Association of Smoking Habits and Height of Residual Bone on Implant Survival and Success Rate in Lateral Sinus Lift: A Retrospective Study

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The primary aim was to evaluate the association of patient-related factors, biomaterials, and implant characteristics on complications' rate of sinus graft surgery and on implant survival rate in grafted sinus. Secondary aims were to measure bone remodeling around implants and patient satisfaction. A retrospective cohort study was designed. Patients who had computerized tomography (CT) before sinus surgery (T0), orthopantomography after implant surgery (T1) and at follow-up (T2), were included. Specific forms were used to collect clinical data. Radiographic measures were: height of residual bone before sinus surgery measured on CT (T0) and apical and marginal bone levels around implants measured on orthopantomography at T1 and T2. Forty-three lateral sinus lifts were performed. Three grafts failed before implant insertion. Out of 83 implants inserted in 29 patients, a total of 19 failed. Mean follow-up (T2) was 6 $\pm$ 1.8 years [4; 11.2 years]. The multilevel models analysis showed no association between complications rate and patient-related factors, biomaterials, and implant characteristics. Smoking (odds ratio [OR]: 8.3; 95% CI 1.46–48.05, $P = .0173$) and height of residual bone (OR: 0.32 for each mm; 95% CI 0.15–0.68, $P = .0034$) were associated with implant failure. Bone remodeling between T1 and T2 was -0.8 ± 0.2 mm for apical bone and -0.6 ± 0.3 mm for marginal bone. General therapy satisfaction measured in a visual analogue scale was 8.4 $\pm$1.4. In conclusion, lower height of residual bone before sinus surgery and smoking habits had a negative prognostic effect on survival rate of dental implants placed in grafted sinuses.

Key Words: lateral sinus augmentation, implant survival, smoking habits, height of residual bone

Introduction

Lateral sinus lift allows filling the sinus floor with different biomaterials.[1–3] This technique is reliable and has low complication rates.[4,5] An implant placed in lifted sinuses showed high survival rate. Pjetursson et al report an annual implant failure of 3.5% and a 3-year implant survival of 90.1%.[6] In a systematic review, after a minimum of 3 years of prosthetic loading, Del Fabbro et al describe a cumulative implant survival rate of 93,7%.[7] Systemic diseases (diabetes, osteoporosis),[8] drug use,[9] smoking habits,[10] alcoholism, height of residual bone at implant site, and anatomical and local factors[6] are variables that could influence implant survival rates.

Smoking more than 15 cigarettes/d and a height of residual bone at implant site <4 mm are associated with reduced implant survival.[31,32] However, a recent review, analyzing only prospective data, fails to confirm the detrimental effect of smoking.[29] Chao et al,[33] in a meta-analysis, report that a minimum height of residual bone of 4.03 mm is associated with a survival rate of 96% at 3 years' follow-up, underlining the importance of residual bone. Despite the data, we do not fully understand the relationship between reduction of height of residual bone and implant failure.

Both autografts and nonautogenous graft demonstrate reliable results.[11,12] All these materials show remodeling around the apical portion of the dental implant,[2,3,13] and this could affect the marginal bone level.[5] Graft stability is a key factor for implant success,[14] and consistent graft volume can reduce intrabony stresses and stress at the bone–implant interface.[15,16]

Moreover, as the patient satisfaction is one aim of the therapy, the use of the visual analogue scale (VAS) and or categorized questions has been recommended.[17]

The primary aim of this study is to analyze the association of smoking habits, height of residual bone, patient-related factors, biomaterials, and implant characteristics with implant survival and sinus surgery's premature complications. Secondary aims are to analyze graft stability and the patient's satisfaction at follow-up.

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Material and Methods

Study design

We designed a retrospective cohort study. Patients were recruited from those who received sequentially lateral sinus floor augmentation and delayed implant-supported fixed prosthesis. All patients were treated by a single expert operator between January 2005 and April 2011.

