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Case Report

Modified Periosteal Inhibition (MPI) Technique for Extraction Sockets: *A Case Series Report*

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Abstract: Several Alveolar Ridge Preservation (ARP) procedures have been proposed over the years. The purpose of this study was to describe the new Modified Periosteal Inhibition (MPI) technique for ARP. Seven patients were enrolled (age range: 28–72 years old; 5 males, 2 females). In total, nine hopeless teeth were treated. Following the elevation of a full-thickness flap, atraumatic tooth extraction was conducted, preserving the buccal bone of the alveolar socket. OsteoBiol® Lamina Soft (Tecnoss®, Giaveno, Italy), 0.5 mm thick, was suitably shaped (8–10 mm in height, extending from the mesial and to the distal corners of the socket). The lamina was gently positioned between the buccal periosteum and the buccal bone plate. Tisseel® (Baxter Healthcare Corporation, Deerfield, IL, USA) was applied to seal the cortical membrane. The flaps were sutured with PTFE 4-0 (Omnia, Fidenza, Italy). Postoperative instructions were provided. Patients were strictly monitored during the follow-up. No early or late biological complications were experienced. Cone Beam Computed Tomography (CBCT) exams were performed at baseline and 4 months later. The thickness of the buccal cortical bone at baseline was 1.18 ± 0.57 mm. The pre-operative and post-operative ridge widths were 10.74 ± 1.54 mm and 11.16 ± 1.57 mm, respectively. A horizontal ridge increase of 0.41 ± 0.21 mm was observed during the healing period. At 4 months of healing, the bone volume was adequate for implant placement and no additional bone regeneration procedures were required. MPI technique was effective in preventing the horizontal contraction of the post-extraction socket. Further studies will be needed in the future to confirm our positive results.

Keywords: Alveolar Ridge Preservation; Socket Preservation; Periosteal Inhibition; cortical lamina; fibrin glue; collagen sponge

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1. Introduction

Alveolar Ridge Preservation (ARP) techniques are used to counteract the physiological bone ridge resorption that occurs after tooth extraction. The literature reports a possible, horizontal alveolar resorption of up to 50%, while vertical resorption also occurs but is less relevant [1,2]. Furthermore, the changes mostly occurred during the first year, especially in the first months of healing. In the past, some authors suggested that immediate implant placement after tooth extraction could prevent the resorption of the alveolar ridge. However, Botticelli et al. proved otherwise [3]. The authors observed that implant insertion failed to avoid alveolar ridge resorption during 4 months of healing. The results were similar to those described by Tan et al. for the spontaneous healing of post-extraction sockets [4].

Internal alveolar preservation techniques involve the use of a biomaterial that can be protected in different ways: with collagen membranes, connective tissue harvesting and d-PTFE membranes [5–7]. A review of the literature did not reveal which technique was the best to adopt. In addition, all of these ARPs do not guarantee complete volume maintenance but only reduce resorption [8–10]. Although there has not been a clear consensus [11], in recent years it has been clear that soft tissues play a key role in the long-term success of dental implants [11–13]. Therefore, the clinician's attention should not only be limited to hard tissues but also include peri-implant soft tissues. Recently, Bambini et al. correlated the apical-coronal position of an implant to the thickness of the soft tissues [14]. This protocol prevented the fixture's exposure due to the formation of a new biological width during the healing process [15,16].

In 2019, Nguyen et al. introduced a new ARP outside the alveolus, modifying the area of interest [17]. Periosteal Inhibition Technique (PI) aimed to inhibit the osteolytic activity on the outer surface of buccal bone. A d-PTFE membrane was placed between the vestibular periosteum and the cortical bone, and no bone grafts were inserted in the sockets. The authors hypothesized that the precursors of osteoclastic cells (9.5 µm in diameter) were unable to come into contact with the outer surface of buccal bone and differentiate due to the porosity of the membrane (0.2–0.3 µm), which acted as a barrier [18–21]. This prevented the osteoclastic activity of the deep periosteum, consequentially reducing the buccal bone resorption. The preliminary results showed a non-significant average loss of 0.4 ± 0.3 mm of the soft tissue and 0.2 ± 0.4 mm of the bony ridge width after 4 months. However, the main drawback of the PI was the second-stage surgery required for the membrane removal.

