Dental Research Journal

Original Article

Clinical outcomes of dental implants placed in the augmented maxillary sinus: A 5-year retrospective study

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ABSTRACT

Background: Factors influencing the success of an implant placed in augmented maxillary sinus need to be recognized. The aim of this study was to investigate the effect of various oral health conditions and treatment plan details on the clinical and radiographical outcomes of implants placed in the augmented sinus.

Materials and Methods: In this clinical retrospective study, 39 participants (81 implants) that received dental implants after sinus lifting between January 2005 and July 2016 were evaluated. All the participants were examined by an operator clinically and radiographically in a blinded manner. A checklist including oral health and host condition, implant and prosthesis characteristics, and surgical approach variables was completed for each participant. The effect of these variables on probing depth (PD), marginal bone loss, bone formation in sinus, and patient satisfaction was analyzed using analysis of covariance models. P <0.05 was considered statistically significant.

Results: Survival rates after surgery and restoration placement were 93% and 100%, respectively. PD was found to be significantly higher in restorations with infragingival finish lines over 1.5 mm and in implants with score "2" for gingival index. Moreover, more bone formation was observed in implants with score "0" compared with score "2" for gingival index. In addition, the participants with plaque score "0" reported significantly more satisfaction than the participants with score "2" for plaque index.

Conclusion: Inflamed gingiva was associated with more PD and less peri-implant bone formation in maxillary sinus. In addition, more patient satisfaction was reported by participants that had better plaque control.

Key Words: Dental implants, sinus floor augmentation, treatment outcome

Received: 25-Feb-2024
Revised: 11-Oct-2024
Accepted: 14-Oct-2024
Published: 20-Feb-2025

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INTRODUCTION

Primary stability is a fundamental requirement for successful implant insertion.[1,2] One common challenge for implant insertion in the maxillary posterior ridge is lack of sufficient bone height caused by sinus pneumatization and ridge resorption. The routine procedure for increasing the insufficient bone volume is sinus floor augmentation procedure. The sinus augmentation procedure increases the quality and quantity of the available bone to provide better primary stability.[2,3]

Access this article online

Website: www.drj.ir
www.drjjournal.net
www.ncbi.nlm.nih.gov/pmc/journals/1480
DOI: 10.4103/drj.drj_96_24

How to cite this article: Naseri R, Ghadirian A, Shirani M. Clinical outcomes of dental implants placed in the augmented maxillary sinus: A 5-year retrospective study. Dent Res J 2025;22:8.

The predictability of sinus lifting has been approved.[4-6] Two techniques for sinus lifting, including lateral window or open approach and osteotome intrusion or closed approach, are well documented.[7] After a 6-month period of sinus augmentation, an appropriate lamellar bone is formed, and implant can be placed.[8]

A desired result after sinus augmentation procedure is implant surrounded by in the middle of the bone in maxillary sinus. Based on the residual ridge height, the surgeon selects the graft method before implant placement or chooses the graftless method.[9,10] The surgical approach and tooth type do not influence the graft height resorption, whereas graft height decreases after sinus lift procedure over time[11,12] independent of the site of implantation.[13]

Bone formation following a graftless closed surgical approach is provided by the potential capacity of Schneiderian mucous membrane.[14] The quality and quantity of residual bone, intact periosteum, Schneiderian membrane, and implant insertion are important factors in the success of sinus lifting procedure.[9]

A common outcome measured in the implant studies is marginal bone loss (MBL). However, there is a controversy over the etiology of MBL, both biomechanical and biological factors have been considered.[15] For many years, implants with < 0.1 mm bone loss per year after the 1st year of implant insertion were assumed to be successful.[16] The recent concepts are talking about zero bone loss.[17,18] In this order, more than 2 mm initial gingival thickness and sufficient keratinized gingiva provide marginal bone stability.[17,19] Peri-implantitis as a significant factor affecting crestal bone loss should be diagnosed in the initial steps to maintain the marginal bone level and to preserve the implant.[20-22]

Little information is available about the potential risk factors causing implant failure.[23,24] Controversial findings have been reported about the clinical outcomes of implants placed after sinus augmentation procedure compared with implants inserted in the native bone.[25-28] Some factors such as MBL, patient satisfaction, and survival rate of implants placed after sinus lift have been discussed well in previous studies. However, the effects of many factors such as plaque and gingival indices, implant length and width, and prosthesis parameters on the outcomes of these implants have rarely been evaluated.[27] Furthermore, the quantity of the bone covering the implant body and apex placed into the maxillary sinus has not been measured in most previous studies.[11] Systematic reviews have reported the lack of sufficient data about implants placed after sinus lift.[27] Hence, studies on these implants with more than 3 years of follow-up are required.[27]

The aim of this study was to investigate the effect of various oral health conditions and treatment plan details on the clinical and radiographical outcomes of implants placed in the augmented sinus. The null hypothesis was that oral health and host condition, implant and prosthesis characteristics, and surgical approach factors would not influence the probing depth (PD), MBL, bone formation in sinus, and patient satisfaction.

