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Platelet-rich plasma may prevent titanium-mesh exposure in alveolar ridge augmentation with anorganic bovine bone

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Abstract

Objective: Bone augmentation with the titanium-mesh (Ti-mesh) technique is susceptible to a large rate of complications such as morbidity of bone graft donor site, and mesh exposure to the oral cavity. The purpose of this study was to evaluate the effectiveness of anorganic bovine bone (ABB) in alveolar bone augmentation with the Ti-mesh technique. In addition, we investigated the effect of platelet-rich plasma (PRP) in preventing mesh exposure by using it to cover the Ti-mesh.

Patients and Methods: Patients included in the clinical trial were randomly allocated by a blinded assistant into two groups. The 30 patients recruited for this study underwent 43 alveolar bone augmentation with the Ti-mesh technique using ABB as graft material in all of them. In 15 patients, the Ti-meshes were covered with PRP (PRP group) whereas in the other 15 the Ti-meshes were not (control group). After 6 months, patients were called for clinical, radiographic, and histological evaluation, and implant placement surgery. A total of 97 implants were placed in the augmented bone and their evolution was followed up for a period of 24 months.

Results: Significant differences were found between the two study groups in terms of complications and bone formation. In the control group, 28.5% of the cases suffered from mesh exposure, while in the PRP group, no exposures were registered. Radiographic analysis revealed that bone augmentation was higher in the PRP group than in the control group. Overall, 97.3% of implants placed in the control group and 100% of those placed in the PRP group were successful during the monitoring period. We suggest that the positive effect of PRP on the Ti-mesh technique is due to its capacity to improve soft tissue healing, thereby protecting the mesh and graft material secured beneath the gingival tissues.

Conclusions: Alveolar bone augmentation using ABB alone in the Ti-mesh technique is sufficient for implant rehabilitation. Besides, covering the Ti-meshes with PRP was a determining factor in avoiding mesh exposure. Ti-mesh exposure provoked significant bone loss, but in most cases it did not affect the subsequent placement of implants.

Key words: anorganic bovine bone; bone regeneration; platelet-rich plasma; soft tissue healing; titanium-mesh exposure

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Conflict of interest and source of funding statement

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Several techniques for alveolar bone augmentation have been described in order to give a solution for inadequate alveolar bone volume, which often precludes the ideal placement of dental implants placement (Adell et al. 1990, Simion et al. 1994a, Buser et al. 1999, Cordaro et al. 2002, Rocchietta et al. 2008). Onlay grafts and guided bone regeneration (GBR) are widely used for alveolar ridge augmentation before or simultaneous to implant placement. Clinical and histological data support the use of these approaches (van Steenberghe et al. 1997, Keller et al. 1999, Parma Benfenati et al. 1999). However, the success of GBR procedures seems to be highly technique sensitive and therefore application to a wide community of operators and clinical settings remains unclear (Simion et al. 1994a, Tinti et al. 1996, Tinti & Parma-Benfenati 1998, Simion et al. 2007, Rocchietta et al. 2008). On the other hand, onlay graft implies the extraction of an autologous bone block that is often traumatic for the patient.

GBR presents several controversies concerning two aspects: the type of barrier and the type of graft used (Boyne et al. 1985, von Arx et al. 1996). Regarding the first issue, two principal barriers have been proposed: cell-occlusive membranes and titanium (Ti) meshes. Cell-occlusive membranes showed very good results obtaining great quantity of regenerated bone, however, they have demonstrated two major inconveniences: (i) low stiffness for maintaining the contour of the regenerated sites, and (ii) a high risk of infection after wound dehiscence and barrier exposure (Simion et al. 1994a–c). A major inconvenience of the Ti-mesh technique concerns the high rate of exposure that may facilitate graft infection or loss (Table 1). In GBR techniques, soft tissue closure over the augmented area plays an important role in preventing wound dehiscence and bacterial contamination of the exposed membrane. In addition, the improved stiffness of GBR using Ti-mesh compared with cell-occlusive membranes permits to obtain predictable results in both lateral and vertical bone augmentation (Malchiodi et al. 1998, Maiorana et al. 2001, Artzi et al. 2003, Rocuzzo et al. 2004, 2007, Proussaefs & Lozada 2006, Corinaldesi et al. 2007, Pieri et al. 2008).

Although GBR technique is much more predictable in bone width augmentation, an increase of vertical bone volume has been described, even in severe cases, in a predictable way (Table 1). Early studies advocated the use of autogenous bone in the augmented space beneath Ti-meshes (Boyne et al. 1985, von Arx et al. 1996). Although the autologous bone is considered the gold standard bone substitute because of its intrinsic properties, its availability is restricted by the limited amount of intraoral grafts, the morbidity associated to second surgery at the donor site, and the high cost for bone harvesting from extraoral sites. Therefore, alternative biomaterials have been developed to substitute this material.

