Healing in Smokers Versus Nonsmokers: Survival Rates for Sinus Floor Augmentation with Simultaneous Implant Placement

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Purpose: *Evidence suggests that smoking is detrimental to the survival of dental implants placed in grafted maxillary sinuses. Studies have shown that improving bone quantity and quality, using rough-surfaced implants, and practicing good oral hygiene may improve outcomes. In this prospective study, the long-term survival rates of implants placed simultaneously with sinus grafting in smokers and nonsmokers were compared.* ***Materials and Methods:*** *Implants with roughened surfaces were immediately placed into maxillary sinus grafts in patients with 1 to 7 mm of residual bone. A total of 2,132 simultaneous implants were placed into the grafted sinuses of 226 smokers (627 implants) and 505 nonsmokers (1,505 implants). A majority of the patients received a composite graft consisting of 50% autogenous bone. In both smokers and nonsmokers, approximately two thirds of the implants had microtextured surfaces; the remainder had hydroxyapatite-coated surfaces. The implants were restored and monitored during clinical follow-up for up to 9 years.* ***Results:*** *Cumulative survival of implants at 9 years was 97.9%. There were no statistically significant differences in implant failure rates between smokers and nonsmokers.* ***Discussion:*** *Implant survival was believed to depend on the following aspects of the technique used: creation of a large buccal window to allow access to a large recipient site; use of composite grafts consisting of at least 50% autogenous bone; meticulous bone condensation; placement of long implants (ie, 15 mm); use of implants with hydroxyapatite-coated or microtextured surfaces; use of a membrane to cover the graft and implants; antibiotic use and strict oral hygiene; use of interim implants and restricted use of dentures; and adherence to a smoking cessation protocol.* (Comparative Cohort Study) Int J Oral Maxillofac Implants 2006;21:551–559

Key words: *dental implants, sinus floor augmentation, smoking*

The adverse effects of smoking on oral wound healing were noted as early as 1970.[1] Since then, there have been several reports associating smoking with dental implant failure[2–11] and, more specifically, with the failure of implants placed in augmented sinuses.[12–15]

Studies have demonstrated significantly higher rates of implant failure in the maxilla in smokers than in nonsmokers, although smoking has no apparent effect on the survival of implants in the mandible.[3,5] De Bruyn and Collaert noted that failures in nonsmokers were generally associated with poor bone quality and suggested that improving bone quantity and quality might reduce the early failure rate (ie, before functional loading) of implants in smokers.[5] Wallace reported implant failure rates of 16.5% for smokers and 6.9% for nonsmokers and showed that using implants of longer-than-average length reduced the failure rate in smokers.[7] It has been suggested that implant failures in smokers are the result not of poor healing or lack of osseointegration, but of exposure of peri-implant tissues to tobacco smoke.[8]

Despite the many reports of the detrimental effects of smoking on implant survival, some studies have not supported these findings. A meta-analysis that evaluated the effects of smoking on implant failure concluded that there was no difference in implant survival rates between smokers and nonsmokers; rather, differences in survival rates were found to be attributable to implant type.[16] Similarly, Kumar and colleagues found that the use of surface-modified dental implants resulted in no significant difference in success rates for smokers and nonsmokers (97.0% versus 98.4%, respectively).[17]

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Table 1 Criteria for Patient Selection and Inclusion in Study

Exclusion criteria	Inclusion criteria
• Use of immunosuppressive medication • Presence of immunodeficiency disease • Use of postirradiation therapy • Presence of sinus pathology (eg, chronic or acute sinusitis, cysts, tumors)	• Posterior maxillary sinus floor bone deficiency (ie, 1 to 7 mm in height unilaterally) • Good periodontal health • Good general health; medical conditions controlled (physician approval required for participation) • Stable mental condition • Ability to complete at least 24 months of clinical follow-up • Willingness to provide signed informed consent

