The Bone Splitting Stabilisation Technique-A modified Approach to Prevent Bone Resorption of the Buccal Wall

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Abstract

The aim of this case series was to clinically demonstrate successful prevention of bone resorption of the buccal wall after alveolar bone splitting by additional stabilization of the lateral bone plate using a biphasic ceramic bone substitute. In three patients alveolar bone splitting was performed with a piezoelectric device. Clinical as well as radiological results after two and five years revealed stable hard and soft tissue conditions with no soft tissue recessions and peri-implant bone loss in three patients. The advantage of this one-stage procedure was the ability to insert dental implants into a very compromised bony site in a simultaneous procedure. Yet the bone splitting stabilisation technique appeared to be a more user-sensitive method.

Key Words: Bone splitting, Piezosurgery, β-tricalcium phosphate, Guided bone regeneration, Dental implants

Introduction

Favorable tissue integration of endosseous implants is notably dependent on sufficient biomechanical as well as biochemical interaction mechanisms between the peri-implant environment and the implant surface [1]. To enable long-term optimal functional and aesthetic results in dental implant therapy sufficient width and height of bone is mandatory at the recipient site. In many situations, however, there is a bone deficiency and a procedure is indicated that predictably leads to sufficient new bone formation [2]. Horizontal augmentation using the principle of Guided Bone Regeneration (GBR), onlay bone block grafts, and alveolar distraction osteogenesis are among the techniques used to enhance the bone volume in case of a narrow alveolar ridge [3-6]. While the GBR procedure can be performed with simultaneous implant placement [7,8], onlay grafting implies a reconsolidation time of at least three months to enable implant placement in a staged procedure [9,10]. Many studies have demonstrated the success of these well-documented surgical approaches, but donor site morbidity, unexpected bone resorption, block consolidation at the site of grafting and infection are among the drawbacks of these conventional techniques [11,12].

Another therapy for treating a narrow bone ridge is the bone splitting/ridge expansion technique introduced by Simion and coworkers in 1992 [13]. According to this procedure, the compromised alveolar ridge is crestally opened and subsequently split with special osteotomes. To avoid the collapse of the expanded ridge, frequently bone substitutes are packed into the created bone defect to maintain the space. Independently of supplementary bone augmentation the ridge heals similar to an extraction socket. Another option is to insert an implant into the expanded space between the medial and buccal bone walls and to allow it to heal in a submerged position. In this context bone splitting presents the advantage of simultaneous implant placement and avoiding bone graft harvesting from secondary donor sites [14,15].

However, ridge expansion also discloses certain technical and physiological limitations. One major drawback of alveolar bone splitting is the requirement of a cancellous bone compartment between the buccal and lingual plates to allow separation. Consequently, although in many cases mainly the mandible is affected by horizontal bone resorption the lack of enough extendable trabecular bone volume often confines the technique to the maxilla. Moreover, without any further modification of the surgical technique or integration of additional grafting techniques a collateral missing vertical bone height cannot be sufficiently rebuilt.

Another disadvantage of the alveolar bone splitting technique, which can be quite severe, may be the risk for bone resorption due to malnutrition of the laterally out displaced buccal bone wall [16]. Although some approaches were proposed to reduce bone resorption evidence for their efficacy is still lacking [17,18]. Animal studies, where the ridge expansion technique was studied, demonstrated marginal bone loss [19], particularly at the buccal bone wall and exposure of implant threads in 60% and implant mobility in 40% of all implants [20].

A possible solution to overcome this challenge may represent the use of bone substitutes. Known from guided bone regeneration certain grafting materials, like e.g. Deproteinized Bovine Bone (DPBB), disclose an extremely slow resorption and thus allow a more stable preservation of the graft volume [21]. By adding autogenous bone to the grafting material the volumetric reduction in the graft can be significantly affected [22]. This influence on graft behavior and resisting power has also recently proven to be clinically effective for different

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ratios of DPBB and autogenous bone for lateral augmentation in humans [23].

Therefore it was the aim of this proof-of-concept trial to provide evidence for the successful prevention of bone resorption of the buccal wall after bone splitting by stabilization of the lateral bone plate using a biphasic ceramic bone substitute. The hypothesis of this initial clinical case trail was that the ridge splitting stabilization technique leads to a safe and sustainable peri-implant hard and soft tissue contour.