Among the available bone substitutes, anorganic bovine bone (ABB) has received a wealth of reports in the literature demonstrating its long-term success when used in alveolar bone augmentation procedures. Bio-Oss® (Geistlich Biomaterials; Wolhusen, Switzerland) is a biocompatible and osteoconductive ABB (Rosen et al. 2002) that provides an excellent scaffold for new bone formation (Hämmerle et al. 1998, Piattelli et al. 1999). It has been extensively used for alveolar bone augmentation (Zitzmann et al. 2001, Fugazzotto 2003a, b) with high clinical success rates (Carmagnola et al. 2003). Accordingly, previous studies have introduced the use of ABB to the Ti-mesh technique, either alone, or combined with autologous bone (Maiorana et al. 2001, Corinaldesi et al. 2007, Pieri et al. 2008) (Table 1).

Platelet-rich plasma (PRP) is an autologous fibrin adhesive with high platelet concentration easily obtained from whole blood by centrifugation (Antoniades 1981, Marx et al. 1998, Anitua 1999) Furthermore, PRP has a high concentration of angiogenic and mitogenic growth factors implicated in soft tissue healing, such as TGF (Wikesjö et al. 1998), PDGF, and EGF (Giannobile et al. 1996). Indeed, several studies have suggested that the application of autogenous PRP can enhance soft tissue wound healing. (Eppley et al. 2006). In this work, we have considered that the healing of soft tissues over Ti-meshes in alveolar ridge augmentation procedures might benefit from local application of PRP, avoiding subsequent exposure of the Ti mesh, and its derived complications.

The recent consensus statements of the European Workshop on Periodontology 2008 highlighted the fact that bone augmentation procedures can fail and that implants placed in these areas do not necessarily enjoy the high

Table 1. Summary of clinical studies reporting the amount bone gained and complications rate using the Ti-mesh technique

Pts/BAP (*n*/*n*)	Type of graft (%)	ABW (mm)	ABH (mm)	ME (%)	Impl (*n*)	Survival (%)	Success (%)	References
20/20	AB (100)	ID	ID	50	28	ID	ID	Von Arx et al. (1996)
25/25	AB (100)	5.65	ID	0	120	ID	100	Malchiodi et al. (1998)
23/23	AB (100) *	ID	5	17.3	ID	ID	ID	Rocuzzo et al. (2004)
18/18	AB (100) *	ID	4.8	22.2	37	100	100	Rocuzzo et al. (2007)
14/23	AB/ABB (50/50)	ID	ID	14.2	59	98.3	ID	Maiorana et al. (2001)
16/19	AB/ABB (70/30)	4.16	3.71	5.3	44	100	100	Pieri et al. (2008)
12/12	AB/ABB (70/30)	ID	ID	0	35	100	100	Corinaldesi et al. (2007)
7/7	AB/ABB (ID)	3.71	2.86	57	ID	ID	ID	Proussaefs & Lozada (2006)
10/10	ABB (100)	ID	5.2	20	20	100	ID	Artzi et al. (2003)

*Block grafts.

Pts, patients; BAP, bone augmentation procedures; ABW, average bone width gained; ABH, average bone height gained; ME, mesh exposure; Impl, implants placed; AB, autologous bone; ID, insufficient data.

long-term survival rates of dental implants placed in pristine sites. The consensus emphasized the research need to solve this problem (Tonetti & Hämmerle 2008). In the present study, a clinical trial was performed to evaluate two aspects regarding the Ti-mesh technique: (i) to examine the outcome of ABB grafting alone, and (ii) the benefit of covering the Ti-mesh with PRP in order to improve soft tissue healing and prevent exposure. The results were obtained by means of clinical investigation, radiographs, and histological analysis.

Patient and Methods

Patients

Before commencing this study, approval was obtained from the Ethical Committee for Clinical Trials of the ''Hospital San Carlos'' (Madrid, Spain) to carry out a pilot clinical study in ''Dental Clinic Alcala'' (Madrid, Spain). Patients were enrolled in the study on the basis of having insufficient bone height ($\leqslant$7 mm), width ($\leqslant$3 mm) or both, in either maxilla or mandible (Fig. 1). Patients who needed simultaneous sinus floor augmentation or nasal floor augmentation were included, while smokers (>10 cigarettes per day) and patients with severe systemic disease [ASA (III or IV) – American Society of Anesthesiology] were excluded. Informed written consent to participate in this study was obtained from all patients after explaining the objectives and protocol of the study, and the possible side effects.

During the study period (from May 2003 to September 2008), 209 patients attended the dental office demanding implant treatment. Among these patients, 30 fulfill the criteria and were recruited for this randomized-controlled clinical trial. The study group was constituted of 17 females and 13 males with an age range between 48 and 76 years old. There was heterogeneity in the systemic diseases present in some of the selected patients such as diabetes, heart failure, and osteoporosis; however, none of these conditions are known to jeopardize the implant's success (Mombelli & Cionca 2006).

Clinical assessment of thin or thick biotype was based on simple visual inspection. However, we are aware that the precision of this method to identify gingival biotype is limited and highly dependent on the clinician criteria (Eghbali et al. 2009).

