Received: 24 May 2019 | Revised: 8 August 2019 | Accepted: 3 September 2019

DOI: 10.1111/clr.13541

ORIGINAL RESEARCH

CLINICAL ORAL IMPLANTS RESEARCH WILEY

The impact of graft remodeling on peri-implant bone support at implants placed concomitantly with transcrestal sinus floor elevation: A multicenter, retrospective case series

Giovanni Franceschetti[1] | Roberto Farina[1,2] | Luigi Minenna[1] | Orio Riccardi[1,3] | Claudio Stacchi[4] | Rosario Di Raimondo[5] | Elisa Maietti[6,7] | Leonardo Trombelli[1,2]

[1]Research Centre for the Study of Periodontal and Peri-Implant Diseases, University of Ferrara, Ferrara, Italy

[2]Operative Unit of Dentistry, University-Hospital of Ferrara, Ferrara, Italy

[3]Private practice, Rimini, Italy

[4]Private practice, Gorizia, Italy

[5]Private practice, Palermo, Italy

[6]Department of Biomedical and Neuromotor Sciences, University of Bologna, Italy

[7]Center of Clinical Epidemiology, University of Ferrara, Italy

Correspondence
Roberto Farina, Research Centre for the Study of Periodontal and Peri-implant Diseases, University of Ferrara, Corso Giovecca 203, Ferrara 44121, Italy.
Email: roberto.farina@unife.it

Funding information
This study was supported by the Research Centre for the Study of Periodontal and Peri-Implant Diseases, University of Ferrara, Italy; a research grant by Regione Emilia-Romagna (Programma di Ricerca Regione-Università, Area 1 "Ricerca Innovativa," Bando Giovani Ricercatori "Alessandro Liberati" 2013; project PRUA1GR-2013-00000168); a research grant of the Osteology Foundation, Lucerne, Switzerland (project #13-063); and a donation from Geistlich Biomaterials, Thiene, Italy.

Abstract

Objectives: To evaluate the impact on peri-implant bone support (as assessed on periapical radiographs) of the remodeling dynamics of varying graft biomaterials used for transcrestal sinus floor elevation (tSFE).

Methods: The study is a multicenter, retrospective series of cases undergone tSFE (performed according to the *Smart Lift* technique) and concomitant implant placement. At operator's discretion, tSFE was performed with bone core (BC) alone or supplemented by deproteinized bovine or porcine bone mineral (DBBM and DPBM, respectively), synthetic hydroxyapatite in a collagen matrix (S-HA), or ß-tricalcium phosphate (ß-TCP). Immediately after surgery, at 6–12 months post-surgery, and at later (≥24 months) follow-up intervals, the percentage proportion of the implant surface in direct contact with the radiopaque area was calculated for the entire implant surface (totCON%). Also, the height of the graft apical to the implant apex (aGH) was assessed.

Results: At 6–12 months following tSFE, median totCON% was 100%, with a median aGH of 1.4 mm. A tendency of aGH to decrease in height was observed at later follow-up intervals for sites treated with all grafting procedures. In all treatment groups, the majority of the implant surface was still surrounded by the radiopaque area at the longest follow-up visits.

Conclusions: Although the height of the peri-implant radiopaque area apical to the implant apex tends to reduce overtime at sites which have received tSFE, the peri-implant bone support seems to be maintained long term irrespective of the graft material used.

KEYWORDS

bone regeneration, dental implants, maxillary sinus, minimally invasive surgical procedures, oral surgical procedures

1 | INTRODUCTION

The loss of one or more maxillary posterior teeth is associated with dimensional alterations of the alveolar bone (Farina, Pramstraller, Franceschetti, Pramstraller, & Trombelli, 2011), which in turn may lead to residual crest dimensions not compatible with implant placement (Pramstraller, Farina, Franceschetti, Pramstraller, & Trombelli, 2011). In atrophic posterior maxillary sextants, transcrestal maxillary sinus floor elevation (tSFE) is an effective option for bone augmentation aimed at implant placement (Corbella, Taschieri, & Del Fabbro, 2015; Del Fabbro, Wallace, & Testori, 2013; Duan et al., 2017; Tan, Lang, Zwahlen, & Pjetursson, 2008). As for other bone augmentation procedures, the key principles of tSFE are space provision and stabilization of the blood clot in close contiguity with vital structures (Dahlin, Linde, Gottlow, & Nyman, 1988). Whereas the maxillary sinus membrane and periosteum and the sinus floor both represent two significant sources of viable cells contributing the maturation of the coagulum into new bone formation (Gruber, Kandler, Fürst, Fischer, & Watzek, 2004; Kim, Choi, Xuan, & Jeong, 2010; Palma et al., 2006; Srouji, Ben-David, Funari, Riminucci, & Bianco, 2013; Srouji et al., 2009, 2010), space provision underneath the elevated sinus membrane and its maintenance during the healing phase remain challenging aspects for the clinician approaching a tSFE procedure.

When implant placement is performed concomitantly with tSFE, space provision is obtained through the mechanical pressure detaching the sinus membrane, submucosa, and periosteum from the sinus floor. The mechanical pressure can be determined by osteotomes (Nedir et al., 2013), a fluid (Peñarrocha-Diago, Galán-Gil, Carrillo-García, Peñarrocha-Diago, & Peñarrocha-Diago, 2012) or a gel (Pommer & Watzek, 2009) injected with a controlled pressure or, more frequently, particulate graft materials with or without bioactive agents (Pocaterra et al., 2016). Once obtained, the space between the membrane and the sinus floor can also be maintained by the concomitantly placed implant. The collapse of the sinus membrane over the implant, however, may limit endosinus bone formation if the space is left filled only with blood clot (Sul, Choi, Li, Jeong, & Xuan, 2008). The adjunctive use of an osteoinductive/osteoconductive graft may enhance space provision and, in addition, contribute endosinusal osteogenesis acting as a source for bone-forming cells or a scaffold for the newly formed bone. In this respect, previous studies on tSFE demonstrated that the space underneath the sinus membrane maintained by a xenograft resulted in the maturation of the graft-supported blood clot, leading to new bone formation associated with a certain amount of residual graft particles (Lombardi et al., 2017; Stacchi et al., 2018; Trombelli, Franceschetti, Trisi, & Farina, 2015). Once tissue maturation has occurred, a greater proportion of implant sites completely surrounded by a radiopaque area was observed when a graft material had been used during tSFE (Nedir, Nurdin, Abi Najm, El Hage, & Bischof, 2017).

There is substantial agreement on the fact that the space augmented with a sinus floor elevation procedure undergoes progressive reduction over time (Abdulkarim, Miley, McLeod, & Garcia, 2013; Brägger et al., 2004; Jung, Choi, Cho, & Kim, 2010; Mardinger et al., 2011; Marković et al., 2016; Nishida et al., 2013; Pjetursson, Ignjatovic, et al., 2009; Tallarico, Meloni, Xhanari, Pisano, & Cochran, 2017; Temmerman et al., 2017). This graft remodeling might potentially lead to a decreased bone support to the endosinusal portion of the implant. Several studies on tSFE procedures showed that the extent of space reduction following the use of a graft material is partly influenced by the physical and chemical characteristics of the graft (Marković et al., 2016). However, whether and to what extent the long-term dimensional alterations of the grafted space following tSFE with different graft materials might affect the amount of peri-implant bone support still remain to be elucidated.

The present study was performed to assess the remodeling dynamics of peri-implant bone support (as radiographically assessed) at implants placed concomitantly with tSFE and grafting procedure. In particular, the impact of graft remodeling on the amount of peri-implant bone support was also investigated in the entire population as well as for each graft material.

2 | MATERIALS AND METHODS

2.1 | Study design and ethical aspects

The study is a multicenter, retrospective case series. The study protocol was approved by the Local Ethical Committee of Ferrara, Italy (protocol number: 170194). Surgical procedures were performed at the Research Centre for the Study of Periodontal and Peri-implant Diseases, University of Ferrara, Italy, and 3 private dental offices involved in previous clinical trials on the tSFE procedure used in this study (Farina et al., 2018, 2019; Franceschetti, Farina, Minenna, Franceschetti, & Trombelli, 2015; Franceschetti et al., 2014, 2017; Trombelli et al., 2012, 2014, 2015; Trombelli, Minenna, Franceschetti, Minenna, & Farina, 2010a).

2.2 | Study population

De-identified data were retrospectively derived from the record charts of patients undergoing tSFE according to a standardized sequence of rotating and manual instruments, that is, the *Smart Lift* technique (Trombelli, Minenna, Franceschetti, Farina, & Minenna, 2008; Trombelli, Minenna, Franceschetti, Minenna, & Farina, 2010a; Trombelli, Minenna, Franceschetti, Minenna, Itro, et al., 2010b), and concomitant placement of one implant in the posterior maxilla associated with a grafting procedure. Patient inclusion in the study was subordinated to the following inclusion criteria: (a) ≥18 years; (b) no systemic and/or local contraindications to implant surgery and tSFE procedures; and (c) availability of a periapical radiograph taken immediately after surgery, at 6–12 months post-surgery, and at a later (≥24 months) follow-up interval. Patients with a history of diseases or exposure to drugs affecting bone metabolism were excluded.

2.3 | Surgical procedure

2.3.1 | Pre-surgery procedures

Treatments were performed as part of the oral rehabilitation plan which had been previously agreed between patients and operators. Before implant placement and tSFE, all oral diseases, including periodontal disease, were thoroughly treated. Two grams of amoxicillin (Zimox 1 g; Pfizer Italia S.r.l) was administered to each patient 1 hr prior to the initiation of the surgical procedure.

