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Do Certain Conditions Favor the Use of Autogenous Bone Graft Over Bone Substitutes for Maxillary Sinus Augmentation?

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Purpose: To investigate whether there are specific surgical or clinical conditions where the use of autogenous bone (AB) is superior to the use of bone substitutes (BSs) for maxillary sinus floor augmentation (MSFA).

Materials and Methods: We retrospectively analyzed 386 implants after MSFA in 178 patients. The implants were divided into five groups according to the sinus graft material used. Risk factors for implant failure in MSFA, and correlation between residual bone height (RBH) and graft materials in terms of implant survival were investigated. To investigate risk factors for implant failure in MSFA, implant survival according to graft materials, patients' sex/age, surgical site, RBH, healing period prior to prosthetic loading, staged- or simultaneous implantation with MSFA, the crown-to-implant ratio, prosthetic type, implant diameter, and opposite dentition were evaluated.

Result: The cumulative 2- and 5-year survival rates of implants placed in the grafted sinus (independent of the graft material used) were 98.7% and 97.3%, respectively. None of the investigated variables were identified as significant risk factors for implant failure. There was also no statistical significance in implant survival between graft materials.

Conclusion: There were no specific surgical conditions in which AB was superior to BSs in terms of implant survival after MSFA.

Key Words: Dental implants; Risk factors; Survival rate

Introduction

The maxillary sinus bone graft technique was introduced by Boyne and James[1] and Tatum[2], and has proven to be very effective in increasing the bone volume and the implant survival rate in edentulous posterior maxillae[3-5]. With the increased implementation of dental implants for replacement of missing

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teeth in the posterior maxillary region, this technique is now routinely employed in patients with poor bone support in the posterior maxilla, and it is considered as one of the most common implant site development options with few complications, in the maxillary posterior region[6,7].

Previous studies have indicated that sinus grafting materials promote bone formation in the space created under the elevated sinus membrane, by facilitating three-dimensional stability of the clot against intra-sinus pressure. To guarantee bone quality and quantity that can ensure the initial and long-term implant stability, researchers have long sought for the ideal space-filling graft materials. Despite some limitations such as possible postoperative patient morbidity, limited quantities, prolonged surgical time, and unpredictable resorption, autogenous bone (AB) has been considered the gold standard for bone grafts to date[8]. Some authors advocate the use of AB because it may have better bone formation capability than bone substitutes (BSs)[9,10]. However, there have been few clear indications or guidelines for the use of AB or BSs in dental implants requiring maxillary sinus bone grafts. Therefore, to date, the clinical decision between using AB or BSs has mainly been based on the surgeon's surgical skill and experience, the patients' preference, as well as scientific evidence.

The purpose of the present study was to investigate whether there are specific surgical or clinical conditions in which AB grafts are more favorable than BSs grafts for maxillary sinus floor augmentation (MSFA) or vice versa. We hypothesized that there are risk factors for implant failure in MSFA, and that AB grafts would be more favorable than BSs for implant survival. To investigate this hypothesis, we evaluated a number of variables to define risk factors: implant survival according to graft materials used (autogenic, allogenic, xenogenic, or combination of two grafts), patients' demography, surgical site, residual bone height (RBH), healing period prior to prosthetic loading, staged- or simultaneous implantation with MSFA, crown-to-implant ratio, implant diameter, prosthetic type, and opposite dentition. We also assessed the correlation between RBH and graft materials in terms of implant survival to determine whether AB is superior to BSs in cases with reduced RBH.

