

**ORIGINAL ARTICLE**

WILEY

Hard and soft tissue analysis of alveolar ridge preservation in esthetic zone using deproteinized bovine bone mineral and a saddle connective tissue graft: A long-term prospective case series

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Abstract

Aim: Although alveolar ridge preservation (ARP) procedures appear to limit bone resorption after dental extraction, long-term outcomes remain limited. The objective of this prospective case series was to evaluate the long-term hard and soft tissue changes after ARP procedure in the aesthetic area, using deproteinized bovine bone mineral (DBBM) and saddle connective tissue graft.

Materials and Methods: Fifteen patients were subjected to ARP and impressions and CT scans were taken at baseline and 3 months. After 5 to 7 years, a secondary long-term clinical and radiological analysis was carried out. Horizontal alveolar bone changes, soft tissue profiles and implant outcomes were assessed.

Results: Although a limited hard and soft tissue remodeling occurred during the first 3 months after ARP, from 3 months to the long-term evaluation, the alveolar bone dimensions remained stable and the soft tissue profiles significantly increased, in the more cervical levels. The implant survival rate after 5 to 7 years yielded 100% and peri-implant bone levels and soft tissue health were good.

Conclusion: Within the limits of the study, the present data confirms the long-term effectiveness of ARP using DBBM and a saddle connective tissue graft offering stable hard and soft tissue conditions up to 5 to 7 years.

KEYWORDS

aesthetic, alveolar bone, alveolar bone preservation, dimensional change, extraction socket management, hard tissue volume, long term, soft tissue profile

1 | INTRODUCTION

Despite the technological advances in the field of dentistry, many reasons can lead to tooth loss, such as caries, traumatism, endodontic failures, or periodontal causes. Tooth removal procedure results in dimensional hard and soft tissue shrinkage, mainly in the first 3 months of the healing process.¹ According to systematic reviews, evaluating

the dimensional changes in hard and soft tissues following tooth extraction, alveolar bone remodeling in the maxilla leads to mean horizontal bone loss of 3.8 mm after 6 months.^{2,3} The severity of this physiological remodeling depends on several factors such as the tooth angulation, the facial bone wall thickness, and other differences in the tooth sites anatomy.⁴⁻⁶ The majority of the horizontal resorption was proven to occur mainly on the buccal aspect of the ridge as thin

buccal plates are tooth-dependent structures.⁷⁻¹⁰ These dimensional changes can result, especially in the aesthetic area, in functional and aesthetic discrepancies and compromise implant placement.

In order to prevent this postextraction bone remodeling, a number of alveolar ridge preservation (ARP) techniques have been described in the literature using various biomaterials including autologous bone, bone substitutes (allografts, xenografts, and alloplasts), bioactive agents, and autologous blood-derived products.¹¹ Several authors emphasized that ARP procedures can significantly limit the bone and soft tissue shrinkage after extraction and although they cannot limit completely the shrinkage, they may be a valid treatment option in order to avoid further bone reconstruction.¹²⁻¹⁹ Furthermore, in order to compensate for this expected bone remodeling and improve the aesthetic outcomes, some authors proposed the use of a saddle connective tissue graft in combination with the biomaterials.^{20,21}

Nevertheless, the studies evaluating the efficacy of ARP were mostly conducted over a follow-up periods running from 12 weeks to 9 months^{13,15} and long-term data remains limited.

The aim of the present study was to evaluate the long-term radiological and clinical outcomes of an ARP technique using

deproteinized bovine bone mineral (DBBM) combined with a saddle connective tissue graft. The primary objective was to describe the hard and soft tissue changes from baseline up to a follow-up period of 5 to 7 years. The secondary objectives were the assessment of implant survival, peri-implant bone stability, and soft tissue health. Moreover, long-term aesthetic outcomes based on the Pink Esthetic Score (PES)²² and patient reported outcomes measures (PROMS) were investigated.

2 | MATERIALS AND METHODS

2.1 | Study population

Patients needing tooth replacement in aesthetic area (tooth 15-25) were recruited from the Department of Periodontology and Oral Surgery of the University of Liège, Belgium. All the patients included in the study met the following inclusion criteria: good general health (ASA 1,2), absence of/or controlled periodontitis, at least 18 years old or with a signed approval document by the parents, and cigarette

