

Barbell Technique: A Novel Approach for Bidirectional Bone Augmentation. Technical Note

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Horizontal bone reconstruction is a common augmentation procedure used in implant dentistry to achieve adequate 3-dimensional ridge reconstruction to permit proper dental implant positioning. However, most available techniques are focused on unidirectional bone reconstruction (grafting only on the buccal side). This study was carried out to validate an innovative device that is indicated for bidirectional bone augmentation. The study consisted of 4 patients who required bidirectional horizontal bone augmentation of the upper jaw. Two computerized tomographies were performed (T0 at baseline and T1 at 6 months postoperative examinations). Mean bone thickness in the studied sites at T0 was 2.30 ± 0.65 and mean bone thickness achieved was 9.11 ± 1.08 mm at T1, with an overall bone gain of 6.81 ± 1.33 mm. Concerning the specific gains in direction, buccal and palatal bone augmentations were 4.89 ± 0.94 and 1.92 ± 0.42 mm, respectively. Based on these results, it can be concluded that the use of this novel device allows for the achievement of bidirectional horizontal bone augmentation.

Key Words: *guided tissue regeneration, bone regeneration, bone grafts, alveolar bone atrophy*

INTRODUCTION

Bone reconstruction is often challenging in the implant dentistry field. Specifically, horizontal bone augmentation can be performed using a number of techniques with no consensus about which technique is the most efficient¹. The prevalence of a horizontal bone defect is high due to the tendency for horizontal bone resorption after tooth extraction.²⁻⁴

Most surgical techniques used for horizontal bone augmentation are focused on buccal bone gain. It is known that loss of bone thickness occurs on both sides (on the buccal and lingual or palatal sides) due to the centripetal resorption of the alveolar crest.⁵ In this regard, Pelegrine et al (2010)³ showed that in the anterior maxilla, 34.82% of the original thickness of the coronal aspect of the socket was lost 6 months after tooth extraction. This percentage represented 2.5 mm of bone loss, with 1.75 and 0.62 mm (median) bone loss on the buccal and palatal sides, respectively. Therefore, it can be stated that the palatal loss is 35% of the buccal loss and besides, the fact that the major horizontal loss occurred at the buccal side does not mean that palatal loss can be neglected. Moreover, with time, the amount of bone loss has a tendency to be higher when there is lack of adequate stimuli to the corticocancellous bone.²

As horizontal bone loss after exodontia occurs in a bidirectional manner, it is reasonable to perform bone augmentation using a bidirectional approach. However, with the current horizontal bone augmentation techniques, it is more common to perform a unidirectional bone reconstruction (such as on the buccal side) due to the difficulty to install screws and pins on the palatal or lingual side. Therefore, by using the tenting screws,⁶ titanium mesh/titanium reinforced membrane,^{7,8} cortical tenting grafting,⁹ or bone block technique,¹⁰ it is common to augment the bone just on the buccal side due to difficulty accessing the lingual or palatal aspect of the alveolar ridge. The ridge split technique does not require positioning tenting screws on the palatal/lingual side and allows significant bone augmentation just on the buccal side as it is common to displace just the buccal portion of the ridge.¹¹ However, the literature showed the possibility to perform bidirectional bone augmentation by using orthodontic tooth movement.¹² However, this approach contains some issues restricting its use such as the need for stable, healthy teeth adjacent to the bone defects and this approach is time-consuming.¹³ Therefore, the development of new versatile surgical techniques that allow bidirectional bone augmentation is timely.

The aim of this study is to present a novel device that allows horizontal bone reconstruction bidirectionally with the aim of overcoming the limitations of currently available techniques. The versatility of use and handling of this device is also discussed.

MATERIALS AND METHODS

Study design

This study was designed as a computerized tomographic (CT) study to document bone gain in the upper jaw and was approved by São Leopoldo Mandic Research Ethics Committee

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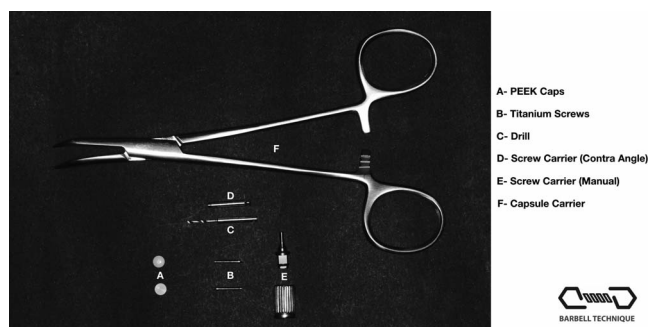


FIGURE 1. Design of the Barbell Technique devices. (a) Polyether ether ketone capsules; (b) titanium screws; (c) drill; (d) screw carrier for contra angle; (e) manual screw carrier and (f) capsule carrier.