Materials and Methods

1. Study Design and Sample

To address the research objectives, the study was designed and implemented as a retrospective cohort study. The study population included all patients who had undergone implantation with an MSFA procedure from January 2008 to December 2015 at Ulsan University Hospital. The patients met the following inclusion criteria: 1) clinical and surgical records available, 2) preoperative panoramic and computed tomography (CT) or cone-beam computed tomography (CBCT) images available, 3) immediate postoperative panoramic or CBCT images available, 4) radiographic images taken immediately before or after prosthetic loading, 5) radiographic images taken during follow-ups, and 6) adherence to periodic maintenance check-ups. Patients with medical conditions compromising bone healing, with heavy smoking habit, with preoperative maxillary sinusitis on the CT or CBCT images, or with untreated periodontitis were excluded. The implants were divided into five groups according to the graft materials used: AB only, allografts only, xenografts only, a combination of allo- and xenografts, and a combination of AB and xenografts. The study protocol was approved by the relevant Institutional Review Board (UUH-201711011).

2. Clinical Variables

The outcome variables were 1) risk factors for implant failure in MSFA, and 2) a correlation between RBH and graft materials in terms of implant survival. To investigate risk factors for implant failure in

MSFA, implant survival according to graft materials, patients' sex/age, surgical site (premolar or molar), RBH, healing period prior to prosthetic loading, staged- or simultaneous implantation with MSFA, the crown-to-implant ratio, prosthetic type (single or splinted), implant diameter, and opposite dentition were evaluated. Information on patients' demography, implant length and diameter, surgical site, graft material, prosthetic type, opposite dentition, and length of healing period prior to loading was obtained from clinical and surgical records. The crown-to-implant ratios were measured on the first follow-up panoramic image taken after loading, which is usually re-evaluated by 3 months after loading. To assess preoperative RBH, the point corresponding to the center of each implant placement was measured on the preoperative panoramic image. To investigate the correlation between preoperative RBH and graft materials in terms of implant failure, the RBH was categorized into three different ranges: RBH<3 mm, 3 mm≤RBH≤5 mm, and RBH>5 mm.

3. Surgical Procedure

After being provided with extensive information about the advantages and disadvantages of each augmentation material, the patient chose to receive either AB or BSs (allogenic, xenogenic, or combinations) for sinus floor augmentation. All MSFAs were performed via the lateral window technique under local or general anesthesia. For maxillary sinus bone grafts, bone was harvested from the chin or mandibular ramal region, as an intraoral donor site, or from the iliac crest, as an extraoral donor site; bone samples were particulated with a bone mill in the AB group. In the xenogenic group, deproteinized bovine bone (Bio-Oss®, spongiosa granules 0.25~1 mm; Geistlich Pharma AG, Wolhusen, Switzerland) was used. In the allogenic group, freeze-dried bone allografts (Allo-Bone plus®, cancellous bone, with a particle size of 0.4~1.6 mm; CGBio, Seongnam, Korea) was used. A 1:1 mixture of Allo-Bone plus and Bio-Oss, or AB and Bio-Oss, were used for combinations of BSs or AB and xenogenic grafts, respectively.

Whenever possible, implantation was performed simultaneously to reduce patients' discomfort and psychological burden. Depending on the patients' choice, installation of one of two different internal types of implants (Osstem, Seoul, Korea, or BioHorizons, Birmingham, USA) was followed by the MSFA procedure. The implants were uncovered and prosthetic rehabilitation proceeded after osseointegration. All surgical procedures were performed by one oral–maxillofacial surgeon.

4. Statistical Analysis

Treatment data were evaluated using descriptive analysis (mean±standard deviation, frequency, and range), and analysis of variance (ANOVA) models, followed by Scheffe post-hoc analysis, were used to compare data between groups. A multivariate logistic regression model was used to evaluate the risk factors for implant failure. All statistical analyses were performed using IBM SPSS Statistics 24.0 (IBM Co., Armonk, NY, USA). The significance level was set at 0.05.

