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Original Article

Clinical outcome of implants placed in grafted maxillary sinus via lateral approach: A 10-year follow-up study

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KEYWORDS
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Abstract *Background/purpose:* The maxillary sinus floor augmentation (MSFA) technique is frequently used for the preparation of implant sites in the maxillary region. The aim of this study was to investigate the 10-year outcome of dental implants placed in a grafted maxillary sinus, and identify possible risk factors for implant failure.
Materials and methods: We retrospectively analyzed 202 implants after MSFA in 97 patients from January 2008 to April 2009. The outcome variables were 1) 10-year cumulative survival rate of the implant, 2) risk factors for implant failure, and 3) correlation between preoperative residual bone height (RBH) and graft materials in terms of implant survival. Graft materials used were divided into five different groups: autogenic, allogenic, xenogenic, combination of allogenic and xenogenic, or combination of autogenic and xenogenic graft.
Results: The cumulative 10-year survival rate for the implants was 96.04%. In regions with a residual bone height of 5.0 mm and less, greater RBH was preferable for long-term implant survival (odds ratio = 3.475; p = 0.035). Implant survival was not significantly different with different graft materials, even when RBH was unfavorable.
Conclusion: The placement of dental implants with MSFA is a reliable procedure. Further, RBH is an important predictor of long-term implant survival.

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Introduction

Placing dental implants in the pneumatized posterior edentulous maxilla can be challenging for practitioners due to its reduced bone height and density. The maxillary sinus floor augmentation (MSFA) technique, first introduced by Tatum[1] and Boyne,[2] is one of the most common surgical options for preparing implant sites in the maxillary posterior region, with few complications.[3,4]

Till date, survival rates of dental implants (ranging from 61.7% to 100%) placed in grafted maxillary sinuses via lateral window technique have been reported by collecting short- and long-term data.[5] Over the decades, the success of implants in sinus graft surgeries is increasing due to the improvement of graft materials used in and micro- and macro-implant design, use of surgical tools such as piezo instruments, and use of less invasive surgical procedures. As the technique gained popularity, many researchers began investigating predictors for implant loss in the grafted maxillary sinus to assess long-term implant stability. Some previous studies have reported clinical outcomes and risk factors for implant failure after MSFA.[6,7] However, additional quantitative studies are still needed to define the rate of long-term implant survival and describe possible predictors for implant failure.

The purpose of the present study was to retrospectively evaluate the 10-year outcome of dental implants placed in a grafted maxillary sinus and identify possible risk factors for implant failure. To investigate our hypothesis that there are possible risk factors for implant failure in MSFA, we set a number of variables to define these factors, such as; implant survival rate according to graft materials used (autogenic, allogenic, xenogenic, or combination of two grafts), patients' demographic data, surgical site, residual bone height (RBH), healing period prior to prosthetic loading, staged or simultaneous implantation with MSFA, crown-to-implant ratio, implant diameter, type of prosthetic, and condition of opposite dentition. We also assessed the correlation between RBH and graft materials in terms of implant survival rate to determine whether a specific graft material may be more favorable in cases with reduced RBH.

Materials and methods

Study design and sample size

We designed a retrospective study with a 10-year follow-up and included a total of 128 patients who underwent implantation with MSFA from January 2008 to April 2009 at our institution. The inclusion criteria were dependent on the availability of the following; clinical and surgical records; preoperative panoramic radiographs and computed tomography (CT) or cone-beam CT (CBCT) images; immediate postoperative panoramic or CBCT images; radiographs taken immediately before or after prosthetic loading; radiographs taken during follow-ups; and adherence to periodic maintenance check-ups. We excluded patients who had untreated periodontitis, underlying medical conditions that compromised bone healing, were heavy smokers, or had maxillary sinusitis as seen on preoperative CT/CBCT images. The implants were divided into five groups according to the graft materials used: autogenous bone (AB) only, allograft only, xenograft only, a combination of allo- and xenograft, and a combination of AB and xenograft. The study protocol was approved by the appropriate Institutional Review Board.

