

Minimally invasive transcrestal sinus floor elevation with deproteinized bovine bone or β -tricalcium phosphate: a multicenter, double-blind, randomized, controlled clinical trial

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Abstract

Aims: To evaluate the outcomes of transcrestal sinus floor elevation (tSFE) performed with a minimally invasive procedure (*Smart Lift* technique) combined with the additional use of deproteinized bovine bone mineral (DBBM) or β -tricalcium phosphate (β -TCP).

Methods: In a multicenter randomized controlled trial, 38 sites in 38 patients were treated with the *Smart Lift* technique in association with DBBM ($n = 19$) or β -TCP ($n = 19$). The extent of the sinus lift (SL) and the height of the graft apical to the implant apex (aGH) were assessed on periapical radiographs taken immediately after surgery and at 6 months following surgery.

Results: (i) Substantial aGH and SL were observed immediately after surgery and at 6 months, with no significant differences between DBBM and β -TCP groups; (ii) a significant graft remodelling was observed from post-surgery to 6-months in the β -TCP group and (iii) limited incidence of complications as well as limited post-operative pain and discomfort were associated with the use of both graft materials.

Conclusions: The *Smart Lift* technique in conjunction with the additional use of either DBBM or β -TCP may provide a substantial elevation of the maxillary sinus floor along with limited post-surgical complications and post-operative pain/discomfort.

Key words: beta tricalcium phosphate; bone regeneration; dental implants; heterologous; maxillary sinus; minimally invasive; outcome assessment; surgical procedures; transplantation

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Conflict of interest and source of funding statement

The authors declare that they have no conflict of interest.

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When the dimensional alterations of the residual ridge occurring after the loss of posterior maxillary teeth limit the insertion of implants of desired length and diameter (Eufinger et al. 1997, 1999, Farina et al. 2011, Pramstraller et al. 2011), maxillary sinus floor elevation with a transcrestal approach (tSFE) represents a validated, effective option to vertically enhance the available bone through an access created in the edentulous bone crest (Tan et al. 2008, Del Fabbro et al. 2012). Recently, we proposed a minimally invasive procedure for tSFE, namely the *Smart Lift* technique, which is characterized by a transcrestal access to the sinus cavity by means of specially designed drills and osteotomes (Trombelli et al. 2008, 2010a,b) and allows for a predictable, apical displacement of the sinus floor (Trombelli et al. 2010b, 2012, Franceschetti et al. 2012, Franceschetti et al. 2013, G. Franceschetti, R. Farina, L. Minenna, G. Franceschetti & L. Trombelli, unpublished data) along with a limited post-operative morbidity (Trombelli et al. 2010b, 2012).

A recent systematic review questioned the adjunctive benefit of the additional use of a graft material in osteotome-based tSFE procedures with respect to implant survival rate (Del Fabbro et al. 2012). However, the only controlled clinical trial evaluating the performance of tSFE with and without graft material indicated that the apical displacement of the sinus floor obtained by tSFE may be enhanced and better maintained by placing a deproteinized bovine bone mineral (DBBM) graft under the elevated sinus membrane (Pjetursson et al. 2009a). To date, DBBM is one of the most investigated graft materials when used for sinus lift, in general, and tSFE, in particular (Jensen & Terheyden 2009, Del Fabbro et al. 2012). Previous studies showed its slow resorption/degradation rate following sinus lift (Lee et al. 2006, Traini et al. 2007, Mordenfeld et al. 2010, Pettinicchio et al. 2012), and indicated that it is associated with considerable sinus floor elevation when used in combination with tSFE (Zitzmann & Schäfer 1998, Deporter et al. 2005, Rodoni et al. 2005, Krennmair et al. 2007, Pjetursson et al. 2009a,b, Jensen & Terheyden 2009, Trombelli et al. 2010b, 2012).

β -tricalcium phosphate (β -TCP) graft materials may be gradually resorbed and replaced by newly formed bone at short time intervals (i.e. 6 months following grafting) (Ozyuvaci et al. 2003, Zerbo et al. 2004, Schulze-Späte et al. 2012). When used in conjunction with sinus floor elevation procedure with either transcrestal (Nkenke et al. 2002) or lateral approach (Meyer et al. 2009, Uckan et al. 2010), β -TCP grafts seem to effectively sustain bone regeneration resulting in a high long-term implant survival rate. To date, no studies comparing DBBM and β -TCP when used with tSFE are presently available.

Therefore, the present randomized controlled trial was conducted to compare the clinical outcomes and post-operative morbidity of the *Smart Lift* technique when used in association with DBBM or β -TCP.

Materials and Methods

Experimental design

The study was designed as a multicenter, double-blind, randomized, controlled clinical trial. All the clinical procedures were performed in full accordance with the Declaration of Helsinki as revised in Tokyo (2004) and the Good Clinical Practice Guidelines (GCPs). Each patient provided a written informed consent before participation. This manuscript was prepared in full accordance with CONSORT guidelines for reporting randomized controlled studies (<http://www.consort-statement.org/>).

Patients were consecutively recruited and treated at 1 University centre and four private dental offices from July 2010 to October 2012. Surgical procedures were performed by five experienced clinical operators (L.T., C.S., L.M., O.R. and R.D.R.) with previous training in tSFE procedures. More specifically, all operators had been previously involved in research protocols on the *Smart Lift* technique (Franceschetti et al. 2012, 2013).

Study population

Inclusion criteria for patient eligibility were as follows: (i) age ≥ 18 years; (ii) systemic and local conditions suitable for implant placement and

sinus floor elevation procedures; (iii) indication for the placement of at least one implant with a length of 8 mm or more simultaneously with tSFE and (iv) patient willing and fully capable to comply with the study protocol.

