the separation by the membrane of the mucosal tissue from the underlying osteoid matrix. In other situations, one or

more releasing incisions must be made to achieve primary closure. If no graft particles are observed, the tissue can heal by secondary intention as the upper part of the osteoid matrix matures. This is based on the healing patterns seen after removal of the d-PTFE membranes being intentionally exposed for up to 30 days in ridge preservation procedures.[12,18,19] The present authors' experience shows that complete epithelialization will occur 4 weeks after membrane removal.[18] Rinsing with chlorhexidine should be continued for at least 10 days after membrane removal. Although chlorhexidine rinsing has shown in vitro toxic effects on fibroblasts,[20] rinsing is still clinically advised in order to aid plaque control at the surgical site and neighboring teeth.

The present authors wish to emphasize that any soft tissue covering the osteoid matrix (pseudoperiosteum) should not be removed at the time of membrane removal, as this will negatively interfere with the regenerative process.[21] In the case of a larger exposure (> 5 mm) and no graft particles visible after membrane removal, a sulcus may be present between the membrane and the flaps. This can be corrected with a gingivoplasty. If the sulcus is minor, the present authors' experience is that this condition will spontaneously resolve over time by soft tissue remodeling.

An important modifier of a Class I exposure is related to the edges of the membrane being covered by tissue (E+) or not (E–) (Figs 2 and 3). The final GBR result can be compromised if E– appears within the