To be included in the study, patients had to match the following inclusion criteria: (1) age > 18 years; (2) previous lateral sinus floor augmentation, mono- or bilateral technique; (3) Follow-up from sinus surgery > 4 years; (4) radiographic exams: computerized tomography (CT) at T0 (before sinus surgery) and orthopantomography (OPT) at T1 (after implant surgery).

Patients were excluded if they underwent (1) intravenous and or oral bisphosphonate therapy after sinus surgery or (2) a different therapy from lateral sinus lift.

The Ethical Committee of the University of Florence (Florence, Italy) approved the study protocol (Ethical Approval Form Protocol Number *OSS.16.231)*. Each patient provided a written informed consent before participation. All clinical procedures were performed in accordance with the Declaration of Helsinki and the Good Clinical Practice Guidelines.

Surgical methods

At T0, before sinus surgery, patients were examined with cone beam CT or CT.

At sinus surgery, patients received local anesthesia using articaine (40 mg/mL) with epinephrine (1/100 000). A muco-periosteal flap was elevated buccally and apically, allowing access to the lateral sinus wall. Then, an osteotomy was performed using a piezoelectric device,[18] and the sinus membrane was carefully elevated.

The sinus was filled with an allograft or a xenograft according to the surgical plan, and the flap was repositioned and sutured using 4/0 absorbable suture (Vicryl, Ethicon, Somerville, NJ) to achieve primary closure. Postoperatively, patients received antibiotics (amoxicillin/clavulanic acid 1 g twice a day for 6 days) and analgesic therapy (ibuprofen, 600 mg or acetaminophen, 1 g as needed, maximum 3 tablets a day). Sutures were removed 2 weeks after surgery. After a period of graft healing of 9–12 months, rough implants were inserted. Number, diameter, and length of implants in each case were determined according to the prosthetic plan and the quality and quantity of the recipient bone. All inserted implants were conical or cylindrical and had a length between 8–12 mm and a diameter between 3.8 and 4.8 mm. Implants had moderately rough surface. (Two steps acid etching and thermal treated, TSA Advance, Defcon, Barcelona, Spain; sand blasted and acid etched, BL-SLA or TL-SLA, Straumann, Basel, Switzerland; sand blasted implemented with fluoride ions, Osseospeed tx, AstraTech, Dentsply Sirona, York, Pa; sand blasted, Exacone, Leone, Sesto Fiorentino, Italy; Laser treated: Way-Milano Geass, Pozzuolo del Friuli, Italy).

At T1, 6–9 months after implant surgery, the patient was evaluated with an OPT and was rehabilitated with prosthetic restoration on implants. At T2 follow-up visit, patients were evaluated radiographically (OPT) and clinically.

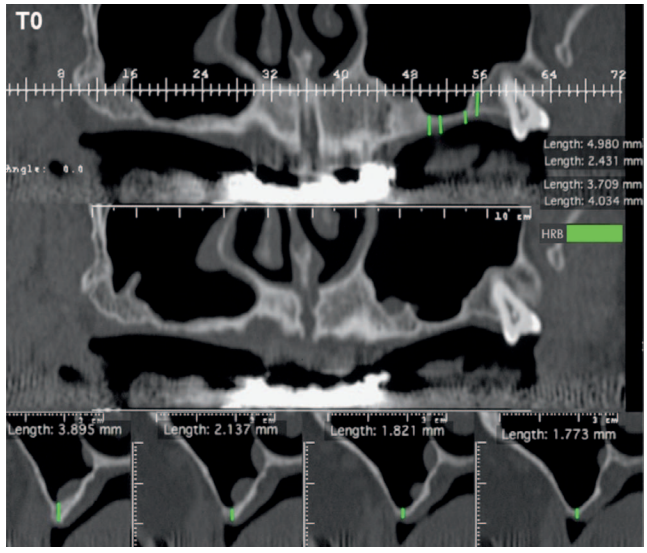

Figure 1. Example of radiographic measures at T0 on cone-beam computerized tomography. Light green: height of residual bone before sinus surgery (HRB).

Variables

Apposite forms were created to collect following variables: cohort description, radiographic measurement, clinical variables, and patient satisfaction.