Result

In total, 482 patients received implantation with MSFA during the study period. Of those, 178 (93 males, 85 females) patients with an average age of 58.54±8.78 years met the inclusion criteria; in these patients, 386 implants were analyzed. The mean follow-up duration after prosthetic loading was 72.81±29.40 months. Various parameters, including patients' demographic information (sex/age), surgical site, duration of prosthetic loading, methods of implant placement (simultaneous/staged), prosthetic type (single/splinted), opposite dentition, and implant diameter are summarized according to the graft materials used, in Table 1. The mean preoperative RBH, healing period prior to loading, and

Table 1. Patients' demographic and clinical data

Graft material	Sex (M/F)	Age (yr)	Surgical site (P1/P2/M1/M2)	Period of prosthetic loading (mo)	Implant diameter (mm)	Opposite dentition			Prosthetic type	
						Implant	Natural tooth	Removable denture	Single	Splinted
Autograft	16/8	54.79±9.45	4/14/24/19	56.38±25.41	4.43±0.50	27 (17.8)	34 (14.9)	0 (0.0)	9 (16.4)	52 (15.7)
Xenograft	9/11	57.10±7.77	2/5/13/11	63.58±25.25	4.47±0.50	9 (5.9)	20 (8.8)	2 (33.3)	8 (14.5)	23 (6.9)
Allograft	16/13	61.48±7.97	4/13/29/23	94.35±32.23	4.15±0.45	27 (17.8)	42 (18.4)	0 (0.0)	6 (10.9)	63 (19.0)
Allo+xenograft	38/38	58.44±9.29	3/25/74/55	72.02±28.07	4.40±0.62	70 (46.1)	85 (37.3)	4 (66.7)	25 (45.5)	134 (40.5)
Auto+xenograft	14/15	52.48±9.14	3/10/30/23	71.73±21.00	4.45±0.62	19 (12.5)	47 (20.6)	0 (0.0)	7 (12.7)	59 (17.8)

M: male, F: female, P1: first premolar, P2: second premolar, M1: first molar, M2: second molar, Allo: allograft, Auto: autograft.
Values are presented as mean±standard deviation or number (%).

Table 2. Preoperative mean RBH

Graft material		Mean±SD (mm)	P-value
RBH<3	Autograft	2.16±0.62	0.926
	Xenograft	2.10±0.56	
	Allograft	2.08±0.63	
	Allo+xeno	2.01±0.67	
	Auto+xeno	2.02±0.73	
3≤RBH≤5	Autograft	4.02±0.51	0.817
	Xenograft	3.87±0.57	
	Allograft	4.12±0.54	
	Allo+xeno	3.95±0.58	
	Auto+xeno	3.96±0.63	
RBH>5	Autograft	6.45±1.09	0.026
	Xenograft	6.82±1.06	
	Allograft	6.89±1.25	
	Allo+xeno	6.26±0.91	
	Auto+xeno	6.21±0.89	

SD: standard deviation, RBH: residual bone height, Allo: allograft, xeno: xenograft, Auto: autograft.

Table 3. Healing period prior to loading

Graft material		Mean±SD (mo)	P-value	Post-hoc (Scheffe test)
RBH<3	Autograft^{a}	10.33±3.36	0.001	a,b,c,d<e
	Xenograft^{b}	9.00±1.41		
	Allograft^{c}	7.92±2.75		
	Allo+xeno^{d}	11.13±3.31		
	Auto+xeno^{e}	12.33±3.45		
3≤RBH≤5	Autograft^{a}	8.06±2.30	0.173	-
	Xenograft^{b}	8.25±2.22		
	Allograft^{c}	9.86±3.23		
	Allo+xeno^{d}	9.75±3.12		
	Auto+xeno^{e}	10.48±3.50		
RBH>5	Autograft^{a}	8.26±2.12	0.005	a,b,c,d<e
	Xenograft^{b}	7.67±1.41		
	Allograft^{c}	8.00±1.54		
	Allo+xeno^{d}	9.30±2.61		
	Auto+xeno^{e}	9.68±3.11		

SD: standard deviation, RBH: residual bone height, Allo: allograft, xeno: xenograft, Auto: autograft.

crown-to-implant ratios in the five RBH categories are summarized in Tables 2~5.

