Simultaneous Sinus Lift and Implant Installation: Prospective Study of Consecutive Two Hundred Seventeen Sinus Lift and Four Hundred Sixty-Two Implants

Hyun-Suk Cha, DDS, MSD, PhD;* Andrew Kim, DDS, MS;† Hessam Nowzari, DDS, PhD;† Hoo-Sun Chang, MD, PhD;‡ Kang-Min Ahn, DDS, MSD, PhD§

ABSTRACT

Purpose: If less than 4 mm of residual bone is remained in posterior maxilla, two-stage operation is recommended for implant installation. However, if primary stability could be obtained using tapered designed implants, one-stage surgery could be performed with reliable success rate in severely resorbed maxilla. The purpose of this prospective study was to evaluate survival and success rates of the implants simultaneously placed into grafted sinus using rough-surfaced implant.

Materials and Methods: A total of two hundred seventeen consecutive sinus lifting through lateral approach and four hundred sixty-two simultaneous implants were installed from November 2003 for 5.5 years. Xenogenic bone was used solely for bone graft materials. Second surgery was performed around 6 months after operation and porcelain fused metal or gold crown was used for definitive restorations. Cumulative survival and success rates were evaluated according to residual alveolar bone height (RABH), smoking status, and Schneiderian membrane perforation.

Results: The mean follow-up was 57.1 ± 15.6 (36–98) months. Of the four hundred sixty-two implants, two hundred sixty-two implants (56.7%: group 1) were installed in posterior maxilla less than 4-mm RABH and two hundred implants (43.3%: group 2) were placed in over 5-mm RABH. The cumulative survival and success rates were 98.91% and 96.54%. There was no statistically significant difference in success rate between group 1 and group 2 ($p = .3135$). Perforation of the membrane was not related to success ($p = .7162$), but smoking status is significantly related with implant failure ($p = .0003$).

Conclusions: Sinus lifting with simultaneous implant placement could be used to treat atrophic maxilla in patients with minimal RABH when initial stability could be obtained by using taper designed implants with surgical techniques. Smoking is a possible factor for implant failure. Membrane perforation did not have an adverse effect on implant success if the membrane was repaired with absorbable membrane and fibrin glue.

KEY WORDS: dental implant, perforation, residual alveolar bone, Schneiderian membrane, sinus lifting, smoking, xenogenic bone

INTRODUCTION

Sinus lifting and implant placement are predictable treatment options for pneumatized sinus and severely resorbed maxillary posterior reconstruction. A minimum of 4 to 5 mm of residual bone height is traditionally recommended for the one-stage surgical procedure of sinus lifting and implant placement to ensure initial stability from preexisting residual bone.[1–4] However, these criteria have been determined arbitrarily without controlled studies.[3–6] In efforts to improve primary stability and osseointegration, implant designs and surface treatments have evolved in recent years.

*Associate professor, Department of Prosthodontics, Asan Medical Center, College of Medicine, University of Ulsan, Seoul, Korea; †Department of Advanced Periodontics, University of Southern California, Los Angeles, CA, USA; ‡Department of Preventive Medicine & Public Health, College of Medicine, Yonsei University, Seoul, Korea; §associate professor, Department of Oral and Maxillofacial Surgery, Asan Medical Center, College of Medicine, University of Ulsan, Seoul, Korea

Reprint requests: Professor Kang-Min Ahn, Department of Oral and Maxillofacial Surgery, College of Medicine, University of Ulsan, Seoul Asan Medical Center, Seoul 138-736, Korea; e-mail: ahnkangmin@hanmail.net

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Reports in the literatures indicate that frictional resistance created by rough-surfaced implant combined with modified surgical techniques can improve initial implant stability.[7,8] In severely resorbed or pneumatized posterior maxilla, optimal initial stability could be obtained by underpreparing implant osteotomies and using tapered designed implants. Various studies have evaluated sinus lifting and simultaneous implant installation and showed no relationship between implant failure and residual alveolar bone height.[9,10] Others have reported that the amount of residual bone height significantly influences the implant survival rate in sinus lifting.[11] Recently, systemic reviews reported that simultaneous and delayed implant installation displayed similar survival rates.[12,13] Peleg and colleagues adopted a one-stage surgical technique that allows implant placement in as little as 1 to 2 mm of residual bone using microtextured or coated implants at least 13 mm in length with predictable success rate.[9,10,14] However, these studies had varying methodologies including implant design, bone graft materials, and healing periods. The effect of preoperative residual bone height on success rate is inconclusive due to the diversity of the study designs.

