

Article

Modified Periosteal Inhibition (MPI) Technique for Immediate Implants: A Multi-Center Retrospective Case Series Study

Andrea Grassi ¹, Lucia Memè ², Roberto Rossi ³, Fabio Faustini ⁴, Fabio Marinotti ⁵, Fabrizio Bambini ^{2,*}
and Stefano Mummolo ⁶

¹ Independent Researcher, 41121 Reggio Emilia, Italy; grassi@dentistire.it

² Department of Clinical Sciences and Stomatology, Polytechnic University of Marche, 60126 Ancona, Italy; l.meme@staff.univpm.it

³ Independent Researcher, 16149 Genova, Italy; drrossi@mac.com

⁴ Independent Researcher, 25110 Brescia, Italy; dr.faustini@dentalfaustini.it

⁵ Independent Researcher, 74015 Martina Franca, Italy; studiomarinotti@gmail.com

⁶ Department of Life, Health and Environmental Sciences, Università degli Studi dell'Aquila, 67100 L'Aquila, Italy; stefano.mummolo@univaq.it

* Correspondence: f.bambini@staff.univpm.it

Abstract: Background: Alveolar socket preservation is a topic of serious interest, and researchers have investigated this problem quite extensively. In terms of aesthetics, it is very important to avoid bone resorption if the clinician decides to insert the implant immediately after the extraction. Recently, a new approach utilizing a barrier external to the socket has been developed, which has advanced the evolution of this technique. Immediate implants have also created some difficulty when re-evaluated in long-term follow-up, especially when an aesthetic result is part of the goal of the procedure. Methods: The modified periosteal inhibition (MPI) technique, which has shown interesting outcomes, is evaluated in this paper on a large group of patients. In this case series, among 14 patients, 11 received immediate implants using the MPI technique and immediate provisionalization, and 3 received immediate implants using the MPI technique and customized healing abutment. All patients showed ridge preservation to different degrees, ranging from 0.02 to 1.17 mm, with an average gain of 0.51 mm. Results: all of the 14 patients maintained the original ridge shape, and 1 showed an increase in bucco-lingual size. Conclusions: This case series confirms the promising information reported in earlier studies on this technique. Larger samples will be necessary to confirm the predictability of this new approach.

Keywords: immediate implants; extraction sockets; wound healing; ridge preservation; implant



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1. Introduction

Immediate implantation is a popular topic in the current dental literature. One reason to place implants at the same time as extraction is to prevent remodeling of the bone in both the horizontal and vertical dimensions. Some authors consider this procedure unpredictable in terms of aesthetics because maintenance of the buccal plate height and width is not always guaranteed [1]; in other words, an immediate implant will not necessarily prevent natural bone remodeling. This is why they suggest letting the body heal first, with natural remodeling, and resuming work later, when the situation is stabilized, and known techniques can be used to restore volume in both hard and soft tissue. In many other studies, the authors promote immediate post-extraction implantation, because this technique seems to be able to preserve the soft and hard tissue after extraction [2–5]. However, there are some specific clinical situations, such as the extraction of molars, in which it is very difficult to insert an implant immediately. A paper by Grassi et al. [6–9] describes a new technique to preserve the bucco-lingual volume of bone after tooth extraction. In this technique, healing by secondary intention results in a good quantity and quality of

keratinized gingiva along with a good quality and density of newly formed bone. They suggested using three layers of pericardium membrane to seal the alveolar socket and showed that this technique would allow the preservation of a good quantity of bone.

When dealing with the upper anterior area, where the volume of buccal bone is often very thin, a staged approach may be wiser. Another approach, which has become quite popular in recent years, involves preserving part of the tooth to protect the thin buccal plate and prevent resorption of the bundle bone. This approach is called the socket shield technique (SST), and it has been revised under different names by many authors [10]. The SST involves extracting only the palatal aspect of the hopeless tooth, leaving the buccal portion of the root to support the buccal plate and prevent remodeling. The implant is placed more palatally so that the gap between the root remains and the fixture is filled with blood clots, later turning into new bone formation and providing osseointegration for the implant.