(opinion number 3.651.056, 2019). The clinical procedures were undertaken with the understanding and written consent of each patient and in full accordance with the ethical principles of the World Medical Association Declaration of Helsinki (2013).

Pregnant, diabetic, or immunocompromised patients, as well as smokers and patients using any medication that could interfere with the surgical protocol or with bone metabolism were excluded from the study. After applying these exclusion criteria, 4 patients (2 women and 2 men), with a mean age of 52 years and the need for bidirectional horizontal bone augmentation in the anterior maxilla prior to implant placement were selected. The residual bone thickness of the sites ranged from 2 to 4 mm.

The maxilla was scanned preoperatively (T0) and 6 months postoperatively (T1), and sagittal sections (1.0 mm in thickness) were obtained as reconstructions. All cone beam computerized tomography (CBCT) scans were acquired using the i-CAT 3D Imaging System. All surgical procedures and CT analysis were accomplished by the one investigator.

Device

Each device consists of 1 titanium screw and 2 polyether ether ketone (PEEK) capsules. The length of the screw can be selected according to the desired bone gain (6, 8, or 10 mm in length), and the diameter of the capsule is fixed at 4.5 mm. Both the screw and caps are installed using a carrier especially designed to fit perfectly around the caps. The screw has a tip on both ends with an external hexagon and the caps have an internal circumference that allows the use of pressure to fit over the external hex of the screw. Due to the characteristic of the final design of the device (after the cap adaptation), this device/technique has also been registered with the name "Barbell" (Figure 1).

Reconstructive augmentation surgery

Patients were instructed to take 2 g of amoxicillin and 8 mg of dexamethasone before surgery. Local anesthesia consisting of mepivacaine 2% (1:100 000 epinephrine) was administered, and a horizontal crestal incision through the keratinized mucosa was performed using a 15C surgical blade followed by 2 vertical incisions (mesial and distal) to release a mucoperiosteal flap. After exposure of the cortical bone, multiple perforations

(vascular channels) were made using a small spherical bur to improve blood supply and graft nutrition (Figure 2).

Based on a previously published classification about horizontal alveolar change classification (HAC),¹⁴ 2 cases that contained only xenogeneic biomaterial were classified as HAC 3, while the other 2 cases were classified as HAC 4 and consisted of a mixture of xenograft and autogenous bone from ramus. To collect the autogenous bone, local anesthesia using the previously described technique was administered to the ramus of the mandible. An incision was made along the mucogingival line from the second premolar extending posteriorly to release a total flap to obtain access to the cortical bone (Figure 3). The particles of autogenous bone were collected using a bone scraper (MX-Grafter, Salvin Dental Specialties, Charlotte, NC) and mixed with the xenogeneic biomaterial (Bio-Oss, Geistlich, Switzerland) (Figure 4). A 4.0 Nylon (Ethicon, Johnson & Johnson, Blue Ash, Ohio) interrupted suture was used to close the flap after the autograft collection.

After the fixation of the screw through the residual bone (Figure 5), the PEEK caps were attached (Figure 6). The bone graft was then inserted to fill the defect and rebuild the contour of the bone based on the prosthetic model. Based on the principle of guided bone regeneration (GBR), all grafts were covered using a collagen membrane (Geistlich Bio-Gide, Wolhusen, Switzerland) to exclude cells from the epithelium and connective tissues (Figures 7 and 8). An internal periosteum incision was made in order to allow tension-free coronal advancement of the flap, wound closure, and suturing. The flaps were closed using 5-0 prolene (B-Braun, Melsungen, Germany) and interrupted mattress sutures (Figure 9).