Study variables

The three outcome variables were: (1) 10-year cumulative survival rate of dental implants placed in the grafted maxillary sinus, (2) risk factors for implant failure in MSFA, and (3) association of implant survival with preoperative RBH and graft material type. The following potential risk factors for implant failure in MSFA were assessed: patient age and sex, surgical site (premolar or molar), RBH, healing period prior to prosthetic loading, staged or simultaneous implantation with MSFA, crown-to-implant ratio, prosthesis type (single or splinted), implant diameter, and condition of the opposing dentition. Patient demographic information and clinical data (implant length and diameter, surgical site, graft material, prosthetic type, opposing dentition, and length of healing period prior to loading) were obtained from clinical and surgical records. The crown-to-implant ratios were measured at the first follow-up using a panoramic image taken at 3 months after loading. To assess preoperative RBH, the point corresponding to the center of each inserted implant was measured on the preoperative panoramic image. For the investigation of a potential association between implant failure and preoperative RBH, the latter variable was categorized as either <3 mm, ≤ 5 mm, and RBH $\leq$ full data.

Procedure

After being provided extensive information about the advantages and disadvantages of the different graft materials, each patient chose to receive either AB or bone substitutes (BSs) (allogenic, xenogenic, or combinations) for sinus floor augmentation. All MSFA procedures were performed via the lateral window technique, under local or general anesthesia. The grafts were harvested from either an intraoral (i.e., chin or mandibular ramus) or extraoral (i.e., iliac crest) donor site, and were sectioned with a bone mill in the AB-only and AB-xenograft groups. In the xenograft group, deproteinized bovine bone with spongiosa granules of 0.25 mm—1 mm (Bio-Oss®, Geistlich Pharma AG, Wolhusen, Switzerland) was used. In the allograft group, freeze-dried cancellous bone with a particle size of 0.4 mm—1.6 mm (Allo-Bone plus®, CGBio, Seongnam, Korea) was used. A 1:1 mixture of deproteinized bovine bone and freeze-dried cancellous bone, deproteinized bovine bone and demineralized bone matrix (Orthoblast II®, Isotis Orthobiologics, Irvine, CA, USA), or AB and deproteinized bovine bone, were used for the combinations of BSs or AB and xenogenic grafts, respectively. All the external windows were covered with a collagen membrane (Ossguide®, Osstem, Seoul, Korea).

Whenever possible, implantation was performed simultaneously to reduce patient discomfort and psychological burden. The type of implant (Osstem®, Seoul, Korea, or

BioHorizons®, Birmingham, AL, USA) used in the MSFA procedure was based on patient preference. The implants were installed as per the manufacturer's instructions. Implants were uncovered and prosthetic rehabilitation was commenced after checking osseointegration. All surgical procedures were performed by the same oral maxillofacial surgeon.

Statistical analysis

The treatment data were evaluated using descriptive analysis (mean ± standard deviation, frequency, and range), and Fisher's exact test and analysis of variance, followed by Scheffe's post-hoc analysisto compare the data between groups. Kaplan–Meier analysis was performed to identify differences in implant failure according to graft materials used and correlation between preoperative RBH and graft materials in terms of implant failure. A uni- and multivariate logistic regression model was used to evaluate the risk factors for implant failure, and a stepwise approach was used to identify possible risk factors. All statistical analyses were performed using Statistical Product and Service Solution software (version 24, SPSS Inc., Chicago, IL, USA) and R package (version 3.5.3, R Foundation for Statistical Computing, Vienna, Austria). The significance level was set at 0.05.