Cohort description variables were registered for patient-related factors, biomaterials, and implant characteristics. Patients' related factors like sex, age, smoking habits (smoker/no-smoker; number of cigarettes/day) were recorded at follow-up. Type of biomaterials, use of a membrane or platelet-rich fibrin), implant length, diameter and brand, prosthetic time, and type of implant–prosthetic rehabilitation were collected from medical charts.

For radiographic measurements, a single trained examiner, different from the surgical operator, measured radiographic variables. The examiner underwent a calibration session for all radiographic variables on a sample of 20 patients, with an intraclass coefficient of correlation for intra-rater agreement between 0.93 and 0.99.

Analogic radiographs were scanned and digitalized at a resolution of 600 dots per inch, with a scanner (HP Scanjet G4050, HP, Palo Alto, Calif). OsiriX (imaging software, Pixmeo, Bernex, Switzerland) software was used to measure radiographic variables. Considering radiographic distortion, measurements on each radiograph were adjusted for a coefficient derived from the ratio: true length of the implant/radiographic implant length (RIL).[19]

Only 1 radiological measure was registered at T0, before sinus surgery, on CT (Figure 1):

- Height of residual bone before sinus surgery (HRB): vertical distance from the alveolar ridge to the most inferior sinus floor before sinus surgery at the projected implant placement site, measured in millimeters.[20]

The following radiological variables were measured on OPT at 2 different time points, T1 and T2 (Figure 2):[19,21,22]

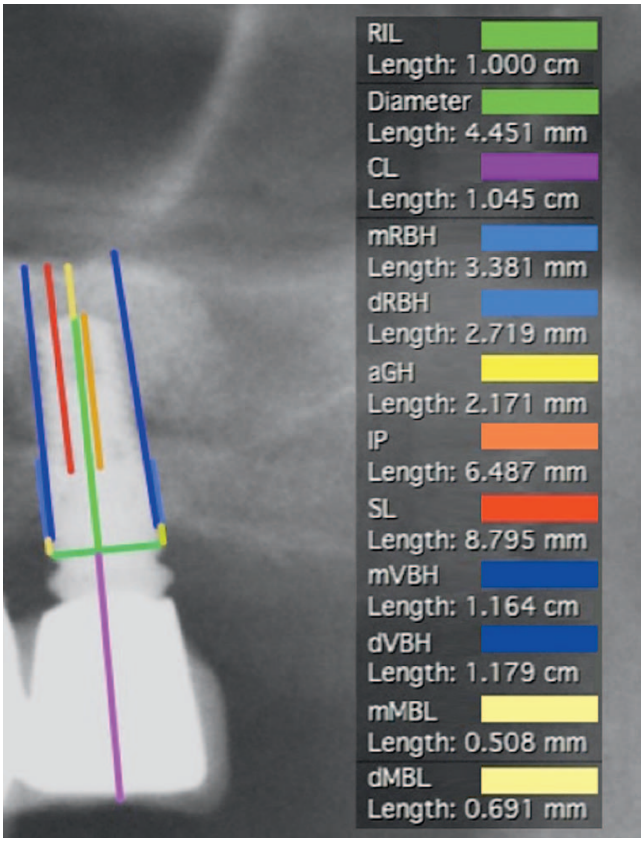

Figure 2. Example of radiographic measures at T1 and T2 on orthopantomography. Green: radiographic implant length (RIL) and diameter. Light blue: height of residual bone at the mesial (mHRB) and distal (dHRB) aspects of the implant. Yellow: height of the graft apically (aGH). Orange: implant penetration (IP). Red: extent of the sinus lift (SL). Light yellow: marginal bone level at the mesial (mMBL) and distal (dMBL) aspects of the implant. Dark blue: vertical bone height at the mesial (mVBH) and the distal (dVBH) aspects of the implants. Purple: crown-to-implant ratio (C/I).