All of the patients received 500 mg of amoxicillin 3 times a day for 7 days and a non-steroidal anti-inflammatory (100 mg) for 5 days after the surgical procedure. Postoperative instructions included a soft diet and use of 0.12% chlorhexidine mouthwash until the sutures were removed between 10 and 15 days after the ridge augmentation procedure.

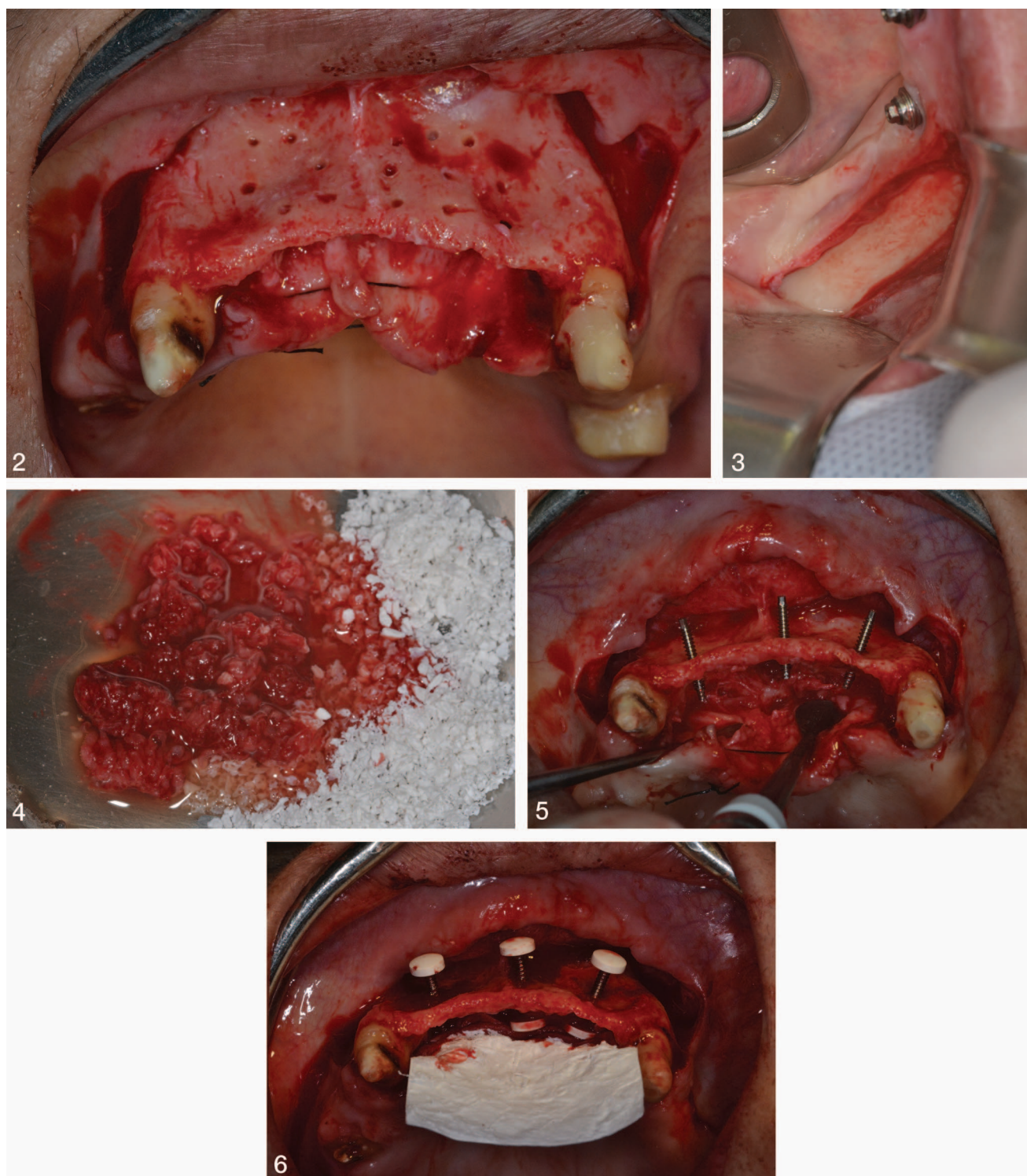
After 6 months, all sites were reopened, the Barbell devices (PEEK caps and screws) were removed and dental implants were installed (Figures 10 and 11).