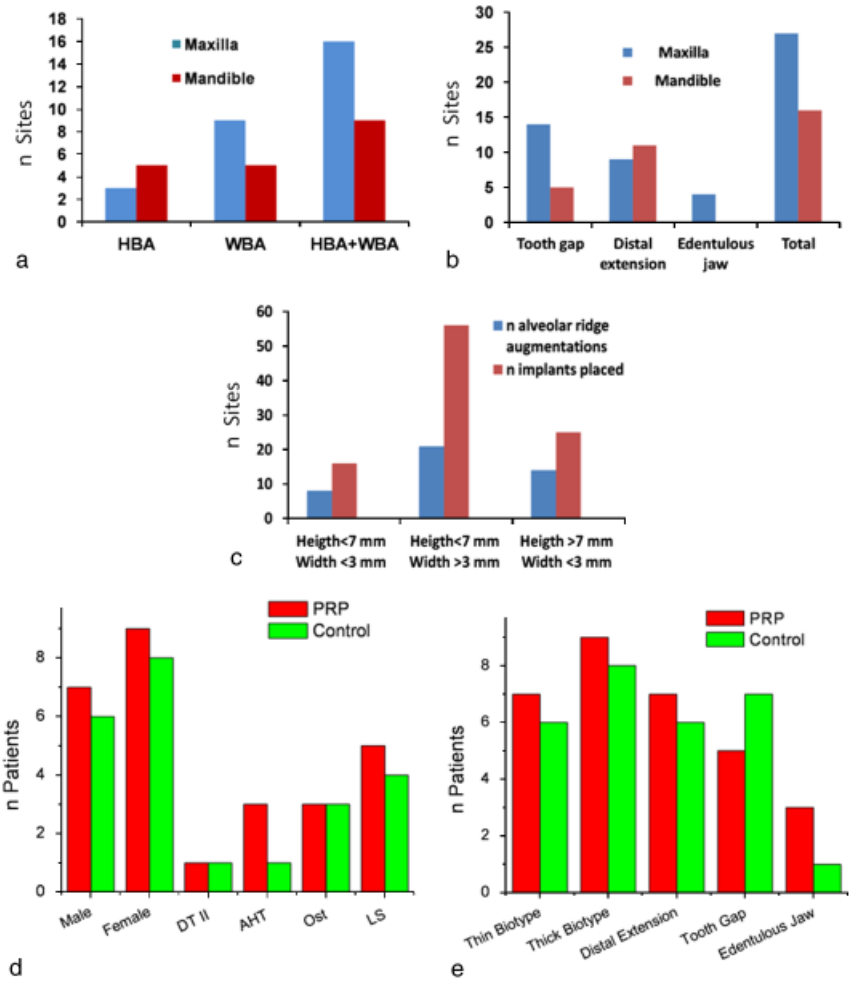

Fig 1. Distribution of surgical sites as a function of: bone augmentation procedure (a), nature of the edentulous space (b), treatment procedures, and residual bone graft size (c). Distribution of study group [platelet-rich plasma (PRP) and Control groups] as a function of the systemic conditions of the patients (d), and the nature of the edentulous space (e). HBA, height bone augmentation; WBA, width bone augmentation; DT II, Type II diabetes; AHT, arterial hypertension; Ost, osteoporosis; LS, light smoker.

Figure 1a–c summarizes the average residual bone height and width, the site of intervention, and the type of GBR procedure performed to the patients. Most of the interventions involved situations of extended tooth gaps, distal extension, and combined vertical and horizontal bone augmentations. Figure 1 d–e summarizes the patient distribution in the experimental and control groups according to their systemic and oral conditions (soft tissue biotype and nature of edentulous space). It can be observed that, even though the group of patients treated in this study was very heterogenic, the control and experimental groups were comparable.

Randomization

Patients included in the clinical trial were randomly allocated by a blinded assistant in two groups, the first was treated with PRP covering of the Ti-mesh (PRP group), while the second one did not receive the PRP treatment (control group). Allocation of participants to intervention groups in a truly unpredictable, randomized sequence was performed by a computerized random number generated using GraphPad-QuickCalc software (GraphPad Software Inc., La Jolla, CA), including the concealment of the allocation schedule until the assignment was made. Subject numbers were assigned at the baseline examination in consecutive order by the

principal investigator. The sample size used has been usual in previous studies for this type of clinical evaluation (Table 1). The presence of systemic disorders was registered and its distribution was balanced among the two treatment groups (Fig. 1d).

Blinding

The surgeon was blinded to the graft material applied over the Ti mesh in each patient throughout the entire procedures preceding graft implantation. Once the Ti-meshes were screwed to the alveolar bone by the surgeon, an assistant handled the PRP or nothing. However, a possible bias could occur during the suturing because at this time the surgeon was not blinded anymore. Clinicians who made the post-surgical follow-up were blinded to study groups.