Results

A total of 128 patients underwent implantation with MSFA during the study period. Of these, 97 (48 men, 50 women) patients with an average age of 58.74 ± 8.64 years met the inclusion criteria and supplied 202 implants for analysis. The mean follow-up time periods after implantation and prosthetic loading were 119.41 ± 18.35 months and 110.89 ± 18.97 months, respectively. Parameters such as patients' demographic information (sex/age), surgical site, and duration of prosthetic loading are summarized according to the graft materials used (Table 1). Other parameters such as preoperative RBH, implant diameter, healing period prior to loading, crown-to-implant ratios, methods of implant placement (simultaneous/staged), prosthetic type (single/splinted), and state of the opposite dentition are summarized in Table 2. The mean preoperative RBH was 4.50 ± 1.67 mm, ranging from 0.99 mm to 7.80 mm.

Eight (3.96%) of 202 implants were failed. Two of those were lost early (prior to prosthetic loading) due to failure of osseointegration, while 6 were lost late (31.33 ± 30.07 months after prosthetic loading). Therefore, the cumulative 10-year survival rates of implants placed in the grafted sinus (independent of the graft material used) were 96.04%, as seen during the follow-up period (Table 2 and Fig. 1).

One (3.33%) implant in the AB group (RBH > 5 mm) was lost after 69 months of loading. In the allogenic bone group, four (9.3%) implants (one early loss, RBH < 3 mm; three late loss, one in RBH < 3 mm and two in RBH > 5 mm) were lost, where one late loss occurred at 1 month, another at 4 months, and the other at 48 months after prosthetic loading. Two (2.98%) implants in the combination of BSs group (one early loss, 3 mm ≤ RBH ≤ 5 mm; and one late loss, RBH < 3 mm) were failed, where one late loss occurred at 63 months after prosthetic loading. In the combination of AB and xenogenic bone group, one (2.17%) implant was failed, which was a late loss occurring at 39 months after loading, with RBH < 3 mm (Figs. 1 and 2).

There was no specific risk factor for implant failure among the given variables except RBH and implant diameter. In regions with a residual bone height of 5.0 mm and less, RBH was affected positively, in that a greater RBH was preferable for long-term implant survival (odds ratio = 3.475; p = 0.035). However when RBH was more than 5 mm, there was no statistical correlation between RBH and long-term implant survival. Implant diameter, in contrast to RBH, negatively affected long-term implant survival when RBH was 5.0 mm or less (odds ratio = 0.033; p = 0.006) (Tables 3–6).

On the other hand, there was no graft material that specifically favored long-term implant survival and we could not identify any correlation between graft materials and RBH in terms of implant survival (Figs. 2 and 3).

Discussion

Although previous studies have evaluated risk factors for implant removal after MSFA,[7,8] additional quantitative studies are needed to define these risk factors and to determine long-term prognosis of implant placed in the grafted maxillary sinus. Moreover, there are still no clear indications or guidelines for choosing graft materials for MSFA and till date, the clinical decision of using AB or BSs is mainly based on the surgeon's surgical skill and experience, the patients' preference, and scientific evidence. In the

Table 1 Patient demographic and clinical data.

	Sex (M/F)	Age (year)	Surgical site (P1/P2/M1/M2)	Period of prosthetic loading (months)
Autograft	9/2	59.43 ± 6.24	2/7/13/8	112.40 ± 9.72
Xenograft	4/6	59.87 ± 5.09	1/1/8/6	113.81 ± 3.58
Allograft	10/12	61.89 ± 7.64	1/7/18/17	105.06 ± 32.90
Combination of BSs	16/17	60.61 ± 9.02	0/11/34/22	112.59 ± 15.79
Combination of auto + xenograft	9/13	52.26 ± 8.24	1/7/22/16	111.86 ± 11.16

BSs, bone substitutes; F, female; P1, first premolar; P2, second premolar; M, male; M1, first molar; M2, second molar.

Table 2 Clinical data according to graft materials: full data.