Modified Periosteal Inhibition (MPI) overcomes the limit of the technique described by Nguyen et al. [17]. The MPI technique aims not only to preserve the vestibular bone by exploiting Periosteal Inhibition but also to increase its thickness by bonding a single or double layer of OsteoBiol® Lamina Soft (Tecnoss®, Giaveno, Italy) 0.5 mm thick. The use of the cortical bone lamina also allows the inclusion of extraction sockets with partial deficiencies in the cortical bone among the indications of the technique. The aim of the study was to describe for the first time the surgical protocol of MPI technique. The primary purpose was to analyze the dimensional changes of the alveolar ridge width over a healing period of 4 months through Cone Beam Computed Tomography (CBCT) comparisons. The secondary purpose was to evaluate the occurrence of early and late biological complications, such as swelling, suppuration, and pain.

2. Case Report

2.1. Study Population

The present retrospective case series study was performed in a private clinic (A.G., E.M.), in compliance with the principles of the Declaration of Helsinki on medical protocol and ethics. Seven consecutive patients, who met the inclusion criteria, were selected for the study (age range: 28–72 years old; 5 males, 2 females). Healthy patients requiring single or double tooth extraction with the vestibular bone intact or partially missing were chosen, for a total of nine cases.

Inclusion Criteria:

- 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.

Exclusion Criteria:

- Pregnancy or lactating period;
- Untreated periodontitis;
- Osteometabolic disease;
- Intravenous bisphosphonates therapy;
- Chemotherapy or radiation therapy history of the neck–head area;
- Heavy smokers (>15 cigarettes/per day);
- Absence of buccal bone plate.

Written informed consent was signed by all patients for both the clinical procedure and the present study. Pre-operative CBCTs were performed. Patients were provided antibiotic prophylaxis starting the day before extraction: 2 g per day of Amoxicillin and Clavulanic Acid for 6 days.

2.2. Surgical Protocol

After local anesthesia (4% articaine with 1:200,000 adrenalin), an atraumatic extraction was performed, preserving the buccal bone, and the alveolar socket was carefully debrided. After papillae incisions, an intra-sulcular incision was made on the vestibular side of the extraction socket, extending to the mesial and distal mid-tooth with a #15c surgical scalpel (Figure 1a,b). A full-thickness flap was lifted (Figure 1c) and the periosteum was disconnected with micro-collars, creating a socket that would allow the insertion of the cortical lamina. The OsteoBiol® Lamina Soft (Tecnoss®, Giaveno, Italy) 0.5 mm thick was left in saline solution for 5 min and then cut to the desired shape, ranging from 8 to 10 mm in height (if possible) and extending up to the mesial and distal margins of the extraction socket. The cortical lamina was conveniently placed and, if necessary, modeled until a perfect fit was achieved. If the bony peaks were higher than the level of the buccal bone plate, it was possible to obtain a shape that perhaps only partially lodged under the gingival papillae (Figure 1d). The edges were rounded to reduce the risk of traumatizing soft tissues during healing. The thrombin portion of human fibrin glue (Tisseel®, Baxter Healthcare Corporation, Deerfield, IL, USA) was diluted with 9 mL of sterile saline, reducing the international thrombin units from 500 to 50. Two or three drops of diluted glue were placed on the cortical lamina, which was then locked with a simple pressure to the vestibular bone, making it coincide with the extraction socket border. If necessary, we inserted a second lamina, smaller in size than the first, to obtain an increase of 1 mm in thickness. A collagen sponge (Condress, Smith & Nephew S.r.l., Monza, Italy) was inserted inside the extraction socket to stabilize the clot (Figure 1e) and blocked with a cross suture 4-0 PTFE (Omnia, Fidenza, Italy), after suturing the papillae with two sling stitches (Figure 1f). The sutures were removed after 7–8 days.