CBCT images

CBCT scans were acquired using the i-CAT 3D Imaging system and i-CAT Vision Software. The maxilla was scanned preoperatively (T0) (Figure 12) and 6 months postoperatively (T1) (Figure 13). Accuracy was limited to the inherent voxel size (0.3 mm of the CBCT machine used for acquiring the scans). Measurements of the thickness were made at the central sagittal slices of the bony defects (baseline) and at the slices containing the device (screw and capsules) at the 6-month postoperative examination. The examiner measured vertically 4 mm apical to the alveolar crest using the software ruler tool.

Statistical analysis

The statistical comparison between T0 and T1 was performed by Wilcoxon signed-rank for paired data. Statistical Analysis System software (SAS Institute, Cary, NC) version 9.1.3 was used for the analyses, and the level of significance was set at $P < 0.05$.

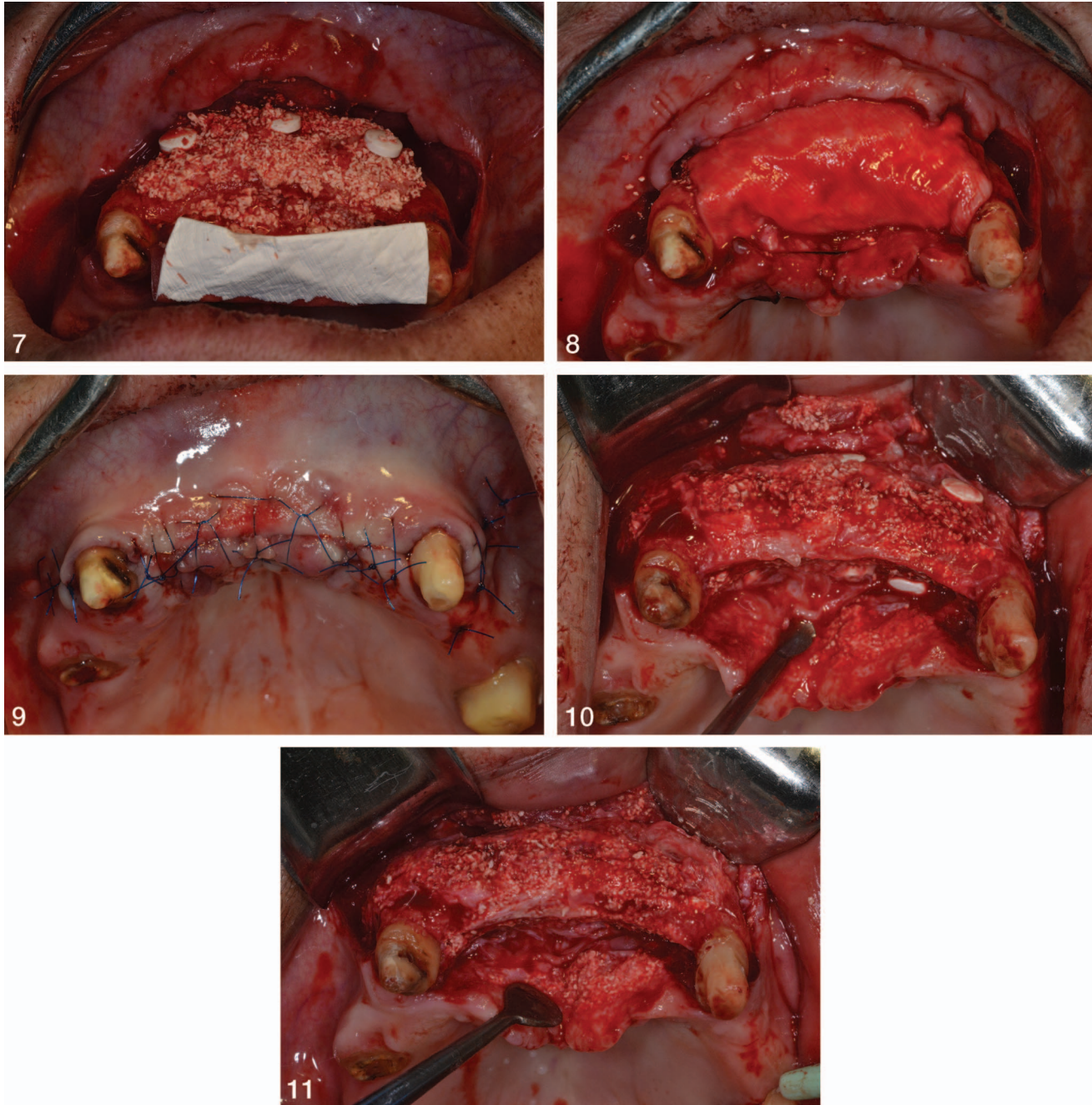


FIGURES 2–6. **FIGURE 2.** Recipient bed after the surgical access and cortical perforations. **FIGURE 3.** Recipient bed exposed to allow autograft obtainment. **FIGURE 4.** Autograft and xenograft immediately before the mixture. **FIGURE 5.** Screws positioned at the recipient bed. **FIGURE 6.** Capsules fixed and membrane adapted at the palatal side.