Inclusion criteria for site eligibility were as follows: (i) at least 6 months elapsed from tooth loss; (ii) residual bone height (RBH) (as intra-operatively assessed with the *Probe Osteotome*) amounting to 4 mm or more and (iii) absence of endodontic lesions at teeth adjacent to the implant site.

Allocation and allocation concealment

All eligible patients were randomly assigned to receive DBBM (Bio-Oss[®] spongiosa granules 0.25–1.0 mm; Geistlich Pharma, AG, Wolhusen, Switzerland) or β -TCP (Ceros[®] β -TCP granules 0.5–0.7 mm; Thommen Medical, Waldenburg, Switzerland). Assignment was performed by a central study registrar according to a computer-generated randomization list. Block randomization was applied to obtain an equal number of sites with surgical working length (sWL, i.e. the anatomical distance between the bone crest and the sinus floor in the exact location where the implant had to be placed as assessed with the *Probe Osteotome*) ≤ 5 and ≥ 6 mm within each treatment group. To conceal assignment from the clinical operator until the time requiring application of DBBM or β -TCP during the surgical procedure, sealed, numbered envelopes containing the treatment assignment to the specific subjects were supplied to each centre. The examiner and the patient were kept blinded as to treatment allocation.

Surgical procedure

Before sinus lift procedure, all oral diseases, including periodontal disease, were thoroughly treated. The RBH at the site where the implant was supposed to be inserted was measured on a periapical radiograph or a CT scan prior to surgery.

The preparation of the implant site was performed according to a standardized sequence of instruments which had been extensively described in previous studies (Trombelli et al. 2010a,b, 2012, Franceschetti

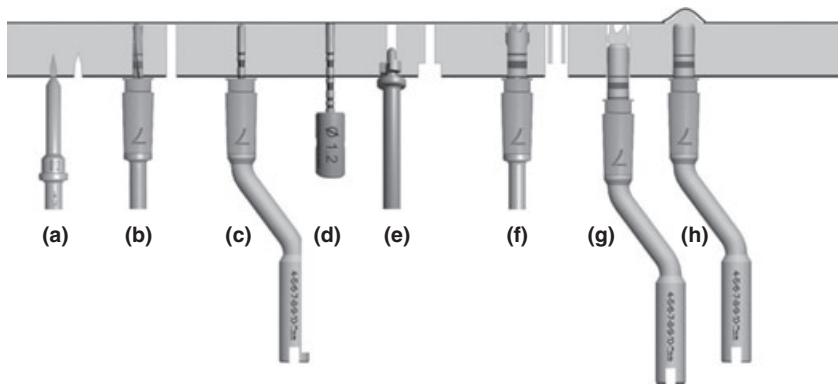


Fig. 1. Smart lift procedure: sequence of rotating and manual instruments. (a) The *Locator Drill* is used to perforate the cortical bone at the site where the implant has to be placed. (b) The *Probe Drill* is used to define the orientation of the implant, with an adjustable stop device set at least 1 mm shorter than the radiographic working length. (c) The *Probe Osteotome* is gently forced in an apical direction until the cortical bone resistance of the sinus floor is met, thus providing the “surgical working length” (sWL). The working action of all instruments included in the succeeding surgical steps is set at the sWL using the proper adjustable stop device. (d) A radiographic pin may be used to check the orientation of the prepared site by means of a periapical radiograph. (e) The “*Guide Drill*” is used to create a crestal countersink. (f) The *Smart Lift Drill* produces a bone core up to the sinus floor. (g, h) The bone core is condensed and malleted to fracture the sinus floor by means of the *Smart Lift Elevator*. A graft biomaterial may be placed into the sinus cavity by gradual increments with the *Smart Lift Elevator* (reprinted from Trombelli et al. 2012).

etti et al. 2013) (Fig. 1a–h, Video S1). Immediately after the fracture of the sinus floor with the *Smart Lift Elevator*, either DBBM or β -TCP was grafted into the sinus by gradual increments with the *Smart Lift Elevator*.

For each site, operators were instructed to use a pre-determined amount of graft material which was related to the extent of sinus floor elevation that had to be achieved. In our previous studies where the *Smart Lift* technique had been used in conjunction with graft materials, we observed a mean sinus elevation of approximately 6 mm (i.e. 4 mm of antral implant penetration (IP) plus 2 mm of graft material apical to the implant) (Trombelli et al. 2012, Franceschetti et al. 2013). Therefore, we calculated the amount of biomaterial (in grams) that was needed to fill the volume of a hemisphere with a radius of 6 mm, after subtracting the volume of the portion of a 4-mm-diameter implant protruding into the sinus for 4 mm (i.e. about 0.4 cm^3). As 1 g of graft material granules corresponds to 2.0 cm^3 of DBBM and 1.3 cm^3 of β -TCP, approximately 0.2 g for DBBM and 0.3 g for β -TCP are needed to fill a volume of 0.4 cm^3 . Smaller or larger amount of

graft biomaterial was then used according to lower or higher, respectively, IP into the sinus.

Immediately after the completion of the sinus lift procedure, all patients received Element[®] RC Inicell implants (Thommen Medical AG, Waldenburg, Switzerland). The implant was inserted with either submerged or transmucosal healing protocol.