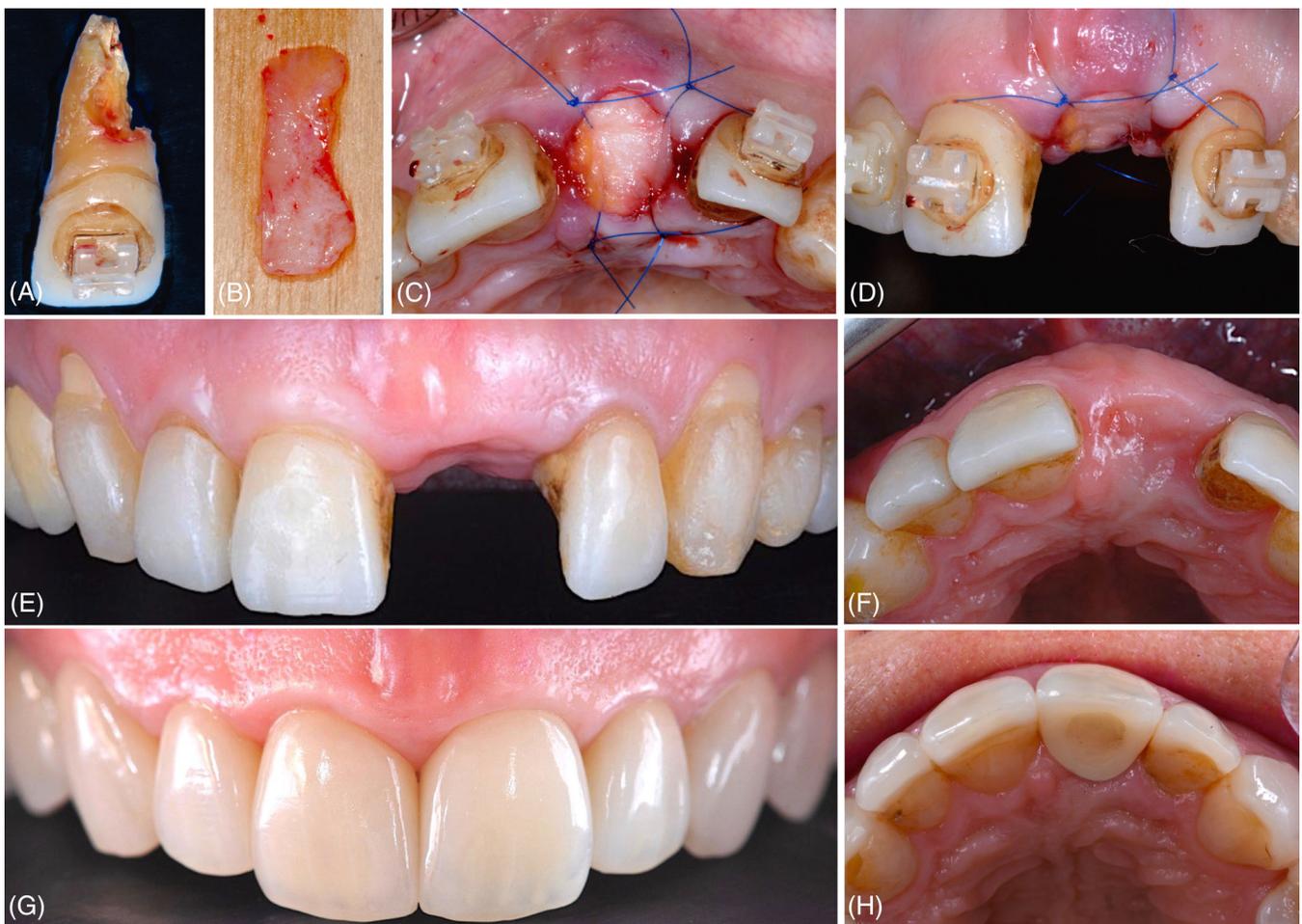


FIGURE 1 Surgical procedure and follow-up. A, Atraumatically tooth extraction. B, After granulation removal, connective tissue graft was harvested from the palate. C, D, The socket was filled with Bio-Oss and the graft was inserted into split-thickness buccal and palatal pouches to cover the extraction site. E, 3-month follow-up frontal and F, palatal, view. G, Long-term evaluation frontal, and H, palatal, view. Prosthodontics : Prof. Amélie Mainjot