Outcome variables are summarized in Tables 5

Table 4. Crown-to-implant ratio

Graft material		Mean±SD	P-value
RBH<3	Autograft	0.94±0.21	0.234
	Xenograft	1.16±0.18	
	Allograft	1.01±0.18	
	Allo+xeno	1.05±0.27	
	Auto+xeno	0.97±0.31	
3≤RBH≤5	Autograft	0.98±0.21	0.685
	Xenograft	0.95±0.17	
	Allograft	0.93±0.27	
	Allo+xeno	0.94±0.23	
	Auto+xeno	0.88±0.22	
RBH>5	Autograft	0.94±0.21	0.375
	Xenograft	0.98±0.26	
	Allograft	0.92±0.23	
	Allo+xeno	0.88±0.22	
	Auto+xeno	0.96±0.20	

SD: standard deviation, RBH: residual bone height, Allo: allograft, xeno: xenograft, Auto: autograft.

Table 5. Correlation between RBH and graft materials in implant survival

Graft material		Total	Removed	Survived	P-value
RBH<3	Autograft	18	0	18	0.446
	Xenograft	9	0	9	
	Allograft	13	2	11	
	Allo+xeno	47	2	45	
	Auto+xeno	21	1	20	
3≤RBH≤5	Autograft	16	0	16	0.881
	Xenograft	4	0	4	
	Allograft	22	0	22	
	Allo+xeno	55	1	54	
	Auto+xeno	23	0	23	
RBH>5	Autograft	27	1	26	0.317
	Xenograft	18	0	18	
	Allograft	34	2	32	
	Allo+xeno	57	0	57	
	Auto+xeno	22	0	22	

SD: standard deviation, RBH: residual bone height, Allo: allograft, xeno: xenograft, Auto: autograft.
Values are presented as number only.

and 6. Nine (2.3%) of 386 implants were lost. Five of those were lost early, prior to prosthetic loading, due to failed osseointegration, while four were lost late, after prosthetic loading (44.5±24.33 months). Therefore, the cumulative 2- and 5-year survival rates of implants placed in the grafted sinus (independent of the graft material used) were 98.7% and 97.3%, respectively. One (1.64%) implant in the AB group (early failure; RBH>5 mm) was lost. In the allogenic bone group, four (5.8%) implants (two early failures, RBH>5 mm; two late failures, RBH<3 mm) were lost, where one late failure occurred at 12 months and another at 48 months after prosthetic loading. Three (1.89%) implants in the combination of BSs group (two early failures, one RBH<3 mm and one 3 mm≤RBH≤5 mm; and one late failure, RBH<3 mm) were lost, where one late failure occurred at 71 months after prosthetic loading. In the combination of AB and xenogenic bone group, one (1.89%) implant was lost; this was a late failure occurring at 47 months after loading, with RBH<3 mm. However, there was no specific risk factor for implant failure among the given variables and there was no statistically significant difference in implant survival between graft materials according to the categorized RBH ranges ($P<0.05$).

Discussion

To maintain space under the elevated maxillary sinus membrane to allow a blood clot to serve as the scaffold on which bone-forming cells arising from the sinus walls[11)] and Schneiderian membrane[12)], can differentiate and form new bone, the use of graft materials in this space is advocated. Although AB is considered to have superior bone formation capability over BSs, previous reports have demonstrated that BSs are biocompatible and are not limited in terms of quantity, and have achieved reliable results in MSFA procedures[13-15)], complicating the choice of appropriate graft material for MSFA. Therefore, the advantages or specific clinical and surgical conditions indicating the use of AB in MSFA must be care-