All patients were prescribed a single dose of rescue anti-inflammatory drug (i.e. ibuprofen 600 mg tablets) on the first post-operative day (evening) and were instructed to assume it pro re nata for the following six post-operative days. A 0.12% chlorhexidine mouthrinse, to be used 10 ml three times in a day for 3 weeks, was also prescribed. Sutures were removed 7 days after surgery.

Experimental parameters

Surgical and post-surgical complications

The incidence of membrane perforation was evaluated by the Valsalva manoeuvre. Other surgical or post-surgical complications associated with the sinus lift procedure, including Benign Paroxysmal Positional Vertigo (BPPV), post-operative infection, post-operative haemorrhage, nasal

bleeding, blocked nose, haematomas, either assessed by the operator or reported by the patient, were also recorded.

Patient-centred outcomes

The following patient-related outcomes were also recorded:

- level of discomfort perceived by the patient ($\text{VRS}_{\text{discomfort}}$): recorded immediately after surgery on a 5-point visual rating scale (VRS) ranging from “0 – no discomfort” to “4 – very severe discomfort”;
- willingness to undergo the same type of surgery ($\text{VRS}_{\text{willingness}}$): recorded immediately after surgery on a 4-point visual rating scale (VRS) ranging from “0 – I will never undergo this type of surgery again” to “3 – no problem to repeat surgery if needed”;
- level of pain perceived by the patient (VAS_{pain}): recorded daily (evening) for 7 days following surgery on a 100-mm visual analogue scale (VAS) (ranging from “no pain” to “intolerable pain”);
- dosage of rescue anti-inflammatory drug (i.e. number of ibuprofen 600 mg tablets) assumed by the patient from the 2nd to the 7th post-operative day.

Duration of the tSFE procedure

The duration of the tSFE procedure was recorded as the time (in minutes) elapsed from cortical perforation with the *Locator Drill* (Fig. 1a) to the completion of the grafting procedure (i.e. immediately before implant placement) (Fig. 1 h).

Radiographic measurements

Radiographs were obtained immediately after surgery and at 6 months with a paralleling technique using a Rinn film holder with a rigid film-object X-ray source, then scanned and digitized. Using an image-processing software, digitized images were stored at a resolution of 600 dpi. On radiographs taken immediately after surgery, the following radiographic measurements were performed using a digital calliper:

- radiographic implant length (rIL): distance (in mm) between the implant shoulder and the

implant apex as assessed at the mid portion of the implant;

- RBH at the mesial (mRBH) and distal (dRBH) aspects of the implant: distance (in mm) between the mesial and distal aspect of the implant shoulder, respectively, and the sinus floor;
- height of the graft apically (aGH): distance (in mm) occupied by a radio-opaque area between the implant apex and the sinus floor as assessed at the mid portion of the implant.

To account for radiographic distortion, radiographic measurements (i.e. mRBH, dRBH and aGH) on each radiograph were adjusted for a coefficient derived from the ratio: true length of the implant/rIL. aGH was re-assessed at 6 months after adjustment for 6-month rIL.

For each patient, the following derived radiographic parameters were obtained:

- RBH: calculated as the mean value of mRBH and dRBH;
- IP: calculated as the difference between rIL and RBH;
- extent of the sinus lift (SL): calculated as the sum of IP and aGH.

On 6-month radiographs, a qualitative assessment of the maturation of the grafted area was performed by using the sinus grafting remodelling index (SGRI) (Bragger et al. 2004).

All measurements were performed by a single trained examiner (G.F.) who had previously undergone a calibration session for aGH assessment on a sample of 15 patients not included in the study (Cohen's k -coefficient for intra-examiner agreement: 0.981) and had participated as clinical examiner in previous clinical trials using the same radiographic measurements (Trombelli et al. 2012, Franceschetti et al. 2013, G. Franceschetti, R. Farina, L. Minenna, G. Franceschetti & L. Trombelli, unpublished data).

Statistical analysis

The statistical analysis was conducted test the null hypothesis that there was no statistically significant and clinically meaningful difference between the two investigated

treatments (*Smart Lift* with DBBM versus *Smart Lift* with β -TCP). Data were entered in a unique database file (STATISTICA[®] software version 7.1; StatSoft, Italia s.r.l., Vigonza, Italy) and expressed as median and inter-quartile range (IR). The patient was regarded as the statistical unit. Therefore, one implant was randomly chosen when two or more implants (either adjacent or not) were placed concomitantly with the tSFE procedure in the same patient. 6-month aGH and 6-month SL were regarded as the primary and secondary outcome variable respectively.

The Kolmogorov–Smirnov test was used to assess the normal distribution fitting of each variable. Within-group comparisons (pre-surgery versus 6 months) were performed with Wilcoxon test and Kruskal–Wallis ANOVA. Inter-group comparisons were performed with Fisher's exact test, χ^2 test and Mann–Whitney U -test.

A multivariate model was built with 6-month aGH and 6-month SL as outcome variables and gender, type of graft and clinical operator as predictors. A Wald test was adopted to test significance of each factor, whereas the significance of the model was tested by comparing the reduction in the $-2\log$ likelihood of the model with a χ^2 distribution. A specific software was used (MIWin 2.27, Centre for multilevel modelling, University of Bristol, UK).

The level of statistical significance was fixed at 0.05. A web-based software (<http://www.dssresearch.com/KnowledgeCenter/toolkit/calculators/statisticalpowercalculators.aspx>) was used for the calculation of the statistical power of the study. According to a sample size calculation performed with a two-sided parametric test (Lehmann 2007), a per-protocol study population of 32 patients (i.e. 16 patients per treatment group) was needed to detect a significant inter-group difference (at $p = 0.05$) with a statistical power of 80%, assuming a standard deviation in aGH of 1.0 mm and an expected inter-group difference in aGH of 1.0 mm on the basis of data previous trials evaluating aGH following *Smart Lift* procedures in association with different graft materials (Trombelli et al. 2012).