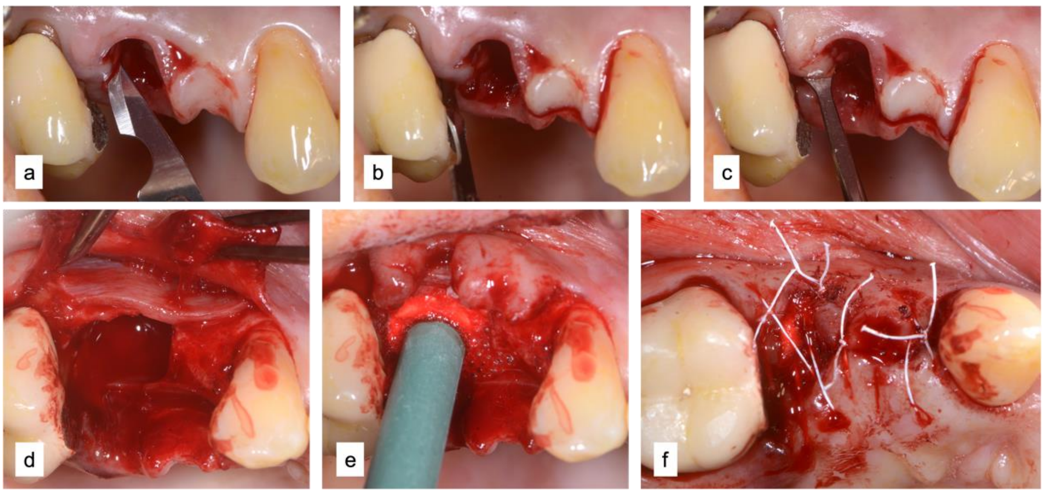

Figure 1. Surgical protocol: (**a**,**b**) intrasulcular incisions; (**c**) mucoperiosteal flap elevation; (**d**) OsteoBiol® Lamina Soft (Tecnoss®, Giaveno, Italy) was adapted to buccal bone; (**e**) Condress (Smith & Nephew S.r.l., Monza, Italy) insertion in the socket; (**f**) flap was closed with a cross suture, while the papilla was closed with two sling stitches.

2.2.1. Case 1—MPI Technique Zone 47

A 43-year-old female patient with a vertical fracture on tooth 47, already with fixed dental prosthesis, presented a periodontal abscess (Figure 2a). After the atraumatic extraction, the MPI technique was performed. After 4 months, the clinical examination confirmed the horizontal gain, and a complete maintenance of the thin vestibular bone already showed in CBCT cross sections (Figure 2b,c).

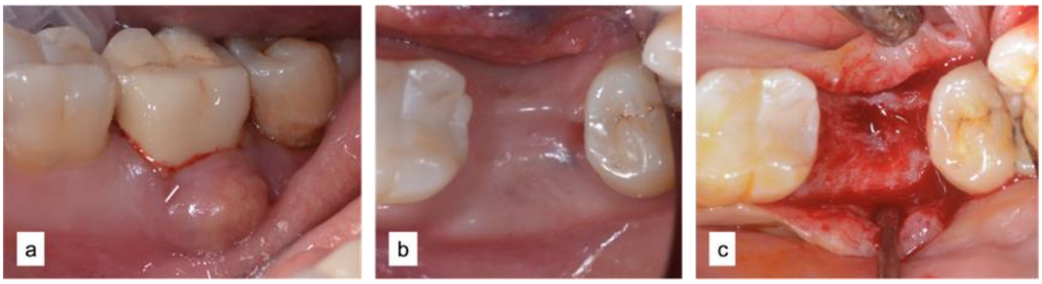

Figure 2. Patient 1. (**a**) Preoperative image of tooth 47. (**b**) Soft tissue healing at 4 months. (**c**) Bone healing at 4 months.

2.2.2. Case 3—MPI Technique Zone 34

A 70-year-old male patient presented a horizontal fracture on tooth 34, which was not salvable. A deep vestibular recession of the soft tissues was noted, although there was still some keratinized tissue (Figure 3a). The decision was made to perform the MPI technique (Figure 3b–d), with a delayed implant placement (Figure 3f). A control CBCT was performed 4 months after the surgery, showing a horizontal increase in the extraction socket size. The keratinized gingival tissues had also increased, resolving the initial deficit (Figure 3e).