		Autograft	Xenograft	Allograft	Combination of BSs	Combination of Auto and Xenograft	p value
Survival period (month)[b]		121.23 ± 9.84	122.13 ± 2.55	114.84 ± 31.38	120.54 ± 15.90	119.91 ± 11.21	0.466
Preoperative RBH (mm)[b]		4.66 ± 1.83	4.53 ± 2.01	4.80 ± 1.49	4.51 ± 1.69	4.10 ± 1.56	0.371
Healing period (month)[b]		8.83 ± 2.12	8.31 ± 1.74	9.26 ± 2.40	7.97 ± 1.28	8.04 ± 1.40	0.002
Implant diameter (mm)[b]		4.45 ± 0.52	4.31 ± 0.48	4.16 ± 0.46	4.26 ± 0.54	4.43 ± 0.54	0.059
Crown/implant ratio[b]		0.90 ± 0.17	1.03 ± 0.21	0.89 ± 0.24	0.89 ± 0.20	0.87 ± 0.21	0.115
Prosthesis type[a]	Single	1 (3.3%)	3 (18.8%)	5 (11.6%)	12 (17.9%)	7 (15.2%)	0.370
	Splint	29 (96.7%)	13 (81.3%)	38 (88.4%)	55 (82.1%)	39 (84.8%)	
Opposing dentition[a]	Implant	17 (56.7%)	5 (31.3%)	12 (27.9%)	37 (55.2%)	13 (28.3%)	0.001
	Natural dentition	13 (43.3%)	9 (56.3%)	31 (72.1%)	26 (38.8%)	33 (71.7%)	
	RPD	0 (0.0%)	2 (12.5%)	0 (0.0%)	4 (6.0%)	0 (0.0%)	
Implant survival[a]	Survival	29 (96.7%)	16 (100.0%)	39 (90.7%)	65 (97.0%)	45 (97.8%)	0.497
	Fail	1 (3.3%)	0 (0.0%)	4 (9.3%)	2 (3.0%)	1 (2.2%)	

BSs, bone substitutes; RBH, residual bone height; RPD, removable partial denture.
[a] Fisher's exact test,
[b] One-way ANOVA.

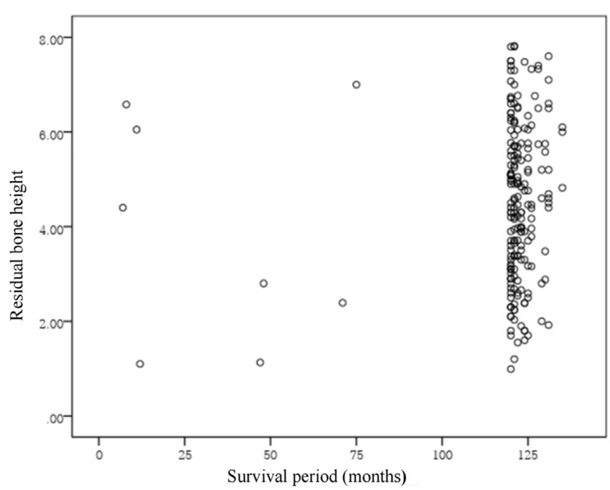

Figure 1 Survival periods according to residual bone heights: full data.