Evidence suggests that smoking is detrimental to the survival of implants in grafted maxillary sinuses. One study reported cumulative success rates of 82.7% and 65.3% in nonsmokers and smokers, respectively ($P = .027$).[18] Another study acknowledged an association between implant failure in the augmented maxillary sinus and smoking; however, interpretation of the findings was difficult because an assortment of augmentation materials was used, including autogenous, allogeneic, and alloplastic bone and combinations of these materials.[14] In another study, the use of autogenous rather than allogeneic bone for sinus augmentation was shown to result in a higher rate of implant success over a 3-year period.[19] Other investigators used deproteinized bone mineral to augment ridges and reported success rates of 100% for implants in nonsmokers and 43% for implants in smokers.[15] Kan and colleagues evaluated a number of factors in the success of implants in grafted maxillary sinuses and concluded that higher failure rates were attributable to a combination of smoking, use of nonthreaded implants, and poor oral hygiene.[13]

Approximately a third of the patients treated by the current authors are smokers. In light of the concerns surrounding smoking, wound healing, and bone grafting, the present article describes a surgical approach developed to improve the outcome of sinus floor augmentation with simultaneous implant placement.

MATERIALS AND METHODS

Patients and Smoking Behavior

The study sample included patients with severe atrophy of the posterior maxilla who underwent sinus floor augmentation with the simultaneous placement of implants and were followed up over a 9-year period. Criteria for patient selection are listed in Table 1. The study included both smokers and nonsmokers. A strict smoking cessation protocol was adopted to optimize the implant success rates. For 1 week prior to surgery, smokers were required to reduce cigarette consumption to 2 to 5 cigarettes per day. They were required to to stop smoking completely 1 day before surgery. After surgery, patients were instructed not to smoke for 10 days.

Graft Composition

Augmentation materials included:

- Autogenous bone alone
- A composite of 50% autogenous bone mixed with 50% bovine-derived xenograft (Bio-Oss; Geistlich Sohne, Wolhusen, Switzerland)
- A composite of 50% autogenous bone mixed with 50% demineralized freeze-dried bone allograft (DFDBA; particle size 500 to 1,000 μm) (Pacific Coast Tissue Bank, Los Angeles, CA)
- Synthetic bone cement alone (BoneSource; Pfizer Howmedica, Parsippany, NJ)

From 1993 to 1998, the autogenous bone used in the grafts was harvested from the following intraoral sites: the mandibular symphysis, maxillary tuberosity, lateral aspect of the mandible, and retromolar area. The bone was collected with a sterile bone trap and ground using a miniature bone mill (BioComp Mini Mill; BioMedical Composites, Ventura, CA). In the sinus augmentations where autogenous bone alone was used, the autogenous bone was harvested from the anterior or posterior iliac crest, since these cases required extra graft material for additional lateral or vertical ridge augmentation. From 1998 to 2003, the Mx-Grafter bone grafting system (Maxilon Laboratories, Hollis, NH) was used to harvest autogenous bone from the following intraoral sites: the anterior maxillary wall, the zygomaticomaxillary buttress, the maxillary tuberosity, and the lateral mandibular body and ramus.

Implants

All patients received implants that were 15 mm in length (Zimmer Dental, Carlsbad, CA). The diameter of the implants varied from 3.25 mm to 4.7 mm. The implants were either hydroxyapatite (HA) -coated cylindric implants (Spline HA cylinder MP-1) or titanium screw-type implants with microtextured surfaces created by blasting with HA particles.[20]

Surgical Techniques

Clavulanate-potentiated amoxicillin (1.5 g) was administered orally 30 minutes before surgery. Patients who were allergic to penicillin were given clindamycin (450 mg) instead. Clavulanate-potentiated amoxicillin 0.5 g 3 times per day or clindamycin 150 mg 4 times per day was continued for 10 days after surgery.

The sinus lift technique was performed using a modified Caldwell-Luc procedure.[21] A large buccal window was created in the lateral wall of the maxillary sinus. Care was taken not to penetrate the sinus membrane. The osteotomy at the inferior aspect of the window was made as close as possible to the level of the superior aspect of the residual alveolar bone. This procedure facilitates the delicate sinus membrane dissection and elevation. Sinus membrane ruptures were repaired using collagen membrane. When indicated, the large window allowed exposure and elevation of the sinus membrane from the sinus bony walls (the lateral wall of the nasal cavity, the maxillary tuberosity, and inferiorly to the floor and the posterior wall of the maxillary sinus) to form a large host site, which is crucial for bone graft consolidation.