There is a line of thought suggesting that after tooth extraction, it is necessary to place a bone graft into the socket along with the implant [11–17]. Many authors have suggested placing immediate implants with the addition of autogenous bone grafts [18], biomaterials, or a combination of both [19–21]. Studies have proven that these procedures are effective, but other authors have criticized the quality of the newly formed bone achieved with such procedures, especially when the density and elasticity of the new bone are taken into account. Ultimately, the quality and quantity of new bone depend on many different factors, such as the origin of the graft, the dimensions, and the way in which the biomaterial can provide new bone regeneration [22–24]. The gap between the implant and the walls of the implant socket can be filled with many different kinds of bone substitutes, and the resulting new bone can differ depending on the material used [25]. It is not clear whether it is useful for the final result and the integration of the implant to insert something inside the socket along with the implant.

This paper evaluates a new topic: whether it is possible to avoid socket remodeling by focusing our attention on the outer portion of the alveolar socket. In fact, bone remodeling was revisited in a study by Nguyen et al. looking at what happens to the outer portion of the extraction socket rather than the inside [26]. The authors reported that upon extraction, they placed a PTFE membrane between the periosteum and the buccal plate without adding any graft or biomaterial into the socket, and this process led to uneventful healing with good maintenance of the overall volume. According to the authors, this type of periosteal inhibition prevents pre-osteoclasts from attaching to the buccal plate, avoiding their transformation into osteoclasts. The only disadvantage of this technique is the use of PTFE, which forces the clinician into performing a second surgery to remove it. Some authors [27–29] introduced the modified periosteal inhibition (MPI) technique following the principles of the Nguyen et al. study, but they substituted the PTFE membrane with a 0.5 mm-thick collagenated porcine bone lamina (Lamina, OsteoBiol by TecnoSS, Coazze, Italy) and affixed it to the buccal aspect of the extraction socket with fibrin glue (Tisseel, Baxter, Rome, Italy). This procedure will provide a new buccal plate when the cortical bone external to the implant is damaged, and a thicker one when the bone is still in place, thus avoiding the need for a second procedure at a later time. In the same publication, another important factor is that the extraction socket was filled only with collagen, and this provided excellent regeneration as well as good-quality bone formation without the use of a graft (autologous or heterologous). The newly formed bone had the same characteristics as the surrounding bone.

Another aspect of immediate implants is the position of the implant, either at bone level or in a more apical position, and if that is the choice, a further factor is how many millimeters below the bone crest to perform the insertion, with many authors describing the advantages of inserting the implant inside and 2 mm below the bone crest. In 2017, Bambini et al. [30] suggested that one way to preserve the bone volume while placing immediate implants was to place the fixture below the bone crest; that placement was decided after measuring the thickness of the soft tissue in a periapical X-ray taken with

a Rinn centrator. In 1996, Berglundh [31] measured a biologic width of 3 mm around implants. Mathematically, the formula describes the condition where the implant is placed in relationship to the bone crest based on the thickness of the soft tissue: $Y = X - 3$, where Y is the measured depth of the implant with respect to the bone crest (0 for bone level implants), and X is the measured thickness of the soft tissue.

All of these results bring the focus back to the role of blood clotting in the healing of the inner portion of the socket. Degidi underlined the important role of blood clotting in the early phase of healing of the implant chamber between the fixture, the residual bone, and the abutment. His paper showed how important it is to trap the blood clot in the immediate extraction socket by using a temporary abutment seal and protecting the clot itself. The clot represents the starting point for the neovascularization of the hard peri-implant tissue [32].

The goals of this paper were to evaluate the possibility of using the described approach along with the placement of immediate implants in order to determine how MPI might be effective in maintaining or augmenting the bony volume and to determine the role of bone substitutes inside the socket.

2. Materials and Methods

2.1. Study Population

The present multi-center retrospective case series study was performed at three different private clinics (Table 1), in compliance with the principles of the Declaration of Helsinki on medical protocol and ethics. Twelve patients who met the inclusion criteria were selected for the study. Healthy patients requiring single or double tooth extraction with the vestibular bone intact or with a fenestration were chosen, for a total of fourteen sites.