2.3.2 | Implant site preparation

A full-thickness flap with vertical releasing incisions was elevated, with the mesio-distal extension kept limited to the future implant site. The preparation of the implant site was performed according to a minimally invasive procedure for tSFE, namely the *Smart Lift* technique (Trombelli et al., 2008; Trombelli, Minenna, Franceschetti, Minenna, & Farina, 2010a; Trombelli, Minenna, Franceschetti, Minenna, Itro, et al., 2010b; Figure 1). The technique is based on a standardized sequence of specially designed rotating and manual instruments that are used with stop devices (Farina et al., 2018, 2019; Franceschetti et al., 2015, 2014, 2017; Trombelli et al., 2012, 2014, 2015, 2008; Trombelli, Minenna, Franceschetti, Minenna, & Farina, 2010a; Trombelli, Minenna, Franceschetti, Minenna, Itro, et al., 2010b).

2.3.3 | Graft materials

According to the operative sequence of the *Smart Lift* technique, a bone core (BC) is isolated with the trephine drill, then condensed, and malleted to fracture the sinus floor by means of a calibrated osteotome. At the operator's discretion, the elevation of the sinus floor was performed with BC either alone as autogenous graft material or supplemented by a xenogeneic or synthetic graft biomaterial placed into the sinus by gradual increments using the osteotome.

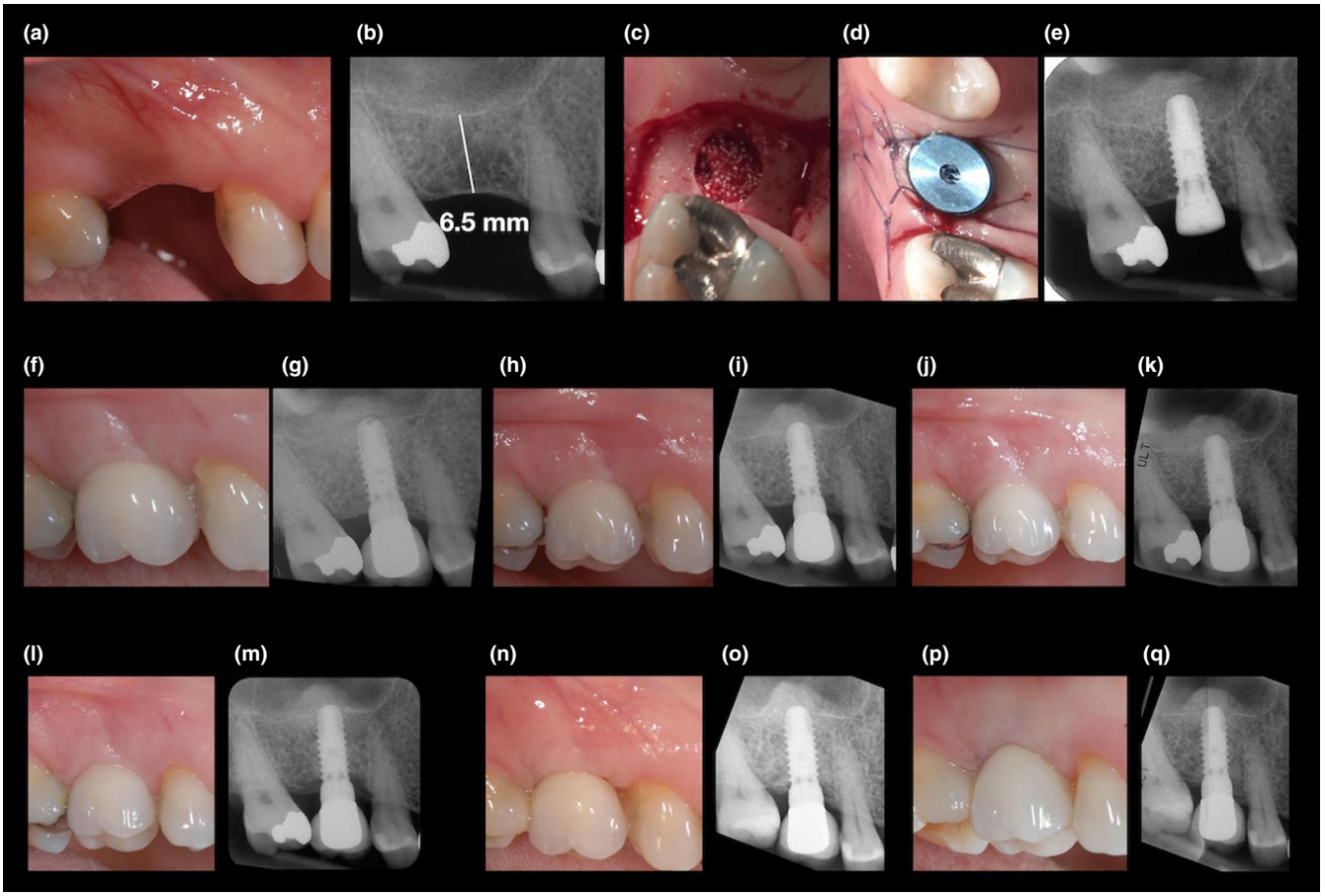

FIGURE 1 Long-term clinical and radiographic follow-up of a tSFE case performed according to the *Smart Lift* technique (Trombelli et al., 2008; Trombelli, Minenna, Franceschetti, Minenna, & Farina, 2010a; Trombelli, Minenna, Franceschetti, Minenna, Itro, et al., 2010b). (a) Healed extraction site in position of the upper right first molar; (b) residual bone height (as assessed radiographically) of 6.5 mm; (c) synthetic hydroxyapatite in a collagen matrix (S-HA) positioned in the implant site during tSFE; (d) clinical aspect at the time of implant insertion and concomitant tSFE according to the *Smart Lift* technique; (e) radiographic aspect immediately after implant placement; (f,g) clinical and radiographic aspect at 6-month follow-up; (h,i) clinical and radiographic aspect at 12-month follow-up; (j,k) clinical and radiographic aspect at 24-month follow-up; (l,m) clinical and radiographic aspect at 36-month follow-up; (n,o) clinical and radiographic aspect at 48-month follow-up; (p,q) clinical and radiographic aspect at 60-month follow-up

When another graft material was used in addition to BC, it was selected by the operator among the followings: deproteinized bovine bone mineral (DBBM; Bio-Oss® spongiosa granules 0.25–1.0 mm; Geistlich Pharma, AG); deproteinized porcine bone mineral (DPBM; Gen-Os® cortical and spongiosa granules 0.25–1.0 mm; Osteobiol Tecnoss Dental); synthetic hydroxyapatite in a collagen matrix (S-HA; Biostite®; GABA Vebas, S); or ß-tricalcium phosphate (ß-TCP; Ceros®, granules 0.5–0.7 mm; Thommen Medical), and its amount was pre-determined in relation to the extent of sinus floor elevation that had to be achieved (Farina et al., 2018, 2019; Franceschetti et al., 2014; Trombelli et al., 2012, 2014).

2.4 | Study parameters

At each center, periapical radiographs were obtained immediately after surgery and at later follow-up intervals (programmed at operator's discretion) with a paralleling technique using a Rinn film holder with a rigid film-object X-ray source. All available radiographs were scanned, digitized, stored at a resolution of 600 dpi, and analyzed using an image processing software (NIS Elements® v4.2; Nikon Instruments). All radiographic measurements were performed by a single trained examiner (G.F.) who had previously undergone a calibration session for linear radiographic measurements on a sample of 15 patients not included in the study and had participated as clinical examiner in previous clinical trials on tSFE (Farina et al., 2018, 2019; Franceschetti et al., 2014, 2015, 2017; Trombelli et al., 2012).

On radiographs taken immediately after surgery, residual bone height at the mesial (mRBH) and distal (dRBH) aspects of the implant was measured as the distance (mm) between the mesial and distal aspect of the implant shoulder, respectively, and the sinus floor.

At each later observation interval, the following radiographic measurements were performed (Figure 2):

- Length (mm) of the implant surface in direct contact with the peri-implant radiopaque area (including both native bone and newly formed tissue), as assessed at the mesial, distal, and apical aspects of the implant;
- Height of the graft apically (aGH): distance (mm) occupied by a radiopaque area between the implant apex and the sinus floor as assessed at the mid-portion of the implant;
- Peri-implant bone level at the mesial and distal aspects of the implant: distance (mm) from the apical margin of the implant shoulder to the first bone-to-implant contact at the mesial and distal aspect of the implant, respectively.

To account for radiographic distortion, linear measurements taken on each radiograph were adjusted for a coefficient derived from the ratio: true length of the implant/ radiographic implant length (rIL) (Farina et al., 2018, 2019; Franceschetti et al., 2014, 2015, 2017; Trombelli et al., 2012, 2014, 2015).

For each observation interval, the extent of implant surface was measured as rIL for the mesial and distal aspects and by implant diameter for the apical aspect. The percentage proportion of the implant surface in direct contact with the radiopaque area was calculated for the entire implant surface (totCON%) as well as separately for the mesial (mCON%), distal (dCON%), and apical (aCON%) implant aspects. For radiographs taken immediately after surgery, these proportions were calculated by accounting the extent of implant surface in contact with native (residual) bone (i.e., mRBH and dRBH). For radiographs taken at later follow-up visits, totCON%, mCON%, dCON%, and aCON% were derived as the ratio between the length (mm) of the implant surface in direct contact with the peri-implant radiopaque area (native bone + newly formed tissue) and the extent of implant surface.