Results

Study population

All 38 patients included in the study completed the experimental phase. Nineteen patients received DBBM, whereas the remaining 19 patients received β -TCP (Table 1). sWL was 6.0 (5.0–7.0) mm in DBBM group and 6.0 (5.0–7.5) mm in β -TCP group. No significant differences in sWL, implant site location, implant length and diameter were seen between groups (Table 1).

At 6 months after surgery, no implant failure was recorded, and the prosthetic rehabilitation was finalized at all implant sites.

Duration of the tSFE procedure

The duration of the tSFE procedure was 20.0 (15.5–28.0) min. and 20.5 (15.0–33.0) min. in DBBM and β -TCP group, respectively, with no significant inter-group differences.

Surgical and post-surgical complications

Membrane perforation was detected at Valsalva manoeuvre in four cases in β -TCP group and one case in DBBM group. No statistically significant difference in the incidence of membrane perforation was observed between treatment groups. Membrane perforation was treated with the insertion of a surgical haemostatic dressing (Gingostat[®]; GABA Vevas, S. Giuliano Milanese, Milan, Italy) through the crestal access, and systemic antibiotics (amoxicillin + clavulanic acid, 1 g t.i.d. for 6 days) was administered post-operatively. In all cases, the grafting procedure was completed, the implant was inserted and the case included for analysis.

Over the course of the first post-operative week, one patient in the β -TCP group presented with BPPV which was homolateral and spontaneously subsided within the first week following surgery.

Patient-centred outcomes

Patient-centred outcomes are reported in Table 2 and Fig. 2. VRS_{discomfort} was similarly low in both groups (Table 2). VRS_{discomfort} was 0 in 11 patients in the DBBM group, and 10 patients in the β -TCP group.

Table 1. Characterization of patients and implants in the DBBM and the β -TCP groups

	DBBM group (n = 19)	β -TCP group (n = 19)	p (Mann–Whitney)	p (χ^2 or Fisher's exact test)
Patients				
Age (years) (median and IR)	55.0 (44.5–59.5)	54.5 (45.0–57.0)	0.893	
Gender (frequency of males/females)	5/14	10/9		0.097
Smoking status (frequency of current smokers/ former smokers/non-smokers)	7/2/10	5/4/10		0.559
Daily cigarette consumption (cigarettes/day) (median and IR)	10.0 (10.0–15.0)	10.0 (10.0–20.0)	0.876	
Smoking exposure (pack \times years) (median and IR)	13.5 (8.8–15.0)	10.0 (10.0–25.0)	1	
Implant sites				
Site location (frequency of 1st pre-molar/2nd pre-molar/1st molar/2nd molar)	1/4/14/0	0/5/14/0		0.857
sWL (frequency of sites)				
4 mm	3	3		
5 mm	5	6		
6 mm	4	2		
7 mm	4	3		
8 mm	2	4		
9 mm	1	1		
sWL (mm) (median and IR)	6.0 (5.0–7.0)	6.0 (5.0–7.5)	1	
Implants				
Implant length (mm) (median and IR)	9.5 (9.5–11.0)	9.5 (9.5–11.0)	0.624	
Implant diameter (mm) (median and IR)	4.0 (4.0–4.0)	4.0 (4.0–4.5)	0.452	

β -TCP, β -tricalcium phosphate; DBBM, deproteinized bovine bone mineral.

VAS_{pain} was similarly low over time, and significantly decreased at 7 days in both DBBM and β -TCP group ($p < 0.001$ for both groups) (Fig. 2). A similarly low amount of post-surgery anti-inflammatory tablets was assumed in both groups (Table 2).

Radiographic measurements

Radiographic measurements are reported in Table 3. Post-surgery SL and aGH amounted to 6.1 (5.6–6.9) mm and 1.5 (1.2–2.3) mm, respectively, in the DBBM group, and 6.8 (6.2–7.5) mm and 2.2 (1.6–3.1) mm, respectively, in the β -TCP group. At 6 months, a significant reduction in aGH and SL with respect to post-surgery values was observed in the β -TCP group. No significant intergroup difference in aGH and SL was observed at 6 months.

SGRI was 1 (1–2) in both DBBM group and β -TCP group ($p = 0.488$). The score was 0 at 1 site, 1 at 11 sites and 2 at 7 sites in the DBBM group, whereas 1 at 10 sites and 2 at 9 sites in the β -TCP group. The pre-surgery, post-surgery and 6-month radiographic aspect of two paradigmatic cases treated with DBBM and β -TCP are illustrated in Fig. 3.

Multivariate analysis

Gender was not a predictor for both outcome variables and thus not included in the final model. The type of graft material was not significant for either 6-month aGH ($p = 0.38$) or 6-month SL ($p = 0.63$). A significant effect of the clinical operator on 6-month aGH was observed ($p = 0.03$), the difference between the operators with the highest and lowest 6-month aGH being 1.35 mm. The clinical operator did not have a significant impact on 6-month SL ($p = 0.08$). The final model was significant ($p = 0.01$, $r^2 = 0.55$).