PRP

PRP was prepared according to Anitua's method (Anitua 1999). Blood was collected from all patients 30 min. before starting the surgery to ensure the blinding of the surgeon. In the PRP group, 10–20 ml of blood was withdrawn via venous aspiration into 4.5 ml test tubes and mixed with a 3.8% sodium citrate solution at a ratio of 5/1 (v/v) achieving anticoagulation through calcium binding. The blood was then centrifuged using a Bti® PRGF System II centrifuge (Bti Biotechnology Institute S.L, Vitoria, Spain) into three basic components: red blood cells (RBCs), PRP, and platelet-poor plasma (PPP) (Fig. 2a). Because of the different densities of the components, the RBC layer forms at the bottom of the tube, the PRP layer in the middle, and the PPP layer at the top. A pipette (Gilson Inc., Middleton, WI, USA) was used to separate the layers, from the less dense to the denser. Therefore PPP was separated first (about 2.25 ml) followed by PRP (about 0.9 ml), leaving as residual the RBCs layer (about 2.25 ml) (Fig. 2b).

Surgical protocol

An alveolar ridge augmentation was performed in all patients following the method described by Boyne et al. (1985) and Von Arx et al. (1996). Under local anaesthesia, a mid-crestal with divergent buccal incisions was performed to allow the elevation of two mucoperiosteal flaps to the buccal and palatal aspects. Perforations into the marrow space were produced. In all patients, ABB particles were adapted to the deficient ridge and a Ti-mesh that was individually trimmed was placed over the grafts and fixed with microscrews. Subsequently, PRP was used as a membrane covering the Ti-meshes in the PRP group, while nothing was added to cover the Ti-mesh in the control group (Fig. 3). Then, releasing periosteal incisions were made and a tension-free, tight wound closure was accomplished. Post-operatively, Amoxicillin 750 mg (Clamoxyl®, GlaxoSmithKline, Middlesex, UK) was prescribed three times a day for 7 days, Ibuprofen 600 mg (Espidifen®, Zambon Switzerland Ltd, Barcelona, Spain) three times a day for 4 days, and clorhexidine 0.20% (Perio-aid®, Dentaid, Barcelona, Spain) three times a day for 10 days.

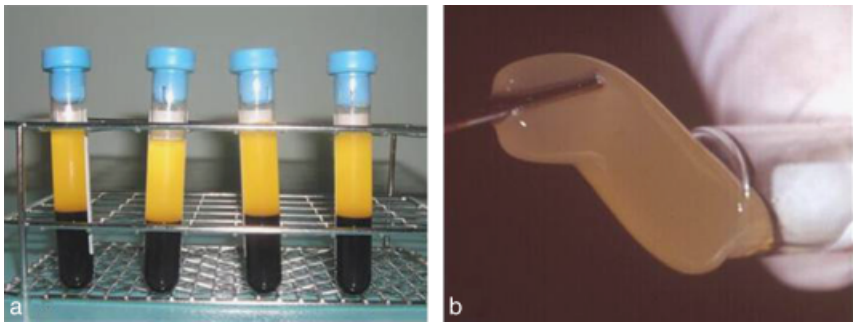

Fig 2. (a) Blood samples after centrifugation to obtain platelet-rich plasma (PRP). Note the separation in two fractions, the red one (containing red blood cells) and the yellow one (containing leucocytes and platelets). (b) PRP as obtained from the blood samples after being activated with a 30% $CaCl_2$ solution forms a viscous gel that can be easily manipulated.

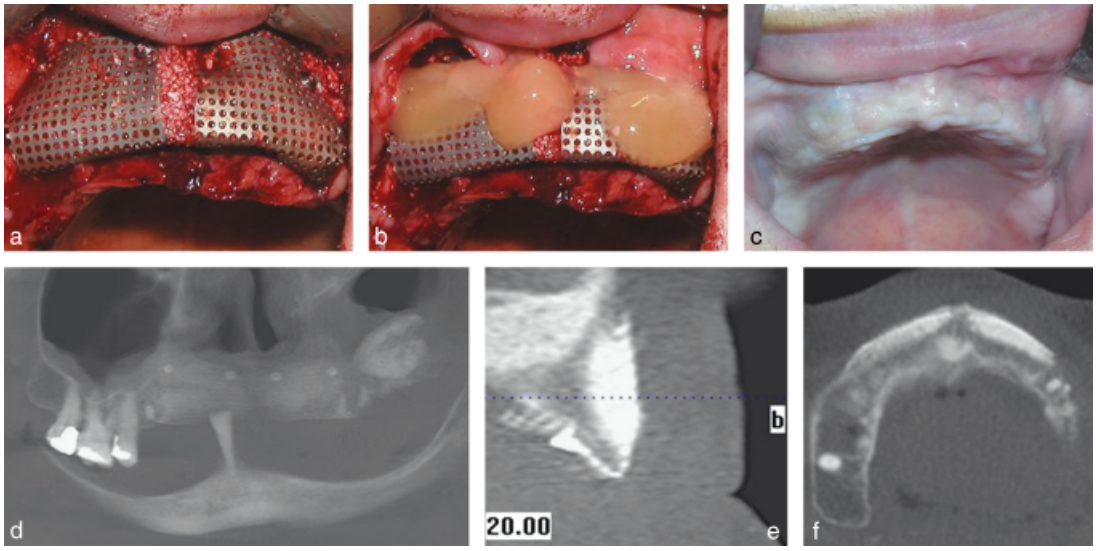

Fig 3. (a) Ti-mesh adapted on the maxillary residual ridge. (b) Placement of platelet-rich plasma gel over the Ti-mesh. (c) Healed alveolar ridge after 6 months without Ti-mesh exposition. A panoramic radiograph (d), a sagittal CT section (e), and a transverse CT section (f) of the treated site 6 months after the intervention showing the alveolar ridge augmentation achieved.