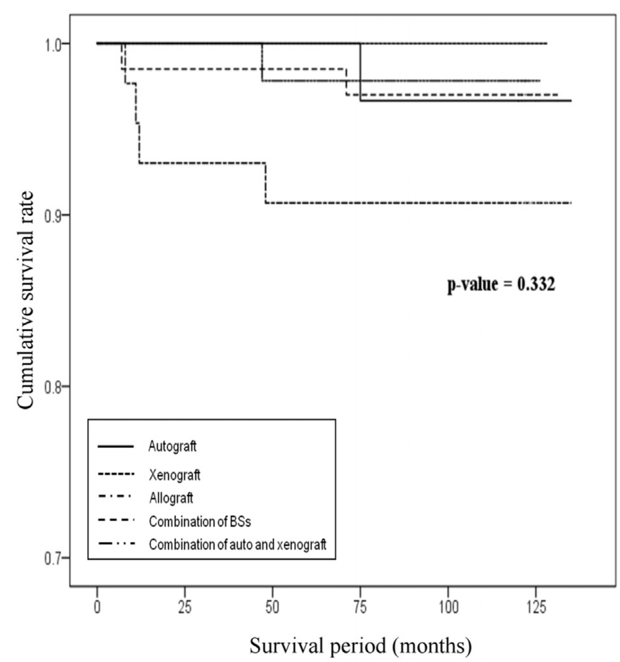

Figure 2 Kaplan–Meier cumulative survival rate according to graft materials used: full data.

present 10-year follow-up study, we evaluated the outcome of dental implants placed during MSFA, described possible predictors for implant failure, and identified a correlation to determine whether a specific graft material is more favorable for ensuring survival in cases with reduced RBH. Our results indicated that implantation during MSFA via lateral approach is a very predictable procedure with a 10-year cumulative survival of 96.04%, and in less than 5.0 mm, RBH is a risk factor for long-term implant survival. Furthermore, it seems that graft material is not a predictor for implant survival with MSFA even when RBH is unfavorable.

Implant survival after MSFA with various graft materials has been evaluated for different RBHs in several studies. The results of the present study concur with a previous study where RBH was regarded as an important factor for implant success and survival after bone grafts.[8–11] Rosen et al. demonstrated that RBH was the most influential factor for implant survival in sinus floor elevation procedures.[8] In their multi-center study, which tested various graft materials, the implant survival rate was 96% or higher when RBH was $\geq$ 5 mm and decreased markedly to 85.7% when the RBH was $\leq$ 4 mm. Similarly, Zinser et al. reported that the RBH is a significant predictor of implant failure in MSFA, where the relative risk of implant failure was increased to 3.01 times when RBH $<$ 3 mm as compared to RBH $>$10 mm.[7] Our results indicate the possibility that the rate of implant failure increased with a decrease in RBH $\leq$ 5 mm, but was not affected by RBH $>$ 5 mm.

Table 3 Univariate logistic regression for implant loss with full data.

		B	S.E.	O.R.	95% C.I.	p value
Sex	Male	Reference				
	Female	−0.124	0.722	0.883	0.215−3.634	0.864
Age		0.017	0.041	1.017	0.938−1.103	0.678
Preoperative RBH		0.219	0.223	1.245	0.804−1.929	0.326
Healing period		0.013	0.201	1.013	0.684−1.501	0.948
Graft material	Autograft	Reference				
	Xenograft	17.836	10048.242	55706029.06	0.000 -	0.999
	Allograft	−1.090	1.145	0.336	0.036−3.169	0.341
	Combination of BSs	0.114	1.245	1.121	0.098−12.858	0.927
	Combination of Auto and Xenograft	0.439	1.434	1.552	0.093−25.795	0.759
Implant diameter		−2.227	0.696	0.108	0.028−0.422	0.001
Crown/implant ratio		0.433	1.760	1.542	0.049−48.560	0.806
Opposing dentition	Implant	Reference				
	Natural dentition	−0.232	0.745	0.793	0.184−3.413	0.755
	RPD	17.907	16408.711	59832401.59	0.000 -	0.999
Prosthesis type	Single	Reference				
	Splint	0.767	0.843	2.154	0.413−11.246	0.363
Surgical site	1st premolar	Reference				
	2nd premolar	0.000	19288.578	1.000	0.000 -	1.000
	1st molar	−18.313	17974.857	0.000	0.000 -	0.999
	2nd molar	−18.112	17974.857	0.000	0.000 -	0.999
Method of implant placement	Simultaneous	Reference				
	Staged	0.286	1.087	1.331	0.158−11.205	0.732

B, beta; C.I., BSs, bone substitutes; confidence interval; O.R., odds ratio; RBH, residual bone height; RPD, removable partial denture; S.E., standard error.