2.5 | Statistical analysis

The patient was regarded as the statistical unit. When the patient had undergone tSFE bilaterally, therefore, only one implant was randomly chosen and included for analysis. For each treatment group and observation interval, the frequency of patients with peri-implant bone level >0 and the frequency of patients with aGH >0 were calculated. For continuous data, median and interquartile range (IQR) along with minimum and maximum (min-max) were reported, while categorical variables were described through absolute and relative (%) frequencies. totCON% was the primary outcome variable, whereas aGH (expressed as both average value and proportion of

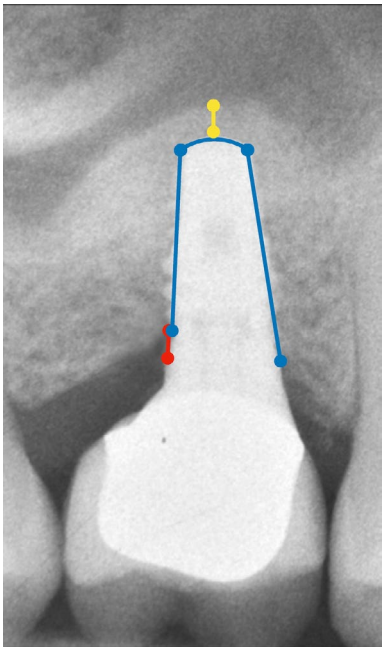

FIGURE 2 Radiographic measurements. In blue: length of the implant surface in direct contact with the peri-implant radiopaque area (including both native bone and newly formed tissue), as assessed at the mesial, distal, and apical aspects of the implant. In yellow: height of the graft apically (aGH), measured as the distance occupied by a radiopaque area between the implant apex and the sinus floor as assessed at the mid-portion of the implant. In red: peri-implant bone level (measured as the distance from the apical margin of the implant shoulder to the first bone-to-implant contact)> 0 as detected at the distal aspect of the implant

TABLE 1 Analysis 1: patient and implant characteristics and length of follow-up in the entire study population and within each treatment group

	No. of patients	Age (years)	Gender	Smoking status	Residual bone height (RBH; in mm)	Implant diameter (mm)	Implant length (mm)	Follow-up (months)
Treatment group	*N*	Median (IQR; min-max)	No. of males/ females	No. of current smokers/former smokers/never smoked	Median (IQR; min-max)	Median (IQR; min-max)	Median (IQR; min-max)	Median (IQR; min-max)
DBBM	35	53.0 (45.0–58.0; 32–73)	13/ 22	8/ 6/ 21	6.1 (4.7–7.0; 3.3–9.1)	4.0 (4.0–4.0; 3.5–6.0)	9.5 (9.5–11.0; 8.0–11.5)	48.0 (36–48; 24–72)
S-HA	14	52.0 (48.3–57.0; 43–69)	8/ 6	8/ 2/ 4	5.7 (5.2–7.1; 3.8–9.4)	4.0 (4.0–4.5; 3.8–5.0)	10.0 (9.5–11.0; 8.0–11.5)	54.0 (36–84; 24–96)
DPBM	16	51.5 (44.8–55.8; 27–60)	8/8	7/ 3/ 6	5.2 (3.9–5.9; 1.7–8.8)	4.0 (4.0–4.0; 4.0–4.5)	8.8 (8.0–9.5; 8.0–11.0)	48.0 (36–60; 24–72)
β-TCP	18	53.5 (50.0–64.5; 43–77)	10/8	6/ 1/ 11	5.6 (5.1–6.3; 2.8–7.5)	4.0 (4.0–4.3; 4.0–5.0)	9.5 (9.5–11.0; 8.0–12.5)	48.0 (36–60; 24–72)
BC	6	44.0 (43.0–51.0; 43–77)	2/4	2/ 4/ 0	6.3 (6.0–6.9; 4.8–9.2)	4.0 (4.0–4.0; 4.0–4.0)	11.0 (9.9–11.0; 8.0–11.0)	84.0 (63–96; 24–96)
Total	89	53.0 (45.0–58.0; 27–77)	41/48	31/ 16/ 42	5.7 (4.8–6.8; 1.7–9.4)	4.0 (4.0–4.1; 3.5–6.0)	9.5 (9.5–11.0; 8.0–12.5)	48.0 (36–60; 24–96)

Abbreviations: BC, bone core (no graft material); DBBM, deproteinized bovine bone mineral (Bio-Oss® spongiosa granules 0.25–1.0 mm; Geistlich Pharma, AG); DPBM, deproteinized porcine bone mineral (Gen-Os®; Osteobiol Tecnoss Dental); S-HA, synthetic hydroxyapatite (Biostite®; GABA Vebas, S); β-TCP, β-tricalcium phosphate (Ceros®, granules 0.5–0.7 mm; Thommen Medical).

TABLE 2 Analysis 2: patient and implant characteristics in the entire study population and within each treatment group

	No. of patients	Age (years)	Gender	Smoking status	Residual bone height (RBH; in mm)	Implant diameter (mm)	Implant length (mm)
Treatment group	*n*	Median (IQR)	No. of males/ females	No. of current smokers/former smokers/never smoked	Median (IQR)	Median (IQR)	Median (IQR)
DBBM	20	51.0 (41.5–55.0)	7/13	6/4/10	6.2 (5.1–7.0)	4.0 (4.0–4.2)	10.0 (9.5–11.0)
S-HA	7	52.0 (49.0–55.0)	4/3	4/1/2	5.6 (5.3–6.3)	4.5 (4.0–4.7)	10.0 (9.5–10.5)
DPBM	9	52.0 (47.0–55.0)	3/6	2/3/4	4.9 (3.6–6.3)	4.0 (4.0–4.0)	9.5 (8.0–9.5)
β-TCP	8	54.5 (53.0–59.8)	4/4	4/1/3	6.0 (4.0–6.7)	4.0 (4.0–4.1)	9.5 (9.5–10.3)
p value		0.306	0.714	0.776	0.280	0.275	0.105
Total	44	53.0 (44.5–55.5)	18/26	16/9/19	5.7 (4.9–6.8)	4.0 (4.0–4.5)	9.5 (9.5–11.0)

Abbreviations: DBBM, deproteinized bovine bone mineral (Bio-Oss® spongiosa granules 0.25–1.0 mm; Geistlich Pharma, AG); DPBM, deproteinized porcine bone mineral (Gen-Os®; Osteobiol Tecnoss Dental); S-HA, synthetic hydroxyapatite (Biostite®; GABA Vebas, S); β-TCP, β-tricalcium phosphate (Ceros®, granules 0.5–0.7 mm; Thommen Medical).

patients with aGH >0 and ≤0) and peri-implant bone level (expressed as proportion of patients with peri-implant bone level >0 and ≤0) were the secondary outcome variables.

Two analyses were performed:

- *Analysis 1 (assessment of the amount of peri-implant bone support over time).*

No additional restrictions were used for patient inclusion in analysis 1 in addition to those used to determine patient eligibility for the study. Data on study parameters were obtained by all radiographs available for the following observation intervals: immediately post-surgery, 6–12 months, and later observation intervals up to 72 months. For this analysis, 6- or 12-month data were considered as a single observation interval, with 6-month data being used only if 12-month data were not available;

- *Analysis 2 (comparison of the remodeling dynamics following different grafting materials).*

Only patients where radiographs had been taken at 6, 12, and 36 months were included in analysis 2. For patients with 6-month aGH ≥ 0, the change in aGH between 6-month visit and later follow-up visits was expressed as a percentage of the 6-month aGH value.

totCON% was considered as the primary outcome variable of both analyses. While analysis 1 was limited to descriptive statistics, both descriptive and inferential statistics were performed in analysis 2. Inter-group comparisons were performed with Kruskal–Wallis test for continuous parameters and Fisher's exact test for categorical variables, followed by multiple post hoc tests with Hommel correction. Within-group comparisons were performed using Cochran test and Friedman test for categorical and continuous variables, respectively. The level of statistical significance was fixed at 0.05, and the analyses were performed using Stata version 13 (StataCorp) and R version 3.5.0 (R core team 2018, R Foundation for Statistical Computing).

3 | RESULTS

3.1 | Demographic data

In analysis 1, the study population consisted of 89 patients (mean age: 52.3 ± 10.0 years; 48 females; 31 current smokers, 16 former smokers, 42 non-smokers). Surgeries were performed between September 2007 and January 2014 using different implant systems with both tissue- and bone-level placement: Element® or Element® Inicell, Thommen Medical AG (62 patients); Certain® or Prevail®, BIOMET 3i, Palm Beach Gardens (seven patients); Standard Plus-Tissue Level®, Straumann AG (eight patients); Osseospeed® AstraTech AB, Molndal, Sweden (six patients); Implus TTS® Leader Italia (one patients); Kohno®, Sweden & Martina S.p.A (two patients); Osstem®; Osstem implant Co (one patient); Pro-Series®, Sybron Implant Solutions (one patient); and Neoss®, Neoss Ltd, (one patient). In 83 patients, the apical displacement of the bone core was followed by the placement of a graft material (DBBM: *n* = 35; DPBM: *n* = 16; β-TCP: *n* = 18; S-HA: *n* = 14), while in the remaining patients, no graft material was used in association with the bone core (BC group: *n* = 6). Patient and implant characteristics as well as the length of follow-up within each treatment group are reported in Table 1.

Forty-seven patients were eligible for analysis 2. Since BC group would have contributed with 3 patients only, it was excluded from analysis. For analysis 2, no significant differences in patient age, patient distribution according to gender and smoking status, RBH and implant dimensions were observed between grafting procedures (Table 2).

3.2 | Radiographic data

3.2.1 | Assessment of the amount of peri-implant bone support over time

Analysis 1 showed that, immediately after surgery, the implant was stabilized in native bone for less than a half of its length (totCON%= 48.7%; Table 3). At 6–12 months, the implant surface was embedded in radiopacity for its entirety (totCON% = 100%) either in the entire study population or within each treatment group (Table 3). When the overall population was considered, median totCON% was 100% up to 60 months and decreased to 84.6% at 72 months. This trend was common to all considered graft biomaterials with the exception of β-TCP where reduced totCON% was already evident at 36 months. Parallelly, the proportion of implants with totCON%= 100% shifted from 77.5% at 6–12 months to 63.9%, 58.3%, and 38.5% at 48, 60, and 72 months, respectively (Appendix S1).

