Maxillary Sinus Augmentation as a Risk Factor for Implant Failure

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Purpose: *The investigators sought to determine whether maxillary sinus augmentation (MSA) was an independent risk factor for implant failure.* ***Materials and Methods:*** *Using a retrospective cohort study design, the investigators enrolled a sample composed of subjects having 1 or more implants placed in the posterior maxilla. The primary predictor variable was MSA status at the time of implant placement (MSA present or absent). MSA consisted of a lateral window (external) or an osteotome (internal) procedure. The outcome variable was implant failure defined as implant removal. Demographic, health status, anatomic, implant-specific, abutment-specific, prosthetic, and perioperative variables were also examined. Overall implant survival was estimated using Kaplan-Meier analysis. Risk factors for implant failure were identified using Cox proportional hazard regression models.* ***Results:*** *The sample consisted of 318 patients and 762 posterior maxillary implants. The mean duration of follow-up was 22.50 ± 19.06 months. The 5-year survival rates for implants in the ungrafted and grafted posterior maxilla were 88.0% and 87.9%, respectively (*P = .08*). After adjustment for covariates, MSA status was not an independent risk factor for implant failure (*P = .9*). Tobacco use (*P < .001*), implants replacing molars (*P < .001*), and 1-stage implants (*P < .001*) were statistically associated with an increased risk for implant failure.* ***Discussion:*** *MSA status was not associated with implant failure risk. This finding may be subject to selection bias, as successful MSA was requisite prior to implant placement.* ***Conclusion:*** *MSA status was not associated with an increased risk for implant failure. Of the 3 factors associated with an increased risk for failure, tobacco use and implant staging may be modified by the clinician to enhance outcome.* (Retrospective Clinical Cohort Study) (More than 50 references) Int J Oral Maxillofac Implants 2006;21:366–374

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Sinus pneumatization and alveolar bone loss limits the bone available for implant support in the posterior maxilla.[1–4] If bone support is inadequate, maxillary sinus augmentation (MSA) may be indicated to reconstruct a deficient alveolus. Although numerous investigators have evaluated implant survival in augmented maxillary sinuses, survival estimates are not clear because of a relative paucity of well-documented, well-populated studies providing long-term data.[5–45]

To estimate implant survival rates associated with MSA, a Medline literature review was conducted. Because there are few prospective studies on this topic, retrospective reports and case series study designs were also selected for evaluation. The search was limited to human, English-language studies involving 20 or more MSA procedures with at least 1 year of follow-up, with implant survival estimated using Kaplan-Meier analyses. Studies involving interpositional or onlay augmentation were excluded. Forty-one reports met the selection criteria.[5–45] The reported mean survival rate of implants placed in the augmented maxillary sinus was 90.4% (range, 61.2% to 100%), with a mean duration of follow-up of 28.8 months (range, 12 to 144 months).

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In a previous study, dentoalveolar reconstructive procedures, when analyzed as a homogenous group, were not statistically associated with an increased risk for implant failure.[46] The purpose of this present study was to determine whether MSA was an independent risk factor for implant failure. The authors hypothesized that the survival rate of implants placed in the native posterior maxilla would equal the survival rate of implants placed in maxillae with grafted sinuses. The specific aim of this study was to estimate the risk of MSA in terms of implant failure given the application of a rigorous multivariate analysis adjusted for clustered, correlated observations.

MATERIALS AND METHODS

Study Design and Sample

The investigators used a retrospective cohort study design and enrolled a sample composed of subjects derived from the population of subjects who had had Bicon implants (Bicon, Boston, MA) placed at the Implant Dentistry Centre at Faulkner Hospital (IDC-FH), Boston, MA. All implants were placed between May 20, 1992, and July 6, 2000. All subjects requiring implant placement in the posterior maxilla whose charts were available were eligible for study inclusion. The posterior maxilla included the premolar and molar regions.