Creating a large buccal window that provides access to the lateral wall of the nasal cavity offers another advantage. In clinical situations in which implants are to be placed in the canine and premolar regions and where the buccopalatal dimension is very narrow, implants cannot be placed at the appropriate degree of inclination (implants tend to incline toward the palate). In these cases, a large buccal window provides greater access and allows fracture of the lateral wall of the nasal cavity, which can be pushed inward to create space for the appropriate angulation of the implants.

Implant sites were marked using a surgical stent, and the osteotomies were performed according to the implant manufacturer's recommendation. The graft material was placed at the superior aspect of the sinus and against the medial aspect of the compartment created in the sinus cavity (the dissected sinus membrane). Meticulous condensation of the graft material was performed at each stage of bone placement. The implants were inserted to half their total length. Then, after further condensation of the graft, the implants were seated in their final positions.

After completion of the sinus floor augmentation and implant placement procedures, the buccal window was covered with a resorbable DFDBA barrier membrane (Lambone; Pacific Coast Tissue Bank). A resorbable membrane (BioMend Extend; Zimmer Dental) or freeze-dried dura mater (University of Miami Tissue Bank, Miami, FL) was placed over the graft in accordance with the principles of guided bone regeneration. No additional procedures were performed to stabilize the membranes. The mucoperiosteal flap was closed over the graft and implants using 3-0 Vicryl vertical interrupted mattress sutures (Johnson & Johnson/Ethicon, Somerville, NJ). After surgery, whenever the clinical or the patient situation permitted, patients who were fully edentulous were fitted with interim implants and provisional prostheses. Patients who wore dentures were instructed not to wear them for the first 2 weeks after surgery. For the 3 months after that, dentures were worn for esthetic purposes only, and no mastication was permitted. Patients were required to follow a soft diet. Dentures were relined periodically with a soft tissue conditioner.

Second-stage surgery to expose the implants was performed 6 to 9 months after implant placement. Prior to implant exposure, patients were evaluated radiographically. Panoramic and periapical radiographs and computerized tomography (CT) scans were used to assess the newly formed bone and its interface with the implants. The clinical evaluation included checking stability in all directions, crestal bone resorption, and any reported pain or discomfort. New bone formation was assessed at second-stage surgery by means of a crestal incision rather than a punch technique, which limits visualization of the implant cover screw. Patients were fitted with a fixed implant-supported prosthesis.

Statistical Analysis

Between-group differences were analyzed using chi-square tests.

RESULTS

Patient characteristics are summarized in Table 2. A total of 731 sinuses were included; 2,132 simultaneous implants were placed in the grafted maxillary sinuses of 226 smokers and 505 nonsmokers. A total of 627 implants were placed in smokers. The distribution of implant types in smokers and nonsmokers, including the distribution by residual maxillary bone height and graft type, is shown in Tables 3 to 5.

A composite graft consisting of 50% autogenous bone and 50% Bio-Oss was used in 391 (53.5%) patients, while 303 (41.4%) patients received a composite graft consisting of 50% autogenous bone and 50% DFDBA. Twenty-one (2.9%) patients received grafts of autogenous bone alone. Synthetic bone cement was used as the graft material in 16 (2.2%) patients.

In both the nonsmoking and smoking subgroups, approximately two thirds of implants had microtextured surfaces; the remainder had HA-coated surfaces (Tables 3a and 3b). There were no statistically significant differences between smokers and nonsmokers in the distribution of implants according to diameter. Compared with nonsmokers, smokers had a greater proportion of implants placed in 1 to 2 mm of residual bone (27.1% versus 17.6%) and a lower proportion of implants placed in > 5 mm of residual bone (23.8% versus 34.9%) ($P < .001$). The proportions of implants placed in 3 to 5 mm of residual bone were similar for smokers and nonsmokers (49.1% versus 47.5%, respectively).

Table 2 Patient Characteristics

Characteristic	No. of patients (%)
Sex	
Male	278 (38)
Female	453 (62)
Smoking behavior	
Smokers	226 (31)
Nonsmokers	505 (69)
Health risk factors	
Hypertension	103 (14.1)
Diabetes, type 1	16 (2.2)
Diabetes, type 2	52 (7.1)
Ischemic heart disease	65 (8.9)
Postmyocardial infarction	35 (4.8)

Mean age was 53 years; range, 42 to 81 years.