Table 1. C1: Andrea Grassi; C2: Fabio Faustini; C3: Fabio Marinotti.

| Center/Case | Sex/Age | Tooth Number | Ridge Thickness before (mm) | Ridge Thickness after (mm) | Follow-up Time | Difference | Immediate Loading |
|-------------|-----------|--------------|-----------------------------|----------------------------|----------------|------------|-------------------|
| C1 case 1 | Female/31 | 21 | 10.00 | 11.00 | 6 months | 1.00 | yes |
| C1 case 2 | Male/63 | 45 | 8.00 | 8.50 | 12 months | 0.50 | no |
| C2 case 3 | Female/50 | 15 | 9.00 | 9.50 | 6 months | 0.50 | yes |
| C2 case 4 | Female/50 | 14 | 9.40 | 9.50 | 6 months | 0.10 | yes |
| C2 case 5 | Female/71 | 21 | 7.50 | 8.00 | 6 months | 0.50 | yes |
| C2 case 6 | Female/63 | 23 | 6.40 | 6.80 | 6 months | 0.40 | yes |
| C2 case 7 | Female/63 | 24 | 5.60 | 5.90 | 6 months | 0.30 | no |
| C2 case 8 | Male/68 | 42 | 6.40 | 6.90 | 6 months | 0.50 | yes |
| C3 case 9 | Male/62 | 21 | 7.18 | 7.20 | 8 months | 0.02 | yes |
| C3 case 10 | Male/58 | 17 | 10.52 | 11.69 | 5 months | 1.17 | yes |
| C1 case 11 | Male/68 | 24 | 10.10 | 10.70 | 6 months | 0.60 | yes |
| C3 case 12 | Female/46 | 11 | 7.81 | 8.43 | 7 months | 0.62 | yes |
| C2 case 13 | Male/77 | 24 | 12.00 | 12.70 | 6 months | 0.70 | yes |
| C1 case 14 | Male/74 | 13 | 7.9 | 8.1 | 4 months | 0.20 | no |

The inclusion criteria were as follows:

- Age >18 years old;
- General good health (ASA I-II);
- Adequate oral hygiene (full mouth plaque score $\leq 20\%$, full mouth bleeding score $\leq 20\%$);
- Presence of one or more hopeless teeth requiring extraction.

The exclusion criteria were as follows:

- Pregnancy or lactation;

- Untreated periodontitis;
- Osteometabolic disease;
- Intravenous bisphosphonate therapy;
- History of chemotherapy or radiation therapy in the neck–head area;
- Heavy smoking (>15 cigarettes per day);
- Absence of buccal bone plate.

The selected population was as follows:

- Age 31–77 years old;
- 7 men and 5 women.

Written informed consent was provided by all patients for both the clinical procedure and participation in this study. Preoperative CBCT was performed. Patients were administered antibiotic prophylaxis starting the day before extraction with amoxicillin and clavulanic acid at 2 g per day for 6 days.

2.2. Surgical Technique

The MPI technique involves gently removing the hopeless tooth (Figure 1), trying as much as possible to preserve the buccal plate or create the least damage to both soft and hard tissue. Once the tooth is removed, the socket is gently debrided and washed with sterile saline solution, and the dental implant is placed in the best prosthetic position, following the guidelines for immediate implants [33]. After the proper placement is completed, the mesial and distal papilla are elevated in a full-thickness flap, creating a buccal envelope. A bone lamina 0.5 mm thick is trimmed and hydrated in sterile saline solution for 30 s to soften it; the size should be 1–2 mm larger and deeper than the residual vestibular bone (usually about 10 mm by 6–7 mm). In those cases where fenestration is present or occurs, the lamina should be trimmed accordingly to extend beyond the defect. The bone lamina is then glued to the buccal bone (Figure 2) with topical fibrin glue (TFG; Tisseel, Baxter, Rome, Italy) diluted by 10% with bi-distilled water and the collagen inside the gap between cortical and implant (Figure 3). The Tisseel fibrin glue syringe is normally stored in the freezer at $-20\text{ }^{\circ}\text{C}$ and is taken out 6 h before surgery. There are 2 compartments in the syringe: the first, marked as tank 1, contains 1 mL of human fibrinogen (clotting protein) and 3000 KIU/mL synthetic Aprotinin, and the second, marked as tank 2, contains 1 mL of human thrombin at 500 IU/mL and 40 μM calcium chloride dihydrate.



Figure 1. Preop.