To the authors' best knowledge, a large-scale prospective study evaluating sinus lifting and simultaneous implant installation using only xenogenic bone in severely resorbed maxilla has not been reported. This prospective study evaluated implants (rough surface ≥10 mm length) immediately placed into grafted maxillary sinuses using lateral window approach (xenogenic bone only) irrespective of residual bone height. The purpose of this prospective study was to evaluate the survival and success rates of the implants simultaneously placed into grafted sinus and evaluate whether there are any differences in survival and success rates regarding residual alveolar bone height, smoking status, and membrane perforation.

MATERIALS AND METHODS

Preoperative Evaluation and Inclusion and Exclusion Criteria

A total of two hundred seventeen consecutive lateral window sinus lifts and four hundred sixty-two implant installations were performed by one experienced oral and maxillofacial surgeon at the Department of Oral and Maxillofacial Surgery at Seoul Asan Medical Center. The Asan Medical Center Institutional Review Board approved the clinical trial. The inclusion and exclusion criteria are reported in Table 1. Every patient underwent a medical and dental history evaluation including the presence of illness, medications, and smoking habits. Patients were examined intraorally and extraorally using panoramic radiograph and cone beam computed tomography (CT) scan.

Implant Selection

Implants (Implantium®, Dentium Co., Seoul, Korea) with microthreads in the coronal part with sand blasting, large grit, and acid etching surface were used in this study. This tapered implant design has a table that is 0.2 mm wider than lower body area to increase initial stability in bone. The coronal aspect (2 mm) of the implant consists of microthreads. The lengths and diameters of the implants that were used in this study were 10

TABLE 1 Criteria for Patient Selection

Inclusion Criteria	Exclusion Criteria
• Posterior maxillary bone deficiency (residual alveolar bone 1–8 mm) without the need for multiple interventions (e.g., simultaneous ridge augmentations) • Good periodontal health • More than 2 months of healing period after extraction • Good general health: those with controlled medical conditions with physician's approval • Stable mental health condition • Ability to complete at least 36 months of clinical follow-up • Willingness to provide signed informed consent form	• Uncontrolled diabetes mellitus and hypertension • History of myocardial infarction within 6 months • Use of immunosuppressive medication • Use of intravenous bisphosphonate • Presence of immunodeficiency disease • History of irradiation associated with head and neck cancer • Evidence of acute and chronic sinusitis • Presence of cyst or tumor in maxillary sinus • History of Caldwell-Luc operation • Pregnancy at the time of operation • Alcohol or drug abuse • Unlikely to comply with study procedures according to investigators' judgment

and 12 mm and 3.3, 3.8, 4.3, and 4.8 mm (determined by the width of the residual ridge), respectively.

Surgical Technique

The modified Caldwell-Luc approach was used to gain access to the sinus cavity. The lateral wall of the maxilla was exposed with a full-thickness mucoperiosteal flap made with crestal incision and two vertical incisions on the buccal side of the residual alveolar ridge mesially and distally. The size of the lateral window was determined by the number of implants to be installed with consideration to minimize the size of the lateral window as possible. A #2 carbide round bur was used to create a window on the lateral maxillary wall using low speed straight angle handpiece. When the Schneiderian membrane was visualized under the groove, a #2 diamond round bur was used to prevent membrane tearing. The window bone was temporarily removed rather than infracturing into the sinus (Figure 1). Implant osteotomy was prepared according to the manufacturer's instructions. Countersink drills were not used to optimize primary stability.

Residual alveolar bone was initially evaluated using panoramic radiograph and CT scans. After sinus membrane elevation, the position of the osteotomy was marked with a sterilized pencil according to surgical stent. The exact measurement of the clinical residual alveolar bone was obtained using a depth gauge (Figure 2).