Study Variables

The primary predictor variable was the presence or absence of MSA. MSA was performed if there was insufficient alveolar bone height to achieve primary implant stability. MSA procedures included internal and external grafting procedures. An internal grafting procedure was performed when more than 4 mm of residual bone height was present. An external grafting procedure was performed when less than 4 mm residual bone height was present. Internal grafting was performed using a modified Summers technique[47] and was accomplished by augmenting the area directly around the osteotomy site. External grafting was performed using a modified Caldwell-Luc technique (described by Kent and Block[48]). External grafts were allowed to consolidate for a period of 4 to 8 months prior to implant placement. Augmentation was carried out with autogenous or nonautogenous graft materials used either alone for internal grafts or in mixtures for external grafts.

The primary outcome variable was implant failure, which was defined as implant removal. The criterion for implant removal was implant mobility. Implant survival was calculated by measuring the time elapsed from implant placement to the date of the last follow-up visit or implant removal.

Data were collected on numerous additional study variables grouped into the following categories:

- **Demographics:** These variables included gender and age at the time of implant placement.
- **Health Status:** Patient health status was defined according to the American Society of Anesthesiology (ASA) system, which has 5 levels.[49] Also noted was the presence of a condition associated with poor wound healing, ie, diabetes, liver disease, or immunosuppression. If 1 of these conditions was present, the patient was considered medically compromised. Tobacco use at the time of implant placement was also recorded.
- **Anatomy:** Anatomic variables included implant location (premolar or molar), bone quality (types 1 to 4), and proximity of the implant to natural dentition or other implants. Bone quality was determined at the time of implant surgery upon examination of the contents of the flutes of a 3.5-mm reamer extracted from the osteotomy. Type 1 bone was defined as compact, near-bloodless bone that completely filled the flutes of the reamer. Bone quality was categorized as type 4 when little or no bone filled the reamer flutes. Types 2 and 3 were intermediate grades. The relationship of the implant to other dentoalveolar structures was categorized as follows: no teeth (edentulous), 1 adjacent natural tooth, 2 adjacent natural teeth, 1 adjacent implant, 2 adjacent implants, or 1 adjacent natural tooth and 1 adjacent implant.
- **Implant-Specific Variables:** These variables included implant diameter (3 to 6 mm), length (6 to 14 mm), well size (2 or 3 mm), coating (uncoated [grit-blasted acid-etched], titanium plasma-sprayed [TPS], or hydroxyapatite [HA]-coated), and staging (1- or 2-stage).
- **Abutment-Specific Variables:** Abutment diameter (3 to 6.5 mm), length (3 to 12 mm), and angulation (0, 15, and 25 degrees) were recorded.
- **Prosthesis-Specific Variables:** Prosthetic variables were grouped into 2 categories, removable (overdenture) or fixed.
- **Perioperative Variables:** Perioperative antibiotic use and the specific oral surgeon involved in patient care were documented.
- **MSA-Specific Variables:** The use of an MSA procedure was documented in the patient chart. If sinus augmentation was performed, the type of augmentation procedure (internal or external) was documented. The timing of the augmentation procedure relative to implant placement was also recorded. Implant placement was classified as

immediate (ie, implant placement was performed at the same time as MSA) or delayed (ie, implant placement was performed at a separate time from MSA). The type of augmentation material (autogenous or nonautogenous) was also recorded.

- **Survival Variables:** The dates of the grafting procedure, implant placement, abutment connection, and restoration insertion were recorded. The date of last follow-up visit or implant failure was also documented.

Data Analysis

Descriptive statistics and survival analyses were computed with SAS statistical software (version 8.2, 2001, SAS Institute, Cary, NC). Descriptive statistics were computed for all study variables. The overall 1- and 5-year survival rates associated with 95% confidence intervals (CIs) were computed based on Kaplan-Meier survival analyses with adjustment for correlated observations.[50,51] Implant survival was defined as the length of time from the date of implant placement to the date of implant failure. Implants that did not fail were considered censored in survival analyses. Cox proportional hazards regression was employed to identify risk factors related to implant failure. Potential risk factors for failure were identified using the univariate Cox proportional hazards regression model and were considered candidate variables if $P \leq .15$. Variables meeting this criterion were included in the multivariate Cox proportional hazards model in order to identify variables statistically associated ($P \leq .05$) with failure. The primary analysis of interest was assessment of the relationship between MSA status and implant survival, adjusted for confounding variables and clustered, correlated observations based on the marginal approach.[52]