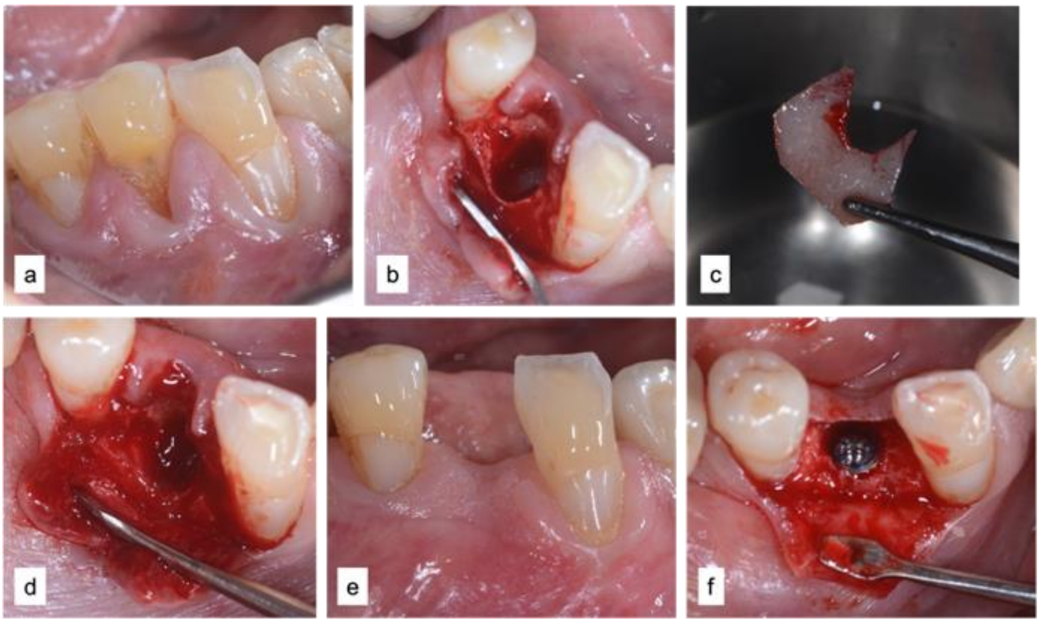

Figure 3. Patient 3. (**a**) Preoperative image of soft tissue recession. (**b**) Thin vestibular bone was exposed. Cortical membrane (**c**) shaped and (**d**) glued. (**e**) Soft tissue healing at 4 months. (**f**) Bone healing and implant placement at 4 months.

2.2.3. Case 6—MPI Technique Zone 16

A 50-year-old female patient presented endo-periodontal lesions and partial destruction of the buccal and palatal cortices on tooth 16 (Figure 4a). This condition can seriously increase the risk of resorption during healing, so the decision was made to apply the MPI technique of alveolar preservation. Two portions of 0.5-mm soft bone cortical lamina were modeled for insertion from both the buccal and palatal sides and fixed with a few drops of previously diluted human fibrin glue (Figure 4b). After 4 months, a clinical examination of the socket revealed that both hard and soft tissues had increased, which was confirmed by CBCT control (Figure 4c,d).

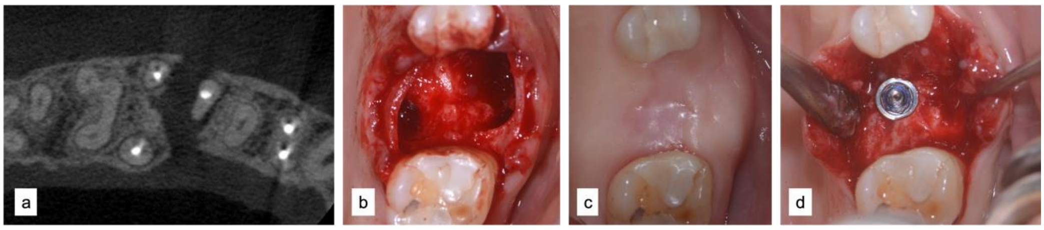

Figure 4. Patient 6: (**a**) CBCT section showed partial destruction of both palatal and buccal cortical bone; (**b**) two layers of cortical lamina, placed on the buccal and palatal sides; (**c**) soft tissue healing at 4 months; (**d**) bone healing and implant placement at 4 months.