Xenogenic bone (Bio-Oss®, Geistlich Pharma, Wolhusen, Switzerland) was soaked with gentamycin (gentamicin sulfate, Choongwae Pharm, Seoul, Korea) for 5

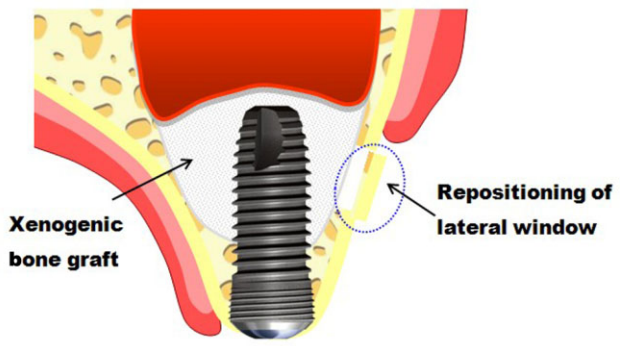

Figure 1 Diagram of the surgical procedure. Lateral window was temporarily removed during the sinus membrane elevation. Xenogenic bone was grafted into the sinus and implant was placed. Implant has the microthreads and tapered design to maximize initial stability.

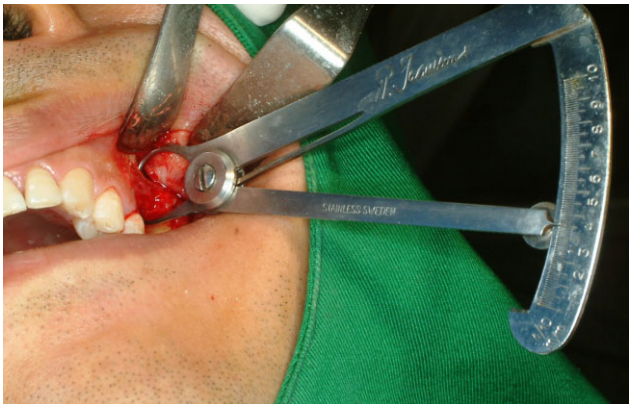

Figure 2 Measurement of the residual alveolar bone using depth gauge.

minutes before application into the maxillary sinus and grafted until it filled the elevated sinus cavity. The dental implants were initially placed into the grafted sites using an automated handpiece and finalized using a hand wrench with a torque gauge. If the initial stability of 15 Ncm was not obtained by torque gauge, it was replaced with larger diameter implant.

In case of membrane perforation, porcine membrane (Bio-Gide, Geistlich Pharma, Wolhusen, Switzerland) and fibrin glue (Greenplast®, Green Cross Co. Ltd., Seoul, Korea) were used to repair the perforated area. The buccal window bone was repositioned to the original site using fibrin glue. All implants were submerged and the mucoperiosteal flap was closed using 4-0 Vicryl (Johnson & Johnson, Ethicon, England).

Implants were divided into two groups. Group 1 included implants installed in the posterior maxilla with residual alveolar bone height of <5 mm. Group 2 included implants installed with alveolar bone height of ≥5 mm. The survival rate of each group was evaluated. The smoking status and membrane perforation were recorded and the same evaluation was performed.

Postoperative Management

Patients were prescribed augmentin (potassium clavulanate 125 mg + amoxicillin sodium 250 mg, two times daily), airtal (aceclofenac 100 mg, two times daily) for 5 days, prednisolone (10 mg, two times daily) for 2 days, and hexamedin (0.2% chlorhexidine mouthwash, three times daily for 5 days). Clindamycin (300 mg, three times daily) was prescribed to patients with penicillin allergy. Patients were instructed to avoid blowing their noses and cough/sneeze with their mouths open when

necessary for at least 2 weeks after surgery to prevent increased pressure in the operated sinus. Sutures were removed 10 days after surgery. Patients with removable prosthesis were instructed not to wear their prosthesis for 2 weeks after surgery. All patients were instructed to follow a soft diet for 1 week. Dentures were relined after sutures removed and monthly thereafter with a soft tissue conditioner.

Time Schedule for Second Surgery and Prosthodontic Treatment

Uncovery surgery was performed about 6 months after implant placement. Marginal bone level, implant mobility, and presence of fistula were examined. Final impression was taken 2 weeks after second surgery. All patients were treated with a fixed implant-supported prosthesis for final restoration. The final tightening torque of abutment was 32 Ncm. The screw-retained porcelain fused metal or gold crown was fabricated for definitive restorations and temporary cement was used for luting. At the day of final restoration, baseline periapical radiographs were taken to evaluate marginal bone resorption. Patients were recalled every 6 months for 3 years after prosthesis delivery and annually after 3 years. Every recall visit, the final restorations were removed and cleaned to examine implant mobility, excessive cement, and screw loosening in splinted bridges.