MATERIALS AND METHODS

This clinical retrospective study was conducted on a population received dental implants after maxillary sinus bone augmentation. The participants had been treated at the Dental Implants Research Center in Isfahan between January 2005 and July 2016. Total population sampling was done for enrolling the participants who received final restorations at the minimum of 2 years before. The same surgical and prosthesis fabrication protocol by a special team of surgeons and prosthodontists was followed for all participants.[15] If there was a need for vertical sinus augmentation of 3 mm or less, the closed sinus lift method was used, and in cases where more than 3 mm augmentation was needed, the open sinus lift method was used.

The participants who met the inclusion criteria and provided written informed consent were included in the study. The exclusion criteria consisted of uncontrolled systematic disease, history of chemotherapy or radiotherapy, taking bisphosphonates or corticosteroid drugs, and pregnancy. Isfahan Regional Bioethics Committee granted the ethical approval of the study protocol (IR.MUI.RESEARCH.REC.1399.020). This study was performed in accordance with the World Medical Association Declaration of Helsinki.

All the participants were examined by one operator. A radiologist prepared panoramic (Planmeca, Helsinki, Finland) and photostimulable phosphor (PSP) plate-based parallel bite-wing radiographs (Dental AG, Bietigheim-Bissingen, Germany) for all the participants. The examiner and radiologist were blind to the surgeon and prosthodontist.

The following information was recorded for each participant using a checklist: age, sex, education, prosthesis age (follow-up period of time), implant brand and implant width/length, implant type (bone level/tissue level), surgeon (attendant/resident), sinus lifting approach (closed/open), replacing tooth type (premolar/molar), presence or absence (P/A) of guided bone regeneration (GBR), prosthesis type (crown/fixed dental prosthesis [FDP]), finish line location (supra gingival/gingival/up to 1.5 mm subgingival/over 1.5 mm subgingival), P/A of history on uncemented prosthesis, opposite dentition (tooth/implant), occlusal contacts of restoration in maximum intercuspation (no/functional/heavy) and during excursive movements (P/A), quality of proximal contact (loose/normal or splinted), keratinized and attached gingival width (mm),[29] gingival biotype (thick/thin), P/A of bleeding on probing, plaque and gingival indices (0–3 scores),[29] mean PD, mean MBL, bone formation around implant in sinus, and patient satisfaction (100 mm Visual Analog Scale).

PD was recorded for each implant at 4 points, including mesiobuccal, midbuccal, distobuccal, and midlingual regions, following which their mean was calculated. Probing was performed using a millimeter-graded color-coded periodontal probe (PCP 15, Hu-Friedy, Chicago, IL USA) until pain was felt (0.24 N). MBL was measured as the distance of mean crestal bone level to the crest module of the implant on both mesial and distal sides using a digital ruler in the PSP software.[15,30]

Bone formation was measured using panoramic radiographs and considered in two methods. For the first method, the presence of bone along with the apical portion of implants was investigated (No/Partial/Complete). If any bone was not formed in the mesial/distal/apical of the implant over the sinus floor, it was regarded as "no bone formation." When the bone was formed throughout each three parts, it was regarded as "complete bone formation." In addition, implants with sectional-formed bone were regarded as "partial bone formation." In the second method, the mean distance from the most apical level of implant surrounding the bone on both mesial and distal sides to the sinus floor in the adjacent regions was measured in the software. For calibration, implant length was used to adjust the magnification of radiography.[11]

In this study, four variables, including mean PD, mean MBL, mean bone formation, and patient satisfaction, were major dependent variables, and the effect of independent variables on these four items was studied. The independent variables with two groups using independent *t*-test and variables with more than two groups using analysis of variance were compared for values of each dependent variable. Finally, independent variables with $P \leq 0.3$ were subjected to an analysis of covariance (ANCOVA) model of each dependent variable. ANCOVA consists of analysis of variance and general linear regression and can manage the effect of confounding factors. The data were analyzed by a statistician who was blind to the data using a statistical software program (IBM SPSS Statistics, v24; IBM Corp, USA) (a = 0.05 for all tests).