Sutures were removed 1 week after surgery. A healing time of 6 months was allowed before implant placement (Osseotite, Biomet 3i Inc., Palm Beach, FL, USA). During the 6-month healing period, patients were instructed not to wear their prosthesis to avoid transmucosal pressure on the augmented area. They were recommended to follow a soft diet, and were recalled every 2 weeks for follow-up. After implant placement, patients were called for follow-up every 6 months until the end of the study period (2 years).

The surgical procedures and implant surgery were performed by the same surgeon in order to avoid possible bias, while the follow-up assessment was performed by another blinded clinician. The exposure of the Ti-meshes was determined by visual inspection, and measured using a periodontal probe. A representative case with this reconstructive method is presented in Fig. 3.

Radiographical analysis

Radiographs (orthopantomography) and computed tomographies (CT) of the treated sites were taken before treatment to set up the baseline conditions, and 6 months post-operatively (see Fig. 4). The scanner was set at a resolution of a voxel size of 0.38 mm^3. ABB, craniofacial bone, and Ti mesh have very different radio-opacity, which enabled their easy differentiation on the CT scans after adjusting the brightness and contrast of the images. The bone volume was automatically quantified in both PRP and control groups using the SIMPlant 7.0 software (Columbia Scientific, Columbia, MD, USA) and therefore calibration of the examiner was not needed. Briefly, the images were transformed into binary and then the software was instructed to analyse the area of interest within the CT image.

Differences between pre-operative and post-operative bone height and width were measured to assure the alveolar bone augmentation obtained (Pieri et al. 2008). Implant osteo-integration and success were assessed by radiographical analysis of the implanted sites 6 months after their placement.

Histological analysis

In order to obtain qualitative data regarding the bone formed beneath the Ti meshes, a histological analysis was performed in the first two patients of each group. At the implant surgery appointment, biopsies were retrieved from the treated sites using a trephine burr ($\varnothing = 3.0\,mm \times 10.0\,mm$ in length) and the holes produced were used to accommodate the dental implants. Biopsies were fixed in 10% formaldehyde (pH 7.4) and stored at 4°C. After dehydration in ascending series of alcohol (60100%), biopsies were embedded in 2-hydroxy-ethyl-methacrylate (Technovit, Leica Microsystems GmbH, Wetzlar, Germany), then polymerized into ready-to-cut sample blocks.

A saw microtome (1200 Leica, Leica Microsystems GmbH) was used to cut 15-μm-thick histological sections from the blocks. Afterwards, surface staining was performed with basic fuchsine and methylene blue (Donath & Breuner 1982). The histological evaluation of bone neoformation was carried out by means of optical microscopy.

Statistical analysis

The distribution of patients' systemic conditions (diabetes, smoking, etc.) among clinical treatments' groups was assessed using the χ^2-test in order to evaluate comparability between groups, patients, and surgical sites. Moreover, *t*-student test analysis was used to find significant differences among the control and experimental groups concerning the Ti-mesh exposure and the amount of gained bone. A statistical software package (SPSS 17.0 Chicago, IL, USA) was used for the statistical analysis.

Results

No complications were registered during the surgical intervention. However, it has to be mentioned that the addition of PRP on the study group increased the volume of augmented tissue, and required a more extensive periosteal release incision to allow tension-free tight wound closure in all cases.

The bone augmentation, and implant placement procedures performed in this study are summarized in Table 2. A flow diagram of the trial is shown in Fig. 5. Mostly, healing was uneventful in all patients because none of them complained of significant pain and no signs or symptoms of infection were reported.

Successful alveolar ridge augmentations allowed the installation of one to three rough-surfaced implants per site (Osseotite, Biomet 3i Inc., Palm Beach, FL, USA) with diameters of 3.3–4.0 mm and lengths of 10.0–13.0 mm.