Radiographic Analysis

Periapical radiographs (long-cone paralleling technique) and panoramic radiographs were taken immediately after surgery, 1 month, 6 months, 1 year postoperation, and annually thereafter. An independent examiner interpreted all radiographs. The changes from baseline (day of final prosthodontic treatment) were calculated for all follow-up periods. The implant used in this study has microthreads in the coronal portion which is 2 mm. Marginal bone loss was measured on radiographs using the implant microthreads as internal standard (Figure 3). Measurement of the marginal bone change was performed with image analysis software (ImageJ, 1.44p, National Institutes of Health, Bethesda, MD, USA).

Criteria for Implant Success Rates and Implant Survival

Those meeting the following parameters were considered as successful implants, which were suggested by Albrektsson and colleagues: (1) absence of persistent pain; (2) absence of peri-implant infection with suppuration; (3) absence of implant mobility; (4) absence of continuous peri-implant radiolucency; and (5) peri-implant bone resorption <1.5 mm in the first year of function and <0.2 mm in the subsequent years.[15] Implant survival was defined as functional implants that followed parameters (1) to (4).

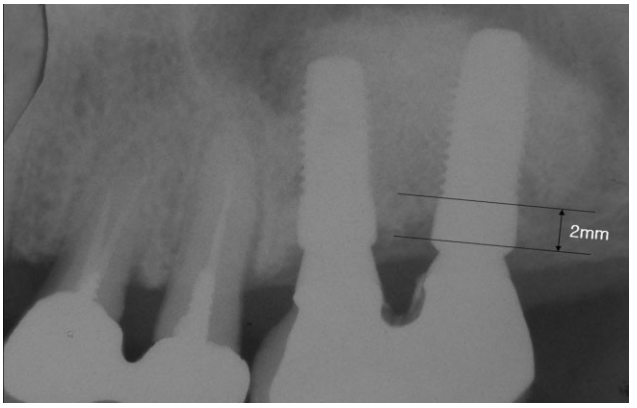

Figure 3 Periapical radiograph of the implants placed in the grafted sinus bone. The known length of the microthreads in implant was used as an internal standard (*arrow* = 2.0 mm).

Statistical Methods

Data were collected with regard to success rate and survival rate according to the residual alveolar bone height and smoking status. Descriptive statistics and survival analyses were computed with SPSS statistical software (version 12.0, SPSS, Inc., Chicago, IL, USA). The primary analysis of interest was the assessment of the relationship between residual alveolar bone height and implant survival rate. The comparison between group 1 and group 2 was performed with the chi-square test. The success rates of implants in smoking versus nonsmoking group and membrane perforated versus nonperforated groups were evaluated with the same methods. Any patient who smoked more than one cigarette a day was considered a smoker following the definition by Wallace.[16] Implant survival was defined as the length of time of implant survival from the date of implant installation to the date of implant failure. Implant survival rate was analyzed using the Kaplan-Meier analysis, and a group comparison was made using the log-rank test. The statistical significance ($p < .05$) of the results was determined.

RESULTS

Summary of Patient Data

A total of two hundred seventeen sinus lifts and four hundred sixty-two implants were placed simultaneously in one hundred sixty-one patients. Among one hundred sixty-one patients, 56 patients (male : female [M : F] = 39:17) received bilateral sinus lifts and one hundred five patients had unilateral sinus lifts and implant installation (M : F = 57:48). The mean duration of follow-up of patients after implant placement was 57.1 ± 15.6 (36–98) months. Implants were installed from the first premolar to second molar area (78.2% molars). A total of two hundred sixty-two of four hundred sixty-two implants (56.7%) were placed in ridges that had residual bone height of <5 mm (group 1) and two hundred implants (43.3%) were installed in ≥5 mm (group 2). Distribution of the implants placed in each group and diameters of implants were listed in Table 2.

Survival and Success Rates

A total of five implants from four patients (M : F = 3:1) were removed during the follow-up periods. The cumulative survival rate was 98.91% (four hundred fifty-seven of four hundred sixty-two). The survival rate was slightly higher in group 2 than in group 1 according to Kaplan-Meier survival analysis but was not statistically significant ($p = .2866$, Figure 4).