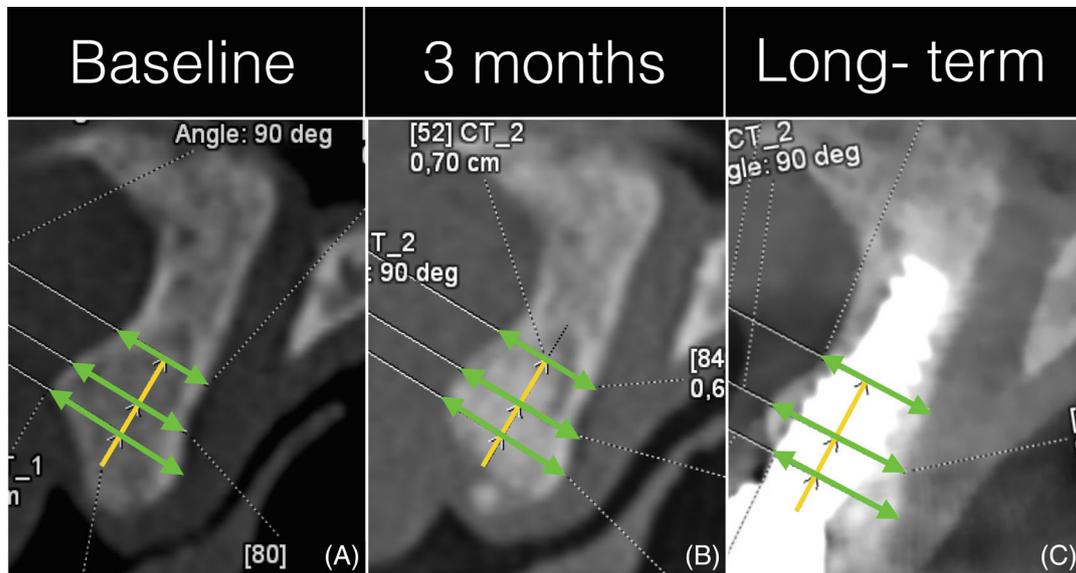


FIGURE 2 Methodology for three-dimensional imaging analysis. Horizontal measurements of the alveolar process (ridge) at the three different levels (-2 , -4 and -7 mm) perpendicularly to the vertical reference line (yellow line) and at the three different timelines (baseline, A; 3 months, B; long-term, C)

smoking less than 10 per day. The exclusion criteria were: pregnant or breastfeeding females, patients included in another study at the same time, patients with bone disease or under bone metabolism-interfering drugs, patients with a history of head and neck radiotherapy, and patients presenting dehiscence or fenestration on the bone wall of the socket.

2.2 | Study design

The present study was designed as a prospective case series. Between September 2009 and September 2011, all patients included in the study were subjected to the same ARP technique performed by two previously calibrated senior periodontists. Radiographic analyses (CT scans) as well as impressions were performed at baseline and 3 months thereafter. In June 2016, all patients were recalled for a secondary long-term analyses during which impression, intraoral radiography, and cone beam CT (CBCT) were carried out. Alveolar bone remodeling and soft tissue changes were then evaluated respectively based on computed axial tomography (CT scans) and models performed at baseline, 3 months and 5 to 7 years after the procedure. Moreover, when applicable, implant survival and success rates, peri-implant bone levels and clinical parameters including PES, plaque index (PI), bleeding on probing (BOP), and pocket depth (PD) were recorded in June 2016. Finally, PROMs were evaluated using VAS questionnaire. This study was performed in full accordance with the declared ethical principles of the World Medical Association Declaration of Helsinki of 1975 (revised in 2008) and the protocol was approved by the ethical committee of the University of Liège, Belgium (B707201628853). The study was registered in the clinical trials registry: www.clinicaltrials.gov (NCT03410251).

2.3 | Surgical procedure

The full surgical procedure was reported in previous articles.^{20,21} In brief, single extractions in the anterior maxilla (14-24) were performed atraumatically and without flap release. After checking the integrity of the buccal and palatal bone plate, a biomaterial (Bio-Oss; Geistlich Pharma AG, Wolhusen, Switzerland) was placed into the socket. A connective tissue graft harvested from the palate was inserted and sutured in buccal and palatal split-thickness pouches in order to cover the socket (Figure 1A-D). Tooth brushing was not recommended at the extraction site for 10 following days and the sutures were removed 10 days after surgery. Prescribed medication consisted in Chlorhexidine spray (0.12%) BID, Ibuprofen 600 mg TID according to the needs, and Amoxicillin (500 mg TID) antibiotherapy administrated for 5 days.

2.4 | Follow-up

Patients were followed at 3 months (Figure 1E,F) and then yearly for regular check-ups. When indicated, implants were placed 4 to 6 months after the ARP. Implants restorations or conventional fixed partial denture (FPD) procedures were performed according to the dentist preference and patient choice. In June 2016, all patients were recalled for a secondary long-term evaluation (Figure 1G,H).

2.5 | Hard tissue analyses

In order to evaluate the alveolar bone remodeling overtime, the patients were subjected to CT scan (Somatom Emotion; Siemens,

TABLE 1 Patient, sites, and implants characteristics Problem with the title of part B, must be placed between tabacoo use and teeth.