- RIL: distance (in mm) between the implant shoulder and the implant apex measured at the midportion of the implant
- Height of residual bone at the mesial (mHRB) and distal (dHRB) aspects of the implant: distance (in mm) between the mesial and distal aspect of the implant shoulder, respectively, and the sinus floor
- Height of residual bone at implant site (HRB-i): calculated as the mean value of mHRB and dHRB
- Height of the graft apically (aGH): distance (in mm) occupied by a radiopaque area between the implant apex and the sinus floor measured at the midportion of the implant
- Implant penetration (IP): calculated as the difference between RIL and HRB-i
- Extent of the sinus lift (SL): calculated as the sum of IP and aGH
- Marginal bone level at the mesial (mMBL) and distal (dMBL) aspects of the implant: measurement (in mm) from the implant abutment junction to the most coronal point of the bone-to-implant contact
- Vertical bone height at the mesial (mVBH) and the distal (dVBH) aspects of the implants: measurement (in mm) from the most coronal point of bone-to-implant contact to the base of the maxillary sinus
- Crown-to-implant ratio (C/I): ratio between height (in mm) of the crowns, measured on the radiographs from the implant abutment interface to the most coronal point on the crown and the length of the implant

The differences for aGH, HRB-I, IP, SL, MBL, and VBH, were calculated between T2 and T1 and defined as ΔaGH, ΔHRB-I, ΔIP, ΔSL, ΔMBL, and ΔVBH.

Clinical variables were examiner-recorded implants survival and clinical variables during the follow-up visit. Bleeding on probing (BoP) and clinical probing depth (PD) were measured at 4 points (buccal, palatal, distal, and mesial) for each implant using a periodontal probe (Pq-W 15 UNC).[23,24,25] Also, recession (REC) was measured at buccal aspect.

Peri-implantitis was evaluated with Roos-Jansaker et al 2006 criteria:[26] bone loss $>$ 1.8 mm after first year, BoP.

Patient satisfaction was recorded with categorized statements and VAS at follow-up. Patients were asked to evaluate 12 statements and 5 categorized scales concerning function, phonetics, esthetics, oral hygiene, general satisfaction, and cost of rehabilitation[17]. In addition, they were asked to mark the respective VAS, a 100 mm straight line with the left end indicating "total discontent" and the right end "total satisfaction." Distance from the right end of the scale to the mark was measured in millimeters.

Statistical analysis

Descriptive statistics using mean and SD for quantitative variables, and frequency and percentage for qualitative variables, were performed. For inferential analysis, multilevel models were performed. Outcome variables were premature complications (perforations and infection of grafted sinus) and implant failures. For premature complications, 2-level logistical models (patient and biomaterials) were performed, and for implant failure, 3-level logistical models (patient, biomaterials, and implant) were performed. Bivariate analyses were conducted, considering every single variable as a predictor variable. Two logistic, multilevel, stepwise backward analyses (for premature complications and for implant failure) were performed using the significant variables in the bivariate analyses as predictors. To compare radiographic variables between T1 and T2, mixed effects models were performed using the patient as a random effect.

Results

Thirty-two patients for a total of 43 lateral sinus grafts were included. Twenty-two were women and 10 were men, ranging from 37 to 81 years old (mean 55.4 $\pm$ 8.1). Thirteen patients (41%) were smokers, 15.4 $\pm$ 4.3 cigarettes/d [10; 25]. Mean follow-up at T2 from sinus surgery was 6 $\pm$ 1.8 [4; 11.2] years.

HRB before sinus surgery was 4.7 $\pm$ 1.3 mm [1.8; 8.1]. In 6 cases small perforations during the surgery were recorded (14%).