RESULTS

Eighty-seven implants had been placed in the augmented sinus. Six implants had been failed before receiving prosthesis (93% early survival rate). In this study, 81 implants were investigated (100% late survival rate). The descriptive characteristics of 39 participants and 81 implants are shown in Table 1. All implants were of regular diameter with a length between 8 and 12 mm.

The results of ANCOVA for comparing PD among independent variables are shown in Table 2. There were significant effects of surgeon, gingival index, finish line site, and prosthesis age on PD after controlling the adjusting factors. The single significant difference in pairwise comparison of gingival index scores was higher PD in the group with score "2" compared with the group with score "1." Further, a significantly higher PD was found in restorations with infragingival finish lines over 1.5 mm compared with gingival finish lines.

The results of ANCOVA for comparing MBL among independent variables are presented in Table 3. The prosthesis type, opposite dentition, and uncemented prosthesis had a significant effect on MBL after controlling the adjusting factors.

The results of ANCOVA for comparing bone formation among independent variables are shown in Table 4. There were significant effects of implant brand, gingival index, and implant length on bone formation after controlling the adjusting factors. In pairwise comparison of four groups of implant brand, the "Snucone" group showed significantly more bone formation than the "Others" group. Moreover, there was no significant difference among the groups. The

Table 1: Description of studied population

Variables	Description			
Age (year)	Mean±SD: 51.57±11.42, minimum: 28, maximum: 71			
Sex	19 males (39 implants) and 20 females (42 implants)			
Prosthesis age (year)	Mean±SD: 5.22±2.55, minimum: 2, maximum: 14			
Variables	**Brand**		**Frequency (%)**	
Implant brand	Zimmer		13 (16)	
	Dio		16 (19.8)	
	Snucone		29 (35.8)	
	Others		23 (28.4)	
	Sum		81 (100)	
Implant type	61 bone level and 20 tissue level			
Tooth type	29 premolar and 52 molar			
Prosthesis type	25 crown and 56 FDP			
GBR	65 no and 16 yes			
Variables	**No BF**	**Partial BF**	**Complete BF**	**Sum**
Sinus lift type and group of BF in sinus				
Close sinus lift	21 (42)	21 (42)	8 (16)	50
Open sinus lift	13 (42)	10 (32)	8 (26)	31
Mean PD (mm)	Mean±SD: 2.37±0.69, minimum: 1, maximum: 4.5			
Mean MBL (mm)	Mean±SD: 0.71±0.64, minimum: 0, maximum: 2.9			
Bone formation (mm)	Mean±SD: 1.55±2.06, minimum: 0, maximum: 7.5			
Patient Satisfaction	Mean±SD: 93.99±10.67, minimum: 50, maximum: 100			

BF: Bone formation; SD: Standard deviation; PD: Probing depth; MBL: Marginal bone loss; FDP: Fixed dental prosthesis; GBR: Guided bone regeneration

Table 2: Results of analysis of covariance for comparing mean probing depth

Independent variables	*B*	*t*	*P*
Surgeon (attendant)	−0.579	−2.085	0.042
Surgeon (resident)	0		
Bleeding on probing (no)	−0.447	−1.313	0.194
Bleeding on probing (yes)	0		
Gingival index (0)	0.19	0.052	0.959
Gingival index (1)	−0.613	−2.795	0.007
Gingival index (2)	0		
Plaque index (0)	−0.238	−0.791	0.432
Plaque index (1)	0.002	0.008	0.994
Plaque index (2)	0		
Occlusal contact in excursive (no)	−0.334	−1.919	0.06
Occlusal contact in excursive (yes)	0		
Opposite dentition (tooth)	0.322	1.719	0.091
Opposite dentition (implant)	0		
Finish line site (supra gingival)	−0.232	−0.897	0.374
Finish line site (at gingival)	−0.584	−2.633	0.011
Finish line site (≤1.5 mm infra gingival)	−0.278	−1.316	0.193
Finish line site (>1.5 mm infra gingival)	0		
Prosthesis age (year)	0.075	2.297	0.025
Keratinized gingival width	0.028	0.344	0.732
Attached gingival width	−0.086	−0.774	0.442

only significant difference in pairwise comparison of gingival index scores was more bone formation in group with score "0" than the group with score "2."

The results of ANCOVA for comparing patient satisfaction among independent variables are indicated in Table 5. The plaque index, occlusal contact in laterotrusive movements, and opposite dentition had a significant effect on patient satisfaction after controlling the adjusting factors. The participants with "0" plaque score reported significantly more satisfaction than the participants that reported score "2" for plaque index.

DISCUSSION

The null hypothesis that stated oral health and host condition, implant and prosthesis characteristics, and surgical approach would not influence the PD, MBL, bone formation, and patient satisfaction was rejected. Plaque and gingival indices as factors presenting biologic conditions affected PD, bone formation, and patient satisfaction.