2.3. Radiographic Evaluation

CBCT exams were performed before dental extraction (baseline) and after 4 months with Carestream 8100 3D (Carestream Dental, Atlanta, GA, USA) (Figures 5 and 6). The measurements were carried out by a single-blinded operator (F.B.). Taking the remaining teeth as a reference, we positioned ourselves in the same coronal cuts, measuring the bone thickness. Measurements were taken 2 mm under the bone vestibular margin or at the palatal margin if the measuring was simpler. Descriptive statistics (mean value and standard deviation) were obtained.

Figure 5. CBCT images of the nine consecutive cases at baseline, before the surgery.

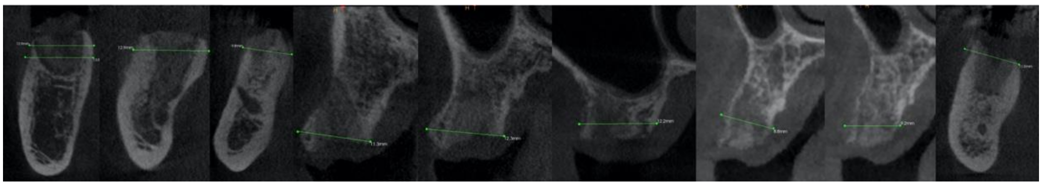

Figure 6. CBCT images of the nine consecutive cases treated with MPI at 4 months of healing.

The linear measurements are reported on Table 1. The initial buccal bone thickness was 1.18 ± 0.57 mm. The preoperative ridge width was 10.74 ± 1.54 mm, while the postoperative width was 11.16 ± 1.57 mm. No volume contraction of the healing sockets was detected. On the contrary, the data showed that the average increase that was obtained was 0.41 ± 0.21 mm.

The maximum increase that was obtained occurred in Case 2 with 0.9 mm. It could be explained by the fact that two layers of 0.5 mm thick cortical lamina were positioned. From the lingual or palatal side, where the lamina was not applied, a slight resorption occurred. This could be the reason why the horizontal augmentation was often less than the thickness of the cortical lamina itself.

2.4. Clinical Outcomes

The nine treated sockets recovered without complications or side effects. Patients were monitored closely during follow-up. Patients did not complain about any pain or swelling. No early or late complications (e.g., wound dehiscence, abscess, or site infection) were experienced.

Table 1. Difference between preoperative and postoperative ridge width. RP = ridge preservation; SD = standard deviation. [a] Postoperative measurements were taken at 4 months after ridge preservation. [b] Same patient, double extraction. [c] Same patient, double extraction. Δ = differences between the preoperative and postoperative ridge width values of the same site.

Case No.	Tooth No.	Initial Buccal Bone Thickness (mm)	Preoperative Bony Ridge Width (mm)	Postoperative Bony Ridge Width (mm) [a]	Δ
1	47	0.80	12.50	12.90	0.40
2	37	0.80	12.00	12.90	0.90
3	34	0.70	9.20	9.80	0.60
4 [b]	24	2.00	11.10	11.30	0.20
5 [b]	25	2.00	12.00	12.30	0.30
6	16	1.20	11.90	12.20	0.30
7 [c]	14	0.70	8.50	8.80	0.30
8 [c]	15	0.70	8.80	9.20	0.40
9	36	1.70	10.70	11.00	0.30
Mean RP		1.18	10.74	11.16	0.41
SD		0.57	1.54	1.57	0.21

After 4 months of healing, a dental implant insertion was scheduled. The flap elevation revealed an adequate bone volume, as already shown in the CBCT exams (Figure 6). The cortical membrane was partially visible. No additional bone augmentation procedures were required (Figure 7a–e).