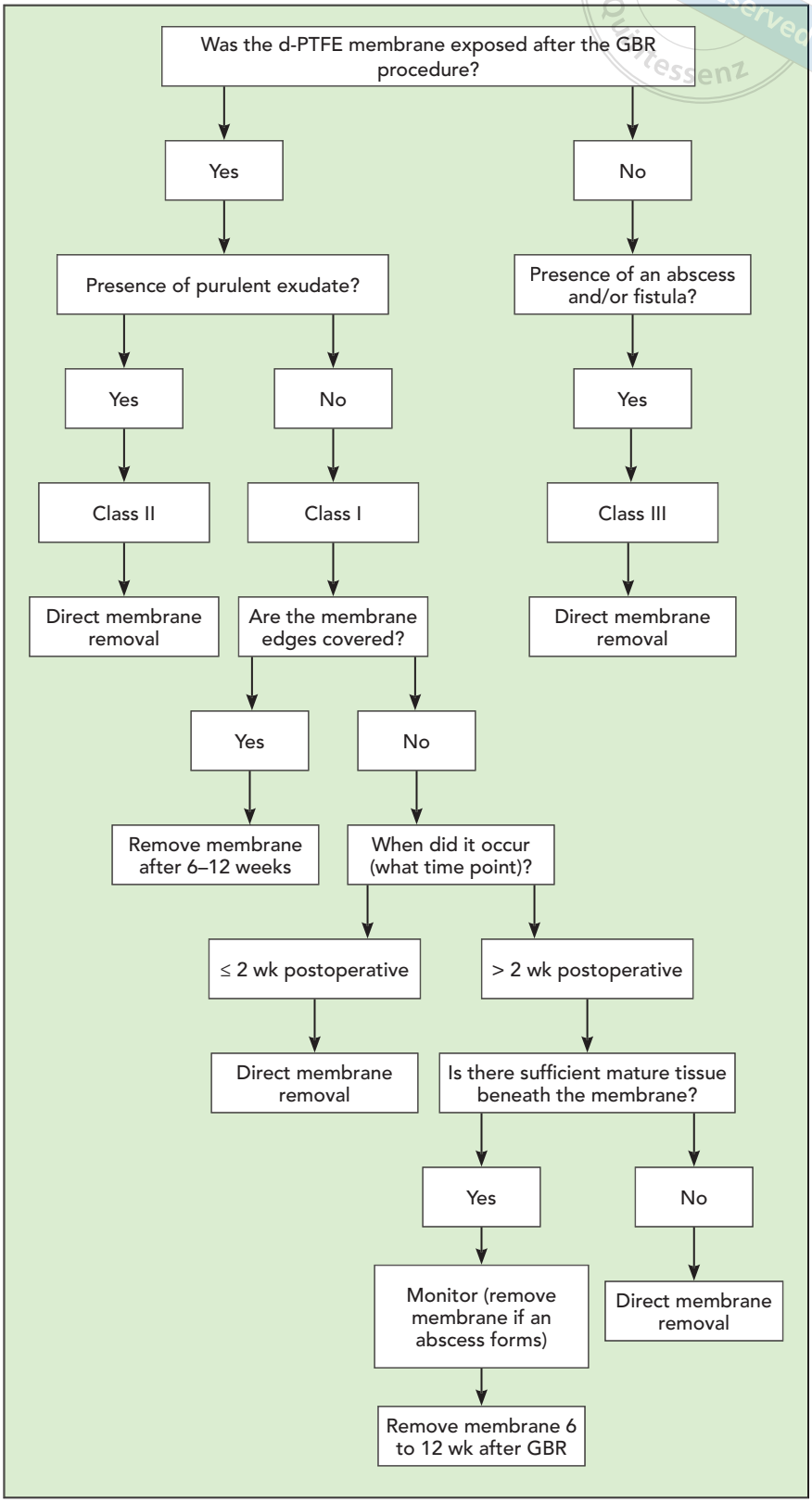

Fig 1 *Flowchart of the proposed classification.*

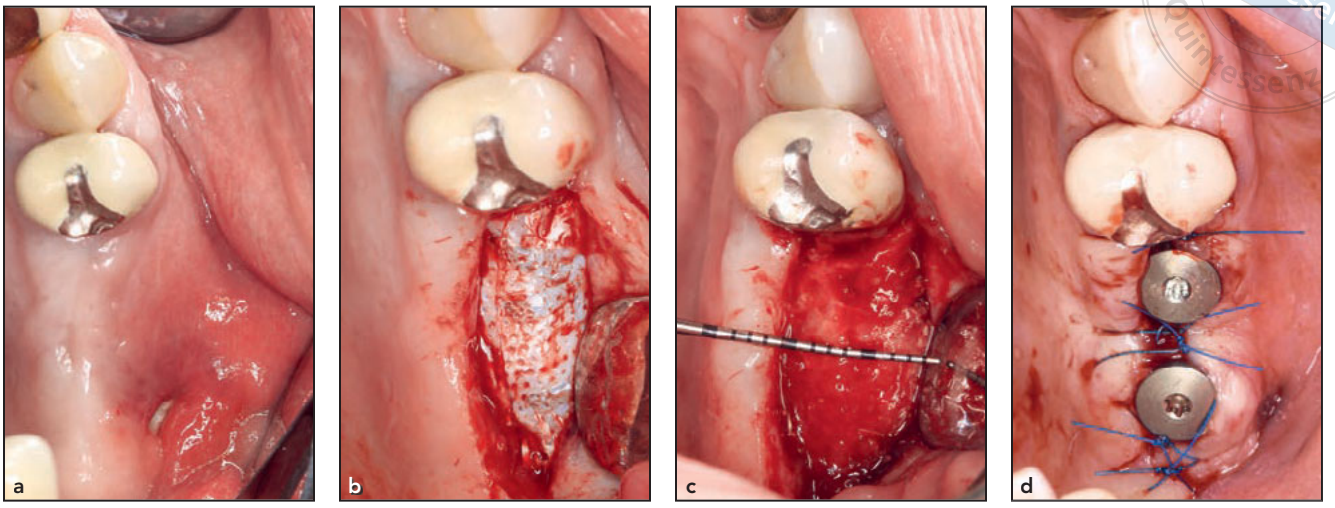

Fig 2 *Class I E– healing complication. T value = 30 days.* (a) *A small exposure was observed 1 month after the regenerative procedure.* (b) *The membrane was removed 8 weeks later. The whitish color indicates that no exposure occurred in the occlusal part.* (c) *Clinical view directly after membrane removal.* (d) *Implants were placed 3 months later.*