Discussion

The results of the present randomized controlled trial indicated that both DBBM and β -TCP may be used to contribute sinus floor elevation with a transcrestal approach. The specific β -TCP graft material has been selected due to its positive performance when used in conjunction with sinus lift procedures (Lindenmüller & Lambrecht 2006). The additional use of both graft materials led to substantial SL, whereas the use of a standardized transcrestal approach minimized post-operative complications as well as patient pain and discomfort. A significant graft

remodelling was observed from immediate post-surgery to 6-months after surgery in the β -TCP group.

In our material, the extent of SL led to a concomitant placement of an implant of the programmed dimensions in cases where the RBH would have otherwise prevented a successful implant-supported rehabilitation. These results compared with data from previous studies where the *Smart Lift* technique had been used in conjunction with different graft materials in varying clinical settings (Trombelli et al. 2012, Franceschetti et al. 2012, 2013). The consistency in achieving a substantial vertical bone gain for implant placement may be ascribed to the standardized sequence of instruments of the surgical procedure. In accordance with this consideration, our multivariate analysis indicated that the clinical operator had no impact on the variability in 6-month SL. Overall, these results seem to support the predictability of the *Smart Lift* technique in association with graft materials to obtain a substantial sinus floor elevation.

Interestingly, the results of the multivariate analysis support the hypothesis that aGH contribution to the overall vertical extent of sinus lift (i.e. SL) may vary depending on

Table 2. Patient-centred outcomes

Post-surgery discomfort (VRS _{discomfort})	DBBM group (n = 19) Median (IR)	β-TCP group (n = 19) Median (IR)*	p (Mann–Whitney)
0 – no discomfort	0 (0–1)	0 (0–1)	0.707
1 – slight discomfort			
2 – mild discomfort			
3 – severe discomfort			
4 – very severe discomfort			
Willingness to undergo the same surgery (VRS _{willingness})	No. patients	No. patients*	(Fisher's exact test)
3 – “No problem to repeat surgery if needed”	18	15	0.604
2 – “I will repeat the surgery, but I would prefer to procrastinate it”	0	1	
1 – “I will repeat the surgery, but I expect to suffer severe pain”	1	1	
0 – “I will never undergo this type of surgery again”	0	1	
Dosage of rescue anti-inflammatory drug (ibuprofen 100 mg tablets)	No. tablets median and IR (no. patients assuming the drug)	No. tablets * median and IR (no. patients assuming the drug)	(Mann–Whitney)
2nd post-operative day	0 (0–1) (7 patients)	1 (0–1) (10 patients)	0.303
3rd post-operative day	0 (0–0) (4 patients)	0 (0–1) (6 patients)	0.363
4th post-operative day	0 (0–0) (2 patients)	0 (0–0) (3 patients)	0.778
5th post-operative day	0 (0–0) (2 patients)	0 (0–0) (2 patients)	0.975
6th post-operative day	0 (0–0) (1 patient)	0 (0–0) (1 patient)	0.975
7th post-operative day	0 (0–0) (1 patient)	0 (0–0) (1 patient)	0.975

*One patient in β-TCP group did not report data.

β-TCP, β-tricalcium phosphate; DBBM, deproteinized bovine bone mineral.

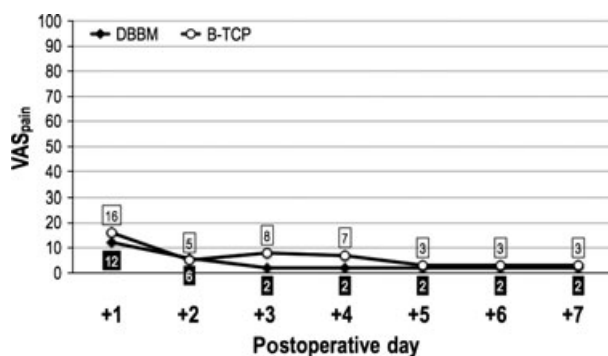


Fig. 2. VAS_{pain} in deproteinized bovine bone mineral (DBBM) and β-tricalcium phosphate (β-TCP) groups.

potential differences in operator skill and experience (in terms of number of years of clinical activity and number of treated cases prior to the involvement in this trial) in implant surgery, in general, and in the appli-

cation of the *Smart Lift* technique, in particular. The clinical performance of many health technologies, especially those based on the intervention of an operator and/or the application of instruments/devices,

varies overtime (Russell 1995). This phenomenon, defined as the *learning curve*, commonly shows improved performance with time, and may be influenced by several factors including the improved familiarity of the operator with the technology (Cuschieri 1995, Bouchard et al. 1996, Mowatt et al. 1998). The learning curve of the *Smart Lift* technique has been recently evaluated in a specifically dedicated study and the results will be reported elsewhere (G. Franceschetti, R. Farina, L. Minenna, G. Franceschetti & L. Trombelli, unpublished data).

All sites undergoing tSFE received an implant with a microrough, sand-blasted and thermal acid-etched surface that was conditioned immediately before implant placement to enhance its surface energy,

Table 3. Radiographic measurements

	DBBM group (n = 19)	β -TCP group (n = 19)	p (Mann-Whitney)
RBH (mm)	5.4 (5.0–6.1)	5.5 (5.2–6.8)	0.488
IP (mm)	4.1 (4.0–5.2)	4.2 (3.9–4.8)	0.564
post-surgery aGH (mm)	1.5 (1.2–2.3)	2.2 (1.6–3.1)	0.070
6-month aGH (mm)	1.6 (1.1–2.3)	2.1 (1.3–2.6)	0.470
p	0.660	0.039	
post-surgery SL (mm)	6.1 (5.6–6.9)	6.8 (6.2–7.5)	0.154
6-month SL (mm)	6.1 (5.8–7.1)	6.4 (5.5–6.9)	0.954
p	0.756	0.038	

Data are expressed as median (IR).