Database management and analyses used SAS-PC version 8.2 environment. To compare the study variables grouped by MSA status, *P* values were constructed using PROC GENMOD with REPEATED subject statements to identify subject (patient) effects in the database. The PROC GENMOD procedures utilized the generalized estimating equations (GEE) approaches to create robust sandwich estimators accounting for clustered observations in the same patient.[53,54] The Cox proportional hazards models were evaluated using PROC PHREG COVSANDWICH (AGGREGATE) statements. The COVSANDWICH option required the robust sandwich estimator for the covariance matrix. When the key word AGGREGATE was enclosed in parentheses after the COVSANDWICH (or COVS) option, a summing of the score residuals for each distinct identification (each patient) was utilized in the computation of the robust sandwich covariance estimator. The COVSANDWICH option in the PROC PHREG statement used the clustered observations robust sandwich estimate of the covariance matrix.[55–57] The specification of COVSANDWICH (AGGREGATE) allowed investigators to sum the score residuals within each ID pattern to compute this covariance estimate.

RESULTS

Between 1992 and 2000, 702 patients received implants at IDC-FH. Records were unavailable for 25 patients because of chart misplacement, patient relocation, or death, resulting in a sample of 677 patients who received 2,349 implants. Subjects within this sample having implants placed in the posterior maxilla were selected for study inclusion. Therefore, the final study sample was composed of 318 patients and 762 implants. Missing data was due to incomplete charting. The mean duration of follow-up was 22.5 months (range, 0 to 90.9 months).

Descriptive statistics of the sample are summarized in Table 1. The mean age of the sample was 56.4 ± 11.9 years for patients who underwent MSA (MSA+) and 55.5 ± 13.1 years for those who did not (MSA–). More than 40% (44.3%) of MSA+ patients were female; 56.3% of MSA– patients were female. The vast majority (> 97%) of patients were healthy (ASA I or II) in both MSA+ and MSA– populations. Tobacco use at the time of implant placement was reported by 9.1% of MSA+ patients and 11.9% of MSA– patients. More than 60% (62.1%) of the implants were placed in reconstructed recipient sites. More than a fourth (26.1%) of the implants were associated with internal lift procedures, and more than a third (36.0%) were associated with external lift procedures. Over a third (34.5%) of the implants were placed at the same time as MSA (immediate), while 27.6% were placed following a period of consolidation (delayed).

Statistically significant differences ($P \leq .15$) between MSA+ and MSA– populations were observed with the following variables (Table 1): implant location ($P < .001$), bone quality ($P < .001$), implant coating ($P < .001$), well size ($P = .008$), implant staging ($P = .006$), immediate implant ($P = .001$), and abutment angle ($P = .009$).

The 1-year survival rates, adjusted only for correlated observations, for implants placed in the posterior maxilla were 96.2% (95% CI, 94.3 to 98.1) and 92.6% (95% CI, 89.3 to 95.9) for MSA+ and MSA– patients, respectively ($P = .04$, Table 2). The 5-year survival rates, adjusted for correlated observations, for implants placed in the posterior maxilla were 87.9%