RESULTS

The thickness measurements at the baseline and 6 months postoperative examinations, and the amounts of horizontal gain are shown in Table 1 and Figure 14.

The horizontal bone gain of 6.81 ± 1.33 mm allowed implant placement in appropriate positions for all 4 patients. Concerning the specific gains in direction, buccal and palatal bone augmentation were 4.89 ± 0.94 and 1.92 ± 0.42 mm, respectively. All Barbell devices (PEEK caps and screws) were



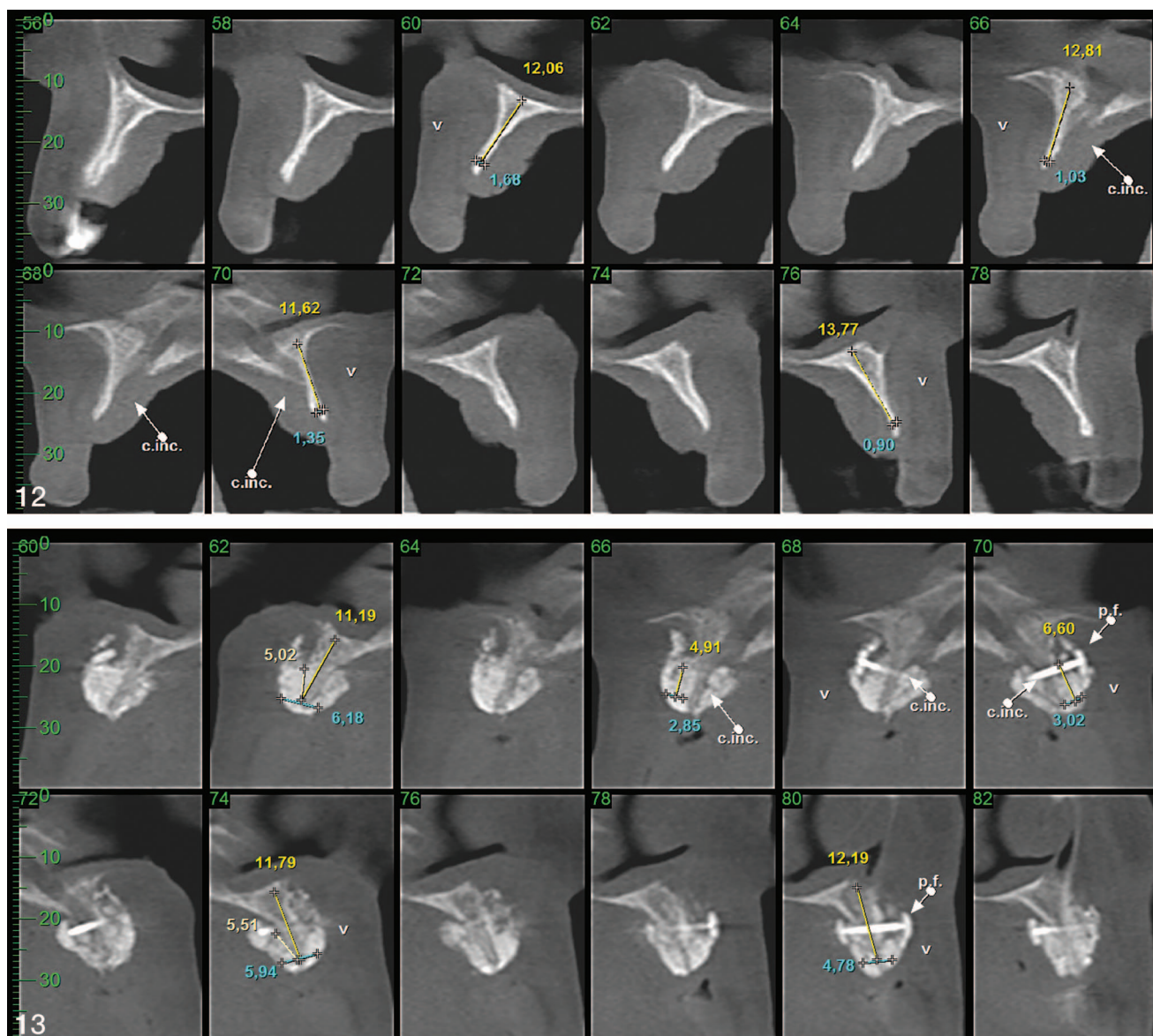
FIGURES 7–11. **FIGURE 7.** Bone graft positioned at buccal and palatal sides. **FIGURE 8.** Collagen membrane covering the graft and the device. **FIGURE 9.** Immediate postoperative view. **FIGURE 10.** Site reopened after 6 months, immediately before the removal of Barbell devices (polyether ether ketone capsules [PEEK] and screws). **FIGURE 11.** Site reopened after 6 months, immediately after the removal of Barbell devices (PEEK capsules and screws).