During the 24-month follow-up period, one case of graft failure and another of implant failure were registered in the control group, while the PRP group

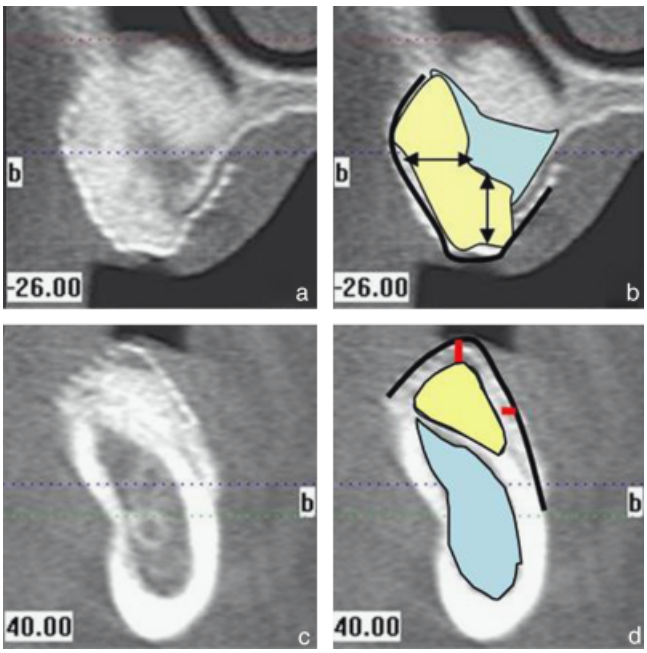

Fig 4. CT images of maxillary (a, b) and mandibular(c, d) ridge augmentation showing the residual ridge (blue), the augmented area (yellow) the Ti-mesh (black line), and the radiolucent space beneath the Ti-mesh (red arrows).

Table 2. Distribution of patients, alveolar ridge augmentations, complications, and implants by Ti-mesh covering

Treatment group	*n* patients/*n* grafts	Graft complications *n* patients/*n* grafts		ABH (mm)	ABW (mm)	BTH	BTW	Impl failed/ Impl total	Impl survival (%)
		mesh exposure	failure						
PRP	15/22	0/0**	0/0	3.5 ± 0.7**	4.1 ± 0.6**	0.5 ± 0.6	NRA	0/51	100
Control†	15/21	6/6	1/1	3.1 ± 0.8	3.7 ± 0.6	0.7 ± 0.6	NRA	1/46	97.3
			[1/1]*	[2.3 ± 0.2]*	[3.1 ± 0.2]*	[1.1 ± 0.9]*	[0.6 ± 0.5]*	[0/12]	[100]
Total	30/43	6/6	1/1	3.3 ± 0.2	3.9 ± 0.2			3/97	98.6

[]Values for exposed meshes.
*Significant differences between exposed and non exposed meshes ($p < 0.05$).
**Significant differences between PRP and control groups ($p < 0.05$).
†Patient who lost complete graft was excluded from statistical analysis.
ABH, average bone height gained; ABW, average bone width gained; Impl, implants placed; BTH, average height of the radiolucent space beneath the Ti-Mesh; BTW, average width of the radiolucent space beneath the Ti-Mesh; NRA, no radiographically appreciated.

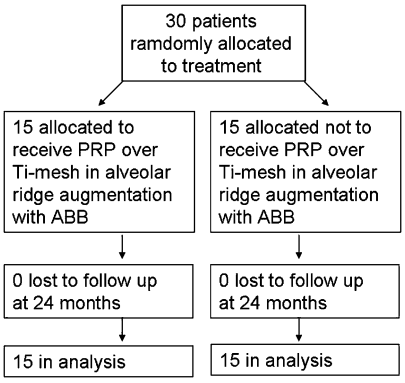

Fig 5. Flow diagram of participants through each stage.

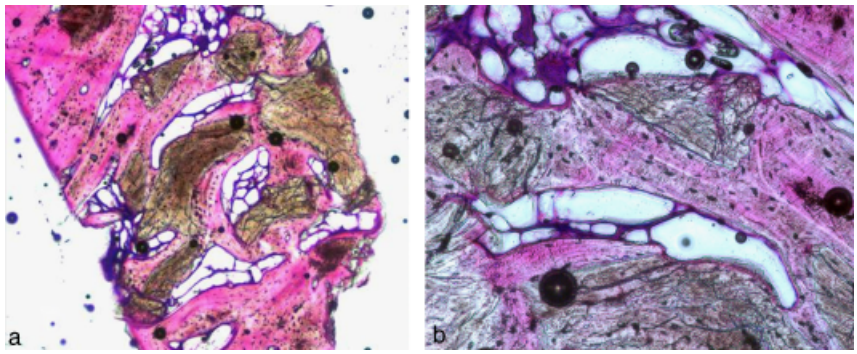

Fig 6. (a) Histological section of biopsy from the anorganic bovine bone (ABB)-treated site beneath the Ti-mesh from a patient of the PRP group. Newly formed bone is stained pink, while ABB granules appeared grey. Original magnification × 4. (b) New bone formation around ABB particles can be observed. Original magnification × 10.

presented no complications (see Tables 2 and 3). Moreover, the amount of bone height and width gained was higher in patients treated with PRP (Table 2). Successful implants were uncovered for fixed prosthetic rehabilitation and no implant complications were registered beyond this point.

Histological observations

Because of the small sample size, quantitative data could not be retrieved from the histological analysis. However, a qualitative analysis of the tissues regenerated beneath the Ti mesh was performed to complement the results obtained from the clinical study. Histological analysis of the regenerated sites revealed the presence of mineralized newly formed bone growing beneath the Ti mesh, surrounding the unresorbed ABB granules (Fig. 6). It is important to notice the absence of fibrous tissue and the complete enclosure of ABB granules within the new bone. These observations confirm the validity of ABB in regenerating bone beneath Ti-meshes for GBR.