Materials and Methods

Surgical method

After a midcrestal incision a full-thickness flap was elevated to expose the underlying alveolar crest. Remaining soft tissue structures were meticulously removed to avoid unintentional ingrowth into the later osteotomy gap. In case of a severe atrophy with a knife-edged bone morphology the alveolar ridge was gently flattened and a small cortical indentation was performed in the center of the alveolar ridge to ease a safe guidance of the cutting device.

The alveolar ridge was crestally cut in the mesio-distal direction with a piezoelectric device (Piezosurgery®,Mectron s.p.a., Carasco, Italy). For the osteotomy an OT7 bone scalpel with special makers for depth measurements was applied. Mesially and distally of the crestal osteotomy, buccal mono-cortical releasing cuts of about 7-10 mm in the coronal-apical orientation were accomplished. In the following the buccal bone plate was gently loosened and subsequently mobilized into the buccal direction with the help of a special osteotome (Ergoplant® Aesculap AG, Tuttlingen, Germany).

Thereafter, the expanded gap was kept open with retraction inserts (Ergoplant® Aesculap AG, Tuttlingen, Germany) avoiding a collapse of the splitted wall. Furthermore, the inserts helped to stabilize the mobile bone plate during implant drilling. Preparation of implant beds was performed according to a standard and approved drilling protocol using rotating pilot and twist drills in ascending order (diameter). All implants could be inserted with primary stability and without and fracture of the buccal wall. Implant were set up on a bone-level height, in such a way that the implant shoulder was flush with the level of the lingual and buccal bone crest. The expanded bone gap was filled with granules consisting of biphasic ceramic bone substitute (Straumann® BoneCeramic, 400-700 µm, Straumann AG, Basel, Switzerland), which is composed of a combination of Hydroxyapatite (HA) and β-tricalcium phosphate (β -TCP). Straumann® BoneCeramic is characterized by a mixture of 60% HA and 40% β -TCP. It is 100% crystalline, highly pure and has a porosity of 90%. The pores are 100–500 mm in diameter. The grafting material was mixed with blood. Additionally a Guided Bone Regeneration (GBR) procedure consisting of a lateral augmentation of the buccal bone plate with the BCP granules mixed with blood and a barrier collagen membrane (BioGide®, Geistlich, Wolhusen, Switzerland) was applied. The membrane was fixed with titanium pins (Altapin®, Camlog, Wimsheim, Germany). Finally, multiple periosteal releasing incisions were performed for tension free soft tissue closure followed by interruptive suturing of the flaps with a non-resorbable material (Seralon 5-0, Serag Wiessner, Germany).

After four months of submerged healing the surgical area was re-entered and implants were uncovered. Prosthodontic restorations were fixed and then implants were loaded.

Case 1

An 83-year-old woman was referred for the rehabilitation of the maxilla with a fixed implant- supported restoration. The patient did not show any absolute or relative contraindications against implant therapy. Preoperative clinical and radiographic examination revealed a narrow crest of less than 3 mm width in the left maxilla (*Figure 1*).

Additionally, a reduced vertical height (< 5 mm) in the left as well as the right maxilla necessitated a bilateral sinus floor elevation. After elevation of a full-thickness flap, the alveolar ridge was splitted with a piezosurgical device in a length of 18 mm (*Figure 2*). The lateral bone segment was expanded for 4 mm to open up the gap. Following, a lateral access osteotomy to the maxillary sinus was performed using the same device.

The sinus membrane was meticulously dissected and

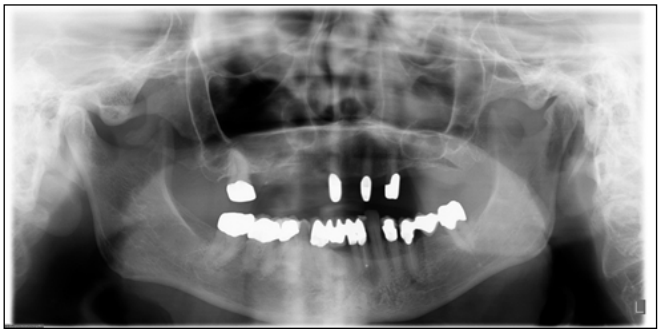

***Figure 1**. Preoperative panoramic radiograph showing the severe atrophy in the maxilla.*

***Figure 2.** Right maxilla after bone-split osteotomy and fixation of a prefabricated surgical template for 3D planned implant placement.*