Mean follow-up was 69 months (range, 24 to 108 months) after second-stage surgery. All patients received a fixed implant-supported prosthesis. There was no clinical or radiographic evidence of sinus complications. CT scans obtained during the follow-up period showed further consolidation of the graft material when compared with the CT scans taken at the time of second-stage surgery.

Life table methods were used to calculate a cumulative implant survival rate of 97.9% over the period of the study (Table 6). A total of 15 implants in 6 sinuses failed to integrate prior to uncovering, and these were removed at second-stage surgery. These implants were successfully replaced with 5-mm-diameter implants at the time of their removal without any additional bone grafting. Another 18 implants were lost between second-stage surgery and the 1-year follow-up examination. A total of 11 implants were lost between 4 and 7 years of follow-up. The failure rate was slightly higher in smokers (16 of 627 or 2.6%) compared with nonsmokers (28 of 1,505 or 1.9%), although the difference was not statistically significant ($P = .392$) (Table 7). The leading cause of implant failure in both smokers and nonsmokers was infection. For the study population overall, a greater proportion of implants failed in 1 to 2 mm of residual bone (4.1%) than in 3 to 5 mm (1.5%) or > 5 mm (1.6%) of residual bone ($P = .003$). Since the smoking subgroup had a greater proportion of implants placed in 1 to 2 mm of residual bone, and bone quantity is known to correlate with implant survival,[5] reduced bone quantity may account for the slightly higher failure rate observed in smokers. There were no statistically significant differences between smokers and nonsmokers in the distribution of failures among HA-coated and microtextured implants for the 3 residual bone heights (Tables 7 and 8).

Table 3a Distribution of Implant Types Placed in Nonsmokers*

Characteristic	No. (%)
Surface type	
MTX	968 (64.3)
HA-coated	537 (35.7)
Length	
15 mm	1,505 (100)
Diameter	
3.25 mm	465 (30.9)
3.75 mm	617 (41.0)
4.0 mm	72 (4.8)
4.7 mm	351 (23.3)
Total no. of implants placed	1,505 (100)

HA = hydroxyapatite; MTX = microtextured.
*Comparisons between smokers and nonsmokers showed no statistically significant differences at the 5% level for surface type or diameter.

Table 3b Distribution of Implant Types Placed in Smokers*

Characteristic	No. (%)
Surface type	
MTX	406 (64.8)
HA-coated	221 (35.2)
Length	
15 mm	627 (100)
Diameter	
3.25 mm	188 (30.0)
3.75 mm	290 (46.2)
4.0 mm	33 (5.3)
4.7 mm	116 (18.5)
Total no. of implants placed	627 (100)

HA = hydroxyapatite; MTX = microtextured.
*Comparisons between smokers and nonsmokers showed no statistically significant differences at the 5% level for surface type or diameter.

Table 4a Distribution of Implant Type by Residual Maxillary Bone Height for Nonsmokers

Residual bone height/ diameter (mm)	Implants		No. placed
	Surface	Design	
1–2 mm			
3.25	HA	Cylinder	112
3.75	MTX	Screw	132
4.0	HA	Cylinder	21
3–5 mm			
3.25	HA	Cylinder	209
3.75	MTX	Screw	293
4.0	HA	Cylinder	23
4.7	MTX	Screw	190
> 5 mm			
3.25	HA	Cylinder	144
3.75	MTX	Screw	192
4.0	HA	Cylinder	28
4.7	MTX	Screw	161

HA = hydroxyapatite; MTX = microtextured.

Table 5a Distribution of Implant Type by Residual Maxillary Bone Height for Smokers

Residual bone height/ diameter (mm)	Implants		No. placed
	Surface	Design	
1–2 mm			
3.25	HA	Cylinder	65
3.75	MTX	Screw	92
4.0	HA	Cylinder	13
3–5 mm			
3.25	HA	Cylinder	85
3.75	MTX	Screw	136
4.0	HA	Cylinder	9
4.7	MTX	Screw	78
> 5 mm			
3.25	HA	Cylinder	38
3.75	MTX	Screw	62
4.0	HA	Cylinder	11
4.7	MTX	Screw	38

HA = hydroxyapatite; MTX = microtextured.