Table 6. Evaluation of risk factors for implant removal

Research variable	B	SE	Odds ratio	95% CI	P-value
Graft material					
Autograft	Reference				
Xenograft	–18.648	5332.415	0.000	0.000–.	0.997
Allograft	0.735	1.623	2.085	0.087~50.172	0.651
Allo+xenograft	–2.820	2.186	0.060	0.001~4.330	0.197
Auto+xenograft	–2.022	2.161	0.132	0.002~9.147	0.349
Sex					
Male	Reference				
Female	1.881	1.452	6.561	0.381~113.055	0.195
Age	–0.062	0.068	0.940	0.822~1.074	0.364
Surgical site					
First premolar	Reference				
Second premolar	–2.952	8248.732	0.052	0.000–.	1.000
First molar	10.328	7573.419	30571.987	0.000–.	0.999
Second molar	9.775	7573.419	17583.750	0.000–.	0.999
RBH	–0.359	0.377	0.699	0.334~1.462	0.341
Implant placement					
Simultaneous	Reference				
Staged	–1.959	2.534	0.141	0.001~20.247	0.439
Prosthetic type					
Single	Reference				
Splinted	0.229	1.643	1.257	0.050~31.473	0.889
Crown-to-implant ratio	–6.585	4.636	0.001	0.000~12.205	0.156
Opposite dentition					
Implant	Reference				
Natural tooth	–1.718	1.707	0.179	0.006~5.090	0.314
Partial denture	–19.240	14096.856	0.000	0.000–.	0.999
Healing period prior to loading	0.261	0.269	1.298	0.765~2.201	0.334
Implant diameter (mm)					
<4.0	Reference				
>4.0, <4.5	0.954	6655.165	2.596	0.000–.	1.000
>5	19.549	6308.197	309194721.600	0.000–.	0.998

B: beta, SE: standard error, CI: confidence interval, Allo: allograft, Auto: autograft, RBH: residual bone height.

fully evaluated. In this comparative study of the use of AB and BSs as graft material in MSFA, we evaluated whether the use of AB grafts is more favorable than that of BSs under specific surgical or clinical conditions. The hypothesis of the present study was rejected as no specific risk factor for implant failure was found among the investigated variables. Moreover, we did not find statistically significant difference in implant survival between the two types of graft materials, according to the RBH categories.

Although some previous studies have evaluated risk factors for implant failure after MSFA[16,17], additional quantitative studies are needed to define these risk factors and to determine whether AB is preferable for MSFA under specific conditions. Implant survival after MSFA with various graft materials have been evaluated for different RBHs in several studies. Previously, RBH has been regarded as an important factor for implant success and survival after bone grafts[17-20]. Rosen et al.[18] have demonstrated that RBH is the most influential factor for implant survival in sinus floor elevation procedures. In their multicenter study, which implemented various graft materials, the implant survival rate was 96% or higher when RBH was ≥5 mm; however, it decreased markedly, to 85.7%, when the RBH was ≤4 mm. Similarly, Zinser et al.[17] reported that the RBH is a significant predictor of implant failure in MSFA, where the relative risk of implant failure was increased 3.01 times for RBH<3 mm as compared to RBH>10 mm. Moreover, in severe atrophic cases with an RBH of<4 mm, autogenic bone grafts showed a superior effect of implant survival over that of BSs; therefore, AB grafts should be considered in highly atrophic cases. However, in the present study, not even severely reduced RBH was found to be very important for implant survival in MSFA, regardless of the graft materials used. 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.[21] demonstrated survival rates of implants with rough surfaces of 98.6% after MSFA using 100% anorganic bovine bone, and there was no statistical significant association with RBH. Al-Nawas and Schiegnitz[13] in their meta-analysis reported that implant survival seems to be independent of the biomaterial used in MSFA. 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.