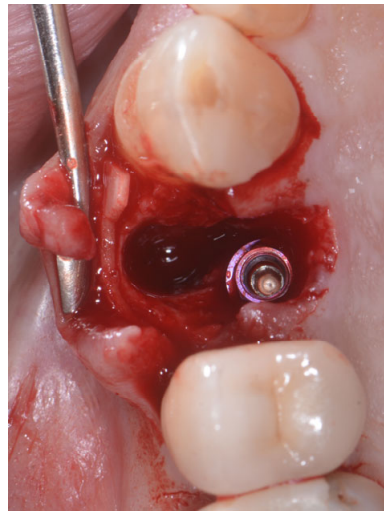


Figure 2. Implant and gap with cortical lamina in place.

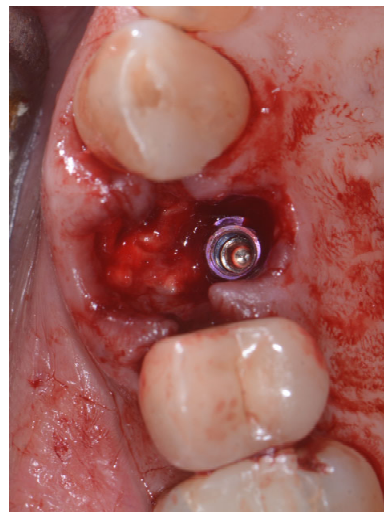


Figure 3. Collagen inside the gap.

In order to have enough time for handling and to avoid immediate hardening of the fibrin glue, it is useful to dilute the contents of tank 2 by 1–9%, particularly the part that contains human thrombin. The dilution is carried out by removing the entire contents of tank 2 of the Tisseel vial with a syringe and placing it into a small sterile steel glass, then adding 9 mL of bi-distilled water to the same container. The two components are then mixed with the aid of a spatula for about 1 min. After this dilution is completed, 1 mL of the mixed solution is re-injected into tank 2. The Tisseel syringe is equipped with a special mixing needle and disposable tip, which facilitate the stabilization of the bone lamina with a few drops of the diluted fibrin glue. Light pressure for 30 s will ensure stability in situ.

Seven patients were treated with porcine bone lamina (Lamina, TecnoSS, Coazze, Italy) and seven with a similar biomaterial but of equine origin (Flex, Bioteck, Arcugnano, Italy). This treatment increases the vestibular bone and keeps the periosteum away from the native bone, creating a mechanical barrier to those cells that would start the resorption process. If the implant has an ISQ of >60 , a temporary abutment and crown are placed (Figure 4) to create a “chamber” effect, as described by Degidi et al. [34]. If the ISQ does not allow immediate loading, a customized healing abutment is created to seal the socket. With this procedure, the gap between the implant and the bone can be left alone with the blood clot or filled with a collagen sponge. The papilla are sutured back using a 4.0 or 5.0 PTFE sling suture.

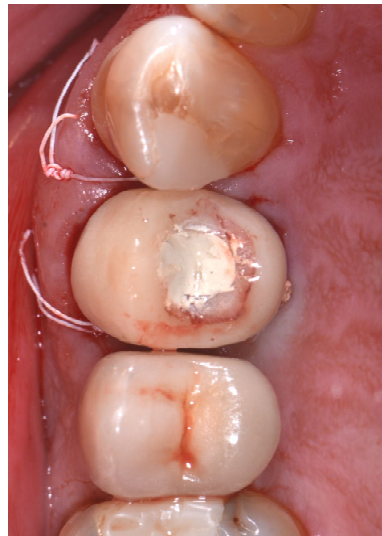


Figure 4. Immediate crown.

2.3. Indications

The indications for this surgical protocol are as follows:

- Sockets that allow simultaneous implant placement;
- Sockets with intact buccal bone;
- Sockets with buccal fenestration.

3. Results

CBCT scans were taken of every single tooth before extraction and at 4 to 12 months postop. Measurements were taken from the center of the implant, using the adjacent teeth for reference, to be sure of the exact section. All cases showed horizontal augmentation ranging from 0.02 to 1.17 mm, with an average gain of 0.51 mm. In a previously published paper on the MPI technique with delayed implant placement, the mean horizontal bone gain was 0.2 mm. These results suggest (Figures 5–7) that immediate placement of the implant, with the protection of blood clotting with a temporary crown or a customized abutment, would improve the outcome.



Figure 5. After 6 months.



Figure 6. Final restoration.



Figure 7. Buccal view of the final restoration.

In the 14 patients treated, the thickness of the bone crest (in mm) was measured before and after surgery (Figures 8 and 9). The data obtained were analyzed using the Wilcoxon matched-pairs signed rank test, a non-parametric statistical test in which each subject is paired with itself in order to evaluate any significance, in this case, that of bone augmentation. The results showed a significance of $p < 0.0001$.