Table 4b Distribution of Implant Type by Graft Type for Nonsmokers

Type	Grafts		Sinuses grafted	Implants placed
	Material	Source		
Individual	Autograft	Iliac crest	14	42
Composite	Autograft + xenograft	Oral + bovine	42	126
Composite	Allograft + autograft	Cadaver + oral	32	97
Composite	Autograft + xenograft	Oral + bovine	138	402
Individual	Bone cement	Synthetic	11	33
Composite	Allograft + autograft	Cadaver + oral	95	280
Composite	Autograft + xenograft	Oral + bovine	80	246
Composite	Allograft + autograft	Cadaver + oral	93	279

Table 5b Distribution of Implant Type by Graft Type for Smokers

Type	Grafts		Sinuses grafted	Implants placed
	Material	Source		
Individual	Autograft	Iliac crest	7	21
Composite	Autograft + xenograft	Oral + bovine	37*	103*
Composite	Allograft + autograft	Cadaver + oral	17	46
Composite	Autograft + xenograft	Oral + bovine	63	176
Individual	Bone cement	Synthetic	5	15
Composite	Allograft + autograft	Cadaver + oral	42	117
Composite	Autograft + xenograft	Oral + bovine	31	84
Composite	Allograft + autograft	Cadaver + oral	24*	65*

*Significant differences between smokers and nonsmokers ($P < .001$).

Table 6 Life Table Analysis of All Implants Placed in Maxillary Sinus Grafts

Time interval (y)	Sinuses	Implants	No. lost	ISR (%)	CSR (%)
		Implants			
0*	731	2,132	15	99.3	99.3
0 to 1†	725	2,117	18	99.1	98.4
1 to 2	722	2,099	0	100	98.4
2 to 3	722	2,099	0	100	98.4
3 to 4	722	2,099	0	100	98.4
4 to 5	722	2,099	6	99.7	98.1
5 to 6	720	2,093	3	99.9	98.0
6 to 7	718	2,090	2	99.9	97.9
7 to 8	718	2,088	0	100	97.9
8 to 9	718	2,088	0	100	97.9

*Placement to second-stage surgery.
†Second-stage surgery to 1 year.
ISR = interval survival rate; CSR = cumulative survival rate.

Table 7 No. of Implant Failures and Reasons for Failure Distributed by Residual Bone Height

Residual bone height/ implant surface	Time of failure	Reason for failure	No. of failures in nonsmokers	No. of failures in smokers
1–2 mm				
HA	BL	Infection, bone loss	1	5
HA	BL	Failure to integrate, bone loss	0	2
MTX	BL	Failure to integrate	2	0
HA	LF	Bone loss	8	0
3–5 mm				
HA	BL	Infection	0	5
MTX	FYL	Infection	7	0
HA	LF	Bone resorption	3	0
> 5 mm				
HA	FYL	Infection	6	3
MTX	BL	Failure to integrate	1	1

BL = before loading; LF = late failure, ie, failure after 4 to 7 years of functioning; FYL = first year of loading.

Table 8 No. of Implant Failures Distributed by Residual Bone Height for Nonsmokers and Smokers

Residual bone height/ implant surface	No. of implants placed		No. of implants failing	
	Nonsmokers	Smokers	Nonsmokers	Smokers
1–2 mm				
HA	133	78	9 (6.8)	7 (9.0)
MTX	132	92	2 (1.5)	0
3–5 mm				
HA	232	94	3 (1.3)	5 (5.3)
MTX	483	214	7 (1.4)	0
> 5 mm				
HA	172	49	6 (3.5)	3 (6.1)
MTX	353	100	1 (0.3)	1 (1.0)