A parameter commonly evaluated in dental implant studies is survival rate. In addition, success rate is sometimes measured. A successful implant is a survived implant that has additional factors such as a predetermined range of crestal bone loss and lack of inflammation. However, the criteria for defining the success rate are controversial.[4,23] This study found 93% survival rate for surgical placement and 100% survival rate after prosthesis delivery. The studies on the outcomes of implants placed in grafted maxillary sinus have reported a survival rate from 85.5% to 100%.[4,9,10] It seems the weak point causing the failure of an implant placed in the augmented maxillary sinus is related to surgical grafting and placement procedures.

This study found better outcomes in participants with good plaque control and healthy gingiva. More PD was found in participants with severe gingival inflammation. In addition, when crown-abutment finish line was placed too deep, PD was increased. Sufficient keratinized gingival width is a useful factor for having healthy gingival tissues.[19] The importance of healthy soft tissues around implants has been approved. Prolonged peri-implantitis is a plaque-related inflammatory condition in the

Table 3: Results of analysis of covariance for comparing mean marginal bone loss

Independent variables	*B*	*t*	*P*
Surgeon (attendant)	−0.579	−1.609	0.113
Surgeon (resident)	0		
GBR (no)	−0.319	−1.865	0.067
GBR (yes)	0		
Bleeding on probing (no)	−0.361	−1.058	0.294
Bleeding on probing (yes)	0		
Implant brand (Zimmer)	0.095	0.394	0.695
Implant brand (Dio)	−0.091	−0.357	0.722
Implant brand (Snucone)	0.385	1.997	0.051
Implant brand (others)	0		
Gingival type (thin)	−0.209	−0.891	0.377
Gingival type (thick)	0		
Gingival index (0)	−0.197	−0.519	0.605
Gingival index (1)	−0.427	−1.899	0.062
Gingival index (2)	0		
Plaque index (0)	−0.42	−1.167	0.248
Plaque index (1)	−0.427	−1.358	0.18
Plaque index (2)	0		
Prosthesis type (crown)	−0.521	−2.766	0.008
Prosthesis type (fixed dental prosthesis)	0		
Occlusion in MIC (nonfunctional)	0.584	1.581	0.119
Occlusion in MIC (functional)	0.36	1.012	0.316
Occlusion in MIC (heavy contact)	0		
Uncemented prosthesis (no)	0.535	2.09	0.041
Uncemented prosthesis type (yes)	0		
Opposite dentition (tooth)	0.404	2.44	0.018
Opposite dentition (implant)	0		
Prosthesis age (year)	−0.014	−0.41	0.683
Implant width	0.31	1.453	0.152

GBR: Guided bone regeneration; MIC: Maximum intercuspation

Table 4: Results of analysis of covariance for comparing mean bone formation

Independent variables	*B*	*t*	*P*
Surgeon (attendant)	−1.123	−1.091	0.279
Surgeon (resident)	0		
Tooth (anterior)	−0.36	−0.708	0.481
Tooth (posterior)	0		
Implant brand (Zimmer)	0.215	0.303	0.763
Implant brand (Dio)	0.948	1.156	0.252
Implant brand (Snucone)	1.627	2.565	0.013
Implant brand (others)	0		
Gingival index (0)	2.861	2.182	0.033
Gingival index (1)	−0.325	−0.513	0.61
Gingival index (2)	0		
Plaque index (0)	0.54	0.515	0.609
Plaque index (1)	−0.347	−0.346	0.731
Plaque index (2)	0		
Sinus lift type (close)	0.247	0.443	0.659
Sinus lift type (open)	0		
Bleeding on probing (no)	−1.252	−1.099	0.276
Bleeding on probing (yes)	0		
Uncemented prosthesis (no)	−1.452	−1.902	0.062
Uncemented prosthesis type (yes)	0		
Implant length	−0.469	−2.126	0.037

peri-implant mucosa that progress to the crestal bone loss.[21,22]

The importance of plaque control should be described for patients in details. In this study, the participants with better hygiene reported more satisfaction. More peri-implant bone formation in the maxillary sinus was observed in participants with healthy gingiva. This result may be related to the role of inflammatory factors that increase in gingivitis and periodontitis.[21,22] These findings emphasize the need for controlling the biologic factors.