Another statistical test, the sample paired t -test, was also performed because the variables were normally distributed, as demonstrated by the Shapiro–Wilk test in which $t = 6.0257$ (Table 2).

Table 2. Statistical analysis.

| | | Before | After | p -Value |
|----------------------|----|---------------|---------------|--------------|
| Ridge thickness (mm) | 14 | 8.4 ± 1.8 | 9.0 ± 2.0 | $p < 0.0001$ |

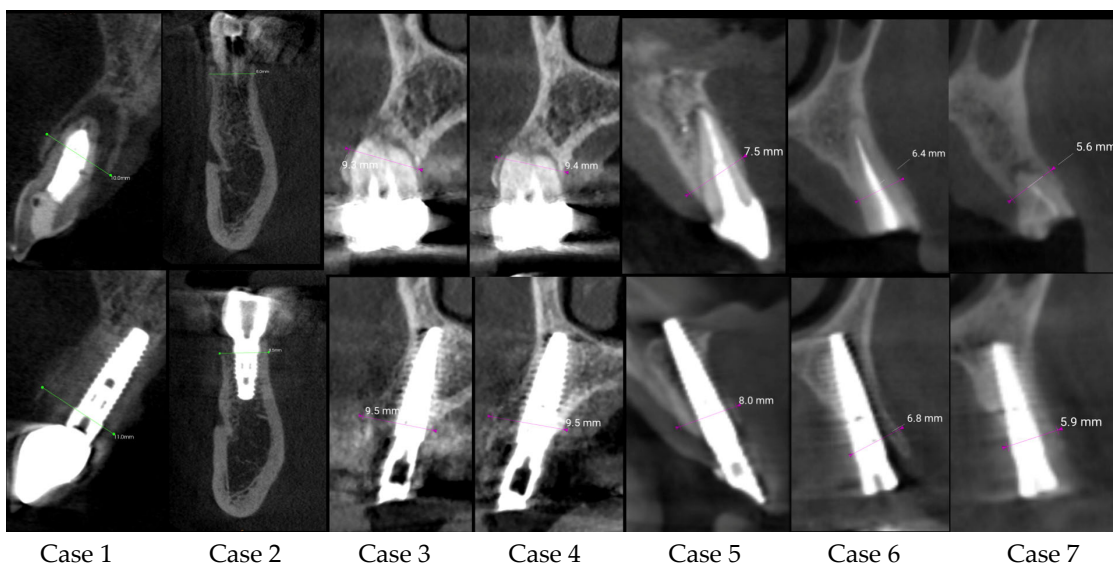


Figure 8. CBCT Cases 1–7 Preop (upper) & Postop (down).