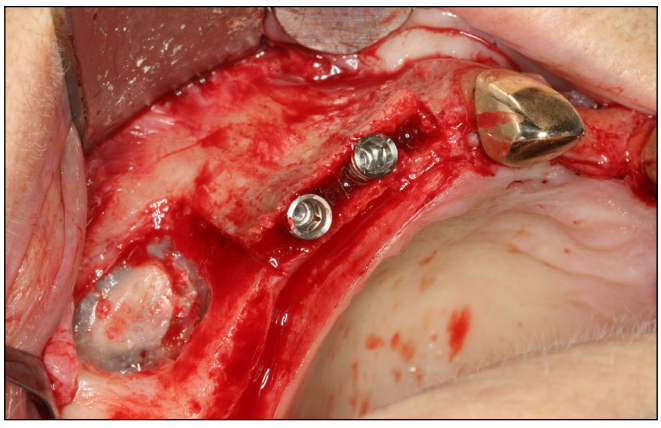

***Figure 3.** Coronal view of the expanded bone split gap with dental implants.*

lifted by elevators. The empty sinus space, the expanded bone gap and the buccal bone plate were grafted with a biphasic ceramic bone substitute (*Figures 3 and 4*). Altogether 7 dental implants (Frialit-2, Dentsply Friadent, Mannheim, Germany) were placed based on static implant planning. After fixation of the barrier collagen membrane, the overall augmented width of the site was measured (8 mm) and the mucoperiosteal flap was repositioned and fixed (*Figures 5 and 6*). All implants were left to heal submerged (*Figure 7*). Implants were uncovered after four months and prosthetic rehabilitation was completed. At this time all implants were functionally stable with sound hard and soft tissue conditions. As far as possible the width of the alveolar crest were measured with a caliber. Without soft tissue the width of the alveolar crest was 8 mm. No buccal recession was obvious. Follow-up examinations were performed routinely 2 days, 10 days and 6 weeks after surgery. The patient showed up for radiographic and clinical control after two and five years (*Figures 8 and 9*).

Case 2

A 65-year-old woman was referred for implant therapy in the left and right maxilla to apply an implant-tooth supported

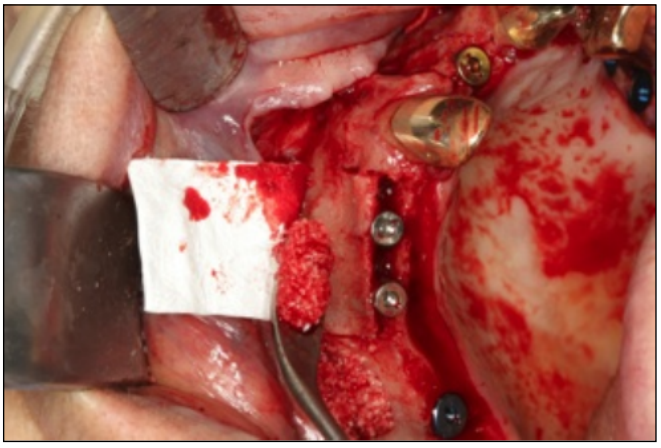

***Figure 4**. Bone split with two implants and lateral augmentation of the buccal bone plate with a biphasic ceramic bone substitute. The barrier collagen membrane is already apically fixed.*

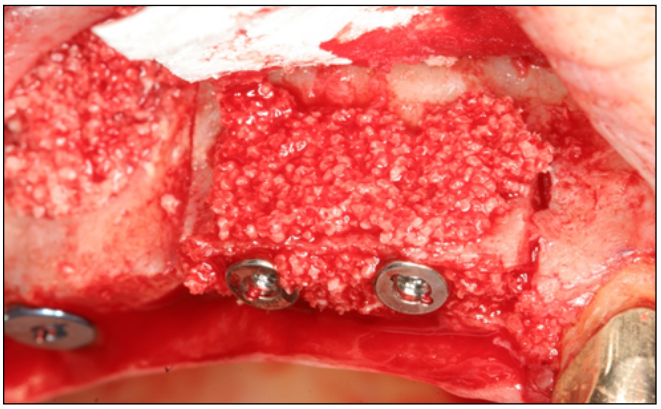

***Figure 5**. Lateral view of the augmentation site. The buccal plate is completely coated with the biphasic ceramic bone substitute.*