Different graft materials were used: demineralized freeze-dried bone allograft or cortico-cancellous xenograft. In some

Table 1

Multilevel statistical analysis for premature complications. Letters (A–G) represent different kind of biomaterial used: (A) DFDBA, granular with cortical bone; (B) DFDBA, granular with high demineralized bone matrix concentration; (C) heterologous cortico-cancellous bone mix, 90% granulated mix, 10% collagen gel; (D) cortico-cancellous heterologous bone mix, 100% granulated mix; (E) deantigenated and decollagenated equine cancellous—cortical granules; (F) Porcine heterologous cortico-cancellous bone mix, 100% cortico-cancellous mix and degraded collagen matrix; (G) bone substitute: beta tricalcium phosphate. None of the variables that resulted were statistically significant ($P < .05$).*

Variables	Odds Ratio	*P* Value
Smoking habits	4.07	.29
Cigarettes/d	1.13	.20
Allogenic graft	1.89	.65
Xenograft	1.03	.98
Allograft	0.67	.72
Collagen membrane	0.76	.80
PRF	0.25	.33
Titanium mesh	11.26	.058
A	4.12	.29
B	0.28	.32
C	2.21	.73
D	6.77	.19
E	0.04	.16
F	0.34	.51
G	1.51	.82
Height of residual bone	0.75	.42

*DFDBA indicates demineralized freeze-dried bone allograft; PRF, platelet rich fibrin.

cases collagen membrane and or titanium mesh and or PRF (were also used.

In 18 sinus augmentation procedures (42%) premature complications were recorded: 15 patients (35%) developed infection of the graft. The infection healed with the use of oral antibiotics while in 3 patients (7%) the infection determined failure of the procedure.

Table 2

Multilevel statistical analysis for implant failure. See caption to Table 1 for definition of letters. Statistically significant values are given in bold (P value $< .05$).*

Variables	Odds Ratio	*P* Value
Male	1.57	.58
Smokers	**6.82**	**.0068**
Allogenic graft	1.48	.67
Xenograft	1.17	.83
Allograft	0.49	.43
Collagen membrane	1.02	.97
PRF	1.61	.52
Mesh	2.00	.46
A	**4.96**	**.0388**
B	0.11	.0550
D	0.57	.53
E	2.52	.29
F	0.42	.51
G	0.69	1.74
Premature complications	2.38	.23
Acid-etching implants	**9.03**	**.0040**
Height of residual bone	**0.26**	**.0004**
Screwed	5.33	.16

*PRF indicates platelet rich fibrin.

Table 3

Logistic multilevel stepwise backward analysis for implant failure as outcome variable. Statistically significant values are given in bold (P value $< .05$).

Variables	Odds Ratio	95% CI	*P* Value
Smoking habits	8.36	1.46; 48.05	**.0173**
Height of residual bone	0.32	0.15; 0.68	**.0034**

A total of 83 implants (mean length 9.7 ± 1.3 mm; mean diameter 4.2 ± 0.4 mm) were inserted in 29 patients and each patient received 1 to 3 dental implants. Eleven implants failed before the prosthetics rehabilitation. Hence, 72 dental implants were rehabilitated with bridges (43 implants, 60%) and single crowns (29 implants, 40%). Following the rehabilitation, 8 implants failed for a total of 19 failed implants.

One patient dropped out and 3 patients lost all implants so 25 patients remained for clinical examinations. Clinical variables were recorded for 61 implants (25 patients). Mean PD was 2.7 ± 0.8 mm, mean REC was 0.7 ± 0.9 mm, BoP was found on 37 implants (61%). For four implants (7%) peri-implantitis was diagnosed.

None of the patient-related factors and biomaterials characteristics influenced premature complications. In particular, smoking habits did not increase the complications' rate after sinus surgery ($P = .29$) but neither did the kind of biomaterials used nor the use of a collagen membrane (Table 1).

Statistical analysis revealed that only 2 variables are related to implant failure (Table 2, Table 3):

- Smoking habits: OR: 8.36 (95% CI 1.46–48.05, $P = .0173$).
- HRB: OR: 0.32 for each mm (95% CI 0.15–0.68, $P = .0034$)

Radiological variables between T1 and T2 were analyzed on 56 implants in 23 patients because 2 patients didn't have OPT at T2. Data are reported in Table 4. Differences for radiographic