Table 1 Descriptive Statistics*

	MSA	No MSA	P
Demographic variables			
Subjects (n)	167 (52.5)	151 (47.5)	—
Implants (k)	473 (62.1)	289 (37.9)	—
Mean age ± SD (y)†	56.4 ± 11.9	55.5 ± 13.1	.3
Gender			.2
Female	74 (44.3)	85 (56.3)	
Male	93 (55.7)	66 (43.7)	
Health status variables			
ASA status	n = 167	n = 148‡	.8
1	79 (47.3)	62 (41.9)	
2	86 (51.5)	84 (56.8)	
3	2 (1.2)	2 (1.4)	
Medically compromised	n = 167	n = 147	.4
Yes	19 (11.4)	12 (8.2)	
No	148 (88.6)	135 (91.8)	
Tobacco use	n = 143	n = 126	.2
Yes	13 (9.1)	15 (11.9)	
No	130 (90.9)	111 (88.1)	
Anatomic variables			
Implant location	k = 473	k = 289	< .001
Molar	219 (46.3)	82 (28.4)	
Premolar	254 (53.7)	207 (71.6)	
Implant proximity	k = 469	k = 288	.7
2 natural teeth	51 (10.9)	89 (30.9)	
2 adjacent implants	107 (22.8)	33 (11.5)	
1 tooth + 1 implant	140 (30.0)	74 (25.7)	
Other	171 (36.5)	92 (32.0)	
Bone quality	k = 383	k = 206	< .001
Type 1	1 (0.3)	0 (0.0)	
Type 2	15 (3.9)	42 (20.4)	
Type 3	43 (11.2)	56 (27.2)	
Type 4	324 (84.6)	108 (52.4)	
Implant-specific variables			
Implant diameter	k = 448	k = 276	.61
3 to 3.5 mm	81 (18.1)	65 (23.6)	
4 to 4.5 mm	233 (52.0)	131 (47.5)	
5 mm	127 (28.4)	74 (26.8)	
6 mm	7 (1.6)	6 (2.2)	
Implant length	k = 448	k = 273	.9
6 mm	2 (0.5)	3 (1.1)	
8 mm	87 (19.4)	52 (19.1)	
11 mm	331 (73.9)	200 (73.3)	
14 mm	28 (6.3)	18 (6.6)	
Implant coating	k = 445	k = 248	< .001
Uncoated	47 (10.6)	58 (23.4)	
TPS	135 (30.3)	86 (34.7)	
HA	263 (59.1)	104 (41.9)	
Immediate implant§	k = 473	k = 289	.001
Yes	28 (5.9)	40 (13.8)	
No	445 (94.1)	249 (86.2)	
Abutment-specific variables			
Abutment length	k = 76	k = 47	
3 to 5 mm	28 (36.8)	10 (21.3)	
6 to 6.5 mm	46 (60.5)	36 (76.6)	
8 to 12 mm	2 (2.7)	1 (2.1)	
Abutment angle	k = 416	k = 239	.009
0 degrees	316 (76.0)	208 (87.0)	
15 degrees	97 (23.3)	29 (12.1)	
25 degrees	3 (0.7)	2 (0.8)	
Prosthetic type	k = 473	k = 289	.7
Crown + fixed	432 (91.3)	267 (92.4)	
Removable	41 (8.7)	22 (7.6)	
Perioperative variables			
Antibiotic use	k = 473	k = 289	.3
Yes	392 (82.9)	250 (86.5)	
No	81 (17.1)	39 (13.5)	
Operator	k = 472	k = 288	.9
Surgeon 1	456 (96.6)	279 (96.9)	
Surgeon 2	16 (3.4)	9 (3.1)	
MSA-specific variables			
Implant placement timing‖	k = 473 (62.1)	k = 289 (37.9)	.88
	263 (34.5)	—	
	210 (27.6)	—	

*Values in parentheses represent percentages.
†Mean ± SD.
‡Data are missing for some of the variables. When the data are missing, n and k represent the total sample size of the available data.
§Immediate implant signifies that an implant was placed immediately following natural tooth extraction.
‖Timing of implant placement is in relation to MSA. Immediate implant placement was defined as occurring simultaneously with MSA. Delayed implant placement occurred following a period of graft consolidation.

(95% CI, 81.3 to 94.5) and 88.0% (95% CI, 82.8 to 93.1) for MSA+ and MSA– patients, respectively ($P = .08$, Table 2).

Table 3 summarizes the univariate analyses between the study variables and implant failure. The following variables were eligible for inclusion in the multivariate model (ie, $P \leq 0.15$) and were associated with an increased risk for implant failure: age at the time of implant placement ($P = .09$), tobacco use ($P < .001$), operator ($P = .005$), implant proximity ($P < .001$), prosthetic type ($P < .001$), implant location ($P = .03$), implant length ($P = .002$), and implant staging ($P < .001$). A multivariate Cox proportional hazards model was created to estimate the association between MSA status and implant failure while controlling for confounding variables and clustered, correlated observations. The multivariate model included variables identified in the bivariate model ($P \leq .15$) as well as biologically important variables, ie, age and gender.