easily removed and no exposure of the graft and/or barrier membrane occurred.

DISCUSSION

Horizontal bone augmentation has always been controversial, and no consensus has been established in the literature concerning the selection of the best technique for each clinical situation.¹⁵ In this regard, 4 techniques have been described: (1)

tenting; (2) bone block; (3) titanium mesh/titanium reinforced membrane; and (4) ridge split techniques. All of them involve raising the periosteum to allow osteoblasts to migrate into the created space and initiate osteogenesis, which is a basic prerequisite for bone reconstruction. However, all of these techniques tend to promote bone augmentation in a unidirectional manner (just at the buccal side), especially due to the difficulty of placing screws and/or pins on the palatal/lingual side (for tenting, blocks, and titanium mesh/titanium



FIGURES 12 AND 13. FIGURE 12. Computerized tomography (CT) images at baseline (T0). Note the lack of bone thickness to allow implant placement. **FIGURE 13.** CT at 6 months postoperative (T1). Note the significant bone volume obtained.

reinforced membranes) and displacing just the buccal portion of the ridge (for ridge split techniques).¹¹ Since horizontal bone changes occur after tooth extraction, bone loss with respect to both aspects (buccal and palatal/lingual)³ results. The development of a device/technique that allows bidirectional bone reconstruction is of major importance.

The “Barbell Technique,” described in this article, enables bidirectional bone reconstruction by allowing raising and maintenance of the soft tissues distant from the recipient bed, which makes the space maintenance property at both sides (such as at the buccal and palatal/lingual sides) possible. Since the titanium screw passes over both sides, and the PEEK capsules remain static after placement, the soft tissues are maintained distant from the native bone despite pressure exerted by the labial muscle forces.¹⁶ This technique enables the bidirectional tenting effect by allowing the insertion of an

oversized screw from the buccal through the palatal/lingual side, thus avoiding the need for screw insertion on the lingual/palatal side, which is much more complicated and in some difficult clinical situations impossible. Moreover, the use of biocompatible PEEK caps could theoretically enhance the pattern of tissue healing when compared with other devices because PEEK surfaces are found to increase osteoblast and gingival fibroblast adhesion, viability, and proliferation when compared to titanium surfaces.¹⁷

All characteristics of this novel device provided key elements that resulted in a more pronounced bone gain in the present study (6.81 ± 1.33 mm) when compared to the mean results for bone blocks and GBR techniques (4.18 ± 0.56 and 3.61 ± 0.27 mm, respectively) found in a systematic literature review published by Elnayef et al.¹⁸ Regarding the specific directional gains, in the present study, buccal and

TABLE 1

Measurement results in preoperative CT (T0), 6 months postoperative CT (T1) and the total amount of bone gain (in millimeters)

Patient number	T0	T1	Bone Gain	P Value
#1	2.95	10.19	7.24	
#2	1.78	9.13	7.35	
#3	1.69	9.48	7.79	
#4	2.77	7.62	4.85	
Median	2.27	9.30	7.29	
Mean + SD	2.30 ± 0.65	9.11 ± 1.08	6.81 ± 1.33	.0625

*CT indicates computerized tomography; T0, baseline; T1, 6 months postoperative; SD, standard deviation.