DISCUSSION

There have been many reports of slower wound healing and higher failure rates for dental implants in smokers compared with nonsmokers, including compromised healing in sinus lift procedures with simultaneously placed implants. Tobacco smoke contains several noxious substances, including nicotine, carbon monoxide, and hydrogen cyanide.[18,22] Nicotine has a number of toxic effects on peripheral circulation and the immune response. It reduces the proliferation of red blood cells, fibroblasts, and macrophages, increases platelet adhesiveness and the risk of microclots, reduces microperfusion, and causes cutaneous vasoconstriction. Nicotine promotes epinephrine and norepinephrine release, resulting in vasoconstriction and decreased tissue perfusion. Carbon monoxide reduces the oxygen-carrying capacity of the blood, and hydrogen cyanide inhibits the enzyme systems necessary for oxidative metabolism. Ischemia is an important pathophysiologic factor in impaired wound healing.

In patients who smoke, higher implant failure rates have been reported for those with high cigarette consumption.[10,23–25] In a prospective study of mandibular implant-supported prostheses, higher implant failure was reported for heavy smokers (30 to 40 cigarettes per day) with type 4 bone.[23] Lindquist and colleagues noted significantly greater marginal bone loss around implants in heavy smokers (> 14 cigarettes per day) than in those with lower cigarette consumption.[24] In a study of 76 implants placed in grafted maxillary sinuses, evaluation at 5 years revealed complications in 2 patients (4 sinuses) who were heavy smokers.[26] Despite the complications, no implants were lost; after administration of antibiotics, symptoms subsided and the implants integrated. More recently, Kan and coworkers retro-

spectively evaluated 228 implants in 84 grafted maxillary sinuses.[18] Although smoking was found to be detrimental to implant success, no correlation was found between implant failure rate and the amount of cigarette consumption.

However, clinical findings often suggest that smoking is only 1 of several factors contributing to slower healing and implant failure.[5,13] No previous study has comprehensively examined the effects of smoking on the survival rate of a large number of implants simultaneously placed with grafting of the maxillary sinus.

The present study has demonstrated a high survival rate for implants placed simultaneously with grafting of the maxillary sinus. No statistically significant differences were found in failure rates between smokers and nonsmokers. These findings may be attributed to the protocol that was followed, which included the following technical guidelines: creation of a large buccal window to allow access to a large recipient site; use of composite grafts consisting of at least 50% autogenous bone; meticulous bone condensation; placement of long implants (15 mm in length); use of implants with HA-coated or microtextured surfaces; use of a membrane to cover the graft and implants; antibiotic use and strict oral hygiene; use of interim implants and restricted use of dentures; and adherence to a smoking cessation protocol. The failure rate was slightly higher in smokers compared with nonsmokers (2.6% versus 1.9%, respectively), which was probably due to the greater proportion of implants placed in 1 to 2 mm of residual bone in the smoking subgroup. The surgical approach that was used appears to counteract the problems observed in other studies associated with the survival of implants placed in sinus floor augmentations in smokers. The large window allows the exposure and predictable elevation of the sinus membrane from the sinus bony walls (the lateral wall of the nasal cavity, the maxillary tuberosity, and inferiorly to the floor and the posterior wall of the maxillary sinus), forming a large host site. The proliferative capacity and health of the host site play crucial roles in early revascularization and maturation of the graft. In general, regeneration of a defect becomes more predictable with more surrounding host bone.

The relationship between bone quality and implant failure is well established. Autogenous bone is the preferred graft material, and the 2-phase theory of osteogenesis during healing has been described.[27–29] Composite bone grafts consisting of 50% autogenous bone and either 50% Bio-Oss or 50% DFDBA promote predictable bone formation without the need for harvesting significant amounts of bone. Allogeneic grafts and xenografts act solely as a scaffold for osteoinduction. The use of at least 50% autogenous bone and the large volume of host bone made available as a result of the surgical approach promoted a more predictable second phase of bone formation within this scaffold as the graft was gradually replaced.