Surgical complications

The main complication registered during the study was Ti-mesh exposure (Fig. 7). This condition was observed in six cases, all belonging to the control group (Table 3). In five of these cases, the exposed area was small ($\leqslant 10\,mm^2$) while in one patient a large exposure occurred ($> 10\,mm^2$). Most of the mesh exposures occurred within the first month after the surgical intervention (Table 3). Sites with exposed Ti meshes revealed little or no bone augmentation, and mesh exposure appeared to be a risk factor regarding graft failure (Tables 2 and 3). Indeed, only patients with Ti-mesh exposures presented obvious evidence of radiolucent space beneath the Ti mesh. Interestingly, no Ti-mesh exposures, or implant failures were observed in the PRP group. Light smoking (< 10 cigarettes per day) appeared not to be an important factor influencing the exposure of Ti meshes, at least within the present study, because only one of the patients with exposed Ti mesh was a light smoker. On the other hand, most of the patients who experience exposure of the Ti meshes had a thin gingival biotype, which may indicate the relevance of this condition (Table 3).

Survival of grafts

Pre and post-operative bone volumes were measured and compared between groups, and also between patients with Ti-mesh exposure *versus* no Ti-mesh exposure for statistical analysis. Vertical bone volume augmentation was defined as the distance between the top of the Ti mesh and the highest point of the crest post-operatively, while the horizontal bone volume augmentation was measure by the distance between the most buccal point of the residual bone and the Ti mesh. The radio-opacity of ABB made the difference between the residual

bone and the new regenerated bone easy (Fig. 3).

In some cases, in CT we observed sections a radiolucent space between the Ti mesh and the graft material indicating that bone augmentation did not occur all the way to the Ti mesh. There was no statistical difference between the two groups in terms of incidence of radiolucent spaces. However, control patients with Ti-mesh exposure showed a significant increase in the radiolucent space beneath the Ti meshes (Table 2).

Graft survival at the secondary surgery was sufficient to allow implant placement in all the patients included in the study except one in which an implant of 5.0 mm × 6.0 mm was placed because of a complete loss of the graft. However, we found that in five cases partial loss of bone graft occurred probably because of Ti-mesh exposure (Table 2).

All patients with PRP treatment did not show any Ti-mesh exposure while patients with no PRP treatment showed a significantly higher incidence (28%) of Ti-mesh exposures, ($p < 0.05$; with a statistical power of 86%) (Tables 2 and 3). Also, vertical and horizontal bone volume augmentation were significantly higher in the PRP group ($p < 0.05$).

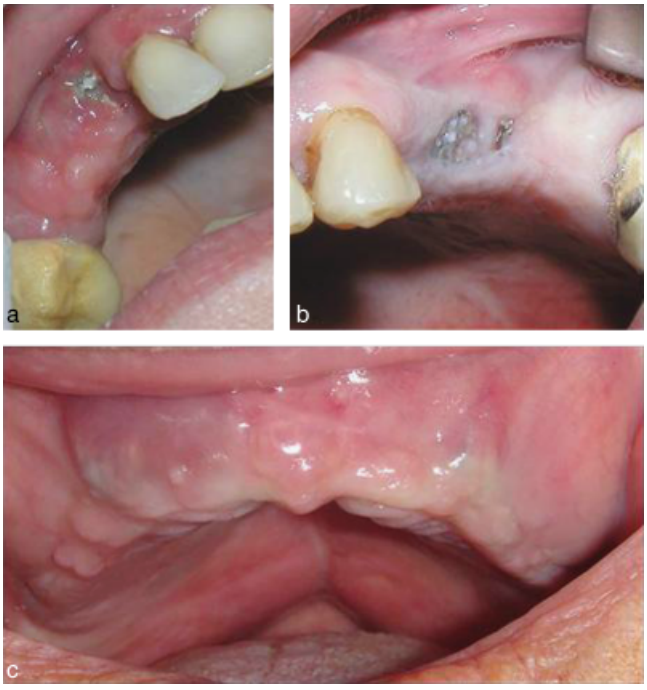

Fig 7. (a, b) Clinical photographs showing exposure of the Ti-mesh in patients from the control group. In spite of Ti-mesh exposure, a re-epithelization beneath the Ti-mesh is observed without signs of infection. (c) Soft tissue over Ti-mesh in a PRP-treated patient shows good healing without Ti-mesh exposure.

Implant survival rates

Implant survival was defined as the percentage of implants remaining in situ during the entire observation period. In this study, over 97 implants were placed, 95 remain in situ, and two failed in the control group, which gave a 97.5% implant survival rate (Table 2). We did not find differences between the PRP and control groups in terms of implant survival, and mesh exposure did not affect implant survival as well.