After second-stage surgery, no patient presented with persistent pain, peri-implant infection with suppuration, and mobility of implant. A total of 11 implants (group 1 = three implants; group 2 = eight implants) in seven patients (M : F = 3:4) showed more bone loss than the acceptable parameters according to Albrektsson and colleagues' success criteria (>1.5 mm of marginal bone loss in the first year of function or >0.2 mm in the subsequent years). Including the five implants that were removed, a total of 16 implants did not follow the implant success criteria. The cumulative success rate was 96.54% (group 1 = 97.33%, group 2 = 95.50%) (Table 3). According to chi-square test (Table 4), there was no statistically significant difference in success rate between the two groups ($p = .3135$). Clinical photographs and radiographs of one-stage surgery and implant installation are shown in Figure 5, A–E.

TABLE 2 Distribution of Implant Diameter by Residual Alveolar Bone Height

	Implants	
RAB	Diameter (mm)	No. Placed
1–4 mm	3.4	3
	3.8	46
	4.3	96
	4.8	117
	Total	262
5–8 mm	3.4	6
	3.8	31
	4.3	86
	4.8	77
	Total	200

RAB = residual alveolar bone.

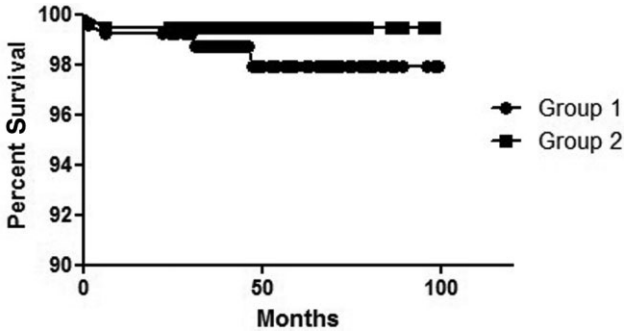

Figure 4 Kaplan-Meier survival analysis between group 1 and group 2.

Sinus Membrane Perforation and Implant Success

A total of 35 of two hundred seventeen (16.13%) sinus membranes were perforated during surgery. Membrane perforations were repaired with collagen membrane, fibrin glue. Bone grafts and implants were installed as planned without delay in any case. A total of 68 of four hundred sixty-two (14.72%) implants were placed in perforated sinuses and three (4.41%) implants of these failed. According to chi-square test with Fisher's exact test (Table 5), there was no statistically significant difference in success rate between the implants placed in perforated and nonperforated sinuses ($p = .7162$).

Smoking Habits in Implant Success

Among one hundred sixty-one patients, 18 patients (M : F = 17:1) were smokers. They were heavy smokers and all of them smoked at least 10 cigarettes a day before

TABLE 3 Residual Alveolar Bone Height and Survival, Success Rate

	RABH (mm)	NOI	Removed	Failed	TF	FR
Group 1	1	37	0	1	1	0.22
	2	60	2	0	2	0.43
	3	92	1	1	2	0.43
	4	73	1	1	2	0.43
Group 2	5	69	0	4	4	0.87
	6	87	1	1	2	0.43
	7	44	0	3	3	0.65
Total		462	5	11	16	3.46

Group 1: residual alveolar bone height of <5 mm; group 2: alveolar bone height of ≥5 mm.
FR = failure rate; NOI = number of implants placed; RABH = residual alveolar bone height; TF = total failed implants.

and after operation. A total of 48 implants were placed in smokers and seven (14.58%) implants failed, whereas a total of four hundred fourteen implants were placed in nonsmokers and nine (2.17%) implants failed. According to chi-square test with Fisher's exact test (Table 6), there was a statistically significant difference in success rate between the smokers and nonsmokers ($p = .0003$) and implants placed in smokers and nonsmokers ($p = .0005$).

Management of Failed Implant

The causes of the five implant removals were the following: one implant with acute infection and suppuration 1 month after surgery, three implants with loss of integration during uncovery surgery, and one implant removal due to significant peri-implant bone loss after 2 years of loading. The implant that was removed due to acute postoperative infection had a membrane perforation. After 3 months of healing, a short implant (8 mm length, 4.8 mm–diameter) was placed in the failed implant site. The implant was considered successful during a 3-year follow-up (Figure 6, A–C).

The three implants (two patients) that were removed during uncovery surgery were replaced with wider diameter implants at the failed sites. All replaced implants integrated after 6 months of healing and definitive restorations were delivered successfully. The implant that was removed after 2 years was the middle implant of three consecutive implants that were restored with a fixed partial denture. The patient was a heavy smoker who smoked more than 40 cigarettes/day. The implant was removed and the void in the definitive restoration that was associated with the failed implant was filled with resin.