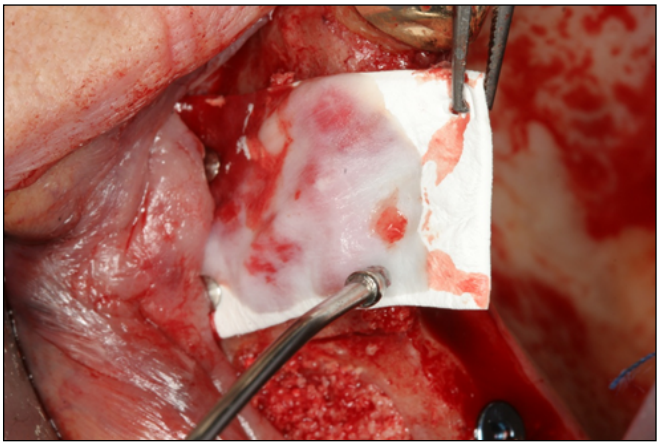

***Figure 6**. Coverage and final fixation of barrier collagen membrane on the palatal site.*

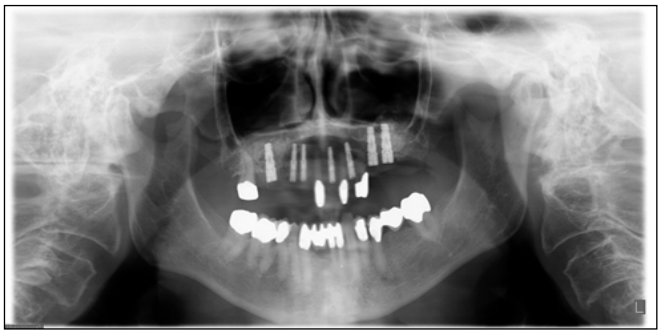

***Figure 7**. Postoperative panoramic radiograph displaying the correct position of the implants and the sinus augmentation site.*

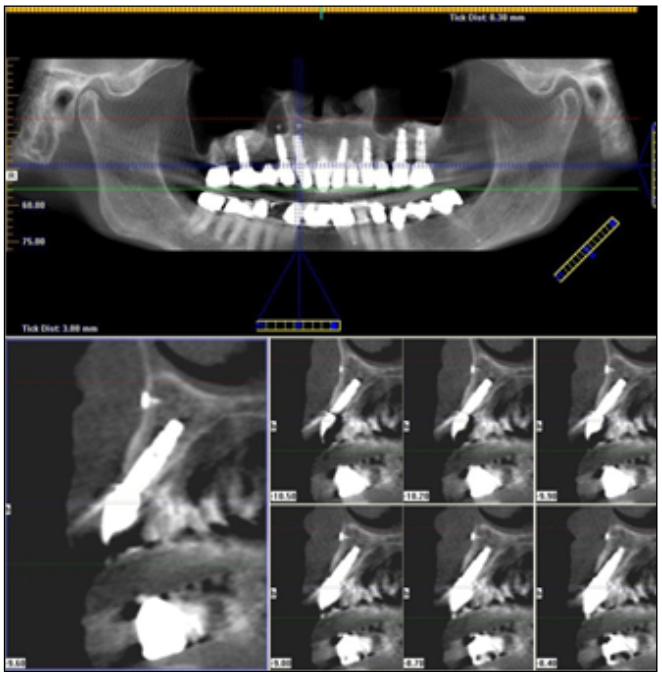

***Figure 8**. Digital volume tomography (DVT) after 5 years. Note stable hard tissue conditions with absence of buccal resorption.*