Data on aCON%, mCON%, and dCON% from analysis 1 suggest that the apical aspect was the most affected by the reduction in peri-implant bone support, while the mesial and distal aspects remained almost completely covered by the radiopaque area (i.e., median mCON% and dCON%> 80%–85%) even at the longest observation intervals (Table 3). In this respect, tSFE procedure resulted in a median aGH of 1.8 mm immediately post-surgery, being present in 87/89 patients (Table 4). At 6–12 months, aGH was slightly reduced to 1.4 mm, being positive in 88% of the cases. However, median values and prevalence progressively decreased throughout observation intervals. Again, this remodeling pattern was common to all materials but S-HA, which showed a stable aGH up to 36 months (Table 4).

Analysis 1 showed that, at all observation intervals, peri-implant marginal bone loss was a rare event (Appendix S2).

3.2.2 | Comparison of the remodeling dynamics for different grafting materials

Within each grafting procedure (analysis 2), totCON% showed a significant reduction from 6 to 36 months within DBBM and β-TCP groups ($p = .011$ and $p = .009$, respectively), whereas it showed stability throughout the study for S-HA, and DPBM groups (Table 5). All grafting procedures experienced a significant, progressive reduction

TABLE 3 Analysis 1: totCON%, mCON%, dCON%, and aCON% as measured at each follow-up visit

		Follow-up visit (months)													
		0 (post-op)		6–12		24		36		48		60		72	
		n		*n*		*n*		*n*		*n*		*n*		*n*	
DBBM	totCON% (median and IQR)	35	50.2% (39.1–56.6%)	35	100% (94.2–100%)	21	100% (100–100%)	22	100% (81.9–100%)	13	100% (100–100%)	4	100% (95.7–100%)	4	78.9% (72.7–88.5%)
	aCON% (% of cases with aCON = 0%; % of cases with aCON = 100%)	35	100%; 0%	35	22.9%; 77.1%	21	23.8%; 76.2%	22	31.8%; 68.2%	13	15.4%; 84.6%	4	25.0%; 75.0%	4	75.0%; 25.0%
	mCON% (median and IQR)	35	62.6% (49.7–76.5%)	35	100% (100–100%)	21	100% (100–100%)	22	100% (100–100%)	13	100% (100–100%)	4	100% (100–100%)	4	93.5% (86.1–100%)
	dCON% (median and IQR)	35	54.7% (44.4–60.7%)	35	100% (100–100%)	21	100% (100–100%)	22	100% (82.7–100%)	13	100% (100–100%)	4	100% (100–100%)	4	95.0% (88.1–100%)
S-HA	totCON% (median and IQR)	14	47.5% (45.9–61.6%)	14	100% (92.4–100%)	11	100% (91.3–100%)	10	100% (73.1–100%)	6	94.9% (83.1–100%)	5	100% (100–100%)	3	100% (100–100%)
	aCON% (% of cases with aCON = 0%; % of cases with aCON = 100%)	14	100%; 0%	14	14.3%; 85.7%	11	18.2%; 81.8%	10	30.0%; 70.0%	6	16.7%; 83.3%	5	0%; 100%	3	0%; 100%
	mCON% (median and IQR)	14	68.9% (55.2–80.1%)	14	100% (100–100%)	11	100% (100–100%)	10	100% (85.8–100%)	6	100% (90.6–100%)	5	100% (100–100%)	3	100% (100–100%)
	dCON% (median and IQR)	14	57.5% (44.5–65.1%)	14	100% (100–100%)	11	100% (100–100%)	10	100% (92.3–100%)	6	100% (90.6–100%)	5	100% (100–100%)	3	100% (100–100%)
DPBM	totCON% (median and IQR)	16	48.8% (36.8–55.6%)	16	100% (100–100%)	11	100% (100–100%)	11	100% (100–100%)	9	100% (89.2–100%)	5	100% (100–100%)	1	89.2%
	aCON% (% of cases with aCON = 0%; % of cases with aCON = 100%)	16	100%; 0%	16	0%; 100%	11	0%; 100%	11	0%; 100%	9	22.2%; 77.8%	5	0%; 100%	1	0%; 100%
	mCON% (median and IQR)	16	65.4% (45.0–76.4%)	16	100% (100–100%)	11	100% (100–100%)	11	100% (100–100%)	9	100% (100–100%)	5	100% (100–100%)	1	84.2%
	dCON% (median and IQR)	16	58.4% (42.1–64.0%)	16	100% (100–100%)	11	100% (100–100%)	11	100% (100–100%)	9	100% (100–100%)	5	100% (100–100%)	1	89.5%

(Continues)

TABLE 3 (Continued)

		Follow-up visit (months)													
		0 (post-op)		6–12		24		36		48		60		72	
		n		*n*		*n*		*n*		*n*		*n*		*n*	
β-TCP	totCON% (median and IQR)	18	45.9% (38.4–52.2%)	18	100% (100–100%)	12	100% (100–100%)	12	92.3% (80.3–100%)	4	95.1% (86.4–100%)	7	83.0% (77.1–88.8%)	2	79.6% (76.3–83.0%)
	aCON% (% of cases with aCON = 0%; % of cases with aCON = 100%)	18	100%; 0%	18	16.7%; 83.3%	12	16.7%; 83.3%	12	41.7%; 58.3%	4	25.0%; 75.0%	7	71.4%; 28.6%	2	100%; 0%
	mCON% (median and IQR)	18	57.3% (50.7–65.1%)	18	100% (100–100%)	12	100% (100–100%)	12	100% (97.4–100%)	4	100% (95.3–100%)	7	100% (91.2–100%)	2	94.4% (88.7–100%)
	dCON% (median and IQR)	18	53.6% (40.3–58.6%)	18	100% (100–100%)	12	100% (100–100%)	12	100% (90.8–100%)	4	100% (92.7–100%)	7	100% (81.7–100%)	2	100% (100–100%)
BC	totCON% (median and IQR)	6	51.8% (47.7–54.7%)	6	100% (98.2–100%)	6	100% (97.4–100%)	3	100% (81.4–100%)	4	91.0% (81.7–100%)	3	100% (82.1–100%)	3	81.7% (80.5–100%)
	aCON% (% of cases with aCON = 0%; % of cases with aCON = 100%)	6	100%; 0%	6	16.7%; 83.3%	6	16.7%; 83.3%	3	33.3%; 66.7%	4	50.0%; 50.0%	3	33.3%; 66.7%	3	66.7%; 33.3%
	mCON% (median and IQR)	6	65.6% (60.0–72.7%)	6	100% (100–100%)	6	100% (100–100%)	3	100% (100–100%)	4	100% (100–100%)	3	100% (100–100%)	3	100% (96.3–100%)
	dCON% (median and IQR)	6	60.0% (56.2–61.6%)	6	100% (95.7–100%)	6	100% (93.7–100%)	3	100% (92.5–100%)	4	96.8% (93.0–100%)	3	100% (94.1–100%)	3	94.1% (93.0–100%)
Total	totCON% (median and IQR)	89	48.7% (41.2–55.8%)	89	100% (100–100%)	61	100% (100–100%)	58	100% (82.7–100%)	36	100% (84.1–100%)	24	100% (84.2–100%)	13	84.6% (80.5–100%)
	aCON% (% of cases with aCON = 0%; % of cases with aCON = 100%)	89	100%; 0%	89	15.7%; 84.3%	61	16.4%; 83.6%	58	27.6%; 72.4%	36	22.2%; 77.8%	24	29.2%; 70.8%	13	53.9%; 46.2%
	mCON% (median and IQR)	89	63.5% (52.0–73.7%)	89	100% (100–100%)	61	100% (100–100%)	58	100% (100–100%)	36	100% (100–100%)	24	100% (100–100%)	13	100% (88.7–100%)
	dCON% (median and IQR)	89	56.4% (44.4–61.0%)	89	100% (100–100%)	61	100% (100–100%)	58	100% (90.4–100%)	36	100% (100–100%)	24	100% (98.5–100%)	13	100% (93.0–100%)

Abbreviations: BC, bone core (no graft material); DBBM, deproteinized bovine bone mineral (Bio-Oss® spongiosa granules 0.25–1.0 mm; Geistlich Pharma, AG); DPBM, deproteinized porcine bone mineral (Gen-Os®; Osteobiol Tecnoss Dental); S-HA, synthetic hydroxyapatite (Biostite®; GABA Vebas, S); β-TCP, β-tricalcium phosphate (Ceros®, granules 0.5–0.7 mm; Thommen Medical).

in aGH from post-surgery to 36 months (Table 6), the residual percentage of 6-month aGH ranging between 72.6% (DBBM group) and 94.0% (S-HA group) at 12 months, and between 46.1% (β-TCP group) and 74.3% (S-HA group) at 36 months (Figure 3). No significant inter-group differences in totCON% and aGH were found at each observation interval (Tables 5, 6). At 36 months, the proportion of patients with totCON%= 100% for each treatment group ranged between 37.5% (β-TCP group) and 88.9% (DPBM group) (p = .179; Appendix S3).

Peri-implant marginal bone loss manifested only at the 36-month interval, and was infrequent and of limited extent for all grafting groups (Appendix S4).

4 | DISCUSSION

The present study was performed to assess the remodeling dynamics of the peri-implant bone support (as radiographically assessed) in a patient cohort undergone a tSFE procedure. Eighty-nine patients, each receiving one implant concomitantly with the *Smart Lift* technique (Farina et al., 2018, 2019; Franceschetti et al., 2014, 2015, 2017; Trombelli et al., 2012, 2014, 2015, 2008; Trombelli, Minenna, Franceschetti, Minenna, & Farina, 2010a; Trombelli, Minenna, Franceschetti, Minenna, Itro, et al., 2010b), were retrospectively selected for analysis.