β -TCP, β -tricalcium phosphate; DBBM, deproteinized bovine bone mineral, RBH, residual bone height.

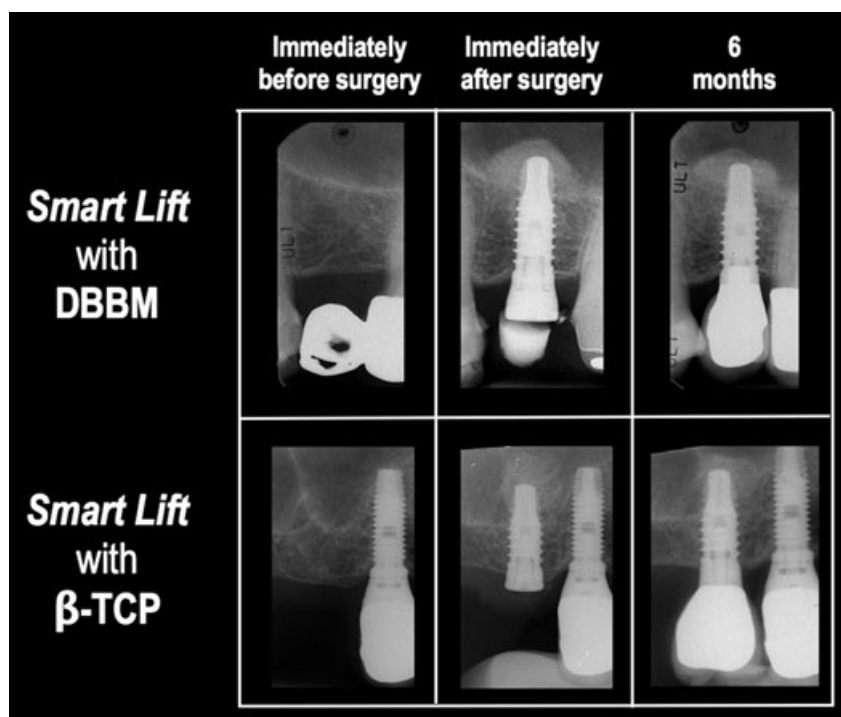


Fig. 3. Radiographic aspect of two sites undergone the Smart Lift procedure in association with deproteinized bovine bone mineral (DBBM) or β -tricalcium phosphate (β -TCP).

wettability and protein adsorption capacity (Tugulu et al. 2010). The potential benefits of this novel implant surface treatment on the early phases of osseointegration and graft maturation in the space underneath the elevated sinus membrane, however, are presently unknown and need to be investigated.

The *Smart Lift* procedure was associated with a low incidence of complications, post-operative discomfort and pain in both DBBM and β -TCP groups, and the study failed to find significant differences between groups. These findings,

which were comparable to those in previous studies where different biomaterials were used in combination with the same tSFE procedure (Trombelli et al. 2010b, 2012), indicate that the graft material per se may not have a relevant influence on patient-related outcomes of the *Smart Lift* procedure.

At 6 months, a statistically significant decrease in both aGH and SL was observed in β -TCP group compared to post-surgery. The reduction in the radio-opaque area evident in the apical part of the implant in the β -TCP group, but not in the DBBM

group, may be partly related to intergroup differences in the rate of resorption/degradation and replacement of the materials by newly formed tissues. In this respect, a recent meta-analysis on the fate of osteoconductive materials grafted into an augmented sinus at the histomorphological level showed that the total bone volume increased over time for both DBBM and β -TCP, suggesting that the two graft materials are at least partially resorbed and replaced by bone (Handschel et al. 2009). However, a variable graft remodelling was reported when the two materials had been used for sinus floor elevation, being faster for β -TCP (Ozyuvaci et al. 2003, Zerbo et al. 2004, Kurkcu et al. 2012, Schulze-Späte et al. 2012) and slower for DBBM (Lee et al. 2006, Traini et al. 2007, Pjetursson et al. 2009a, Mordenfeld et al. 2010, Pettinicchio et al. 2012, Kurkcu et al. 2012, Trombelli et al. 2012). Recently, a histomorphometric study on sinus floor elevation showed that DBBM resulted in a greater proportion of newly formed bone compared to β -TCP at 6 months (Kurkcu et al. 2012). Overall these observations seem to suggest that the differences in aGH variations observed in this study may indeed reflect the variability in the dynamics of graft replacement and subsequent newly bone formation between DBBM and β -TCP.

In conclusion, the results of this study indicate that both DBBM and β -TCP may safely support sinus lift procedures when performed with the *Smart Lift* technique. However, the study failed to find significant differences in clinical outcomes and post-operative morbidity between sites treated with DBBM and β -TCP.