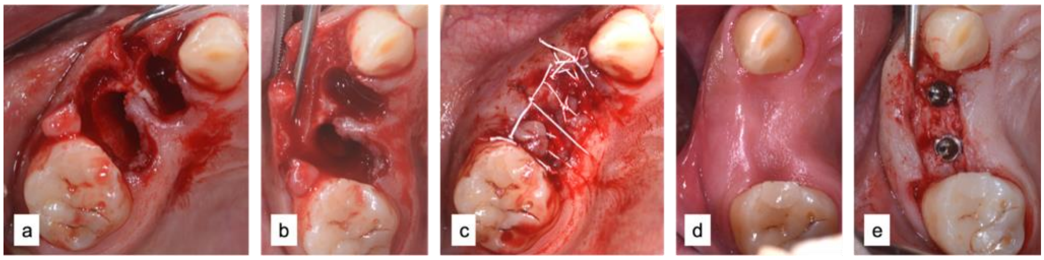

Figure 7. Cases 4–5: (**a**) vestibular bone of zone 24–25 was exposed, and an envelope was created; (**b**) cortical lamina glued on the vestibular bone; (**c**) sockets were filled with collagen sponge, single sutures on papilla and cross sutures to lock the sponge; (**d**) soft tissue healing at 4 months; (**e**) bone healing and implants' placement at 4 months.

The implants were prothesized 3 months after the insertion. Radiographic evaluations at 7 months showed the stability of bone levels around the implants (Figure 8).

Figure 8. Radiographic evaluations of the implants at 7 months.

3. Discussion

All ARP techniques involving the filling of the extraction socket with biomaterials have shown results that were not always predictable. The volume shrinkage was often reduced but not completely eliminated [22]. Furthermore, the disadvantages deriving from the insertion of a biomaterial, such as the lengthening of the healing time and formation of vital bone, are much fewer than those resulting from spontaneous healing or from only using collagen [23,24].

As put forward by Hürzeler et al. [25], the only ARP capable of preserving the internal osteo-gingival architecture seems to be the Socket Shield Technique, thanks to the preservation of the vestibular part of the root and periodontal ligament [26–28]. Complete preservation at 10 years has been achieved with this procedure. The Modified Socket Shield technique without implant placement with a concomitant extraction socket reconstruction was proposed by Glocker et al. [29]. The disadvantages of the technique include a difficulty to perform it and therefore the dependence on an operator, the fact that it takes a long time to perform, and the fact that the residual root occupies part of the implant space.

The PI technique shifted attention to the outside of the extraction socket, working against the osteolytic activity deriving from the deep periosteum [17]. The preliminary results showed an almost total preservation of both hard and soft tissue volumes, without the need to either maintain root fractions inside the socket or resort to a biomaterial. The advantages therefore include extreme ease and speed of execution and a return to normality in 4 months, a relatively short time, not forgetting the most important aspect, which is the formation of only viable bone within the extraction socket.

The PI technique's limits include having to remove the d-PTFE membrane later and not being able to increase alveolar volumes but only preserve them. The MPI technique aims to overcome these limitations. Thanks to the use of soft cortical lamina and human fibrin glue, nothing is removed during implant placement. Comparing the preoperative and postoperative ridge width of the present study, the radiographic measurement showed an increase equal to 0.41 $\pm$ 0.21 mm (primary purpose), suggesting a good Periosteal Inhibition effect by the bone lamina. No biological complications occurred during the follow-up, and healing was uneventful (secondary purpose). The MPI technique could therefore be the first ARP technique to provide an extraction socket with an increased volume in only 4 months.

OsteoBiol® Lamina Soft (Tecnoss®, Giaveno, Italy) is a membrane made of collagenated porcine cortical bone [30]. Several studies have shown its osteoconductive properties for both horizontal and vertical bone augmentation procedures [31–33]. Fischer et al. [34] demonstrated that the cortical membrane, positioned on the outer surface of the buccal bone, was able to maintain the ridge volume of the socket. The histological analyses at 4 months showed the formation of new bone below the membrane and the absence of resorption of the buccal bone. In cases of injury or inflammation, a portion of monocytes can differentiate into preosteoclast. Through the vessels of the periosteum, these precursors migrate to the affected bone cortex. Mononuclear precursors only fuse to form osteoclasts after attaching to the bone surface [18–21]. Not only does the cortical lamina prevent this destructive process from affecting the bone cortex, but at the same time it allows the latter to increase or be recreated if partially damaged. Since the bone lamina is more resistant than the d-PTFE membrane, we can extend the indications for the technique to extraction sockets with partial deficits of the buccal bone, greatly increasing the range of cases that can be treated.