At 6–12 months post-surgery, implants were on average entirely surrounded by a radiopaque area extending 1.4 mm apical to the implant apex, with 77.5% of patients having their implant completely embedded in the radiopaque area. Consistent with these findings, previous prospective and retrospective clinical trials repeatedly showed that the standardized sequence of manual and rotating instruments of the *Smart Lift* technique allows for a predictable, apical displacement of the sinus floor, and reported similar height of the radiopaque area apical to the implant apex immediately post-surgery (Farina et al., 2019; Franceschetti et al., 2015, 2014, 2017; Trombelli et al., 2012, 2014, 2015; Trombelli, Minenna, Franceschetti, Minenna, Itro, et al., 2010b).

In each patient, the apical displacement of the sinus floor was performed by a bone core created with a trephine drill during implant site development mostly combined with the placement of a graft with a well-documented efficacy in SFE. Hydroxyapatite-based biomaterials are the most investigated graft materials when used for sinus lift, in general, and tSFE, in particular (Del Fabbro, Corbella, Weinstein, Ceresoli, & Taschieri, 2012; Jensen & Terheyden, 2009). Among these, deproteinized bovine bone mineral (DBBM) is associated with considerable sinus floor elevation when used in combination with tSFE (Deporter, Caudry, Kermalli, & Adegbembo, 2005; Jensen & Terheyden, 2009; Krennmair, Krainhöfner, Schmid-Schwap, & Piehslinger, 2007; Pjetursson, Ignjatovic, et al., 2009; Pjetursson, Rast, et al., 2009; Rodoni, Glauser, Feloutzis, & Hämmerle, 2005; Trombelli et al., 2012; Trombelli, Minenna, Franceschetti, Minenna, Itro, et al., 2010b; Zitzmann & Schärer, 1998) and was shown to undergo slow resorption/degradation rate following sinus lift (Lee et al., 2006; Mordenfeld, Hallman, Johansson, & Albrektsson, 2010; Pettinicchio et al., 2012; Traini, Valentini, Iezzi, & Piattelli, 2007). Synthetic hydroxyapatite in a collagen matrix (S-HA) was successfully used in association with sinus floor elevation with either a transcrestal (Trombelli et al., 2008; Trombelli, Minenna, Franceschetti, Minenna, & Farina, 2010a; Trombelli, Minenna, Franceschetti, Minenna, Itro, et al., 2010b) or lateral approach (Garlini, Redemagni, Donini, & Maiorana, 2010; Maiorana, Sigurtà, Mirandola, Garlini, & Santoro, 2005). When used in conjunction with sinus floor elevation procedure with either transcrestal (Jung et al., 2010; Nkenke, Schlegel, Schultze-Mosgau, Neukam, & Wiltfang, 2002) or lateral approach (Meyer et al., 2009; Uckan, Deniz, Dayangac, Araz, & Ozdemir, 2010), ß-tricalcium phosphate (ß-TCP) grafts were shown to effectively support bone regeneration resulting in a high long-term implant survival rate. However, ß-TCP graft materials may be gradually resorbed and replaced by newly formed bone at short time intervals (i.e., 6 months following grafting) (Ozyuvaci, Bilgiç, & Firatli, 2003; Schulze-Späte et al., 2012; Zerbo et al., 2004).

In all treatment groups, a clear tendency of the peri-implant bone support to decrease over time was observed. Regardless of the type of grafting procedure, available evidence based on radiographic analyses consistently indicates that, after its displacement with tSFE, the maxillary sinus floor tends to return to the original position, although this tendency did not consistently reach statistical significance in all studies (Diserens, Mericske, & Mericske-Stern, 2005; Marković et al., 2016; Nedir et al., 2017; Pjetursson, Ignjatovic, et al., 2009; Pjetursson, Rast, et al., 2009; Temmerman et al., 2017). In our material, the limited incidence and extent of peri-implant marginal bone loss indicate that the variations in totCON% observed in the present study population can be mostly ascribed to the remodeling of the peri-implant bone support at the apical portion of the implants, thus confirming that the remodeling process progresses on a cranial–caudal direction. According to our data, tissue remodeling occasionally resulted in less than optimal contact between the radiopaque area and either the apical aspect or, to a minor extent, the lateral aspects of the implant. Some considerations may be advanced to explain the observed remodeling pattern. First, intra-sinus pressure generated during respiration over the cranial portion of the grafted volume was demonstrated to affect the quantity and fate of newly formed bone. Following maxillary sinus floor elevation in rabbits without ostial occlusion, the space underneath the elevated mucosa was filled with blood clot and granulation tissue at 1 week post-surgery, but was almost entirely lost at 3 weeks. Differently, in rabbits with ostial occlusion, the space obtained at 1 week matured into a fully formed bone mass after 3 weeks, with signs of further tissue maturation (e.g., mature trabeculae, peripheral corticalization) at 6 weeks (Asai, Shimizu, & Ooya, 2002). Second, although the Schneiderian membrane and periosteum hold mesenchymal progenitor cells and cells (Gruber et al., 2004; Srouji et al., 2013, 2010, 2009) contributing bone formation after its elevation, its osteogenic role was shown to be weaker than that of the maxillary sinus floor (Rong, Li,

TABLE 4 Analysis 1: aGH (in mm) as measured at each follow-up visit

	0 (post-op)			6–12 months			24 months		
	No. of patients	No. of cases with aGH > 0	Median (IQR)	No. of patients	No. of cases with aGH > 0	Median (IQR)	No. of patients	No. of cases with aGH > 0	Median (IQR)
DBBM	35	33	1.9 (1.2–2.8)	35	27	1.3 (0.3–2.1)	21	16	0.8 (0.3–2.0)
S-HA	14	14	2.5 (2.3–3.4)	14	13	2.5 (1.3–3.6)	11	9	2.4 (0.4–3.4)
DPBM	16	16	1.5 (1.1–2.1)	16	16	1.3 (0.6–1.7)	11	11	0.8 (0.5–1.4)
β-TCP	18	18	1.5 (1.2–2.6)	18	17	1.5 (0.9–4.3)	12	10	0.9 (0.5–1.2)
BC	6	6	1.4 (1.3–1.5)	6	5	0.9 (0.6–0.9)	6	4	0.8 (0–0.9)
Total	89	87	1.8 (1.2–2.6)	89	78	1.4 (0.7–2.2)	61	50	0.9 (0.4–2.0)

Abbreviations: BC, bone core (no graft material); DBBM, deproteinized bovine bone mineral (Bio-Oss® spongiosa granules 0.25–1.0 mm; Geistlich Pharma, AG); DPBM, deproteinized porcine bone mineral (Gen-Os®; Osteobiol Tecnoss Dental); S-HA, synthetic hydroxyapatite (Biostite®; GABA Vebas, S); β-TCP, β-tricalcium phosphate (Ceros®, granules 0.5–0.7 mm; Thommen Medical).
*One patient was excluded (the apical portion of the radiopaque area was not visible on periapical radiograph).

TABLE 5 Analysis 2: aCON%, mCON%, dCON%, and totCON% as measured at 6-, 12-, and 36-month follow-up visits

		totCON%				mCON%			
		Median (min-max range)				Median (min-max range)			
	n	6 months	12 months	36 months	*p* value (within-group)	6 months	12 months	36 months	*p* value (within-group)
DBBM	20	100% (69.8–100%)	100% (54.4–100%)	100% (50.9–100%)	.011 (12 m vs. 36 m: .026; 6 m vs. 36 m: .049)	100% (88.3–100%)	100% (67.1–100%)	100% (70.7–100%)	.050 (no significant post hoc comparisons)
S-HA	7	100% (88.5–100%)	100% (75.0–100%)	100% (59.0–100%)	.135	100% (77.3–100%)	100% (79.2–100%)	100% (73.4–100%)	.223
DPBM	9	100% (100–100%)	100% (100–100%)	100% (89.2–100%)	.368	100% (100–100%)	100% (100–100%)	100% (84.2–100%)	.368
β-TCP	8	100% (82.6–100%)	100% (77.6–100%)	92.3% (50.9–100%)	0.009 (no significant post hoc comparisons)	100% (100–100%)	100% (91.4–100%)	100% (88.7–100%)	.061 (no significant post hoc comparisons)
p value (between-group)		0.392	0.121	0.233		0.440	0.392	0.713	
Total	44	100% (69.8–100%)	100% (54.4–100%)	100% (50.9–100%)	<.001 (6 m vs. 12 m: .025; 12 m vs. 36 m: <.001; 6 m vs. 36 m: <.001)	100% (77.3–100%)	100% (67.1–100%)	100% (70.7–100%)	.001 (6 m vs. 36 m: .005)

Abbreviations: DBBM, deproteinized bovine bone mineral (Bio-Oss® spongiosa granules 0.25–1.0 mm; Geistlich Pharma, AG); DPBM, deproteinized porcine bone mineral (Gen-Os®; Osteobiol Tecnoss Dental); S-HA, synthetic hydroxyapatite (Biostite®; GABA Vebas, S); β-TCP, β-tricalcium phosphate (Ceros®, granules 0.5–0.7 mm; Thommen Medical).