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References

- Bouchard, S., Barkun, A. N., Barkun, J. S. & Joseph, L. (1996) Technology assessment in laparoscopic general surgery and gastrointestinal endoscopy: science or convenience? *Gastroenterology* **110**, 915–925.
- Bragger, U., Gerber, C., Joss, A., Haenni, S., Meier, A., Hashorva, E. & Lang, N. P. (2004) Patterns of tissue remodeling after placement of ITI dental implants using an osteotome technique: a longitudinal radiographic case cohort study. *Clinical Oral Implants Research* **15**, 158–166.
- Cuschieri, A. (1995) Whither minimal access surgery: tribulations and expectations. *American Journal of Surgery* **169**, 9–19.
- Del Fabbro, M., Corbella, S., Weinstein, T., Ceresoli, V. & Taschieri, S. (2012) Implant survival rates after osteotome-mediated maxillary sinus augmentation: a systematic review. *Clinical Implant Dentistry and Related Research* **14** (Suppl. 1), e159–e168.
- Deporter, D. A., Caudry, S., Kermalli, J. & Adegbembo, A. (2005) Further data on the predictability of the indirect sinus elevation procedure used with short, sintered, porous-surfaced dental implants. *International Journal of Periodontics and Restorative Dentistry* **25**, 585–593.
- Eufinger, H., König, S. & Eufinger, A. (1997) The role of alveolar ridge width in dental implantology. *Clinical Oral Investigations* **1**, 169–177.
- Eufinger, H., König, S., Eufinger, A. & Machten, E. (1999) [Significance of the height and width of the alveolar ridge in implantology in the edentulous maxilla. Analysis of 95 cadaver jaws and 24 consecutive patients]. *Mund-, Kiefer- und Gesichtschirurgie* **3**(Suppl. 1), S14–S18.
- Farina, R., Pramstraller, M., Franceschetti, G., Pramstraller, C. & Trombelli, L. (2011) Alveolar ridge dimensions in maxillary posterior sextants: a retrospective comparative study of dentate and edentulous sites using computerized tomography data. *Clinical Oral Implants Research* **22**, 1138–1144.
- Franceschetti, G., Farina, R., Minenna, L., Rizzi, A., Stacchi, C., Di Lenarda, R., Di Raimondo, R., Minenna, P., Riccardi, O.R., Cucchi, A. & Trombelli, L. (2012) Radiographic outcomes of sinus floor elevation performed with a minimally-invasive technique. *EUROPERIO* **7**. Wien, Austria; June 7–9 (abstract).
- Franceschetti, G., Farina, R., Stacchi, C., Di Lenarda, R., Di Raimondo, R. & Trombelli, L. (2013) Radiographic outcomes of transcresal sinus floor elevation performed with a minimally-invasive technique in smoker and non-smoker patients. *Clinical Oral Implants Research*. doi: 10.1111/clr.12188.
- Handschel, J., Simonowska, M., Naujoks, C., Deppe, R. A., Ommerborn, M. A., Meyer, U. & Kübler, N. R. (2009) A histomorphometric meta-analysis of sinus elevation with various grafting materials. *Head & Face Medicine* **11**, 5–12.
- Jensen, S. S. & Terheyden, H. (2009) Bone augmentation procedures in localized defects in the alveolar ridge: clinical results with different bone grafts and bone-substitute materials. *International Journal of Oral and Maxillofacial Implants* **24** (Suppl.), 218–236.
- Krennmair, G., Krainhöfner, M., Schmid-Schwab, M. & Piehslinger, E. (2007) Maxillary sinus lift for single implant-supported restorations: a clinical study. *International Journal of Oral and Maxillofacial Implants* **22**, 351–358.
- Kurucu, M., Benlidayi, M. E., Cam, B. & Sertdemir, Y. (2012) Anorganic bovine-derived hydroxyapatite vs -tricalcium phosphate in sinus augmentation: a comparative histomorphometric study. *Journal of Oral Implantology* **38**, 519–526.
- Lee, Y. M., Shin, S. Y., Kim, J. Y., Kye, S. B., Ku, Y. & Rhyu, I. C. (2006) Bone reaction to bovine hydroxyapatite for maxillary sinus floor augmentation: histologic results in humans. *International Journal of Periodontics and Restorative Dentistry* **26**, 471–481.
- Lehmann, E. L. (2007) *Nonparametrics: Statistical Methods Based on Ranks*, pp. 76–81. Berlin: Springer-Verlag.
- Lindenmüller, I. H. & Lambrecht, J. T. (2006) Sinus floor elevation and implantation - a retrospective study. *Schweizer Monatsschrift für Zahnmedizin* **116**, 142–149. (article in german).
- Meyer, C., Chatelain, B., Benarroch, M., Garnier, J. F., Ricbourg, B. & Camponovo, T. (2009) Massive sinus-lift procedures with beta-tricalcium phosphate: long-term results. *Revue de Stomatologie et de Chirurgie Maxillofaciale* **110**, 69–75.
- Mordenfeld, A., Hallman, M., Johansson, C. B. & Albrektsson, T. (2010) Histological and histomorphometrical analyses of biopsies harvested 11 years after maxillary sinus floor augmentation with deproteinized bovine and autogenous bone. *Clinical Oral Implants Research* **21**, 961–970.
- Mowatt, G., Bower, D. J., Brebner, J. A., Cairns, J. A., Grant, A. M. & McKee, L. (1998) When is the 'right' time to initiate an assessment of a health technology? *International Journal of Technology Assessment in Health Care* **14**, 372–386.
- Nkenke, E., Schlegel, A., Schultze-Mosgau, S., Neukam, F. W. & Wiltfang, J. (2002) The endoscopically controlled osteotome sinus floor elevation: a preliminary prospective study. *International Journal of Oral and Maxillofacial Implants* **17**, 557–566.
- Ozyuvaci, H., Bilgiç, B. & Firatli, E. (2003) Radiologic and histomorphometric evaluation of maxillary sinus grafting with alloplastic graft materials. *Journal of Periodontology* **74**, 909–915.