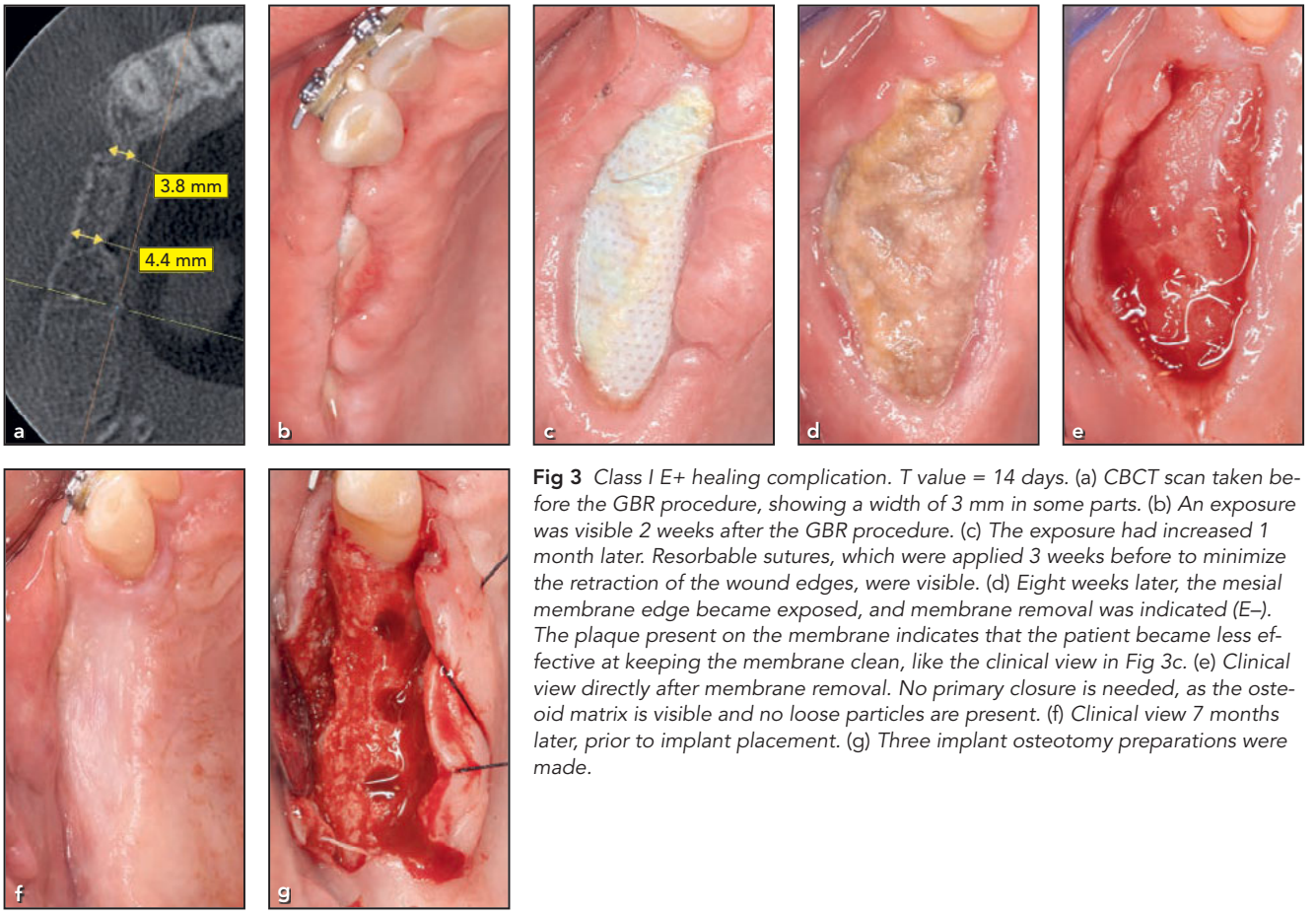

Fig 3 *Class I E+ healing complication. T value = 14 days.* (a) *CBCT scan taken before the GBR procedure, showing a width of 3 mm in some parts.* (b) *An exposure was visible 2 weeks after the GBR procedure.* (c) *The exposure had increased 1 month later. Resorbable sutures, which were applied 3 weeks before to minimize the retraction of the wound edges, were visible.* (d) *Eight weeks later, the mesial membrane edge became exposed, and membrane removal was indicated (E–). The plaque present on the membrane indicates that the patient became less effective at keeping the membrane clean, like the clinical view in Fig 3c.* (e) *Clinical view directly after membrane removal. No primary closure is needed, as the osteoid matrix is visible and no loose particles are present.* (f) *Clinical view 7 months later, prior to implant placement.* (g) *Three implant osteotomy preparations were made.*