Table 4 summarizes the results of the multivariate model. MSA status was not identified as a risk factor for implant failure ($P = .9$, adjusted hazard ratio = 1.1, 95% CI = 0.6 to 1.9). The adjusted hazard ratio for tobacco use was 3.5 ($P < .001$, 95% CI = 1.7 to 7.2) indicating that the risk of implant failure is 3.5 times more likely in smokers compared to nonsmokers. The adjusted hazard ratio for implant location was 0.4 ($P < .001$, 95% CI = 0.2 to 0.6), indicating that implants replacing premolars are 60% less likely to fail compared to implants replacing molars. For implant staging, the adjusted hazard ratio was 0.1 ($P < .001$, 95% CI = 0.07 to 0.30), suggesting that 2-stage implants are 90% less likely to fail than 1-stage implants.

Table 2 Kaplan-Meier Survival Estimates

Time (mo)	Overall survival (%)	95% CI	P
12			
MSA+	96.2	94.3 to 98.1	.04
MSA-	92.6	89.3 to 95.9	
60			
MSA+	87.9	81.3 to 94.5	.08
MSA-	88.0	82.8 to 93.1	

Survival estimates adjusted for clustered, correlated observations, but not adjusted for confounding variables.

Table 3 Univariate Analysis of Potential Factors Associated with Implant Failure for 318 Patients and 762 Implants

Exposure	Hazard ratio	95% CI	P
Mean age (y)	1.0	0.9 to 1.1	.09
Gender (female vs male)	1.1	0.6 to 1.9	.7
MSA status (positive vs negative)	0.7	0.4 to 1.2	.2
Tobacco use (smoker vs nonsmoker)	3.9	2.1 to 7.5	< .001
Operator	4.2	1.5 to 11.2	.005
Implant proximity	0.2	0.1 to 0.3	< .001
Prosthetic type	1.9	1.5 to 2.4	< .001
Implant location			
Premolar	0.6	0.3 to 0.9	.03
Molar	1.0	—	—
Implant length	0.8	0.7 to 0.9	.002
Implant stage (2- vs 1-stage)	0.2	0.1 to 0.3	< .001

Cox proportional hazards regression model. Only variables with *P* values ≤ .15, the predictor variable (MSA status), and biologically important variables (ie, age and gender) were included.

Table 4 Multivariate Cox Model (Adjusted) Analysis of Potential Factors Associated with Implant Failure*

Exposure	Hazard ratio	95% CI	P
MSA status (positive vs negative)	1.1	0.6 to 1.9	.9
Tobacco use (smoker vs nonsmoker)	3.5	1.7 to 7.2	< .001
Implant location (premolar vs molar)	0.4	0.2 to 0.6	< .001
Implant staging (2- vs 1-stage)	0.1	0.07 to 0.3	< .001
Age	1.02	0.99 to 1.05	.22
Gender (female vs male)	1.09	0.61 to 1.95	.77

*Adjusted for age at implant placement and gender.

DISCUSSION

The purpose of this study was to determine whether MSA was an independent risk factor for implant failure. The investigators hypothesized that the survival rate of implants placed in posterior maxillae of patients with grafted sinuses would equal the survival rate of implants placed in the native posterior maxilla. The results of this retrospective study demonstrate that the 1-year unadjusted survival rates for implants placed in the posterior maxilla were 96.2% (95% CI = 94.3 to 98.1) and 92.6% (95% CI = 89.3 to 95.9) for MSA+ and MSA– patients, respectively ($P = .04$, Table 2), while the 5-year unadjusted survival rates for implants placed in the posterior maxilla were 87.9% (95% CI = 81.3 to 94.5) and 88.0% (95% CI = 82.8 to 93.1) for MSA+ and MSA– patients, respectively ($P = .08$, Table 2). Variables associated with implant failure ($P \leq .15$) and of biologic importance (age, gender) were incorporated into a multivariate Cox proportional hazards model adjusted for correlated observation. After adjusting, MSA status was not an independent risk factor for implant failure at 1 or 5 years (adjusted hazard ratio = 1.1, $P = .9$). This finding suggests that implants placed in successfully grafted maxillary sinuses are not associated with an increased risk for failure when compared to implants placed in nongrafted sinuses.