36 months			48 months			60 months			72 months		
No. of patients	No. of cases with aGH > 0	Median (IQR)	No. of patients	No. of cases with aGH > 0	Median (IQR)	No. of patients	No. of cases with aGH > 0	Median (IQR)	No. of patients	No. of cases with aGH > 0	Median (IQR)
22	15	0.4 (0–1.6)	13	10	0.9 (0.4–1.1)	4	3	0.8 (0.3–2.1)	4	1	−0.7 (−2.0–0.8)
10	7	1.6 (0–3.1)	6	5	1.3 (1.0–2.6)	5	5	2.2 (1.1–2.7)	3	3	2.7 (1.9–3.0)
11	11	0.8 (0.4–1.5)	9	7	0.8 (0.3–0.9)	5	5	0.9 (0.8–1.0)	1	1	0.7
12	7	0.7 (0–1.2)	4	3	0.5 (−0.1–1.0)	7	2	0 (−1.2–1.2)	2	0	−0.6 (−1.3–0)
3	2	0.5 (0–0.7)	4*	1*	0* (0–0.6)	3	2	0.6 (0–0.6)	3	1	0 (0–0.6)
58	42	0.7 (0–1.5)	36*	26*	0.8* (0–1.2)	24	17	0.8 (0–1.2)	13	6	0 (0–1.6)

dCON%				aCON%			
Median (min-max range)				% of cases with aCON = 0%; % of cases with aCON = 100%			
6 months	12 months	36 months	*p* value (within-group)	6 months	12 months	36 months	*p* value (within-group)
100% (79.9–100%)	100% (64.0–100%)	100% (52.0–100%)	.012 (12 m vs. 36 m: .026; 6 m vs. 36 m: .049)	15.0%; 85.0%	25.0%; 75.0%	25.0%; 75.0%	.135
100% (94.2–100%)	100% (73.8–100%)	100% (72.5–100%)	.156	0%; 100%	14.3%; 85.7%	28.6%;71.4%	.223
100% (100–100%)	100% (100–100%)	100% (89.5–100%)	.368	0%; 100%	0%; 100%	0%; 100%	-
100% (100–100%)	100% (96.5–100%)	97.5% (73.8–100%)	.023 (no significant post hoc comparisons)	12.5%; 87.5%	12.5%; 87.5%	37.5%; 62.5%	.135
0.175	0.147	0.311		0.583	0.431	0.237	
100% (79.9–100%)	100% (64.0–100%)	100% (52.0–100%)	<.001 (12 m vs. 36 m: .001; 6 m vs. 36 m: .001)	9.1%; 90.9%	15.9%; 84.1%	22.7%; 77.3%	.011 (6 m vs. 36 m: .042)

TABLE 6 Analysis 2: aGH (in mm) as measured at 6-, 12-, and 36-month follow-up visits

		6 months		12 months		Δ 6–12 months	36 months		Δ 6–36 months	Δ 12–36 months	
	n	No. of cases with aGH > 0	Median (IQR)	No. of cases with aGH > 0	Median (IQR)	Median (IQR)	No. of cases with aGH > 0	Median (IQR)	Median (IQR)	Median (IQR)	*p* value
DBBM	20	17	1.3 (0.6–2.5)	15	1.1 (0.1–2.0)	0.4 (0.1–0.8)	15	0.6 (0.1–1.6)	0.5 (0.3–0.8)	0.1 (0–0.3)	<.001 6 months versus 12 months: < .001 12 months versus 36 months: .072 6 months versus 36 months: <.001
S-HA	7	7	2.4 (1.3–3.1)	6	2.3 (0.3–2.7)	0.2 (0–0.9)	5	1.8 (0–3.1)	0.5 (0.3–1.0)	0.4 (0.1–0.9)	.028 6 months versus 12 months: .127 12 months versus 36 months: .128 6 months versus 36 months: .128
DPBM	9	9	1.1 (1.0–1.5)	9	0.7 (0.5–1.6)	0.2 (0.1–0.4)	9	0.7 (0.4–0.9)	0.5 (0.2–0.6)	0.2 (0.1–0.4)	.004 6 months versus 12 months: .086 12 months versus 36 months: .076 6 months versus 36 months: .023
β-TCP	8	7	1.8 (1.0–2.2)	7	1.5 (0.8–1.8)	0.4 (0.1–0.6)	5	0.8 (−0.6–1.2)	1.1 (0.5–1.3)	0.6 (0.4–0.9)	.001 6 months versus 12 months: .030 12 months versus 36 months: .023 6 months versus 36 months: .023
p value			0.311		0.309	0.408		0.458	0.206	0.037 β-TCP versus DBBM: 0.024	
TOTAL	44	40	1.4 (0.8–2.4)	37	1.2 (0.4–1.9)	0.3 (0.1–0.6)	34	0.8 (0.3–1.5)	0.6 (0.3–0.8)	0.3 (0–0.6)	<.001 6 months versus 12 months: < .001 12 months versus 36 months: <.001 6 months versus 36 months: <.001

Abbreviations: DBBM, deproteinized bovine bone mineral (Bio-Oss® spongiosa granules 0.25–1.0 mm; Geistlich Pharma, AG); DPBM, deproteinized porcine bone mineral (Gen-Os®; Osteobiol Tecnoss Dental); S-HA, synthetic hydroxyapatite (Biostite®; GABA Vebas, S); β-TCP, β-tricalcium phosphate (Ceros®, granules 0.5–0.7 mm; Thommen Medical).

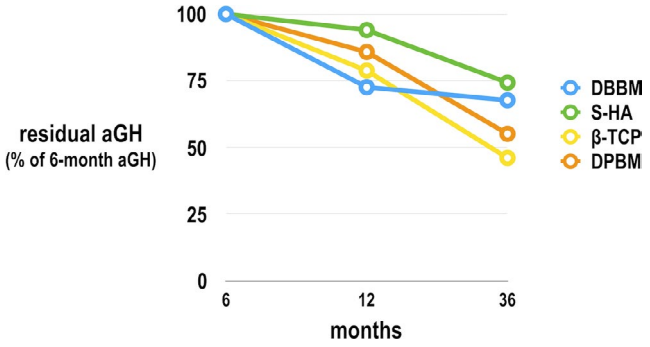

FIGURE 3 Analysis 2: residual aGH (expressed as % of the post-surgery value) as assessed at 6-, 12-, and 36-month visits

Chen, Zhu, & Huang, 2015). These findings were corroborated by other recent animal studies, suggesting that bone formation starts at the sinus floor and sprouts along the implant surface in a cranial direction (Jungner et al., 2015; Scala et al., 2016). It may therefore be hypothesized that newly formed tissue close to the sinus membrane may present some structural differences compared to that formed in proximity to the maxillary sinus floor, thus resulting in greater propensity to undergo remodeling/resorption on the long term. In particular, the radio-opacity observed in the most apical portion of the grafted area at 6–12 months could have been mainly due to residual graft particles, with no relevant bone formation (Stacchi et al., 2018). Since the majority of the implant surface was still surrounded by a radiopaque area even at the longest follow-up visits (60–72 months), however, the resorption rate seems to be (on average) sufficiently slow to maintain the increased amount of peri-implant support derived from tSFE over the years. This consideration assumes even greater relevance when considering that some studies suggested that most of the radiographic reduction in the grafted bone height seems to occur within the first 2 years following tSFE (Jung et al., 2010).

The presence of a radiopaque area entirely surrounding the implant apex was observed post-surgery in cases treated with either BC alone or in combination with an adjunctive biomaterial. The isolation of a BC with a trephine drill at the implant site and its implosion with osteotomes to obtain the elevation of the maxillary sinus floor has been already described in association with delayed (Fugazzotto & De Paoli, 2002; Kolerman, Moses, Artzi, Barnea, & Tal, 2011) and immediate implant placement (Soltan & Smiler, 2004; Teng et al., 2013). On the other hand, the effectiveness of the association of BC with graft materials such as ß-TCP, DBBM, DPBM, and S-HA is well documented for tSFE procedures and immediately followed by implant positioning (Farina et al., 2018, 2019; Franceschetti et al., 2014, 2015, 2017; Trombelli et al., 2012, 2014; Trombelli, Minenna, Franceschetti, Minenna, Itro, et al., 2010b). To date, there is no consensus regarding the need for a material (either autologous, heterologous/synthetic or their combination) to optimize the long-term prognosis of implants placed concomitantly with tSFE. While all the studies mentioned above report high survival rates on the short term, limited data are currently available on the long-term performance of implants placed concomitantly with tSFE with or without grafting procedures (Zill et al., 2016). Differently, the majority of available long-term data are derived from studies where tSFE was associated with reconstructive/regenerative devices (Corbella et al., 2015; Del Fabbro et al., 2012, 2013; Esposito, Felice, & Worthington, 2014; Pocaterra et al., 2016; Tan et al., 2008).

The present results must be considered in the light of some methodological limitations inherent to the study design. First, retrospective convenience sampling resulted in limited sample size for some grafting procedures (e.g., BC), preventing the possibility to include all grafting procedures in the comparative analysis. Moreover, all study parameters were assessed on periapical radiographs. When used to monitor the outcomes of sinus floor elevation, periapical radiographs may not always allow for the visualization of the implant apex and the surrounding area, may suffer from dimensional distortion due to deformation of the film on the palate, and allow for the evaluation of the mesial, distal, and apical implant aspect only. Although a recent study on 13 patients showed that linear radiographic measurements of bone anchorage and implant protrusion into the sinus taken on periapical radiographs at 10-year follow-up following tSFE have an acceptable level of agreement with those measured on CBCT (El Hage, Nurdin, Abi Najm, Bischof, & Nedir, 2019), whether or not radiographic observations on periapical radiographs may be sufficient and systematically used to monitor tSFE outcomes on the long term still needs to be evaluated in details.

In the present retrospective study, different implant systems were used in association with the investigated technique. It may be hypothesized that such technical aspect may to some extent have influenced the observed results. Previous studies, however, did not find any significant effect of implant system on radiographic outcomes following tSFE (Kim, Park, Suh, Sohn, & Lee, 2011). Also, no information on the incidence of membrane perforation could be exhaustively retrieved for the selected cases, thus preventing the possibility to investigate the impact of such complication on the long-term radiographic outcomes of tSFE. To date, limited evidence is available on this topic. Recently, a sub-analysis in the study by Farina et al. (2019) suggested that membrane perforation may have a limited impact on radiographic linear measurements performed on the peri-implant radiopaque area at 12 months following tSFE. Although the relevance of such intra-operative complication for the long-term dimensional modifications of the residual volume that persists under the repaired mucosa is probably even lower than at 12 months, the impact of membrane perforation on long-term remodeling of the peri-implant bone support remains unexplored.

In conclusion, within their limits, the results of the present study indicate that although the height of the peri-implant radiopaque area surrounding the implant (particularly, in its apical portion) tends to reduce overtime at sites which have received tSFE, the peri-implant bone support seems to be maintained long term irrespective of the graft material used.