Table 4 Clinical data with residual bone height of 5 mm and less.

		Autograft	Xenograft	Allograft	Combination of BSs	Combination of Auto and Xenograft	p value
Survival period (month)[b]		122.73 ± 4.06	121.40 ± 1.43	116.38 ± 27.33	118.80 ± 20.20	119.39 ± 13.11	0.859
Preoperative RBH (mm)[b]		3.14 ± 1.09	3.25 ± 1.22	3.71 ± 0.92	3.40 ± 1.09	3.31 ± 0.97	0.487
Healing period (month)[b]		9.27 ± 2.19	9.00 ± 1.56	9.96 ± 2.56	8.00 ± 1.24	8.06 ± 1.32	0.000
Implant diameter (mm)[b]		4.29 ± 0.51	4.20 ± 0.42	4.18 ± 0.44	4.30 ± 0.52	4.45 ± 0.56	0.308
Crown/implant ratio[b]		0.86 ± 0.13	1.07 ± 0.24	0.91 ± 0.27	0.90 ± 0.17	0.84 ± 0.20	0.045
Prosthesis type[a]	Single	0 (0.0%)	3 (30.0%)	2 (8.3%)	3 (7.5%)	6 (18.2%)	0.112
	Splint	15 (100.0%)	7 (70.0%)	22 (91.7%)	37 (92.5%)	27 (81.8%)	
Opposing dentition[a]	Implant	10 (66.7%)	3 (30.0%)	12 (50.0%)	22 (55.0%)	7 (21.2%)	0.001
	Natural dentition	5 (33.3%)	6 (60.0%)	12 (50.0%)	14 (35.0%)	26 (78.8%)	
	RPD	0 (0.0%)	1 (10.0%)	0 (0.0%)	4 (10.0%)	0 (0.0%)	
Implant survival[a]	Survival	15 (100.0%)	10 (100.0%)	22 (91.7%)	38 (95.0%)	32 (97.0%)	0.833
	Fail	0 (0.0%)	0 (0.0%)	2 (8.3%)	2 (5.0%)	1 (3.0%)	

BSs, bone substitutes; RBH, residual bone height; RPD, removable partial denture.
[a] Fisher's exact test,
[b] One-way ANOVA.

Generally, it is well known that AB grafts are consolidated more rapidly than BSs.[6,12] Moreover, some authors advocate the use of AB graft in severely atrophic cases with an RBH of < 4 mm. These grafts, when compared to BSs, show a superior effect on implant survival and should therefore be the first-choice in highly atrophic cases.[7] However, in the present study, graft materials used in MSFA were not found to be predictors for long-term implant survival, even in unfavorable conditions of RBH < 3 mm (Fig. 3).

The healing periods observed prior to prosthetic loading were longer than those of previous studies (Table 2).

Table 5 Univariate logistic regression for implant loss with a residual bone height of 5 mm or less.

		B	S.E.	O.R.	95% C.I.	p value
Sex	Male	Reference				
	Female	0.286	0.931	1.331	0.214–8.259	0.759
Age		0.056	0.046	1.058	0.967–1.157	0.218
Preoperative RBH		1.032	0.497	2.805	1.060–7.428	0.038
Healing period		−0.192	0.211	0.826	0.546–1.249	0.364
Graft material	Autograft	Reference				
	Xenograft	0	16408.714	1.000	0.000 -	1.000
	Allograft	−18.805	10377.785	0.000	0.000 -	0.999
	Combination of BSs	−18.258	10377.785	0.000	0.000 -	0.999
	Combination of Auto and Xenograft	−17.737	10377.785	0.000	0.000-	0.999
Implant diameter		−3.147	1.119	0.043	0.005–0.385	0.005
Crown/implant ratio		−1.759	1.979	0.172	0.004–8.336	0.374
Opposing dentition	Implant	Reference				
	Natural dentition	0.585	0.932	1.794	0.289–11.156	0.531
	Denture	18.37	17974.842	95027931.93	0.000 -	0.999
Prosthesis type	Single	Reference				
	Splint	−18.178	10742.024	0.000	0.000 -	0.999
Surgical site	1st premolar	Reference				
	2nd premolar	0.000	29958.017	1.000	0.000 -	1.000
	1st molar	−18.313	28420.665	0.000	0.000 -	0.999
	2nd molar	−18.135	28420.665	0.000	0.000 -	0.999
Method of implant placement	Simultaneous	Reference				
	Staged	0.032	1.141	1.032	0.110–9.665	0.978