- Pettinicchio, M., Traini, T., Murmura, G., Caputi, S., Degidi, M., Mangano, C. & Piattelli, A. (2012) Histologic and histomorphometric results of three bone graft substitutes after sinus augmentation in humans. *Clinical Oral Investigations* **16**, 45–53.
- Pjetursson, B. E., Ignjatovic, D., Matuliene, G., Bragger, U., Schmidlin, K. & Lang, N. P. (2009a) Transalveolar maxillary sinus floor elevation using osteotomes with or without grafting material. Part II: Radiographic tissue remodeling. *Clinical Oral Implants Research* **20**, 677–683.
- Pjetursson, B. E., Rast, C., Bragger, U., Schmidlin, K., Zwahlen, M. & Lang, N. P. (2009b) Maxillary sinus floor elevation using the (transalveolar) osteotome technique with or without grafting material. Part I: implant survival and patients' perception. *Clinical Oral Implants Research* **20**, 667–676.
- Pramstraller, M., Farina, R., Franceschetti, G., Pramstraller, C. & Trombelli, L. (2011) Ridge dimensions of the edentulous posterior maxilla: a retrospective analysis of a cohort of 127 patients using computerized tomography data. *Clinical Oral Implants Research* **22**, 54–61.
- Russell, I. (1995) Evaluating new surgical procedures. *BMJ* **311**, 1243–1244.
- Rodoni, L. R., Glauser, R., Feloutzis, A. & Hämmerle, C. H. (2005) Implants in the posterior maxilla: a comparative clinical and radiologic study. *International Journal of Oral and Maxillofacial Implants* **20**, 231–237.
- Schulze-Späte, U., Dietrich, T., Kayal, R. A., Hasturk, H., Dobeck, J., Skobe, Z. & Dibrat, S. (2012) Analysis of bone formation after sinus augmentation using β -tricalcium phosphate. *Compendium of Continuing Education in Dentistry* **33**, 364–368.
- Tan, W.C., Lang, N.P., Zwahlen, M. & Pjetursson, B.E. (2008) A systematic review of the success of sinus floor elevation and survival of implants inserted in combination with sinus floor elevation. Part II: transalveolar technique. *Journal of Clinical Periodontology*, **35**(8 Suppl.), 241–254.
- Traini, T., Valentini, P., Iezzi, G. & Piattelli, A. (2007) A histologic and histomorphometric evaluation of anorganic bovine bone retrieved 9 years after a sinus augmentation procedure. *Journal of Periodontology* **78**, 955–961.
- Trombelli, L., Minenna, P., Franceschetti, G., Farina, R. & Minenna, L. (2008) SMART-LIFT: una nuova procedura minimamente invasiva per la elevazione del pavimento del seno mascellare. *Dental Cadmos* **76**, 71–83 (article in italian).
- Trombelli, L., Minenna, P., Franceschetti, G., Minenna, L., Iro, A. & Farina, R. (2010a) Minimally invasive technique for transcresal sinus floor elevation: a case report. *Quintessence International* **41**, 363–369.
- Trombelli, L., Minenna, P., Franceschetti, G., Minenna, L. & Farina, R. (2010b) Transcresal sinus floor elevation with a minimally invasive technique. *Journal of Periodontology* **81**, 158–166.
- Trombelli, L., Franceschetti, G., Rizzi, A., Minenna, P., Minenna, L. & Farina, R. (2012) Minimally invasive transcresal sinus floor elevation with graft biomaterials. A randomized clinical trial. *Clinical Oral Implants Research* **23**, 424–432.
- Tugulu, S., Löwe, K., Scharnweber, D. & Schlotzig, F. (2010) Preparation of superhydrophilic microrough titanium implant surfaces by alkali treatment. *Journal of Material Science. Materials in Medicine* **21**, 2751–2763.
- Ucan, S., Deniz, K., Dayangac, E., Araz, K. & Ozdemir, B. H. (2010) Early implant survival in posterior maxilla with or without beta-tricalcium phosphate sinus floor graft. *Journal of Oral and Maxillofacial Surgery* **68**, 1642–1645.
- Zitzmann, N. U. & Schärer, P. (1998) Sinus elevation procedures in the resorbed posterior maxilla. Comparison of the crestal and lateral approaches. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics* **85**, 8–17.
- Zerbo, I. R., Zijderveld, S. A., de Boer, A., Bronckers, A. L., de Lange, G., ten Bruggenkat, C. M. & Burger, E. H. (2004) Histomorphometry of human sinus floor augmentation using a porous beta-tricalcium phosphate: a prospective study. *Clinical Oral Implants Research* **15**, 724–732.

Supporting Information

Additional Supporting Information may be found in the online version of this article:

Video S1. Video illustrating the surgical steps for the preparation of the implant site according to the *Smart Lift* procedure.

The video shows the sequence of the

Smart Lift instruments for the preparation of a site with a radiographic working length (i.e. rWL, as assessed on the pre-operative periapical radiograph) of 7 mm and a residual ridge height (i.e. sWL, as assessed with the *Probe Osteotome*) of 7 mm. Immediately after the completion of the tSFE procedure, an implant (Thommen Medical AG,

Waldenburg, Switzerland), 11 mm long and 4.5 mm wide, has been placed.

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Clinical Relevance

Scientific rationale for the study:

The study was performed to compare the effect of DBBM and β -TCP on treatment outcomes of transcrestal sinus floor elevation.

Principal findings: The study failed to find significant differences in

clinical outcomes and post-operative morbidity between sites treated with the *Smart Lift* technique in association with either DBBM or β -TCP. However, differences in post-surgery graft remodelling seem to reflect the variability in the dynamics of graft replacement and subsequent new

bone formation between DBBM and β -TCP.

Practical implications: Both DBBM and β -TCP may safely support sinus lift procedures when performed with the *Smart Lift* technique.