Festa et al. [35] described the use of the cortical membrane in combination with a porcine-derived xenograft (OsteoBiol GenOs®, Tecnoss®, Giaveno, Italy) for ARP. After 6 months of healing, the authors observed a reduction of the ridge width from 9.8 $\pm$ 1.2 mm to 8.0 $\pm$ 1.1 mm in test sites (treated with the ARP technique). On the contrary, the control group (spontaneous healing) showed a horizontal reduction of the alveolar ridge from 9.9 $\pm$ 1.0 mm to 6.2 $\pm$ 1.3 mm. In both cases, the reductions were statistically significant ($p < 0.05$), although it was greater on the control side. The technique described by the authors differed from MPI. Indeed, Festa et al. [35] positioned the membrane so as to have it cover the socket, while in MPI the membrane was placed between the buccal periosteum and the outer surface of the alveolar ridge. Furthermore, unlike Festa et al. [35], in MPI no bone substitutes were inserted in the sockets, leaving the blood clot to form the matrix for new bone formation.

In the MPI surgical protocol, the extraction sockets were filled with resorbable collagen sponges. It could be assumed that the material could affect the healing process and, consequentially, the results. Collagen sponges act as a provisional extracellular matrix that promotes the early stages of socket healing [36]. However, they have not been effective in preventing alveolar ridge shrinkage after dental extraction [37]. Recently, Crespi et al. [38] compared the dimensional changes of alveolar sockets filled with collagen sponges and porcine cortico-cancellous bone (MP3, OsteoBiol®, Tecnoss, Coazze, Italy) in the molar and premolar areas. After 3 months, the width of the alveolar ridge decreased by 2.9 (0.9) mm and 3.9 (1.4) mm, respectively. The difference was statistically significant between the two groups ($p < 0.0001$). These data confirmed that the collagen sponges were not effective for ARP, showing similar results to spontaneous healing [39]. Most importantly, the use of a porcine xenograft alone within the socket did not prevent the horizontal contraction of the alveolar ridge during the healing period. The results of this study were in line with those reported by Barone et al. [39].

The major limitation of this study is the absence of a control group. However, analyzing the recent data in the literature [2], it is possible to observe in the molar area an average horizontal resorption of the crest equals 3.61 mm (95% CI: 3.24–3.98) after dental extraction. These data are essentially in line with the systematic review of Tan et al. [4], according to which the horizontal resorption of the ridge was 3.79 ± 0.23 mm after 6 months of healing. Considering the data of the present study, MPI has shown promising results. Further clinical trials will be needed in the future to compare the effectiveness of MPI with both spontaneous socket healing and other ARP procedures.

4. Conclusions

The results obtained with the MPI technique demonstrate its capacity, already observed for the PI technique with d-PTFE, to inhibit osteoclastic activity on the external surface of an extraction socket with a cortical bone lamina. For the first time, an ARP technique was able not only to completely preserve the original extraction socket volumes but to increase them after only 4 months, forming only viable bone within the extraction socket. The MPI technique, after the PI technique, completely changes the approach to extraction sockets. It will no longer be necessary to use biomaterials inside the socket to compensate for events that occur outside it. All of the cases reported in the article concerned posterior, premolar and molar areas. The technique can also be used in the anterior area in order to evaluate soft tissue healing capacity and papillae maintenance. Like the PI technique, the MPI technique can also be performed with immediate positioning of an implant. However, we have preferred to report these data in a second article. Further studies are needed to support the application of the MPI technique in routine clinical practice.

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Informed Consent Statement: Written informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the patients to publish this paper.

Data Availability Statement: The data presented in this study are available on request from the corresponding Author, A.G., upon reasonable request.

Conflicts of Interest: The authors declare no conflict of interest.

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