B, beta; BSs, bone substitutes; C.I., confidence interval; O.R., odds ratio; RBH, residual bone height; S.E., standard error.

Table 6 Multivariate logistic regression for given variables with residual bone height of 5 mm and less.

	B	S.E.	O.R.	95% C.I.	p value
RBH	1.246	0.589	3.475	1.095–11.030	0.035
Implant diameter	−3.426	1.240	0.033	0.003–0.369	0.006

B, beta; C.I., confidence interval; O.R., odds ratio; RBH, residual bone height; S.E., standard error.

Usually, longer healing periods can improve graft maturation and bone quality, which subsequently increases implant survival rates.[13] de Vicente et al. reported that a healing period of 9 months after MSFA with demineralized bovine bone and AB resulted in an implant survival rate of 98.9%.[14] Jensen et al. demonstrated that early bone-to-implant contact in MSFA was most favorable with autogenous grafts and worst with xenografts.[15] However, in contrast with the early phase, there was no statistically significant difference between the grafting materials in the later phase.[12] This agreed with a meta-analysis that compared bone graft materials via histomorphometrical evaluation of human bone biopsies from MSFA, where AB enabled faster initial bone formation, but the final amount of bone formation did not differ from the value observed with BSs.[16] The present study implies that, if implants inserted during MSFA are allowed healing periods that are sufficient for graft maturation, bone quality, and prosthetic loading, the graft material itself would no longer be a risk factor for implant survival and there would be no correlation where a specific graft material is preferable in case with unfavorable RBH. This is in agreement with several previous reports in which implant survival after MSFA with various graft materials and different RBHs was analyzed. Ferreira et al. demonstrated survival rates of 98.6% in implants with rough surfaces after MSFA using 100% an organic bovine bone, and there was no statistically significant association with RBH.[11] Al-Nawas et al. in their meta-analysis reported that implant survival seems to be independent of the biomaterial used in MSFA.[17] Likewise, when considering only the graft materials used for MSFA and RBH in terms of implant survival, AB did not seem to have marked advantages over BSs.

Wide diameter of implants were found to be another risk factor for implant failure when RBH $\leq$ 5.0 mm. Seven of the removed eight implants had a wide diameter. From a biomechanical point of view, large diameter implants should benefit the patient due to stress distribution, and in general, narrow diameter implants are known to be susceptible to implant failure[7,18] or peri-implant disease. Daniel Rodrigo et al. reported that an implant diameter of $\leq$ 3.5 mm was a high-risk factor peri-implant disease.[19] In contrast, many recent studies have reported that implant diameter does not influence the long-term prognosis of the dental implants.[20–22] de Souza et al. reported that narrow diameter implants placed to support single crowns in the posterior region did not differ from standard diameter implants in terms of marginal bone level, implant survival, and success rates.[23] There was a high tendency to choose a wide diameter implant in areas where bone quality and RBH