DISCUSSION

Sinus lifting is a predictable treatment option for hard tissue augmentation in the maxillary sinus for facilitation of implant placement. In a systematic review of dental implants placed in the posterior maxilla using sinus lifting and bone graft, Wallace and Froum[17] demonstrated an average survival rate of 92.6% and Del Fabbro and colleagues[12] reported an average survival rate of 91.5%. A systematic review about simultaneous sinus lifting and implant placement reported a survival rate of 90.1% after 3 years of follow-up.[18] In the present study, the cumulative survival and success rates were

TABLE 4 Implant Success according to the Residual Alveolar Bone

	Number of Implants			
	Success	Failure	Success Rate	*p* Value
Group 1	255	7	97.33% (255/262)	.3135
Group 2	191	9	95.50% (191/200)	
Total	446	16	96.54% (446/462)	

Group 1: residual alveolar bone height of <5 mm; group 2: alveolar bone height of ≥5 mm.

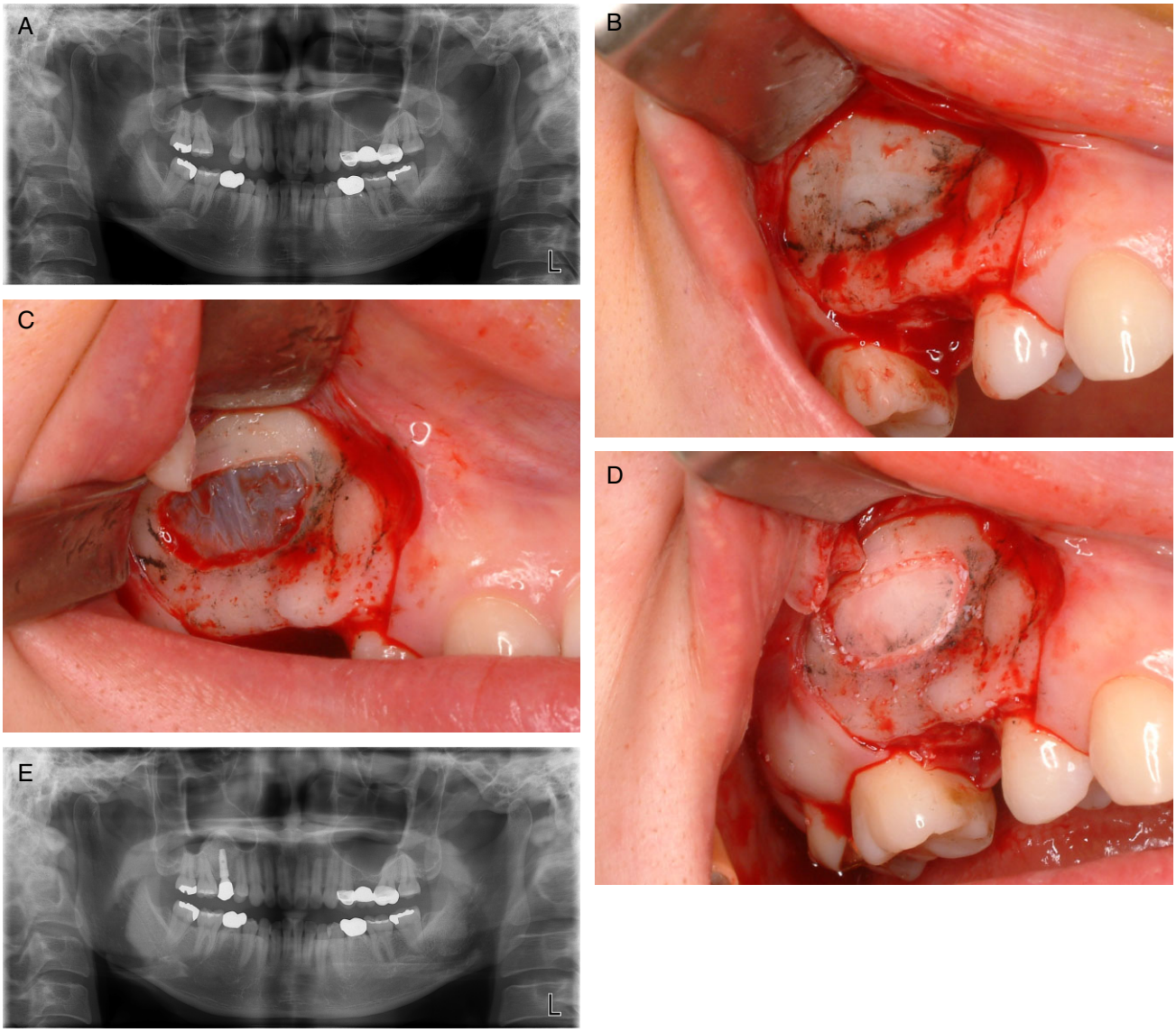

Figure 5 *A*, Panoramic radiograph showing loss of right maxillary second premolar and pneumatization of the maxillary sinus. The residual alveolar bone was 3 mm. *B*, After elevation of the full-thickness flap, window design was drawn using sterilized pencil. *C*, Removal of the lateral sinus wall (wall-off technique). *D*, After bone graft and implant installation, lateral wall was repositioned to the original site. *E*, Panoramic radiograph 4 years after operation.

TABLE 5 Sinus Membrane Perforation and Implant Success

MP	No. of Sinus	Success	Failure	*p* Value
Yes	35	65	3	.7162
No	182	381	13	
Total	217	446	16	

Failure = failed implant; MP = membrane perforation; Success = successful implant.

98.5% and 95.6%, respectively, with an average follow-up of 57.1 ± 15.6 (36–98) months. The results were favorable compared with other reports despite the fact that the implants were placed immediately during sinus lift surgery irrespective of residual bone height using only Bio-Oss as the bone substitute.[19–21] These differences may be attributed due to implant design, surface treatment, and surgical skill.