Table 4

Linear radiographic measurements at T1 and T2.*

Time	Variables	Mean (mm ± SD)	Range (min; max)
T1 (after implant surgery)	aGH	2.9 ± 1.5	(0.5; 7.6)
	HRB-i	5.3 ± 1.6	(2.0; 9.2)
	IP	4.5 ± 1.8	(1.5; 9.5)
	SL	7.3 ± 2.5	(2.5; 14.0)
	MBL	0.6 ± 0.4	(0.03; 2.2)
	VBH	11.8 ± 2.0	(7.2; 15.7)
T2 (at the follow-up)	aGH	2.0 ± 1.4	(0.3; 7.7)
	HRB-i	4.6 ± 1.5	(1.7; 8.5)
	IP	5.1 ± 1.9	(1.8; 9.8)
	SL	7.1 ± 2.4	(2.7; 13.1)
	MBL	1.2 ± 1.0	(0.0; 5.1)
	VBH	10.4 ± 2.2	(6.6; 14.5)

*aGH indicates height of the graft apically; HRB-I, height of residual bone at implant site; IP, implant penetration; SL, extent of the sinus lift; MBL, marginal bone level at implant site; VBH, vertical bone height at implant site.

Table 5

Linear radiographic bone/graft remodeling between T1 and T2 (Δ). Statistically significant values are given in bold (*P* value < .05).*

Time	Variables	Mean (mm)	95% CI	*P* Value
ΔT1-T2	ΔaGH	−0.8	−0.7; −1.0	**<.0001**
	ΔHRB-i	−0.6	−0.5; −0.8	**<.0001**
	ΔIP	+0.6	0.5; 0.8	**<.0001**
	ΔSL	−0.2	−0.4; 0.04	.1005
	ΔMBL	+0.6	−0.4; −0.8	**<.0001**
	ΔVBH	−1.4	−1.1; −1.7	**<.0001**

*ΔaGH indicates height of the graft apically; ΔHRB-I, height of residual bone at implant site; ΔIP, implant penetration; ΔSL, extent of the sinus lift; ΔMBL, marginal bone level at implant site; ΔVBH: vertical bone height at implant site.

measurements between T1 and T2 are reported in Table 5. Apical graft remodeling (ΔaGH) and marginal (ΔMBL) bone remodeling around dental implants had statistically significant results for both parameters: ΔaGH −0.8 mm (95% CI −0.7 to −1.0, $P < .0001$) and ΔMBL−0.6 (95% CI −0.4 to −0.8, $P < .0001$) (Table 5).

VAS analysis was conducted at the follow-up visit. Data are reported in Table 6.

Table 6

Visual analog scale scores for patient satisfaction

Category of Questions	Mean ± SD	Range (min; max)
Function	8.2 ± 1.2	(5; 10)
Esthetics	7.7 ± 1.8	(4; 10)
Hygiene	7.5 ± 1.7	(4; 10)
Bleeding	6.9 ± 2.0	(3; 10)
Expectation	8.0 ± 1.5	(5; 10)
Costs	7.4 ± 1.6	(3; 10)
General satisfaction	8.4 ± 1.4	(6; 10)

Discussion

Despite the limits of a retrospective study with a small number of patients and a high number of heterogeneous characteristics, it was possible to analyze different variables and their associations with implant survival and success rate.

From literature, a systematic review reported an implant survival rate in sinus lifted maxillae between 61% and 100% after 3 years of follow-up.[27] Another review reported implant success rate between 46% and 100% after 3 years of follow-up.[6] Many of those studies present a wide range of survival and success rates, highlighting heterogeneous data and low levels of evidence, as reported by Del Fabbro et al on a more recent systematic review that registered survival rate from 75.5% to 100% after 3 years of follow-up.[7]

In this study the overall survival rate was 77% and success rate was 70% (4.0 to 11.2 years of follow-up). Due to the retrospective design of the study it was not possible to use strictly inclusion criteria and this may have jeopardized results.

One limit of this study was the retrospective design with a small number of patients and a high number of heterogeneous characteristics. However, a cohort composed of patients with different features, for example, smokers and nonsmokers with different heights of residual bone before sinus surgery, allows us to evaluate the association of these factors on implant survival.