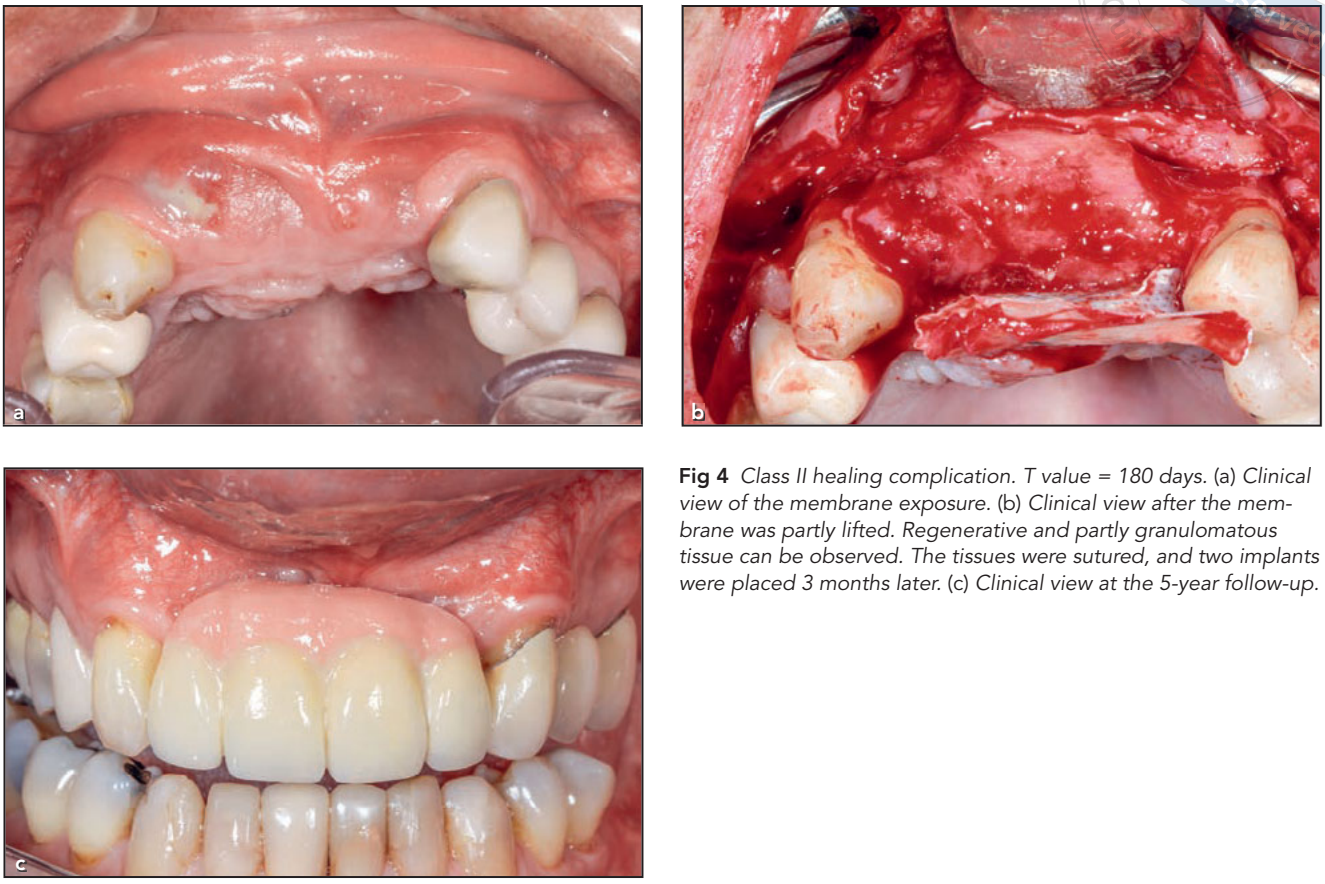

Fig 4 *Class II healing complication. T value = 180 days.* (a) *Clinical view of the membrane exposure.* (b) *Clinical view after the membrane was partly lifted. Regenerative and partly granulomatous tissue can be observed. The tissues were sutured, and two implants were placed 3 months later.* (c) *Clinical view at the 5-year follow-up.*

first 2 postoperative weeks, if no visible osteoid matrix formation is observed after membrane removal, and if soft tissue with no firm consistency is primarily seen. An edge exposure (E–) occurring after 2 weeks may still result in bacterial entry under the membrane, but if sufficient maturation of the tissue has occurred, the exposure may be managed by trimming the loose membrane part and closely monitoring the site at clinical follow-ups for complications, such as soft tissue recession or infection under the membrane. If exudate is present, the complication has progressed to a Class II and should be managed accordingly.

Class II

A Class II complication is defined as membrane exposure combined with the presence of purulent exudate. This indicates an infection of the area underneath the membrane. Membrane removal on short notice is indicated, along with vigorous irrigation to remove any involved graft material. Primary closure should be achieved if possible, and consideration should be given to using a collagen membrane over the exposed graft. After membrane removal, graft material that is not loose indicates that it is enmeshed in fibrous tissue that is presumably/potentially healthy. Solid and well-vascularized tissue will most likely survive. Loose material does not contribute toward regeneration or healing, and loose particles or particles obviously involved with purulence should be removed (Fig 4). Therefore, it is advised to gently rinse the top part of the augmentation area and to not remove any soft tissue.