Tobacco use, implants replacing molars, and 1-stage implants were statistically associated with an increased risk of implant failure. Tobacco users at the time of surgery had a 3.5-fold greater risk for implant failure compared to nonsmokers (adjusted hazard ratio = 3.5, $P < .001$). Implants replacing premolar teeth were associated with a 60% decreased risk for implant failure compared to implants replacing molar teeth (adjusted hazard ratio = 0.4, $P < .001$). Two-stage implants were associated with a 90% decreased risk for implant failure compared to 1-stage implants (adjusted hazard ratio = 0.1, $P < .001$).

Of significance, the large sample size provided this study with sufficient power to apply rigorous statistical analysis and evaluate sinus augmentation as a risk factor for implant failure. To the authors' knowledge, no existing studies have been able to do this. The present results are slightly lower than past studies' reported survival rates for implants placed in the augmented sinus (average reported survival rate, 90.4%; range, 61.2% to 100%; mean length of follow-up, 28.8 months; range, 12 to 144 months).[5–45]

Discrepancies between this study's results and those of prior studies may be because of differences in sample size, method of data analysis, differences in the definition of implant failure, prosthetic types, opposing dentition, duration of graft healing time, or

length of follow-up, as well as differences in implant design and type of graft material. A meta-analysis by Tong and colleagues reported that survival rates for implants placed in the grafted maxillary sinus varied depending on the augmentation material selected.[58] This meta-analysis reported an implant survival rate of 87% for HA (average 18 months follow-up), 90% for autogenous bone (6 to 60 months follow-up), 94% for an HA/autogenous bone combination (average 18 months follow-up), and 98% for demineralized freeze-dried bone (7 to 60 months follow-up). The current study did not examine outcomes related to specific graft material, as these subgroups were composed of sample sizes too small to provide meaningful analyses. Further studies on this topic are warranted.

The finding that tobacco use was a risk factor for implant failure in the posterior maxilla is in accordance with previous studies.[9,46,59] The deleterious effects of smoking on implant survival are well documented, and these effects may be even more detrimental to implants placed in the grafted maxillary sinus.[28,60–62] Because this present study sought to provide a general overview of the effects of variables on implant failure, detailed information regarding smoking history (ie, duration, number of cigarettes/day) was not recorded. The investigators did not document whether multiple implant failures occurred in individual smokers. Future studies examining the effects of specific smoking habits on implant failure is recommended.

Bone quality was not identified as a risk factor for implant failure in this study. This was unexpected, as bone quality has been demonstrated to be influential to implant survival in prior reports.[28,46,60–64] It is possible that bone quality was not identified as a risk factor for implant failure because the sites with the poorest bone volume were successfully rehabilitated with delayed augmentation prior to implant placement. This stipulation indicates that delayed augmentation is inherently associated with selection bias, as implants were placed only after graft viability and enhanced bone volume were ensured. Although delayed sinus augmentation procedures that failed and therefore did not undergo implant rehabilitation were not considered in this study, this population is important to consider in terms of occlusal rehabilitation and morbidity, and future investigation is warranted. An understanding of the incidence of cases where implant placement was not possible because of failed graft consolidation would be valuable. Given these observations, the statistically significant difference between the MSA+ and MSA– populations with respect to bone quality (poorer bone quality was more common in MSA+ patients, $P < .001$) does bias the results and may explain why bone quality was not identified as a risk factor for implant failure.