Another advantage of the approach followed in this study is the use of long implants. Other investigators have previously noted the importance of using longer-than-average implants with respect to implant survival.[7] The surface of the implants also appears to be a critical factor for achieving osseointegration in patients who smoke.[16,17] According to Kasemo and Lausmaa, roughened implant surfaces with micropits measuring less than about 100 μm but well above the nanometer scale (ie, 1/1,000 μm) may influence the biologic response at the bone-implant interface, since the micropits are within the size range of cells and large biomolecules.[30] In contrast, micropits measuring approximately 100 μm and larger may serve the strictly mechanical function of aiding in stress transfer. While the regular, horizontal grooves found in machined titanium surfaces have been observed to influence the pattern of cellular attachment at the microscopic level,[31] roughened implant surfaces have been reported to actually increase the attachment of osteoblasts compared to machined surfaces.[32,33] Kasten and associates reported that gingival cells also attached to roughened titanium surfaces 3 times more frequently than to smoother surfaces.[34] It has been hypothesized that increasing the surface roughness of implants would increase calcium and phosphorus deposition after immersion in a simulated physiologic solution and increase protein production and calcium uptake by osteoblast-like cells.[35] Numerous other histomorphometric and biomechanical tests, animal studies, human clinical trials, and in vitro experiments have demonstrated that implants with roughened surfaces achieve greater bone-to-implant apposition and interfacial strength than implants with conventional machined surfaces.[36–40]

In the surgical approach described here, initial axial and lateral implant stability were ensured by meticulous condensation of the particulate bone graft around the implants, thus optimizing direct bone-to-implant contact and increasing cellular density. The greater the cellular density of the transplanted osteocompetent cells, the greater the potential for new bone formation.[41] Meticulous condensation will eventually lead to the formation of type 2 or 3 bone rather than the type 4 bone that is normally found in the posterior maxilla. Increasing bone quantity and quality may reduce the failure rate of early implants in smokers.[5] The placement of a membrane barrier over

the buccal window will exclude proliferation of epithelial cells and fibroblasts and favor the proliferation of bone cells. In a relatively long healing period of 6 to 8 months, this guided bone regeneration concept is essential.

A number of reports of dental implant procedures have highlighted the value of maintaining strict oral hygiene, particularly in smokers,[13,24,25] and of using antibiotics perioperatively.[8,10] Sinus floor augmentation and implant placement procedures increase the risk of introducing pathogenic bacteria into the sinus and nose, and the prophylactic use of antibiotics reduces the risk of infection.[42] The use of high-dose antibiotics preoperatively not only reduces the incidence of postoperative infection[43] but also significantly reduces implant failure rates during second-stage surgery.[42]

The use of interim implants and the restriction of denture wearing to avoid pressure on the soft tissues during the first 3 months following surgery were additional precautions to optimize conditions for implant survival. A stress-free environment may be important, because movement of as little as 10 to 20 μm during the early stages of wound healing can be enough to direct differentiation of mesenchymal cells into fibroblasts instead of osteoblasts.[44]

The benefits of smoking cessation protocols on surgical outcomes have been reported previously. Miller reported similar success rates for nonsmokers and smokers who stopped smoking immediately prior to and for 2 weeks following periodontal surgery.[45] Because of the increased risk of skin slough in patients undergoing plastic surgery who continued to smoke postoperatively, Riefkohl and coworkers advised patients to stop smoking 1 day before and for 5 days after surgery.[46] In a prospective study of implant surgery, Bain described a smoking cessation protocol in which patients stopped smoking 1 week before and for 8 weeks after implant surgery.[47] Significantly lower implant failure rates were observed in smokers who followed this protocol (11.8%) than in those who did not (38.5%).

The benefits of a nicotine-free period around the time of surgery have been supported by the results of several animal studies. A study in rats has shown that smoking appears to have more adverse effects on cancellous bone than it does on cortical bone.[48] In a rabbit model of bone graft revascularization, it was shown that inhalation of nicotine decreased vascular ingrowths into autogenous cancellous bone grafts.[49] In the latter study, some animals exposed to nicotine showed this effect while others did not; predisposition may play a role. In those animals that showed decreased vascular ingrowths, the vascular effects were reversible within 2 weeks of elimination of nicotine.

In conclusion, the adverse effects of smoking on implant success are well recognized. There is no consensus in the literature regarding the most effective cessation protocol. The protocol used for this study was based on the literature,[45] is very practical, and allows the patients to accept and comply with the protocol easily. The present study suggests that smokers who abstain from smoking prior to surgery and for 10 days afterward can avoid the complications that are frequently observed in smokers.

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