The outcome of the GBR procedure will greatly be influenced by

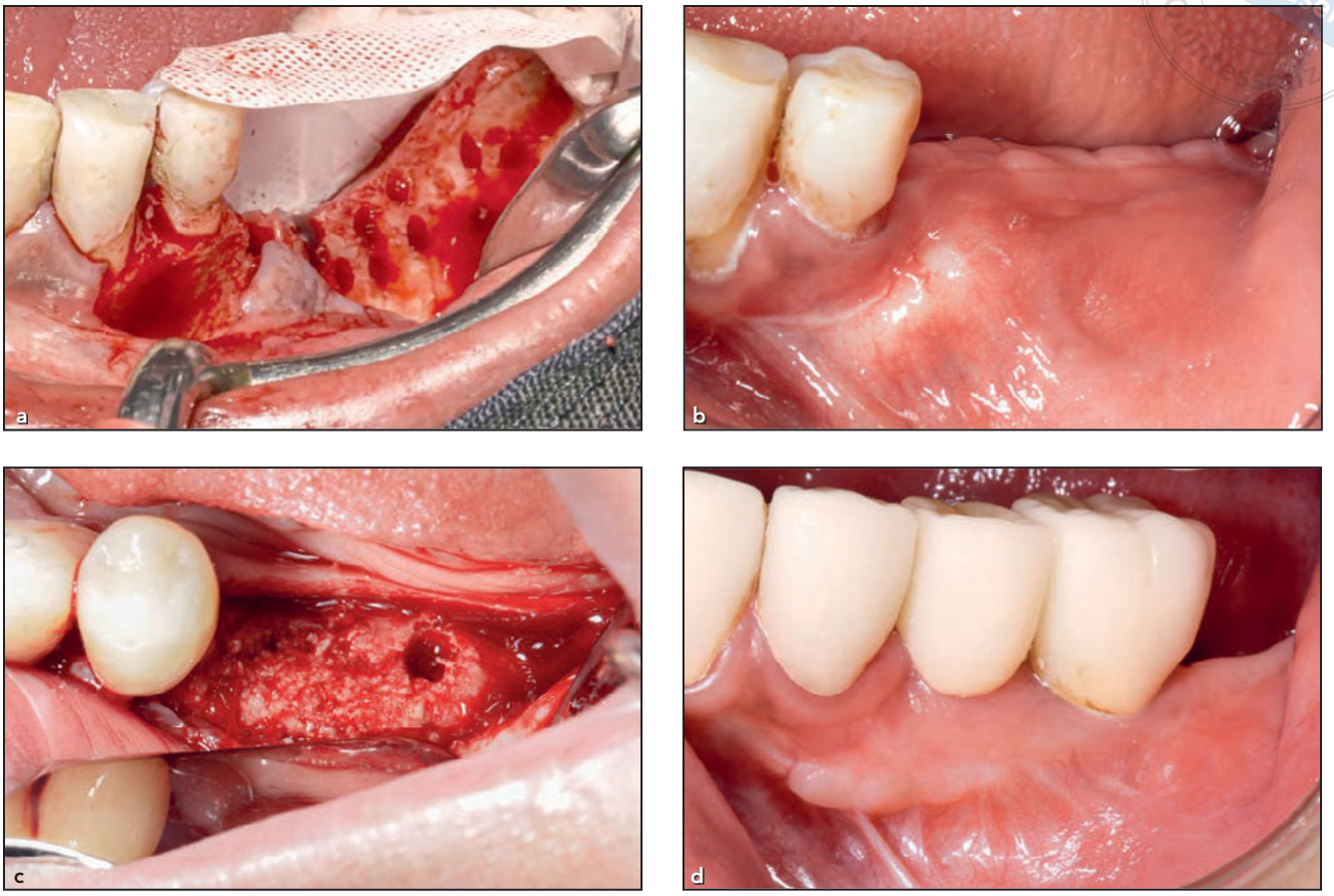

Fig 5 *Class III healing complication.* (a) *Clinical view at time of d-PTFE membrane placement in a horizontal/vertical GBR procedure.* (b) *After 2 months, a swelling occurred without exposure. The membrane was removed immediately.* (c) *Nine months after membrane removal, two implants could be placed.* (d) *Clinical view at the 3-year follow-up, with provisional abutments in place.*

the T value and the extent of graft infection. Experience indicates if the infection occurs within 15 days after the GBR procedure, a total loss of the graft material can be expected, as there was not sufficient time to form an osteoid matrix.

Class III

A Class III complication is defined as an abscess and/or fistula without membrane exposure. Clinically, an erythematous swelling can be observed and is movable when applying light pressure. In the present authors' observations, Class III exposures typically occur 1 to 4 months after the GBR procedure. As the presence of an abscess and/or fistula indicates an infection of the augmentation area, immediate membrane removal is necessary. After the membrane has been removed, loose graft material is removed with vigorous irrigation. Primary closure should be achieved, and consideration should be given to using a collagen membrane over the exposed graft. The clinical handling is the same as described for a Class II complication. The final outcome of the GBR procedure is highly influenced by the T value, indicating the time the membrane was in place without infection (Fig 5).

Discussion

Membrane exposure and infection in GBR procedures have been

identified as major complications. Studies on GBR procedures that used e-PTFE membranes report exposure as a major complication resulting in less/poor bone formation. This is likely due to bacteria migration through the membrane interstices, causing infection of the tissues/graft, with the membrane remaining a major source of infection.