In the present study, healing periods prior to prosthetic loading were longer than those in other previous studies (Table 3). Usually, longer healing periods can improve graft maturation and bone quality, which subsequently increases implant survival rates[22]. de Vicente et al.[23] reported that a healing period of 9 months after maxillary sinus augmentation with bovine-derived hydroxyapatite and AB resulted in an implant survival rate of 98.9%. Jensen et al.[24] demonstrated that early bone-to-implant contact in MSFA was more advanced with autogenous grafts, and worst with xenografts. However, in contrast with the early phase, there was no statistically significant difference between the grafting materials in the later phase[3]. 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 that observed with BSs[25]. The present study implies that, if implants inserted in MSFA are allowed healing periods that are sufficient for graft maturation and bone quality, so as to allow prosthetic loading, the healing period itself would no longer be a risk factor for implant survival.

In respect of the implant placement stage after MSFA, Zinser et al.[17] reported that a two-stage delayed implantation had a 2.56 times lower risk of implant failure than one-stage procedures. However the present study showed no statistically significant difference in implant removal between one- or two-stage implantation procedure, which is in accordance with Felice et al.[26] In their research, implants placed in 1 to 3 mm of bone height were evaluated and no statistically significant differences were observed. In the present study, the implant was inserted into the grafted sinus simultaneously, if the primary implant stability could be ensured; thus, treatment time and patients' discomfort and psychological burden for another surgery for implantation.

From a biomechanical point of view, the crown-to-implant ratio, prosthetic type (splinted or non-splinted-implant crown), implant diameter, and opposite dentition could be risk factors for implant removal. In terms of stress distribution, a lower crown-to-implant ratio and splinted multiple crowns with a large diameter implant could theoretically be more beneficial. Similarly, denture wearing mandibular dentition could be more favorable than implant dentition. Blanes et al.[27] stated in their systematic review that the crown-to-implant ratio implant-supported prosthesis does not influence the peri-implant crestal bone loss. On the other hand, Villarinho et al.[28] reported that the clinical crown-to-implant ratio is a predictor of bone loss. In the present study, the crown-to-implant ratio was 0.96±0.24 mm (range from 0.5 to 1.78). The result means within the data assessed, the crown-to-implant ratio itself is not risk factor of implant failure. Likewise, there were no statistically significant differences in terms of implant survival in single- or splinted-crown restoration, implant diameter, and opposite dentition, which is in accordance with the findings of previous studies[16,29]. Overall, MSFA is a predictable surgical procedure that allows implants with long-term survival in atrophic edentulous posterior maxilla, irrespective of the initial clinical and surgical conditions.

The present study had some limitations, as other retrospective studies. Additionally, we could not ascertain whether maxillary sinus membrane perforation occurred during the procedure, based on the medical records and radiographic images of the study samples. Although maxillary sinus membrane perforation during a sinus lifting procedure is usually known not to affect implant survival rates[30,31], possible graft contamination and consequent failure in osseointegration could not be excluded. Another limitation was 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 that of a guided bone regeneration procedure, where intact bony wall is considered as the critical factor. Likewise, the more graft material has contact with the bony sinus wall, the more bone formation could 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[11]. From this point of view, longer healing periods in the AB and xenograft combination group in Table 3 might reflect a wider sinus configuration than that in the other groups, and likewise there was no significant difference between the AB group and the other groups, except for the combination of AB and xenograft group. Moreover, due to the limitations of retrospective study, we could not make clear the occurrence of postoperative complications, such as postoperative maxillary sinusitis or infection, according to bone graft materials.

Although the paper has some limitations, our findings offer reasonable scientific evidence for clinicians and patients to choose a less invasive graft material for MSFA in specific surgical conditions, by avoiding harvesting intra/extra AB, by defining implant risk factors in MSFA, as well as determining the correlation between RBH and graft materials in implant survival.

Conclusion

The results of the present study suggest that the risk factors for implant removal in MSFA could not be defined within our limited variables. There are no specific surgical conditions where AB is superior to BSs, and RBH is not a very important factor when choosing graft materials. However, because the results may not mean that there is no specific risk factor for implant failure in MSFA, but rather that the risk factors may be multi-factorial, future studies with more variables should determine the risk factors for implant failure in MSFA.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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