***Figure 9**. Clinical situation after 5 years with satisfying soft tissue conditions.*

removable partial denture. Prior to surgery, basic evaluation was undertaken including medical history, smoking habits as well as an examination of the oral cavity. Clinical and radiographic examination revealed a narrow crest of 3 mm width on both sides of the maxilla. After soft tissue preparation and piezoelectric alveolar ridge splitting in a length of 25 mm, each two implants (SLA®, Straumann AG, Basle, Switzerland) could be placed into the expanded (4 mm) ridges (*Figure 10*). An additional GBR procedure was performed laterally and soft tissue structures were readapted (*Figures 11-13*). After augmentation the width of the site was 9 mm. Implants were left to heal submerged. After four months implants were uncovered and the prosthetic rehabilitation could be finished. At this time the overall width of the alveolar crest was 9 mm. All implants were functionally stable and there was no hard or soft tissue dehiscence on the buccal aspect. During follow-up examinations at two years clinical as well as radiographic status left unchanged (*Figure 14*).

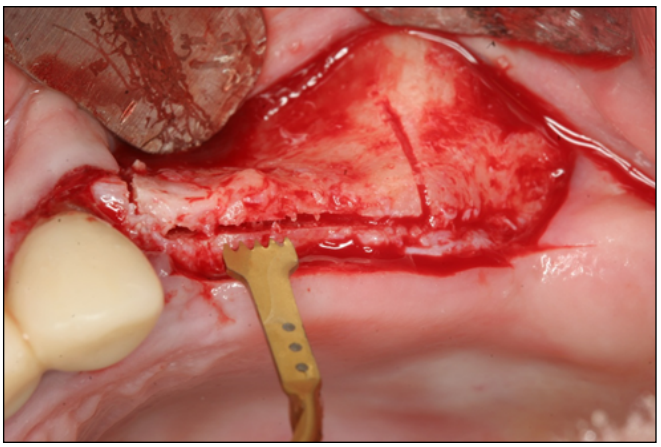

***Figure 10**. Piezoelectric osteotomy in the left maxilla. Mesially and distally of the crestal osteotomy, buccal mono-cortical releasing cuts are visible.*

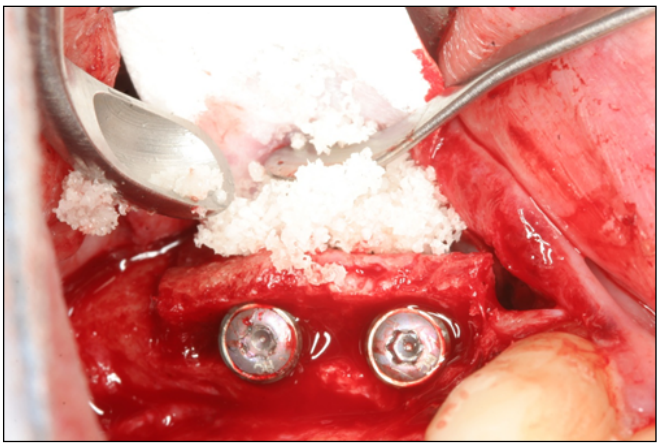

***Figure 11**. Lateral augmentation of the buccal plate with a biphasic ceramic bone substitute.*

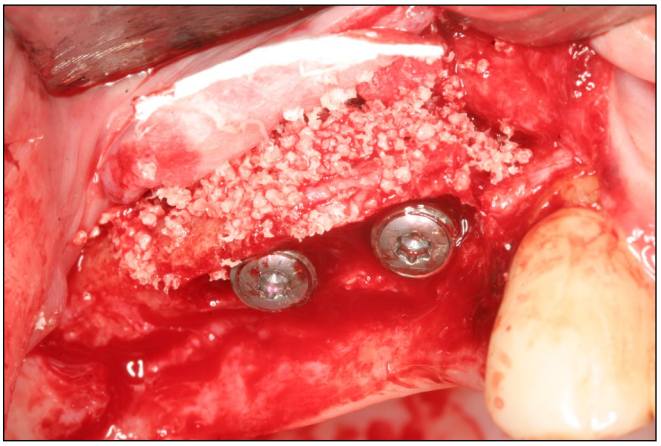

***Figure 12**. Complete lateral augmentation of the buccal bone of wall. The crestal bone gap is still without any augmentation material.*