ACKNOWLEDGEMENTS

This study was supported by the Research Centre for the Study of Periodontal and Peri-Implant Diseases, University of Ferrara, Italy, a research grant by Regione Emilia-Romagna (Programma di Ricerca Regione-Università, Area 1 "Ricerca Innovativa," Bando Giovani Ricercatori "Alessandro Liberati" 2013; project PRUA1GR-2013-00000168), a research grant of the Osteology Foundation, Lucerne, Switzerland (project #13-063), and a donation from Geistlich Biomaterials, Thiene, Italy.

AUTHOR CONTRIBUTIONS

G.F., R.F., and L.T. designed the study and finalized the manuscript for submission. G.F., R.F., L.M., O.R., C.S., R.D.R, and L.T. performed the investigated treatments and drafted the manuscript. G.F. performed all radiographic measurements and prepared the study dataset, and E.M. performed data analysis.

ORCID

Roberto Farina https://orcid.org/0000-0002-4621-7809
Claudio Stacchi https://orcid.org/0000-0003-4017-4980

REFERENCES

Abdulkarim, H. H., Miley, D. D., McLeod, D. E., & Garcia, M. N. (2013). Short-term evaluation of bioactive glass using the modified osteotome sinus elevation technique. *Implant Dentistry*, *22*, 491–498. https://doi.org/10.1097/ID.0b013e31829d1a0b

Asai, S., Shimizu, Y., & Ooya, K. (2002). Maxillary sinus augmentation model in rabbits: Effect of occluded nasal ostium on new bone formation. *Clinical Oral Implants Research*, *13*, 405–409. https://doi.org/10.1034/j.1600-0501.2002.130409.x

Brägger, 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. https://doi.org/10.1111/j.1600-0501.2004.00988.x

Corbella, S., Taschieri, S., & Del Fabbro, M. (2015). Long-term outcomes for the treatment of atrophic posterior maxilla: A systematic review of literature. *Clinical Implant Dentistry and Related Research*, *17*, 120–132. https://doi.org/10.1111/cid.12077

Dahlin, C., Linde, A., Gottlow, J., & Nyman, S. (1988). Healing of bone defects by guided tissue regeneration. *Plastic and Reconstructive Surgery*, *81*, 672–676. https://doi.org/10.1097/00006534-198805000-00004

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. https://doi.org/10.1111/j.1708-8208.2011.00399.x

Del Fabbro, M., Wallace, S. S., & Testori, T. (2013). Long-term implant survival in the grafted maxillary sinus: A systematic review. *International Journal of Periodontics and Restorative Dentistry*, *33*, 773–783. https://doi.org/10.11607/prd.1288

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.

Diserens, V., Mericske, E., & Mericske-Stern, R. (2005). Radiographic analysis of the transcrestal sinus floor elevation: Short-term observations. *Clinical Implant Dentistry and Related Research*, *7*, 70–78. https://doi.org/10.1111/j.1708-8208.2005.tb00049.x

Duan, D. H., Fu, J. H., Qi, W., Du, Y., Pan, J., & Wang, H. L. (2017). Graft-Free maxillary sinus floor elevation: A systematic review and meta-analysis. *Journal of Periodontology*, *88*, 550–564. https://doi.org/10.1902/jop.2017.160665

El Hage, M., Nurdin, N., Abi Najm, S., Bischof, M., & Nedir, R. (2019). Osteotome sinus floor elevation without grafting: A 10-year study of cone beam computerized tomography vs periapical radiography. *International Journal of Periodontics and Restorative Dentistry*, *39*, e89–e97.

Esposito, M., Felice, P., & Worthington, H. V. (2014). Interventions for replacing missing teeth: Augmentation procedures of the maxillary sinus. *Cochrane Database of Systematic Reviews*, *13*, CD008397. https://doi.org/10.1002/14651858.CD008397.pub2

Farina, R., Franceschetti, G., Travaglini, D., Consolo, U., Minenna, L., Schincaglia, G. P., … Trombelli, L. (2018). Morbidity following transcrestal and lateral sinus floor elevation: A randomized trial. *Journal of Clinical Periodontology*, *45*, 1128–1139. https://doi.org/10.1111/jcpe.12985

Farina, R., Franceschetti, G., Travaglini, D., Consolo, U., Minenna, L., Schincaglia, G. P., … Trombelli, L. (2019). Radiographic outcomes of transcrestal and lateral sinus floor elevation: One-year results of a bi-center, parallel-arm randomized trial. *Clinical Oral Implants Research*, *30*(9), 910–919. https://doi.org/10.1111/clr.13497

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. https://doi.org/10.1111/j.1600-0501.2010.02087.x

Franceschetti, G., Farina, R., Minenna, L., Franceschetti, G., & Trombelli, L. (2015). Learning curve of a minimally invasive technique for transcrestal sinus floor elevation: A split-group analysis in a prospective case series with multiple clinicians. *Implant Dentistry*, *24*, 517–526. https://doi.org/10.1097/ID.0000000000000270

Franceschetti, G., Farina, R., Stacchi, C., Di Lenarda, R., Di Raimondo, R., & Trombelli, L. (2014). Radiographic outcomes of transcrestal sinus floor elevation performed with a minimally invasive technique in smoker and non-smoker patients. *Clinical Oral Implants Research*, *25*, 493–499. https://doi.org/10.1111/clr.12188

Franceschetti, G., Rizzi, A., Minenna, L., Pramstraller, M., Trombelli, L., & Farina, R. (2017). Patient-reported outcomes of implant placement performed concomitantly with transcrestal sinus floor elevation or entirely in native bone. *Clinical Oral Implants Research*, *28*, 156–162. https://doi.org/10.1111/clr.12774

Fugazzotto, P. A., & De Paoli, S. (2002). Sinus Floor Augmentation on at the Time of Maxillary Molar Extraction: Success and Failure Rates of 137 Implants in Function for Up to 3 Years. *Journal of Periodontology*, *73*, 39–44. https://doi.org/10.1902/jop.2002.73.1.39

Garlini, G., Redemagni, M., Donini, M., & Maiorana, C. (2010). Maxillary sinus elevation with an alloplastic material and implants: 11 years of clinical and radiologic follow-up. *Journal of Oral and Maxillofacial Surgery*, *68*, 1152–1157. https://doi.org/10.1016/j.joms.2009.05.440

Gruber, R., Kandler, B., Fürst, G., Fischer, M. B., & Watzek, G. (2004). Porcine sinus mucosa holds cells that respond to bone morphogenetic protein BMP-6 and BMP-7 with increased osteogenic differentiation in vitro. *Clinical Oral Implants Research*, *15*, 575–580. https://doi.org/10.1111/j.1600-0501.2004.01062.x

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.

Jung, J. H., Choi, S. H., Cho, K. S., & Kim, C. S. (2010). Bone-added osteotome sinus floor elevation with simultaneous placement of non-submerged sand blasted with large grit and acid etched implants: A 5-year radiographic evaluation. *Journal of Periodontal and Implant Science*, *40*, 69–75. https://doi.org/10.5051/jpis.2010.40.2.69

Jungner, M., Cricchio, G., Salata, L. A., Sennerby, L., Lundqvist, C., Hultcrantz, M., & Lundgren, S. (2015). On the early mechanisms of bone formation after maxillary sinus membrane elevation: An experimental histological and immunohistochemical study. *Clinical Implant Dentistry and Related Research*, *17*, 1092–1102. https://doi.org/10.1111/cid.12218

Kim, H. R., Choi, B. H., Xuan, F., & Jeong, S. M. (2010). The use of autologous venous blood for maxillary sinus floor augmentation in conjunction with sinus membrane elevation: An experimental study. *Clinical Oral Implants Research*, *21*, 346–349. https://doi.org/10.1111/j.1600-0501.2009.01855.x

Kim, S. M., Park, J. W., Suh, J. Y., Sohn, D. S., & Lee, J. M. (2011). Bone-added osteotome technique versus lateral approach for sinus floor elevation: A comparative radiographic study. *Implant Dentistry*, *20*, 465–470. https://doi.org/10.1097/ID.0b013e31823545b2

Kolerman, R., Moses, O., Artzi, Z., Barnea, E., & Tal, H. (2011). Maxillary sinus augmentation by the crestal core elevation technique. *Journal of Periodontology*, *82*, 41–51. https://doi.org/10.1902/jop.2010.090682

Krennmair, G., Krainhöfner, M., Schmid-Schwap, 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.

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.

Lombardi, T., Stacchi, C., Berton, F., Traini, T., Torelli, L., & Di Lenarda, R. (2017). Influence of maxillary sinus width on new bone formation after transcrestal sinus floor elevation: A proof-of-concept prospective cohort study. *Implant Dentistry*, *26*, 209–216. https://doi.org/10.1097/ID.0000000000000554

Maiorana, C., Sigurtà, D., Mirandola, A., Garlini, G., & Santoro, F. (2005). Bone resorption around dental implants placed in grafted sinuses: Clinical and radiologic follow-up after up to 4 years. *International Journal of Oral and Maxillofacial Implants*, *20*, 261–266.

Mardinger, O., Chaushu, G., Sigalov, S., Herzberg, R., Shlomi, B., & Schwartz-Arad, D. (2011). Factors affecting changes in sinus graft height between and above the placed implants. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics*, *111*, e6–11. https://doi.org/10.1016/j.tripleo.2010.09.064

Marković, A., Mišić, T., Calvo-Guirado, J. L., Delgado-Ruíz, R. A., Janjić, B., & Abboud, M. (2016). Two-center prospective, randomized, clinical, and radiographic study comparing osteotome sinus floor elevation with or without bone graft and simultaneous implant placement. *Clinical Implant Dentistry and Related Research*, *18*, 873–882. https://doi.org/10.1111/cid.12373

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. https://doi.org/10.1111/j.1600-0501.2010.01939.x

Nedir, R., Nurdin, N., Abi Najm, S., El Hage, M., & Bischof, M. (2017). Short implants placed with or without grafting into atrophic sinuses: The 5-year results of a prospective randomized controlled study. *Clinical Oral Implants Research*, *28*, 877–886. https://doi.org/10.1111/clr.12893

Nedir, R., Nurdin, N., Khoury, P., Perneger, T., Hage, M. E., Bernard, J. P., & Bischof, M. (2013). Osteotome sinus floor elevation with and without grafting material in the severely atrophic maxilla. A 1-year prospective randomized controlled study. *Clinical Oral Implants Research*, *24*, 1257–1264.