Sinus lifting and implant placement are typically separated into two stages of surgery when residual alveolar bone height is less than 4 to 5 mm. However, these criteria were arbitrarily established when parallel

TABLE 6 Smoking and Implant Success

Smoking	No of Pt.	Success	Failure	*p* Value	NOI	Success	Failure	*p* Value
Yes	18	12	6	.0003	48	41	7	.0005
No	143	138	5		414	405	9	

NOI = number of implants; Pt = patients.

implant designs were the only available options. Studies demonstrated that marginal bone loss was not related to the amount of preoperative residual bone and that success rate was similar when primary stability was achieved.[9,19] In the present study, residual alveolar bone was divided into two groups according to Jensen's criteria of 4 mm and showed that residual alveolar bone had no effect on the survival and success rates of implants. The benefits for sinus lifting and simultaneous implant placement are the following: reduced number of surgeries, reduced treatment time, and lateral window access to the maxillary sinus during implant placement. Fixture designs (e.g., implant taper) can affect the initial stability of the implant.[22] Tapered implant designs increase the compression of bone and primary stability when placed into a conventional parallel osteotomy.[23] O'Sullivan and colleagues demonstrated that a 1° taper had more initial stability than parallel implants and a 2° taper could not be inserted completely in the same osteotomies. Because primary stability is important in achieving osseointegration,[2,19] selecting implants that maximize primary stability is essential when bone is limited in the maxillary sinus. In this study, tapered implants were used and had comparable success rates between residual bone heights of 1 to 4 and 5 to 8 mm.