†Wilcoxon signed-rank for paired data ($P < .05$ is statistically significant).

palatal bone augmentation were 4.89 ± 0.94 and 1.92 ± 0.42 mm, respectively. Therefore, the resulting buccal bone gain is comparable to that achieved by standard bone block technique as demonstrated by Elnayef et al.¹⁸ However, using the Barbell Technique resulted in not only a 4.89 ± 0.94 mm buccal gain but also a 1.92 ± 0.42 mm palatal gain, which is not observed with other bone block techniques. Nevertheless, it is important to state that the present study is a preliminary report based on a small sample size and that a long term randomized clinical trial should be performed to allow a comparison between techniques. The importance to perform a randomized controlled trial study is justified by the fact that, although successful bone augmentation was clinically observed in this preliminary study, a statistical significant difference between T0 and T1 was not verified due to the small sample size. However a tendency ($P = .0625$) for increased bone volume was observed.

Concerning the bone graft material used to perform horizontal bone augmentation, it is important to state that all of the previously reported surgical techniques allow for the use of autogenous bone graft or bone substitute biomaterials. In this study, in some cases, a xenograft mixed with the autograft was used. To support the decision for using only the xenograft or a mixture of 50% xenograft with 50% autograft, a previously published classification (HAC) was adopted.¹⁴ Since 2 patients had HAC 3 horizontal defects and two patients had HAC 4 defects in our study, the HAC guidelines led us to use the autograft just in 2 cases (in HAC 4 cases). In the other 2 cases, which were classified as HAC 3 defects, only the xenograft was used.

The device presented in this study allowed graft stability due to its space maintainer characteristics to be achieved. In an in vitro study, Mertens et al¹⁹ showed that the use of the standard guided bone regeneration technique for horizontal bone augmentation, using xenograft and collagen membrane

with or without pin fixation, had less bone volume stability compared to techniques in which stronger space maintainers were used (such as bone blocks and titanium-reinforced membranes). However, if a bidirectional horizontal bone augmentation is desired, the space maintaining devices must be fixed on both sides (such as buccal and palatal/lingual). From this perspective, it seems that the Barbell technique would facilitate the surgical approach. However, future clinical studies should be designed to allow for comparison of Barbell with other techniques used for horizontal bone augmentation.

This novel technique is described for bidirectional horizontal bone augmentation, but this technique is also indicated for unidirectional horizontal as well as vertical bone augmentation by placing only one PEEK cap instead of two. However, the outcomes for unidirectional augmentation in the horizontal and/or vertical direction must be verified with additional clinical studies.

CONCLUSIONS

The use of the novel Barbell technique device allows the achievement of bidirectional horizontal bone augmentation.

ABBREVIATIONS

CBCT: cone beam computerized tomography
 CT: computerized tomography
 HAC: horizontal alveolar change classification
 PEEK: polyether ether ketone

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NOTE

The authors declare no conflicts of interest.

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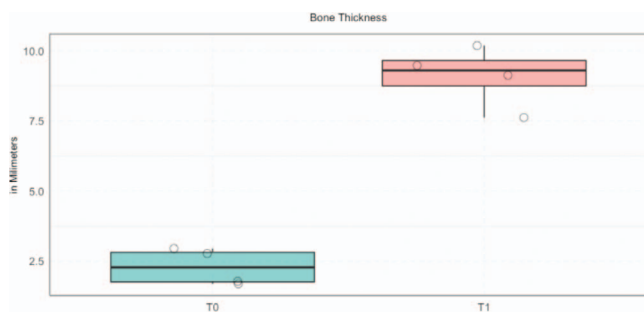


FIGURE 14. Boxplot of bone thickness across the time points.

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