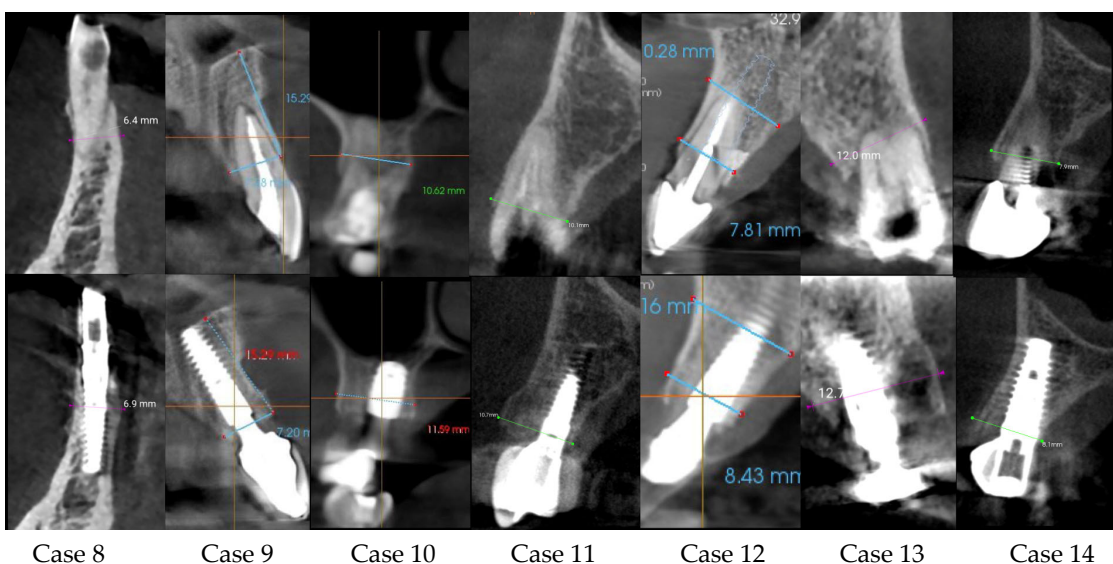


Figure 9. CBCT Cases 8–14 Preop (upper) & Postop (down).

4. Discussion

Immediate post-extraction implantation certainly raises numerous questions regarding positive outcomes, especially in the long term. In the literature, the possibility of resorption of the alveolar process occurring within 5 years of implant placement has been described, with the inevitable exposure of the first implant threads and the consequent onset of mucositis and peri-implantitis if the problem remains unresolved [35]. This also has major repercussions in terms of the aesthetics of anterior implants. Other authors have not considered inserting the implant immediately after tooth extraction to be useful for maintaining the alveolar process.

Today, the primary objective when positioning an immediate post-extraction implant with provisionalization is to obtain an optimal aesthetic result through maintenance or reconstruction of hard and soft tissues [36]. The immediate placement of an implant, in itself, does not avoid the resorption of hard tissues and the consequent change in soft tissues [33]. Various techniques have therefore been proposed to address this problem, which differ based on the presence or absence of the vestibular cortex. We are faced with two completely different situations: if the cortex is present, we have to counteract its

reabsorption, and if it is absent, we will have to rebuild it instead. It is not obvious whether it is easier or more predictable to prevent resorption than to reconstruct a lost cortex.

The mere insertion of biomaterial inside the alveolus has raised questions about the effectiveness of the graft in maintaining the alveolus, and even if it is maintained, questions are raised about the real quality in terms of regenerated, well-functioning, and revascularized bone. This is an aspect that, in the long term, raises questions about the actual functional permanence of the tooth-implant system immersed in bone mixed with non-resorbed material [34,37].

In 2010, the socket-shield technique was proposed for the first time, in which immediate implant placement is associated with maintaining a buccal portion of the root with its periodontal ligament. This technique, which provides for the insertion of a biomaterial in the event of a large root implant gap, has shown very encouraging results in terms of both the maintenance of hard tissues and the architecture of soft tissues.

In 2019, the periosteal inhibition technique was published. With this technique, the goal is no longer to fill the residual gap to compensate for the resorption of cortical bone, but to mechanically prevent it by using a d-PTFE sheet placed in the external portion of the extraction socket. Preosteoclasts from the vessels of the deep periosteum seek contact with the bone wall, and only after bonding with the cortical plate can these cells merge to form osteoclasts, which are then able to resorb the buccal bone. For the first time, there is a technique that aims to avoid osteolytic activity outside the extraction socket. Periosteal inhibition can be associated with the immediate placement of an implant; however, this requires removing the d-PTFE sheet in a second surgical phase after 4 months. Both the socket shield and periosteal inhibition techniques are indicated for sockets with a completely intact buccal wall.

In the case of a total absence of the buccal plate, the multi-layer technique (MLT), which was proposed in 2021, can be used. After immediate insertion of the implant, this technique involves taking a connective graft from the palate and placing 0.5 mm Soft lamina and biomaterial in the gap between the fixture and the lamina. The Flex or Soft cortical plate, of heterologous origin (equine or porcine), is completely biocompatible and does not require a second surgery, since it integrates to replace the missing buccal wall. It is a semi-rigid barrier made of cortical bone, and studies have shown that over a slightly longer time than needed by autogenous bone, it resorbs and transforms into new bone, or sometimes it simply integrates into the area where it is applied.