Discussion

Early studies on the Ti-mesh technique based on the use of autologous bone achieved promising results regarding bone volume augmentation and implant survival (Table 1). However, the use of autologous bone is restricted by its associated morbidity, surgical cost, and limitation of intraoral grafts.

Recent studies (Maiorana et al. 2001, Proussaefs et al. 2003, Proussaefs & Lozada 2006, Pieri et al. 2008) proposed the combination of autologous bone with ABB in order to reduce the need of bone harvesting from patients. These procedures achieved positive results that encouraged consequent trials evaluating the potential of using ABB alone in Ti-mesh vertical bone augmentations (Table 1).

In this study, ABB alone achieved similar results to those described previously for autologous grafts Ti-mesh GBR. Our results suggested that vertical and horizontal bone augmentation with Ti mesh, using ABB alone as graft material, is predictable and has a low incidence of major complications. These results have major implications; thus, by eliminating the need for autologous grafts in GBR procedures, a larger scope

Table 3. Detail of patients with Ti-mesh exposure

Gender	Age (years)	Light Smoker	Gingival biotype	Pre-operative conditions		Ti-mesh exposure		Post-operative conditions		Implants' Position
				BH (mm)	BW (mm)	size of exposure (mm^2)	time of exposure (days)	BH (mm)	BW (mm)	
M	55	No	Thin	10	3	< 10	30	10	5.5	13,23
F	42	No	Thin	9	2.5	< 10	15	11.5	5.5	24,26,27
F	62	No	Thin	7	6	< 10	15	10	6	46,47
F	58	No	Thin	9	3	< 10	60	11.5	6.5	35,37
F*	51	Yes	Thick	5	7	< 10	30	5	7	46*
M†	69	No	Thin	10	3	> 10†	15	10	5.5	23,24

*In this patient infection and total graft loss occurred, but still a 6.0 mm long × 5.0 mm wide implant was placed leaving the upper machined part of the implant over the bone residual bone crest.

†Large exposure area of the Ti-mesh, but it did not prevented implant placement

of patients may be treated. Moreover, unlike autologous grafts, ABB grafts proved to be dimensionally stable during the 2-year follow-up period. This is attributed to the combination of biocompatibility, osteoconductivity, and low resorption properties of ABB in vivo (Schlegel et al. 2003, Zitzmann et al 2001).

Ti-mesh exposure has been correlated to subsequent complications, such as graft resorption and loss, often impairing implant treatment (Von Arx 1996). These facts were confirmed in this study because graft resorption and loss occurred only in cases were exposure of the Ti-mesh occurred. The patients of the control group suffered from a rate of complications similar to that reported previously for GBR with autologous graft and Ti meshes (Tables 1 and 2). On the other hand, PRP may prevent the incidence of Ti-mesh exposure (Table 2).

It was observed that soft tissue healing was better when PRP was applied over the Ti-mesh compared with controls without PRP coverage. This was likely to translate into an improved gingival biotype and subsequent important resistance to Ti-mesh exposure.

There is a large controversy regarding the usefulness of PRP in bone regeneration procedures (Torres et al. 2009). Many studies have shown that PRP is unable to influence bone growth in cavities and defects. However, most of the dental literature has been focused on evaluating its effect on hard tissues, ignoring the potential benefits on surrounding soft tissues. PRP may enhance soft tissue healing by concentrating the large amounts of fibrin and growth factors secreted by platelets that increase both angiogenesis and fibroblast cell differentiation (Tamimi et al. 2007). PRP increases early wound strength by reducing the inflammatory phase of wound healing allowing early deposition of collagen, glycosaminoglycan, and fibronectin. Moreover, PRP has also been found to decrease patient morbidity and pain (Bashutski & Wang 2008).

Interestingly, gingival healing seemed to have an effect on the underlying bone formation. Bone grafts in the control group experienced resorption beneath the Ti mesh, while in the PRP group the amount of augmented bone was higher and no graft resorption was observed. We believe this phenomenon occurs mainly due to soft tissue protection rather than by direct effect on bone formation.

Conclusion

The results of the present study demonstrated that ABB alone may be used as graft material in the Ti-mesh technique, obtaining predictable results in localized ridge augmentation procedures. Moreover, applying PRP over the Ti mesh, may prevent complications such as mesh exposure, and graft failure.

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Clinical Relevance

Scientific rationale for the study: Osteoconductive properties of ABB have been described in many bone augmentation procedures with good results, and hence it seemed reasonable to expect similar outcomes when applied in the Ti-mesh technique. Although the use of PRP in bone regeneration is a moot question, its effects over soft tissue seems to be clearer. In this study, we compared both the efficacy of ABB alone and the effect of PRP over soft tissues in the Ti-mesh technique.

Principal findings: ABB alone produces sufficient bone volume augmentation for implant rehabilitation, and the use of PRP covering the Ti mesh can improve the soft tissue healing over the Ti mesh preventing its exposure.

Practical implications: ABB alone is an excellent graft material for the Ti-mesh technique that achieves alveolar bone augmentation without the need of autologous graft. Moreover, PRP can be an excellent tool for preventing mesh exposure in the Ti-mesh technique.