A. Patient-related descriptive analyses n = 15		
Age (years)	Mean (\pm SD)	43.4 (\pm 13.3)
	min-max	16.7-62.1
Gender	Male	6 (40%)
	Female	9 (60%)
Tobacco use (at the cross-sectional long-term evaluation)	No	9 (60%)
	<10c/d	4 (26.7%)
	>10c/d	2 (13.3%)
B. Site characteristics n = 15		
Teeth	Incisors	9 (60%)
	Canine	0 (0.0%)
	Premolar	6 (40%)
Rehabilitation	Implant	12 (80%)
	FPD	3 (20%)
C. Implant characteristics and outcomes n = 12		
Implant type	Straumann BL	10 (83.3%)
	Nobel Active	1 (8.3%)
	Intralock, MDL (Mini Drived- Lock) 2.5 mm	1 (8.3%)
PI ^a	Sites with plaque (%)	6/48 (12.5%)
BOP ^a	Sites with BOP	17/48 (35.4%)
PD (mm) ^a	Mean (\pm SD)	2.96 (\pm 0.84)
	min-max	2-4.8
DIB (mm)	Mean (\pm SD)	-0.05 (\pm 0.73)
	min-max	-1.2-1.3
Implant survival rates		12 (100%)

BOP, bleeding on probing; DIB, distance between implant shoulder and first bone to implant contact; FPD, fixed partial denture; PD, pocket depth; PI, plaque index.

^aAt four aspects around implants (mesial, buccal, palatal, distal).

Munich, Germany) at baseline and at 3 months. For these examinations, a slide thickness of 0.6 mm was always used. At the long-term evaluation, for ethical reasons and because of the advances in imaging technologies, a CBCT (Newtom 5G; Sitech, France) was chosen to reduce radiation dose. CBCT was performed using a reduced field of view to cover the desired area at 0.2 mm voxels according to Garib et al²³ and a reduced exposure protocol.

2.5.1 | Methodology for 3D imaging analysis

The measurements were performed by matching and superimposing baseline and 3-month CT scans as well as long-term CBCT scans, using three-dimensional (3D) reconstruction software (SyngoVia; Siemens). After an adequate calibration, two independent operators made all the measurements (GB and PEC). The scans were

automatically superimposed by the software two by two (baseline/3 months and 3 months/long term). For each case, the measurements were made on a parasagittal section going through the middle edentulous segment determined on the 3-month CT scan. On this buccal-palatal section, a vertical reference line was drawn in the center of the alveolar crest in order to measure the ridge (Figure 2, yellow line). The horizontal dimensions of the alveolar bone crest were measured perpendicularly to the vertical reference line at the three following levels: -2, -4, -7 mm below the most coronal point of the 3-month section (Figure 2A-C). Thereafter, the same measurements were taken on the baseline CT and long-term CBCT images by superimposing the 3D images as well as the reference line which was reported exactly at the same place in the different scans thanks to the superimposition. Altogether, three measurements were taken at each time point giving a total of nine measurements per patient. Long-term bone dimensional changes (expressed both in percentage and in mm) were then calculated both from baseline to 3 months and from 3 months to the long-term follow-up.

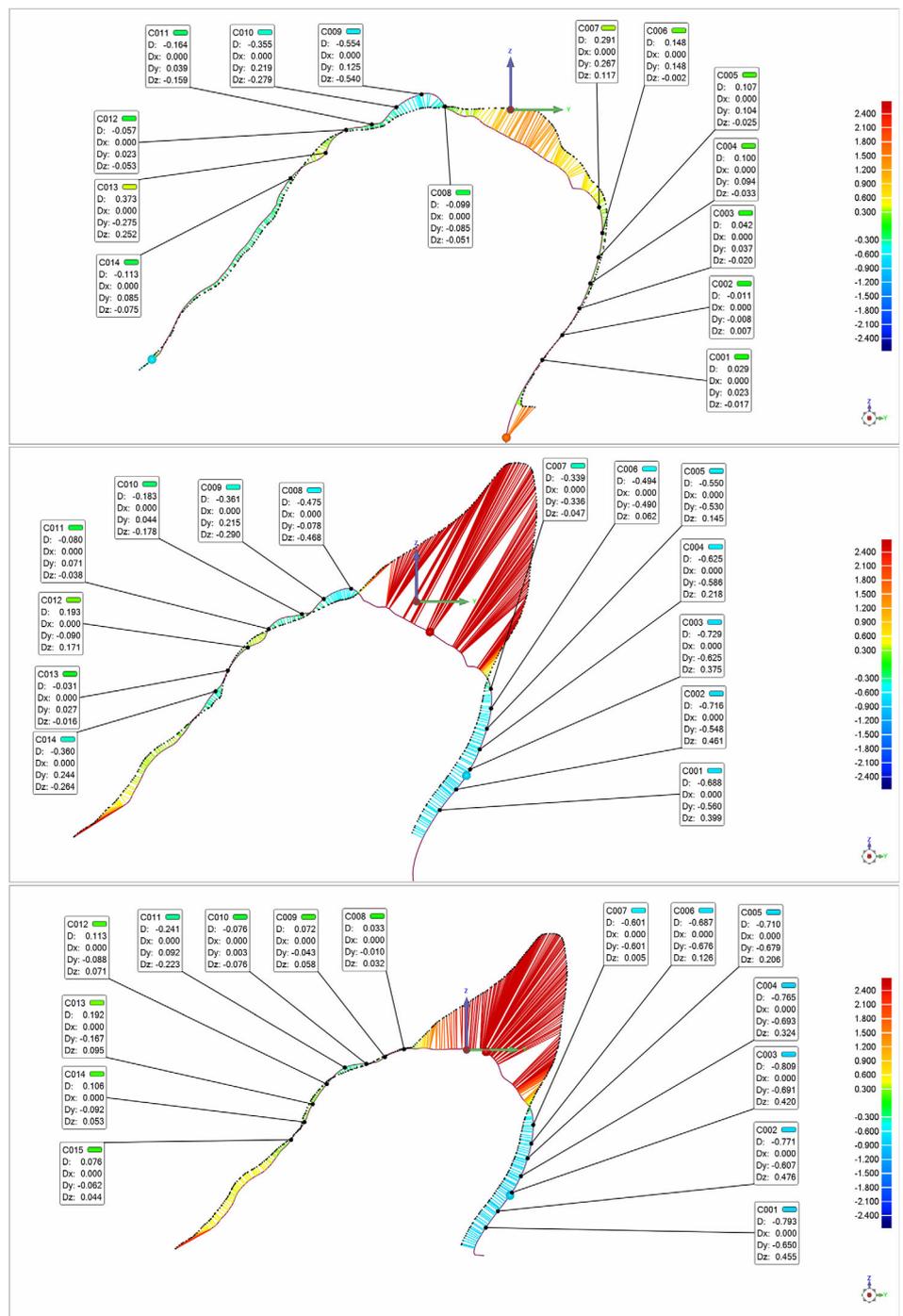
2.6 | Soft tissue outlines volumetric analyses