Case 3

A 64-year-old female patient presented to our department requesting treatment of his partially edentulous maxilla with a fixed implant-tooth supported denture. Medical history was without pathological findings. The patient showed a comprehensive centripetal bone resorption. On the left side of the maxilla disclosed a width of 3 mm and on the right side a width of 4 mm. Thus an alveolar ridge splitting had to be performed at all four preoperatively planned implant sites (SLA®, Straumann AG, Basle, Switzerland). On the left side the piezosurgical cut was 40 mm and on the right side 15 mm. On both sides the gap was expanded for 4 mm. Overall, surgical intervention was uneventful and without any complications. All implants could be placed in a stable position and according to the treatment plan (*Figures 15 and 16*). Overall the augmentation site revealed a width of 8 mm. After 4 months implants were uncovered and prosthetic rehabilitation could be finished. At this time the alveolar ridge showed an overall width of 8 mm. During follow-up examinations at two and five years no adverse effects at the hard and soft tissue interface could be detected (*Figures 17 and 18*).

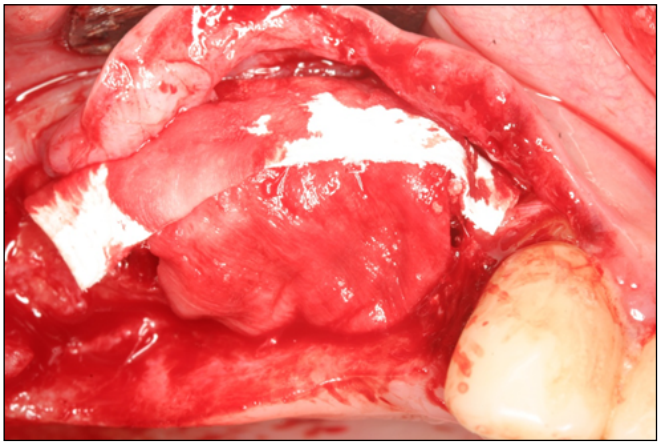

***Figure 13**. Coverage of the surgical site with a of barrier collagen membrane.*

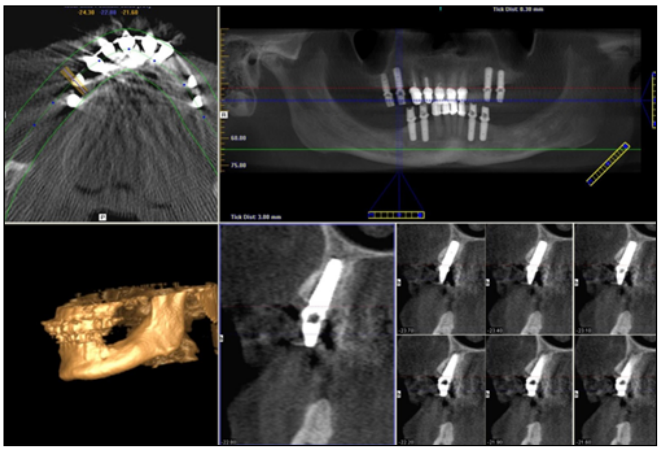

***Figure 14.** Digital volume tomography (DVT) after 4 years. Note stable hard tissue conditions with absence of buccal resorption.*

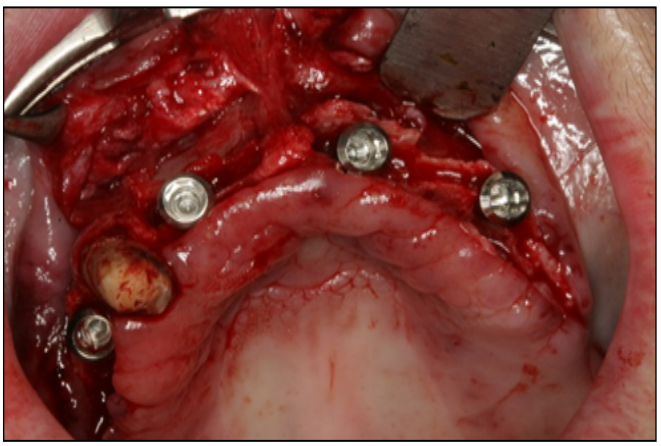

Figure 15. *Intraoperative site of the maxilla with three implants placed into the widened gaps after alveolar ridge splitting.*