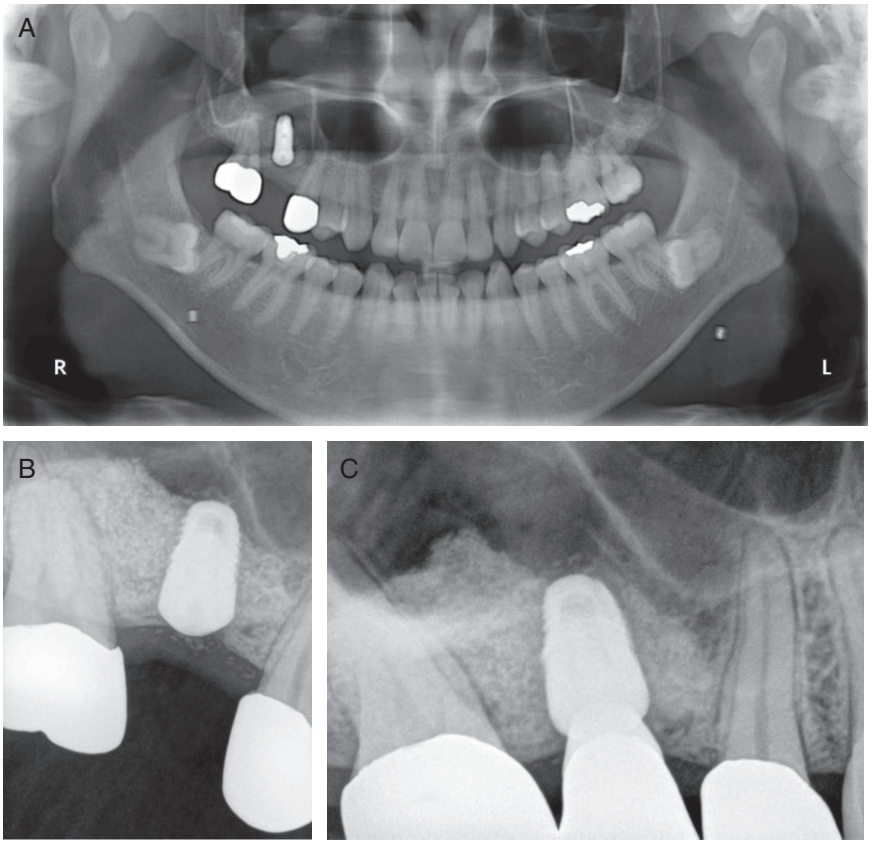

Figure 6 *A*, Sinus lifting and implant installation. Membrane was perforated during sinus lifting. Implant was removed after 1 month. *B*, Short implant was placed 3 months after healing. *C*, Definitive restoration after 3-year follow-up.

A variety of bone graft materials may be used for sinus augmentation including autogenous bone from intraoral and extraoral sites, no graft, mineralized or demineralized freeze-dried allogeneic bone, xenogenic bone, alloplastic (e.g., hydroxyapatite and tricalcium phosphate), growth factors, or combination of materials.[24–29] Hurzeler and colleagues[30] reported that there were no differences in implant survival rate with five different grafting materials. Maiorana and colleagues demonstrated that alloplasts and xenografts were reliable for bone regeneration in subantral cavities.[25] In the present study, xenograft alone was used to augment the maxillary sinus floor. The advantages of xenografts are the following: no additional surgical site for bone harvesting, reducing surgical time, and lower resorption rate.[31]

The most common intra-operative complication in sinus lifting is the perforation of the Schneiderian membrane that has an average occurrence of 19.5% (range 5–56%).[32–35] This investigation had a membrane perforation rate of 16.13%, which was comparable with other studies. Several authors have reported that membrane perforation was associated with an increased failure rate,[32] whereas other studies demonstrated that adequately repaired perforations have no effect on the survival of implants.[9] In the present study, membrane perforations were repaired with Bio-Gide and fibrin glue, and its occurrence did not have a significant adverse effect on implant survival and success. A modified Caldwell-Luc approach was used in this study. To prevent membrane exposure, a diamond bur was used when the window preparation was in close proximity to the Schneiderian membrane. After isolating the lateral bony window, it was temporarily removed (rather than infracturing into the sinus), which increased access and visibility for membrane dissection and insertion of sinus elevation instruments. After placement of graft materials, the sinus opening was covered with the lateral bony window[36] to function as a barrier membrane. Studies reported that placement of a membrane over the lateral window had higher implant survival rates than without a membrane.[13,37] Cho and colleagues suggested that the repositioned bony window is an adequate membrane after demonstrating healing of the window and regeneration in the gap with the lateral wall borders.[38]

Smoking has been associated with increased risk of implant failure.[39,40] In a prospective clinical investigation, Bain and Moy demonstrated an implant failure rate of 11.3% for smokers and 4.8% for nonsmokers. Dental implants placed in grafted maxillary sinuses are also associated with higher implant failures. Kan and colleagues demonstrated higher failure rates in smokers than in nonsmokers in a retrospective study, evaluating dental implants in grafted sinuses. The present study is in agreement with these findings and revealed an association of smoking with a higher failure rate (14.58% for smokers and 2.17% for nonsmokers) of implants placed immediately into grafted sinuses.

CONCLUSION

Sinus lifting with simultaneous implant placement can be used to treat the atrophic maxilla in patients irrespective of residual bone when careful surgical methods and taper designed implants are used. Immediate sinus lift with implant placement can reduce the number of surgeries and overall treatment time. Smoking is a possible factor for implant failure. Membrane perforation did not have an adverse effect on implant success if the membrane was properly repaired.

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