The impression and pouring protocols were standardized. Baseline, 3month and long-term alginate impressions were taken with the same impression material (CavexColorChange^o, Cavex Holland BV, Haarlem, The Netherlands) and using an alginate mixer. The impressions were poured in plaster within a period of 24 hours. Two different operators took the baseline and 3- month impressions while all long-term impressions were taken by a third single operator. The casts were scanned with a 3D laser scanner (D250, 3Shape, Copenhagen, Denmark). The .stl files obtained from each model were subsequently transferred to a digital shape sampling and processing software for re-elaboration of 3D models from the 3D scan data (Studio, Geomagic, Research Triangle Park, North Carolina). For each patient, baseline and long-term models were superimposed following a previously reported protocol.²⁴ Prior to taking the measurements, the baseline model was set as the reference, while the 3-month and long-term model were set as the test. For each superimposed model, 2D labio-palatal sections were obtained in the middle of the extraction area, perpendicular to the alveolar crest. Subsequently, the linear distance between the preoperative and postoperative soft tissue profiles was measured. These measurements were taken at the top of the crest and were repeated at 2 and 4 mm in the apical direction (Figure 3).

2.7 | Long-term aesthetic outcomes

At the long-term evaluation, the PES as described by Fürhauser et al was collected for each patient.²² The contralateral tooth was used as control whenever it was possible; otherwise, PES was calculated based on ideal tooth proportions. The threshold for clinical acceptability was set at an arbitrary score of 8 out of 14.²⁵

FIGURE 3 Two dimensional comparison of the superimposed models perpendicular to the alveolar crest (Baseline- 3 months, top; 3 months- long-term, middle; Baseline- long-term, down)



Additionally, aesthetics from a patient perspective were evaluated using a VAS questionnaire. The following questions were asked: 1. How satisfied are you with your aesthetic rehabilitation?; 2. Do you have the feeling that the aesthetic appearance of your rehabilitation has changed overtime?

2.8 | Long-term implants outcomes

At the long-term evaluation, in patients who benefited from an implant rehabilitation, implant survival, and success rates were

recorded. Success was defined according to the criteria of Buser,²⁶ which are (a) absence of suppuration (recurring peri-implant infection), (b) absence of persistent complaints like pain, foreign body sensation, and/or dysaesthesia, (c) absence of continuous radiolucency area around the implant, (d) absence of implant mobility. Additionally, the peri-implant bone levels were assessed on periapical radiography using the parallel technique: the linear distance between the implant shoulder of the bone level implants and the first bone to implant contact (DIB in mm) was measured at the mesial and distal aspects²⁷ using the specific software Image J64 (National Institutes of Health, Bethesda, Maryland). The health of peri-implant soft tissues was also