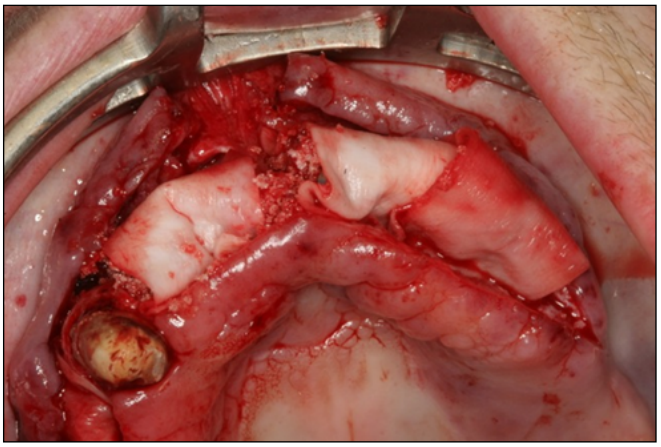

Figure 16. *Surgical site directly before soft tissue closure. Three barrier membranes cover the lateral as well as the crestal part of the alveolar ridge.*

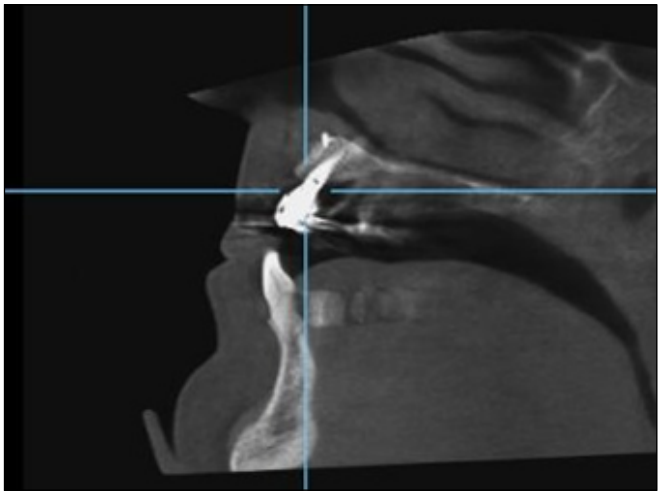

Figure 17. *The digital volume tomography (DVT) image after 2 years reveals no major bone resorption on the lateral aspect.*

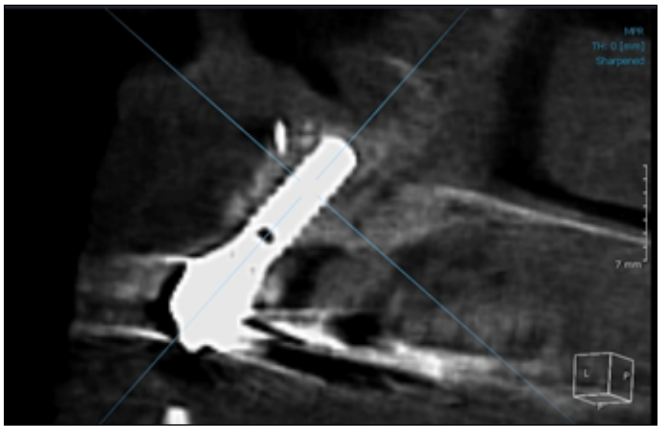

Figure 18. *After 5 years hard tissue conditions demonstrate stable results.*

Discussion

It was the aim of this case series to clinically investigate successful prevention of bone resorption of the buccal wall after alveolar bone splitting by additional augmentation of the lateral bone plate using a biphasic ceramic bone substitute. Clinical as well as radiological results after two years revealed stable hard and soft tissue conditions with no soft tissue recessions and peri-implant bone loss.