All GBR procedures are subject to flap dehiscence as a complication, and the exposure rates vary between 5% and 54% in lateral GBR procedures and between 0% and 45% in vertical GBR procedures.[22,23] These percentages show a widespread occurrence of exposures. Interestingly, studies by Ronda et al,[16] Urban et al,[24] and Fugazzotto[25] have reported exposure rates of 0%. This illustrates that these surgeons, who performed the GBR procedures in their studies, were able to predictably maintain primary closure through proper surgical planning, specific surgical techniques, and adequate postoperative care. If an exposure occurs, it will negatively influence the amount of regenerated tissue.[6–8]

The e-PTFE and d-PTFE membranes have shown no clinical differences in vertical augmentation procedures around implants when no exposures occurred.[16] However, based on the present authors' extensive clinical experience with both e-PTFE and d-PTFE membrane materials, there is a difference in clinical response to exposure, largely due to the differences in porosity in the two biomaterials; the advantage of d-PTFE over e-PTFE is the fact that the former is impermeable to bacteria. This is because the d-PTFE membrane has a lower porosity (< 0.3 µm) compared to an e-PTFE membrane (5 to 25 µm).[26] This results in distinct differences in the clinical handling of exposures around d-PTFE membranes.

In the present authors' experience, the observed clinical results and subsequent approach can typically be placed in one of three categories.

Category 1: Most of the regenerated tissue has not been compromised, and implants can be placed after a sufficient healing period of 6 to 9 months for bone regeneration.

Category 2: Part of the bone graft has not turned into bone or has been removed. In this case, the remaining bone is radiographically examined (CBCT) 3 months after membrane placement to determine whether it is sufficient for implant placement after 3 to 6 months. If the amount of bone is too limited after 3 to 6 months, an additional bone/tissue augmentation will be required, possibly combined with implant placement. Otherwise, if there is sufficient bone, implant placement can be performed after applying the appropriate healing period of 6 to 9 months for bone regeneration.

Category 3: Most of the bone graft is lost, and after a healing period of 2 to 3 months, a new GBR procedure with a d-PTFE membrane is indicated.

A topic of interest is the distribution of the proposed complication classes and the above categories of GBR complications, all of which occurred in the authors' private practices over a period of 10 years. This topic will be the aim of a future retrospective study.

Several studies in which the d-PTFE membrane in ridge preservation was left intentionally exposed for up to 30 days report clinically and histologically successful bone regeneration and bone composition.[18,19,27–30] These studies report histologically vital bone percentages (varying from 24% and 47%) at 18 to 20 weeks postextraction. Interesting to notice is that studies on vertical ridge augmentation in which d-PTFE membranes were used in closed procedures report histologically vital bone percentages—varying from 25% to 39%—around 24 weeks after membrane placement.[16] The ability to withstand membrane exposure without infection in extraction sites suggests that it would be likely to resist infection if an exposure occurred in an alveolar bone augmentation procedure. This indicates that bone regeneration in Class I complications can also be expected in early membrane exposures where the edges are covered with soft tissue. In a ridge preservation procedure, Laurito et al[12] reported histologically dense connective tissue directly under an intentionally exposed d-PTFE membrane after 28 days, which is comparable to the tissue present in a natural healing socket. In 2014, Ronda et al[16] histologically described the tissue present under a nonexposed d-PTFE membrane in vertical GBR 6 months after placement as "...a layer of osteoid covered by osteoblast which seemed to form new bone." From

these histologic observations, the present authors' opinion is that one can expect a dense connective tissue layer directly under the membrane when a d-PTFE membrane is exposed. This will result in a reduced final amount of regenerated bone, which can be expected compared to the closed and uneventful healing of GBR procedures with d-PTFE. Because studies on healing complications in GBR procedures with d-PTFE are lacking, more research on this topic is needed.

Conclusions

The proposed clinical classification and treatment of healing complications specifically applies to the d-PTFE membrane (nonperforated). Although e-PTFE and d-PTFE are both made from the same polymer, the distinct manufacturing processes used to produce each material result in unique microstructure differences. These differences result in fundamental distinctions in clinical performance in exposure cases, and this must be recognized by clinicians. This classification and management proposal should help clinicians recognize these differences and thus make the appropriate treatment decisions.

Acknowledgments

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