TABLE 2 Hard and soft tissue remodeling (significant p- value in bold)

n = 15		Baseline-3 months	P-value	3 months-long term	P-value	Baseline-long term	P-value
Bucco-palatal hard tissue remodeling mm (\pm SD)	Cervical level -2 mm	-1.41 (\pm 0.64)	<.0001	0.01 (\pm 0.78)	.97	-1.40 (\pm 0.86)	<.0001
	Medial level -4 mm	-0.76 (\pm 0.36)	<.0001	-0.24 (\pm 0.58)	.13	-1.00 (\pm 0.69)	<.0001
	Apical level -7 mm	-0.45 (\pm 0.36)	.0003	-0.43 (\pm 0.37)	.0008	-0.88 (\pm 0.48)	<.0001
Buccal soft tissue remodeling mm (\pm SD)	Cervical level 0 mm	-0.6 (\pm 0.97)	.032	+0.89 (\pm 1.32)	.024	+0.26 (\pm 0.76)	.202
	Medial level -2 mm	-0.52 (\pm 0.58)	.004	+0.58 (\pm 0.97)	.036	+0.06 (\pm 0.63)	.708
	Apical level -4 mm	-0.29 (\pm 0.4)	.015	+0.31 (\pm 0.81)	.164	+0.02 (\pm 0.66)	.893

assessed at four sites per implant, including: PI, BOP and PD. For PI and BOP, a dichotomous score was given (PI: 0 = no visible plaque, 1 = plaque at the soft tissue margin; BOP: 0 = no bleeding, 1 = bleeding) and PD was measured by means of a periodontal probe (CP 15 UNC, Hu-Friedy, Chicago, Illinois) and rounded off to the nearest millimeter.²⁸

2.9 | Statistical analysis

The results were expressed as means and SD for the continuous variables and as frequency tables for the categorical variables. The intraclass correlation coefficient (ICC) was used to test the concordance between the two examiners for each measurement, at each timeline and for each measurement level. Statistics were performed on the mean of both examiners for each parameter. The evolution of the measures between baseline and 3 months, 3 months and long-term and baseline and long-term data was evaluated by a paired Student *t* test. The analysis of variance was used to compare the levels. The comparison of the differences between patients with implant and patients without implant was done by a Student *t* test. Results were considered significant at the 5% critical level ($P < .05$). The calculations were performed using the SAS version 9.4 for windows (SAS Institute, Cary, North Carolina).

3 | RESULTS

3.1 | Patient demographics

In total, 29 subjects met the inclusion criteria and were enrolled in this study. Of these, nine patients dropped out and did not show up for the secondary long-term analysis, two disagreed to undergo the CBCT, two had missing data, and one was excluded because a guided bone regeneration was performed in the neighboring site over the follow-up period. Therefore, 15 subjects (six men and nine women, mean age: 43.4 [SD \pm 13.3], min: 16.7-max: 62.1) were considered in this study. The patients were recalled after a mean follow-up of almost 6 years (mean: 70 months, min: 57.3 months-max: 81.6 months). A dropout analysis emphasized that no significant difference was found between the dropout and followed patients. No

patient smoked more than 10 cigarettes per day at the time of the inclusion, but 2 patients started smoking more than 10 cigarettes a day over the follow-up period (Table 1A). Overall, socket management procedures were applied in nine incisors and in six premolars sites. To restore the edentulous spaces, 12 patients received an implant and 3 were managed by a conventional FPD (Table 1B).

3.2 | Hard tissue analyses

The 3D imaging measurements showed high reliability, as inter- and intraexaminer observations were concordant for all measurements (ICC mean: 0.98; min: 0.95). The results of measurements are presented in Table 2.

The measurements of the horizontal bone remodeling revealed that significant bone loss occurred at the three corono-apical levels only during the early phase after extraction (baseline-3 months). Bone losses of -1.41 mm ($P < .0001$), -0.76 mm ($P < .0001$), and -0.45 mm ($P = .0003$) were respectively found for -2, -4, and -7 levels. Further losses from 3 months to the long-term follow-up remained below 0.5 mm and were not significant except in the more apical region ($P = .0008$) (Table 2).

3.3 | Soft tissue volumetric analyses

Based on the superimposition of the digitalized impressions performed at baseline, 3 months and 5 to 7 years after the ARP, the data revealed a mild buccal shrinkage of the soft tissue outlines from baseline to 3 months. From 3 months to the long-term follow-up, a significant gain in the soft tissue contours was observed buccally at the cervical and medial levels. The resulting variation in soft tissue volume from baseline to 5 years was not significant for each level. The detailed results are displayed in Table 2.

3.4 | Long-term aesthetic outcomes

The results of PES are displayed in Table 3. The analysis revealed a mean PES value of 10.9 (min: 8-max: 14) out of 14 points as a maximum²² and 100% of the implants were considered aesthetically

TABLE 3 Pink Esthetic Score values

PES score	Mesial papilla	Distal papilla	Level soft tissue margin	Soft tissue contour	Alveolar process	Soft tissue color	Soft tissue texture	Total PES
0	0/15 (0%)	1/15 (6.6%)	2/15 (13.3%)	1/15 (6.6%)	0/15 (0%)	0/15 (0%)	1/15 (6.6%)	10.9 (min: 8-max: 14)
1	6/15 (40%)	6/15 (40%)	7/15 (46.6%)	8/15 (53.3%)	1/15 (6.6%)	3/15 (20%)	6/15 (40%)	
2	9/15 (60%)	8/15 (53.3%)	6/15 (40%)	6/15 (40%)	14/15 (93.3%)	12/15 (80%)	8/15 (53.3%)	