Nishida, T., Takenouchi, Y., Mori, K., Ariji, M., Nishida, K., & Ito, K. (2013). Remodeling of autogenous bone grafts after osteotome sinus floor elevation assessed by limited cone beam computed tomography. *International Journal of Dentistry*, *2013*, 931708. https://doi.org/10.1155/2013/931708

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. https://doi.org/10.1902/jop.2003.74.6.909

Palma, V. C., Magro-Filho, O., de Oliveria, J. A., Lundgren, S., Salata, L. A., & Sennerby, L. (2006). Bone reformation and implant integration following maxillary sinus membrane elevation: An experimental study in primates. *Clinical Implant Dentistry and Related Research*, *8*, 11–24. https://doi.org/10.2310/j.6480.2005.00026.x

Peñarrocha-Diago, M., Galán-Gil, S., Carrillo-García, C., Peñarrocha-Diago, D., & Peñarrocha-Diago, M. (2012). Transcrestal sinus lift and implant placement using the sinus balloon technique. *Medicina Oral, Patologia Oral Y Cirugia Bucal*, *17*, e122–128. https://doi.org/10.4317/medoral.17268

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. https://doi.org/10.1007/s00784-010-0484-9

Pjetursson, B. E., Ignjatovic, D., Matuliene, G., Brägger, U., Schmidlin, K., & Lang, N. P. (2009). Transalveolar maxillary sinus floor elevation using osteotomes with or without grafting material. Part II: Radiographic tissue remodeling. *Clinical Oral Implants Research*, *20*, 677–683. https://doi.org/10.1111/j.1600-0501.2009.01721.x

Pjetursson, B. E., Rast, C., Brägger, U., Schmidlin, K., Zwahlen, M., & Lang, N. P. (2009). 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. https://doi.org/10.1111/j.1600-0501.2009.01704.x

Pocaterra, A., Caruso, S., Bernardi, S., Scagnoli, L., Continenza, M. A., & Gatto, R. (2016). Effectiveness of platelet-rich plasma as an adjunctive material to bone graft: A systematic review and meta-analysis of randomized controlled clinical trials. *International Journal of Oral and Maxillofacial Surgery*, *45*, 1027–1034. https://doi.org/10.1016/j.ijom.2016.02.012

Pommer, B., & Watzek, G. (2009). Gel-pressure technique for flapless transcrestal maxillary sinus floor elevation: A preliminary cadaveric study of a new surgical technique. *International Journal of Oral and Maxillofacial Implants*, *24*, 817–822.

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. Erratum. In: Clinical Oral Implants Research 2011;22:235.

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.

Rong, Q., Li, X., Chen, S. L., Zhu, S. X., & Huang, D. Y. (2015). Effect of the Schneiderian membrane on the formation of bone after lifting the

floor of the maxillary sinus: An experimental study in dogs. *British Journal of Oral and Maxillofacial Surgery*, *53*, 607–612. https://doi.org/10.1016/j.bjoms.2015.02.010

Scala, A., Lang, N. P., Velez, J. U., Favero, R., Bengazi, F., & Botticelli, D. (2016). Effects of a collagen membrane positioned between augmentation material and the sinus mucosa in the elevation of the maxillary sinus floor. An experimental study in sheep. *Clinical Oral Implants Research*, *27*, 1454–1461. https://doi.org/10.1111/clr.12762

Schulze-Späte, U., Dietrich, T., Kayal, R. A., Hasturk, H., Dobeck, J., Skobe, Z., & Dibart, S. (2012). Analysis of bone formation after sinus augmentation using â-tricalcium phosphate. *Compendium of Continuing Education in Dentistry*, *33*, 364–368.

Soltan, M., & Smiler, D. G. (2004). Trephine bone core sinus elevation graft. *Implant Dentistry*, *13*, 148–152. https://doi.org/10.1097/01.ID.0000127525.98819.B6

Srouji, S., Ben-David, D., Funari, A., Riminucci, M., & Bianco, P. (2013). Evaluation of the osteoconductive potential of bone substitutes embedded with schneiderian membrane- or maxillary bone marrow-derived osteoprogenitor cells. *Clinical Oral Implants Research*, *24*, 1288–1294. https://doi.org/10.1111/j.1600-0501.2012.02571.x

Srouji, S., Ben-David, D., Lotan, R., Riminucci, M., Livne, E., & Bianco, P. (2010). The innate osteogenic potential of the maxillary sinus (Schneiderian) membrane: An ectopic tissue transplant model simulating sinus lifting. *International Journal of Oral and Maxillofacial Surgery*, *39*, 793–801. https://doi.org/10.1016/j.ijom.2010.03.009

Srouji, S., Kizhner, T., Ben-David, D., Riminucci, M., Bianco, P., & Livne, E. (2009). The Schneiderian membrane contains osteoprogenitor cells: In vivo and in vitro study. *Calcified Tissue International*, *84*, 138–145.

Stacchi, C., Lombardi, T., Ottonelli, R., Berton, F., Perinetti, G., & Traini, T. (2018). New bone formation after transcrestal sinus floor elevation was influenced by sinus cavity dimensions: A prospective histologic and histomorphometric study. *Clinical Oral Implants Research*, *29*, 465–479. https://doi.org/10.1111/clr.13144

Sul, S. H., Choi, B. H., Li, J., Jeong, S. M., & Xuan, F. (2008). Histologic changes in the maxillary sinus membrane after sinus membrane elevation and the simultaneous insertion of dental implants without the use of grafting materials. *Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology and Endodontics*, *105*, e1–5. https://doi.org/10.1016/j.tripleo.2007.11.019

Tallarico, M., Meloni, S. M., Xhanari, E., Pisano, M., & Cochran, D. L. (2017). Minimally invasive sinus augmentation procedure using a dedicated hydraulic sinus lift implant device: A prospective case series study on clinical, radiologic, and patient-centered outcomes. *International Journal of Periodontics and Restorative Dentistry*, *37*, 125–135. https://doi.org/10.11607/prd.2914

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.

Temmerman, A., Van Dessel, J., Cortellini, S., Jacobs, R., Teughels, W., & Quirynen, M. (2017). Volumetric changes of grafted volumes and the Schneiderian membrane after transcrestal and lateral sinus floor elevation procedures: A clinical, pilot study. *Journal of Clinical Periodontology*, *44*, 660–671. https://doi.org/10.1111/jcpe.12728

Teng, M., Liang, X., Yuan, Q., Nie, J., Ye, J., Cheng, Q., … Mo, A. (2013). The inlay osteotome sinus augmentation technique for placing short implants simultaneously with reduced crestal bone height. A short-term follow-up. *Clinical Implant Dentistry and Related Research*, *15*, 918–926. https://doi.org/10.1111/cid.12088

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. https://doi.org/10.1902/jop.2007.060308

Trombelli, L., Franceschetti, G., Rizzi, A., Minenna, P., Minenna, L., & Farina, R. (2012). Minimally invasive transcrestal sinus floor elevation with graft biomaterials. A randomized clinical trial. *Clinical Oral Implants Research*, *23*, 424–432. https://doi.org/10.1111/j.1600-0501.2011.02318.x

Trombelli, L., Franceschetti, G., Stacchi, C., Minenna, L., Riccardi, O. L., Di Raimondo, R., & Farina, R. (2014). Minimally-invasive transcrestal sinus floor elevation with a deproteinized bovine bone or ß-tricalcium phosphate: A multicenter, randomized, controlled clinical trial. *Journal of Clinical Periodontology*, *41*, 311–319.

Trombelli, L., Franceschetti, G., Trisi, P., & Farina, R. (2015). Incremental, transcrestal sinus floor elevation with a minimally invasive technique in the rehabilitation of severe maxillary atrophy. Clinical and histological findings from a proof-of-concept case series. *Journal of Oral and Maxillofacial Surgery*, *73*, 861–888. https://doi.org/10.1016/j.joms.2014.12.009

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.

Trombelli, L., Minenna, P., Franceschetti, G., Minenna, L., & Farina, R. (2010a). Transcrestal sinus floor elevation with a minimally invasive technique. *Journal of Periodontology*, *81*, 158–166. https://doi.org/10.1902/jop.2009.090275

Trombelli, L., Minenna, P., Franceschetti, G., Minenna, L., Itro, A., & Farina, R. (2010b). Minimally invasive technique for transcrestal sinus floor elevation: A case report. *Quintessence International*, *41*, 363–369.

Uckan, 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.

Zerbo, I. R., Zijderveld, S. A., de Boer, A., Bronckers, A. L., de Lange, G., ten Bruggenkate, 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. https://doi.org/10.1111/j.1600-0501.2004.01055.x

Zill, A., Precht, C., Beck-Broichsitter, B., Sehner, S., Smeets, R., Heiland, M., … Henningsen, A. (2016). Implants inserted with graftless osteotome sinus floor elevation - A 5-year post-loading retrospective study. *European Journal of Oral Implantology*, *9*, 277–289.

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. https://doi.org/10.1016/S1079-2104(98)90391-2

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

How to cite this article: Franceschetti G, Farina R, Minenna L, et al. The impact of graft remodeling on peri-implant bone support at implants placed concomitantly with transcrestal sinus floor elevation: A multicenter, retrospective case series. *Clin Oral Impl Res*. 2020;31:105–120. https://doi.org/10.1111/clr.13541