In this study, smoking habits did not influence premature complication rates of sinus surgery. This is in accordance with a recent controlled study with 6 months follow-up, which underlined the absence of differences between smoker and no-smoker groups for premature complications.[19]

However, smoking habits influenced the implant survival rate. A recent review affirmed that more than half (62.5%) of the studies found that smoking adversely affects implant survival in sites of sinus floor augmentation. Although smoking was associated with implant failure in most of the individual studies and in the overall meta-analysis, the detrimental effect of smoking was not confirmed when only prospective data were assessed.[29] In a consensus report Tonetti and Hämmerle identified a difference between implant survival rate for an implant inserted in sinus-lifted maxillae between smoking and nonsmoking groups, but this difference was not significant from a statistical point of view, highlighting heterogeneity and low evidence of studies.[30]

HRB was identified in the present study as another variable that highly influenced implant survival rate with a risk 3.8 times greater for each millimeter less. This is in accordance with Testori et al who found that smoking > 15 cigarettes/d and a residual ridge height < 4 mm were significantly associated with reduced implant survival.[31] Also, Geurs reported a residual ridge height <4 mm as a risk factor for implant failure.[32]

A meta-regression analysis has been recently conducted to identify the prognostic effect of the height of residual bone, the results from 21 selected and analyzed studies show that a minimum height of residual bone of 4.03 mm is needed to have a 96% survival rate at 3 years follow-up.[33]

Also graft stability has been considered from some authors as an important factor for the success of the sinus therapies.[14]

One of the major limits of the study could be the analysis of bone remodeling on OPT. The local ethical committee did not approve a CBCT exam at mid-long term follow-up visit (4 to 11.2 years). Moreover, due to the retrospective design, we couldn't plan the use of CBCT after the implant's placement. The OPT is bidimensional, so we reported only linear measurements for graft remodeling. However, the CBCT and a processing software could add 3-dimensional and volumetric information and should be used in prospective clinical trial. Also periapical radiographs were excluded because of the difficulty of apical sinus graft remodeling analysis. In this study, even if intraoral radiographic examinations could be indicated for marginal bone level analysis, implants were used as internal caliper for measurements on OPT. Moreover, some authors underlined the low clinical relevance of 0.2 mm discrepancy between marginal bone level measures with periapical and OPT radiography around dental implants.[35]

Apical graft remodeling around the implant between T1 and T2 was ΔaGH -0.8 ± 0.2 mm after a minimum follow-up of 4 years in accordance with Sbordone et al that found that overall change of apical graft from 1 to 5 years of follow-up ranged from +0.7 mm to −0.6 mm.[13] Jensen at al considered a

graft with a remodeling of 2 mm stable after 3 years of follow-up.[14]

Sinus augmentation and implant therapy seem to be well accepted by patients.[36] Implant-supported rehabilitation on grafted sinus satisfied patients esthetically and functionally although lateral sinus augmentation was a highly invasive procedure. The costs associated with sinus surgery and implant therapy were considered acceptable by patients.

Conclusion

Despite the limits of this study, HRB and smoking habits of patients are associated with implant failure in grafted sinuses.

The current findings should be verified through investigation of a greater number of implants and a longer period of observation. For this reason, more studies are required to confirm these data.

Abbreviations

aGH: height of the graft apically
BoP: bleeding on probing
CBCT: cone-beam computerized tomography
C/I: crown-to-implant ratio
CT: computerized tomography
dHRB: height of residual bone at the distal aspects of the implant
dMBL: marginal bone level at the distal aspects of the implant
dVBH: vertical bone height at the distal aspects of the implant
HRB: height of residual bone before sinus surgery
HRB-i: height of residual bone at implant site calculated as the mean value of mHRB and dHRB
IP: implant penetration
mHRB: height of residual bone at the mesial
mMBL: marginal bone level at the mesial aspects of the implant
mVBH: vertical bone height at the mesial aspects of the implant
OPT: orthopantomography
PD: probing depth
PRF: platelet rich fibrin
REC: recession
RIL: radiographic implant length
SL: extent of the sinus lift
VAS: visual analogue scale

Note

The authors have nothing to declare. Each of the authors additionally reports no conflict of interest.

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