TABLE 4 Patient reported outcomes measures (PROMs) (n = 16)

	How satisfied are you with the aesthetic of your rehabilitation?	Did you have the feeling that the aesthetic appearance of your rehabilitation decreases overtime?
	1 = not satisfied 100 = very satisfied	1 = yes, a lot 100 = Not at all
Mean (±SD)	91.3 (±9.15)	92.0 (±9.41)
Min-max	70-100	70-100

acceptable according to the criteria. The PROMs related to aesthetic satisfaction (see question 1) reached a mean VAS score of 9.13 (min: 7-max: 10) out of 10 and the one assessing aesthetic stability (see question 2) over time displayed a mean VAS score of 9.20 (min: 7-max: 10) out of 10. The detailed aesthetic outcomes based on patient opinions are displayed in Table 4.

3.5 | Long-term implant outcomes

Detailed implant characteristics and outcomes are listed in Table 1C. All of the 12 implants were osseointegrated at the long-term evaluation time point, leading to an implant survival rate of 100%. The mean DIB value calculated on the long-term peri-apical radiographs was -0.05 mm (SD ± 0.73). Implants demonstrated fairly healthy peri-implant soft tissues. Local plaque deposit was registered in 6 out of 48 (12.5%) sites around the implants and BOP was found in 17 out of 48 (35.4%) sites. Finally, the mean PD value was 2.96 mm (SD ± 0.84).

4 | DISCUSSION

This study demonstrated that extraction socket management combining the use of DBBM and a saddle connective tissue graft limited the bucco-palatal bone shrinkage in the 3 first months after the ARP (1.4 mm in the cervical area) when compared to the mean remodeling of 3.8 mm described in the literature after extraction alone.³ Thereafter, the hard tissue dimensions remained stable up to 7 years, except in the most apical region where a fairly low additional loss of 0.4 mm was observed. Moreover, the connective tissue graft used to compensate for the expected bone remodeling, and insure proper soft tissue outlines, was found to be effective in the long term.

According to recent systematic reviews, even though the benefits of ARP procedures are nowadays recognized, follow-up studies

evaluating the possible influence of these treatments on the long-term aesthetic and implant outcomes are lacking.^{12,13,16,17} To the best of our knowledge, the present report is one of the few studies²⁹ assessing long-term outcomes of alveolar ridge preservation procedures and the first study assessing long-term hard tissue changes on 3D images.

4.1 | Hard tissue remodeling

In the present study, the main bone dimensional changes were observed during the first 3 months following the ARP procedure and afterwards they remained stable up to 5 to 7 years. A recent literature review assessing the hard tissue shrinkage after ARP procedures using a xenograft emphasized a mean bucco-palatal bone loss of 1.3 mm after 3 months.³⁰ Although, the heterogeneity of the extracted tooth types and of measurements protocols limits the comparison, these results are in agreement with the present results. Moreover, several studies describe higher horizontal bone remodeling in the cervical region and the values decrease progressively towards the apical level.^{6,20,31} The present study described a similar outcome from baseline to 3 months but interestingly, the pattern is inverted from 3 months to the long-term follow-up. Indeed, from 3 months to the long-term follow-up, the bone dimensions were found to be very stable in the cervical and medial levels while a further horizontal loss (0.4 mm) was observed at the apical level. Although significant, this additional loss is extremely limited from a clinical point of view. The dimensional stability in the more cervical levels might be related to the nonresorbable characteristics of the biomaterial used in the procedures.³² The initial remodeling would be the consequence of the buccal bone plate resorption and then³³ the nonresorbable or slowly resorbable biomaterial placed in the socket would provide the long-term dimensional stability. The slight resorption observed in the apical region might be related to a physiological remodeling related to facial growth in absence of biomaterials in this apical region.³⁴ Therefore, the nonremodeling properties of the chosen biomaterial might be of capital importance for the long-term stability of ARP. Further comparative studies would be, however, necessary to confirm this hypothesis.

4.2 | Soft tissue remodeling

Looking at the soft tissue outlines, it is interesting to observe a loss of volume from baseline to 3 months and a gain from 3 months to the

long-term follow-up. This observation might be attributed to two distinct phenomena. On the one hand, the loss of transgingival support at the time of extraction and restoration of a transgingival part at implant loading may have an influence on the buccal gingival outlines.³⁵ On the other hand, the tissue creeping after connective tissue graft described by some authors may also be responsible for this gain of volume in the long term.³⁶ However, an impression after the abutment connection and the restoration of the implant would have been necessary to accurately assess the effect of these hypotheses.