One-stage implants were identified as a risk factor for implant failure. However, the majority of 1-stage implants were placed in MSA– sites ($P = .006$), which suggests that a higher failure rate with 1-stage implants may only be true for the MSA– population and not for the MSA+ population. As a result, it may be that 1-stage implants placed in successfully augmented sites may not have an increased risk factor for failure compared to 2-stage implants. Further studies comparing implant failure rates of 1- and 2-stage implants in equivalent populations with and without MSA are warranted. Recent studies have shown favorable outcomes for 1-stage implants placed in the posterior maxilla.[65–67] In the present study, the increased failure rate associated with 1-stage implants is probably not because of poor bone quality or any of the other variables included in the statistical model, as this method of data analysis takes into account confounding factors. The higher failure rate with 1-stage implants compared to 2-stage implants is best accounted for by the already-mentioned explanations for differences in the present study compared to prior reports.

As shown in Table 1, in addition to bone quality and implant staging, there were significant differences between the MSA+ and MSA– subjects for the following variables: immediate implants, implant staging, abutment angle, well size, implant coating, and implant location. As this study was not designed as a randomized clinical trial, but as a retrospective cohort study, it is not surprising that there were significant differences in the distribution of many of the study variables between the 2 samples. While the investigators used multivariate modeling to assess the relationship between MSA status and implant survival adjusted for confounding and biologic variables, it is still of interest to discuss why these differences may exist between the 2 samples. For example, immediate implant selection is prudent only when sufficient supporting bone is present; therefore, immediate implants were more common in the MSA– population. Angulated abutments and smaller well sizes were selected more frequently in the MSA+ population compared to the MSA– population. This discrepancy is attributed to inherent differences between augmented and nonaugmented implant sites.

Because some authors have questioned the long-term survival of HA-coated implants,[68,69] it was initially hypothesized that the higher use of HA-coated implants in the MSA+ group would be associated with a disproportionate number of late failures in this population and would explain why the initial difference in implant survival after 1 year (MSA+ implants performed significantly better) was no

longer apparent after 5 years. However, a large number of late failures of HA-coated implants was not observed. There were a total of 14 failed (removed) HA-coated implants in the database. Two HA-coated implants from the MSA– group and 12 HA-coated implants from the MSA+ group failed. However, the mean failure time of the 2 HA implants in the MSA– group was 25.15 months, whereas the mean failure time of the 12 HA implants in the MSA+ group was 14.24 months. As such, a disproportionately higher number of HA-coated implants in the MSA+ late failure group was not observed. The disproportionate number of HA-coated implant failures in the MSA+ population may be related to HA integration potential in native bone versus graft. Future studies on this topic are warranted.

It is interesting to note that a greater number of implants replaced molars in the MSA+ group versus the MSA– group ($P < .001$) and that molar replacement was identified as a risk factor for implant failure. It is possible that differences between the 2 groups biased the results such that MSA+ implants replacing molars have an increased risk for failure versus MSA– implants replacing molars. However, the facts that molar teeth bear the majority of the occlusal load and that the native posterior maxilla has inherently lower bone density[70,71] suggest that failure would be higher for implants used to replace molars versus premolars, regardless of augmentation status. Future studies looking at implant failure rates in the molar region in equal cohorts of MSA+ and MSA– patients is advised.

The loss of data in several data categories with respect to MSA+/MSA- status is unfortunate but is commonly associated with retrospective study designs. One of the weaknesses of a retrospective analysis is that such studies depend on chart review as the data source, and the amount of detail in the chart can vary from patient to patient.

There was minimal clustering of failures within subjects. A total of 38 subjects had 52 implant failures. Twenty-nine patients had 1 implant failure each. Six patients had 2 failures each. One patient had 3 failures. Two patients had 4 failures each. Subgroups composed of subjects with clustered implant failure were too small for substantive bivariate or multivariate analyses.

Two of the 3 risk factors for implant failure identified in this study, tobacco use and 1-stage implants, can be modified by the clinician or patient. This knowledge may allow the clinician to adjust clinical protocols in an effort to decrease implant failure rates.

CONCLUSION

This retrospective study of 318 patients with 762 implants demonstrated no significant difference ($P = .08$) in the 5-year survival rate between implants placed in the ungrafted posterior maxilla and those placed in the grafted posterior maxilla; both groups demonstrated survival rates of about 88%. Variables associated with an increased risk of implant failure were tobacco use, molar replacement, and 1-stage implants. MSA was not an independent risk factor for implant failure.

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