In 2022, the modified periosteal inhibition (MPI) technique was presented, which involves the use of a soft cortical lamina instead of a d-PTFE sheet, affixed with a few drops of human fibrin glue (Tisseel). The cortical lamina proved to be able to block osteoclastic activity outside the alveolus, leading for the first time to control, 4 months after extraction, with increased alveolar volume and without the need to insert biomaterial inside the extraction site. This was possible because the cortical lamina, in addition to inhibiting resorption, creates a horizontal increase in bone thickness, providing support to the soft tissues, which also provides quantitative improvement. In that study, nine extraction sockets treated with MPI demonstrated an average horizontal bone gain of 0.2 mm at 4 months postop. Covani et al. presented a different hypothesis in this regard, suggesting that the detachment of periosteum creates a chamber where the bone forms. This theory accounts for the force of shrinkage exerted by blood clotting in the socket wall caused by the differentiation of fibroblasts into myofibroblasts [38]. Two important activities in the healing phase of the extraction socket are explained in this paper: mechanical support of the periosteum and inhibition of myofibroblastic activity through quick re-epithelialization of the socket. This second hypothesis of myofibroblastic vs. osteoclastic inhibition can better explain the results achieved with MPI combined with implant placement compared to MPI alone.

The same modified periosteal inhibition technique was applied in this study, with simultaneous implant placement and immediate restoration when possible. The Flex (equine) and Soft (porcine) cortical lamina products have expanded the indications for

the technique with respect to the use of d-PTFE, including cases with bone fenestration (Figure 10). In a study published by Grassi et al. in 2021, cortical lamina was not only found to be effective in preventing reabsorption of the buccal plate, but also made it possible to obtain a horizontal increase in the entire area, giving support to the soft tissue profile, which changed, presenting an aesthetically pleasing vestibular convexity (Figure 11). Immediate provisionalization supports and maintains the interdental papillae; furthermore, the cortical lamina can be cut out by creating triangles that slip under the papillae (Figure 12).

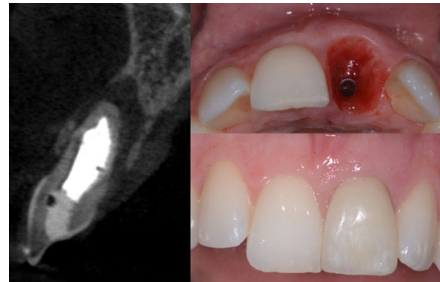


Figure 10. Buccal fenestration.



Figure 11. Buccal convexity (4 mm).



Figure 12. Lamina under the buccal flap.

The results of this study show that both the Flex and Soft cortical lamina were able to prevent osteolytic activity on the external cortex and counteract myofibroblastic activity, thus avoiding potential resorption after immediate implant placement without the use of a biomaterial inside the alveolus, in both the anterior and posterior areas. Other studies will be necessary, particularly a multi-center study with a rigorous and repeatable protocol such as the one described here, to confirm and consolidate the excellent results achieved in this case series.

5. Conclusions

The purpose of this case series was to investigate the effectiveness of placing a collagenated bone lamina between the periosteum and the buccal bone in immediate implants. This technique is called modified periosteal inhibition (MPI). In the study, xenogenic bone lamina of either porcine or equine origin was used with the same thickness, 0.5 mm. The bone membrane was affixed to the buccal aspect of the extraction site with Tisseel fibrin glue, and CBCT scans were taken after healing, highlighting the membrane's ability to

preserve the integration and mineralization of horizontal resorption, thus supporting the soft tissue buccal to the implant.

In most of the cases treated with this procedure, the application of bone lamina resulted in maintenance of the original bone volume, and in all cases, this produced a slight increase in bone volume, with a mean horizontal bone gain of 0.51 mm.

The soft tissue in all cases benefited from the placement of the barrier, with good volume maintained and interdental papilla preserved. A positive outcome of this study was that no patient reported postoperative discomfort or complication, healing was uneventful, and the aesthetic outcome was mostly appreciated.

Preserving the status quo when extracting teeth is one of the main objectives of periodontal and implant therapy. A technique using a minimally invasive surgical procedure to help maintain and support both hard and soft tissue, such as MPI, deserves further attention and investigation to support the excellent outcomes observed in this case series. The clinical successes achieved in the treated cases are based on the application of simple biological principles which allow a dentist, even with average skills, to be able to obtain excellent results. This technique was successful in this group of patients, not only from the clinical point of view, but also in terms of reduced morbidity and postoperative discomfort. The lack of immediate or late complications and postoperative pain is a fundamental aspect to consider for a surgery that is intended to be increasingly minimally invasive. The objective of this work was precisely to try to confirm the effectiveness of a simple procedure that could be useful for clinicians with more or less expertise. Further studies will certainly be useful to confirm the positive results seen in this group of patients.

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