4.3 | Implant survival and success

This study demonstrated that single implant placement 4 months after ridge preservation procedure provides successful long-term outcomes. Indeed, the implant survival rate was 100% and a mean DIB value of -0.05 mm (SD ± 0.73) was found. One of the limitations of this study is the absence of a standardized x-ray after the implant placement; however, the DIB was already proposed by some authors to assess the peri-implant bone environment.²⁷ These results corroborate the findings of a recent study demonstrating equal success when implants were placed in preserved vs nonpreserved alveolar ridges.³⁷ Additionally, the peri-implant soft tissue health is considered to be an important criterion of implant success.³⁸ Comparable PI, BOP, and PD values were found in a prospective study on immediate implants placed in the aesthetic area at 5-year follow-up,²⁸ and these clinical findings were considered as successful implant outcomes. However, better BOP (18.4%) results were found in a 10-year follow-up prospective study²⁹ on implants placed after ridge preservation using a xenograft as well. The better BOP described in that study may be associated with the strict maintenance care program that patients received, which indeed may be paramount for long-term implant success.

4.4 | Aesthetic outcomes

At the long-term follow-up, the PES value reached 10.9 out of 14, which can be considered as a very good score according to some authors.^{22,28} Moreover, similar or even a better cervical level of the mucosal margin was found compared to the contralateral tooth, while mid-facial recession is considered as frequent complication of immediate implant placement in the aesthetic zone.^{25,28,39-42} These observations provide some evidence that, in the aesthetic area, socket management procedure using CTG and delayed implantation could be more predictable for long-term stability of facial hard and soft tissues. However, these results have to be interpreted carefully in the absence of PES baseline values. Moreover, it is important to mention that out of the 15 patients, 3 were restored with a conventional bridge while the PES as described by Fürhauser et al was developed to assess the aesthetics of implant rehabilitations.

Although the white esthetic scores (WES) were not considered in the present study as the restorative protocol was not standardized,

the aesthetic outcomes from a patient's perspective displayed excellent results (>9 out of 10). It means that patients were highly satisfied with the aesthetic appearance of their implant rehabilitation in the long term, which is also an important aspect of success.

The present protocol should also be compared to alternative implant treatment options in the aesthetic zone such as extraction and early or delayed implant placement combined with lateral Guided Bone Regeneration (GBR).^{43,44} This approach was widely described and seems to display short- and long-term effectiveness as well as hard and soft tissue dimension stability over time.⁴⁵ However, compared to GBR technique, the advantage of the present protocol is the absence of flap release and need for a membrane, and therefore potentially reducing costs and patient morbidity.⁴⁶ As suggested by some authors, to further reduce the morbidity, the connective tissue graft might be performed only if necessary at the time of implant placement.⁴⁷ In this case, at the time of extraction, it might be relevant to use a connective or a collagen plug to cover the socket and protect the biomaterials underneath.⁴⁸

4.5 | Study limitations

The present study suffers from several limitations that should be highlighted. First of all, the study was designed as a case series and does not allow a comparison with another treatment concept. Moreover, the limited samples size and the significant number of dropouts are further weakness of the present study. Although the dropout analysis did not emphasize any significant difference between the dropout and followed patients, this limitation should be considered when interpreting the results.

Finally, from a methodological perspective, the use of two different radiographic methods (CT and CBCTs) may also be critical; however, some authors demonstrated no statistically significant difference in terms of linear measurements accuracy between CT and CBCT scans.^{15,49} Additionally, the use of 3D imaging to evaluate ARP has already been described in the literature and consists in a well-established method for the detection of bone dimensional changes.^{20,30,50}

Despite these limitations, the study still provides relevant long-term information on extraction socket management with DDBM and saddle connective tissue graft.

5 | CONCLUSION

Despite the limitations of the present study, the management of intact extraction socket with DDBM and saddle connective tissue graft seems to be effective for the preservation of alveolar hard and soft tissues up to 5-7 years post-treatment. The present long-term study revealed bone dimensional changes only during the 3 first months after the ARP procedure and stable soft tissue outlines from baseline up to 5 to 7 years. Additionally, this surgical technique allowed implant placement after a follow-up period of 4 to 6 months without any further bone regeneration therapy, as well as long-term

implant success rates and aesthetic outcomes. This long-term study therefore suggests that this treatment modality is a reliable option for the replacement of missing teeth in the aesthetic area. However, further investigations and controlled studies are warranted.

CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

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How to cite this article: Botilde G, Colin P-E, González-Martín O, Lecloux G, Rompen E, Lambert F. Hard and soft tissue analysis of alveolar ridge preservation in esthetic zone using deproteinized bovine bone mineral and a saddle connective tissue graft: A long-term prospective case series. *Clin Implant Dent Relat Res*. 2020;1-10. <https://doi.org/10.1111/cid.12899>