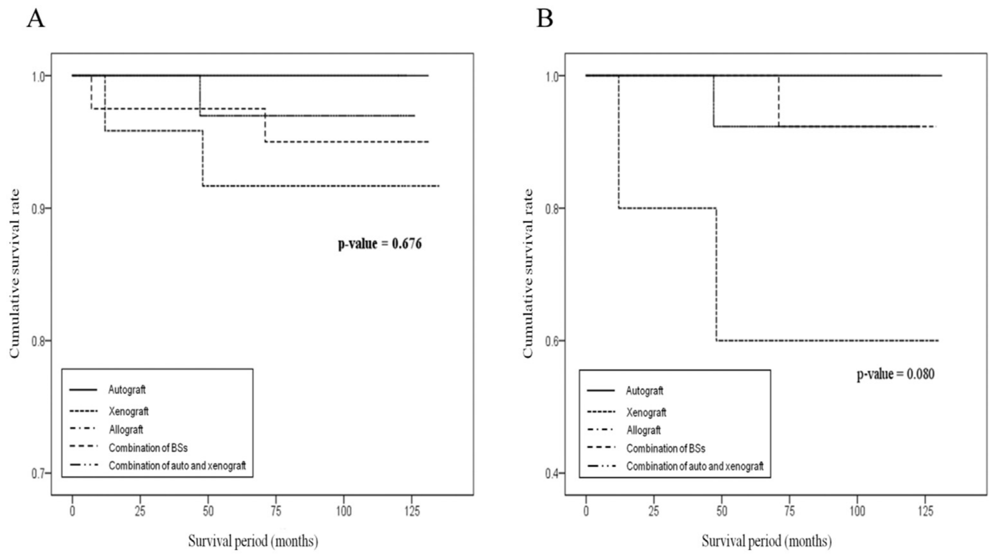

Figure 3 Correlation between preoperative residual bone height and graft materials in terms of implant failure: Kaplan–Meier cumulative survival rate. A, Residual bone height of 5 mm and less. B, Residual bone height of less than 3 mm.

was reduced, to compensate for unfavorable conditions in the present study. Buccal cortical thickness has been shown to be an important factor when it comes to preventing bone loss, therefore, we presume that the reason for wide diameter implant being a predictor is related to the narrowing of the buccal wall after installation of wide diameter implant at unfavorable RBH.

The present study had some limitations, the primary one being that it was a retrospective study. Additionally, we could not ascertain whether maxillary sinus membrane perforation occurred during the procedure, as the medical records and radiographic images of the study samples did not reveal this information adequately. Although maxillary sinus membrane perforation during a sinus lift procedure is not usually known to affect implant survival rates,[24,25] the possibility of graft contamination and consequent failure of osseointegration cannot be excluded. Another limitation was that we did not take into consideration the configuration of the maxillary sinus. Maxillary sinus width, i.e., the distance between the lateral and medial wall, is an important consideration for sinus bone augmentation. The MSFA procedure basically resembles a guided bone regeneration procedure, wherein the intact bony wall is considered as a critical factor. Likewise, the more graft material is in contact with the bony sinus wall, the more bone formation can be expected. A narrower sinus width is more favorable than a wider configuration in terms of faster vascular supply from the wall into the graft material.[26]

Although the study has some limitations, our 10-year follow up result supports the use of MSFA for long-term implant survival in the atrophic posterior maxilla. Furthermore, it describes the possible risk factors of MSFA and offers reasonable scientific evidence for clinicians to choose a less invasive graft material. In conclusion, the current study shows that placing dental implants with MSFA is a reliable procedure with 10-year cumulative survival rates of 96.04%. RBH is an important predictor for long-term implant survival, because in regions with bone height of 5.0 mm and less, RBH was affected positively, and higher RBH is preferable for long-term implant survival. The graft material is not an important factor for long-term implant survival as long as sufficient healing periods are allowed for bone consolidation. However, the risk factors for implant failure in MSFA may be multi-factorial and future studies with more variables are should be designed to determine the risk factors for long-term implant survival in MSFA.

Declaration of Competing Interest

The authors have no conflict of interest to declare.

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