This study found more MBL when the implants were restored with FDPs. This finding is in line with the etiology of MBL, including biologic and bio-mechanic factors.[15] When FDPs were applied, plaque control has been making difficult, and also the force applied to the pontics could provide implant overload. One advantage of splinted restoration on implants is more retention and less uncemented prosthesis. On the other hand, splinting the restorations makes flossing difficult.[22]

A 3-year follow-up study reported no significant influence of variables such as age, sex, type of restoration, and implant region on the implant failure.[24] These findings are in line with the results of the present study. This study considered the effect of many variables on implant therapy outcomes in designed models. Factors such as age, sex, GBR, and occlusion in maximum intercuspation did not influence the evaluated outcomes. However, deeper PD was observed in the participants with higher prosthesis age.

New bone substitutes,[8,13,20] leukocyte and platelet-rich fibrin,[10,31] membranes,[20,27] and surgical approaches[10,27] have been introduced and evaluated in sinus augmentation studies. Moreover, the role of implant geometry and surface texture have been investigated.[23,28] In this study, "Snucone" implants provided more bone formation. This finding is related to the surface of implant which can affect bone growth induction.[9] For implants with longer length, significantly less bone was formed around the implants in the maxillary sinus. This finding may present an inverse relationship between the potential bone formation capacity of Schneiderian mucous membrane[14] and the amount of membrane displacement.[12]

When a restoration is placed, a perfect occlusal adjustment should be considered. This fact is more

Table 5: Results of analysis of covariance for comparing patient satisfaction

Independent variables	*B*	*t*	*P*
Surgeon (attendant)	−0.696	−0.118	0.907
Surgeon (resident)	0		
Sinus lift type (closed)	4.619	1.465	0.15
Sinus lift type (open)			
Bleeding on probing (no)	5.678	0.642	0.524
Bleeding on probing (yes)	0		
Uncemented prosthesis (no)	3.577	0.776	0.442
Uncemented prosthesis type (yes)	0		
Implant brand (Zimmer)	6.75	1.517	0.137
Implant brand (Dio)	−1.193	−0.234	0.816
Implant brand (Snucone)	−3.204	−0.710	0.482
Implant brand (others)	0		
Gingival index (0)	2.81	0.352	0.727
Gingival index (1)	4.832	1.331	0.191
Gingival index (2)	0		
Plaque index (0)	14.845	2.683	0.01
Plaque index (1)	8.414	1.608	0.115
Plaque index (2)	0		
Occlusal contact in laterotrusive (no)	11.353	2.989	0.005
Occlusal contact in laterotrusive (yes)	0		
Opposite dentition (tooth)	−8.469	−2.332	0.025
Opposite dentition (implant)	0		
Proximal contact (loose)	−3.315	−1.124	0.267
Proximal contact (normal or splinted)	0		
Prosthesis age (year)	0.436	0.734	0.467
Implant width	−1.858	−0.478	0.635
Keratinized gingival width	−0.877	−0.781	0.439

important when implant restorations are to be placed.[15] The results of the present study showed the effect of occlusion and opposite dentition on patient satisfaction and MBL. Future studies are suggested to evaluate the effect of occlusal contact in laterotrusive movements on patient satisfaction when posterior teeth are to be replaced.

A limitation of this study was the small sample size and retrospective design of the study. In this order, the role of confounding factors was controlled using model designing by ANCOVA. Another limitation was the lack of 3-dimensional radiography and histological evaluation of augmented bone in maxillary sinus, which is because of human studies and ethical limitations.

The implants placed in augmented sinus with more than 4 mm initial bone height showed better outcomes.[10] However, the required amount and importance of bone formation around the implants in maxillary sinus have not been well stablished. In this study, the augmented bone was measured in the mesial and distal regions of the implant. In addition, the group of bone formation was reported for both open and closed methods in three manners no, partial, and complete [Table 1]. Based on these findings, both methods provided some cases of complete bone formation. However, more percent of complete bone formation was observed in the open method, which needs more consideration in future studies. Hence, future studies are recommended to investigate the quality, quantity, and importance of peri-implant bone formation in the maxillary sinus.

CONCLUSION

With the caution of this study limitation, it was concluded that:

- Inflamed gingiva was related to more PD and less peri-implant bone formation in maxillary sinus
- More PD was observed in restorations with finish lines deeper than 1.5 mm
- More MBL was found when the implants were restored by FDPs compared with single crowns
- More patient satisfaction was reported by participants that had better plaque control
- In the apical portion of longer dental implants, significantly less bone was formed in maxillary sinus.

Financial support and sponsorship

This work was supported by Dental Research Center, Isfahan University of Medical Sciences. Research Grant #398892. Ethical code: IR.MUI.RESEARCH.REC.1399.020.

Based on a thesis submitted to the undergraduate school of Isfahan University of Medical Sciences in partial fulfillment of the requirement for the Doctor of Dental Surgery degree.

Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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