Generally, after tooth extraction an average 40–60% decrease of horizontal as well as vertical dimensions of the alveolar ridge occurs during the first 2 years [24]. Bone resorption and three-dimensional changes of the crest are predominantly more pronounced at the buccal than on the lingual aspect of the extraction socket [25]. In order to cope with the almost inevitable loss of bone volume, several approaches have been advocated, whereby the socket preservation technique using various bone substitutes is widely accepted as one of the most predictable treatment concepts to maintain the dimensions of the alveolar ridge [26]. Beneath allogenic and xenogenic bone grafting materials, synthetic bone substitutes, like e.g. calcium phosphate (CaP)-based biomaterials are well approved, because of their favourable biodegradability, bioactivity and osteoconductivity [27]. Straumann Bone Ceramic® is a biphasic ceramic bone substitute, which is composed of a combination of Hydroxyapatite (HA) and β-tricalcium phosphate (β-TCP). At physiological conditions HA is resistant against resorption and thus is often recommended for preservation of the alveolar ridge. In contrast β-TCP provides an osteoconductive matrix, which is slowly resorbed and subsequently replaced by new bone. During hard tissue modeling β-TCP particles are incorporated into the woven bone. By the combination of both materials, undisturbed bone remodelling with resorption (β-TCP) and new bone formation can take place in a shielding and space maintaining scaffold matrix (HA) [28]. This characteristic properties and effects of HA and β-TCP have been also verified for guided bone regeneration of lateral bone defects [29].

Since buccal bone resorption is also evident after ridge expansion, reduction of resorption of the mobilized buccal bone is an issue of great clinical importance. One possible approach may be a combined simultaneous ridge expansion and horizontal GBR procedure as demonstrated in the present case series. Clinically, this one-stage procedure disclosed promising results with successful and sustainable dental implant incorporation. Bone splitting with concomitant horizontal ridge augmentation could be reliably accomplished. The graft could be firmly packed and modelled. Fixation of the resorbable barrier membrane with titanium pins at the mobilized lateral bone plate was unproblematic due to the stable support from the previously augmented bone split. Albeit, surgical approach, osteotomy technique and bone augmentation did not cause any major intricacies, soft tissue management called for some alignment. Firstly, due

to supplementary lateral augmentation as well as the mesial and distal releasing osteotomies, the periosteum had to be removed from the buccal plate to facilitate unconfined access to the bone. Secondly, the increased horizontal bone volume after splitting and augmentation necessitated a comprehensive soft tissue preparation.

To mobilize intraoral soft tissue structures, usually the periosteum at the recipient site is incised to achieve a tension-free closure of the wound. For the ridge splitting stabilisation technique this was also necessary. However, not only revascularization of the flap is affected by this procedure, but also the natural barrier function of the periosteum is compromised. If the periosteum is damaged or does not cover a grafting site, osteogenesis and angiogenesis of donor bone graft healing is impaired [30]. The result is less new bone and cartilage formation.

After any trauma to the bone the periosteum undergoes a series of changes to initiate enchondral and intramembraneous bone formation at the injury site. Periosteal stem/progenitor cells are part of a complex and well-orchestrated process, which is responsible for subsequent neovascularization, bone formation, and remodelling [31]. Absence of periosteum also results in a reduction of osteoclasts, which finally leads to a reduced bone remodelling activity.

In the present case series this effect was not crucial. Yet, as only 3 cases were analyzed in this pilot trial, further investigations with a higher number of patients are necessary to exclude the possible risk. Especially in the first 12 months after surgery and implant insertion, the amount of overall bone loss has to be accurately assessed, as this is the most critical phase of initial bone loss around dental implants [32].

In this context, another vital point to account for is a potential soft tissue dehiscence due to forced wound closure or inappropriate flap design and manipulation. As the ridge splitting stabilisation technique definitely requires a more extensive mobilisation of the mucosa, anatomical as well as biomechanical muscles forces have to be carefully considered to avoid any iatrogenic damage or sequela. Similar to spacious augmentations using iliac crest grafts, however, this can be managed by a thorough pre-operative planning.

Conclusions

The present case series demonstrated that none of the implants placed in the bone gap created by ridge expansion was lost and all were successfully osseointegrated. Hard as well as soft tissue structures revealed favourable and stable results with a follow-up from two to five years. Overall, the advantage of this treatment procedure was the ability to insert dental implants into a very compromised bony site in a simultaneous procedure, meaning only one operation in total with less total healing time compared to the established treatment methods. But like with other delicate surgical techniques, the ridge splitting stabilisation technique appears to be more user-sensitive.

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