Bone Reformation with Sinus Membrane Elevation: A New Surgical Technique for Maxillary Sinus Floor Augmentation

Stefan Lundgren, DDS, PhD;* Sten Andersson, DDS;* Federico Gualini, DDS, PhD;†
Lars Sennerby, DDS, PhD*‡

ABSTRACT

Background: Various maxillary sinus floor augmentation techniques using bone grafts and bone substitutes are frequently used to enable placement of dental implants in the posterior maxilla. A previous case report demonstrated the possibility of promoting bone formation in the sinus by lifting the membrane without using a grafting material. However, the predictability of the technique is not known.

Purpose: The aim of this study was to investigate whether sinus membrane elevation and the simultaneous insertion of titanium implants without additional grafting material constitute a valid technique for bone augmentation of the maxillary sinus floor.

Materials and Methods: The study group comprised 10 patients in whom a total of 12 maxillary sinus floor augmentations were performed. A replaceable bone window was prepared in the lateral sinus wall with a reciprocating saw. The sinus membrane was dissected, elevated superiorly, and sutured to the sinus wall to create and maintain a compartment for blood clot formation. One to three dental implants were inserted through the residual bone and protruded at least 5 mm into the maxillary sinus. The bone window was replaced and secured with the overlying mucosa. Bone height was measured directly at each implant site at the time of insertion. Resonance frequency analysis (RFA) was performed on each implant at the time of initial placement, at abutment surgery, and after 12 months of functional loading. Computed tomography (CT) was performed in the immediate postoperative period and 6 months later, prior to exposure of the implants.

Results: A total of 19 implants (Brånemark System®, TiUnite™, Nobel Biocare AB, Gothenburg, Sweden) in lengths of 10 to 15 mm were placed, with an average residual bone height of 7 mm (range, 4–10 mm). All implants remained clinically stable during the study period. Comparisons of pre- and postoperative CT radiography clearly demonstrated new bone formation within the compartment created by the sinus membrane elevation procedure. RFA measurements showed mean implant stability quotient values of 65, 66, and 64 at placement, at abutment connection, and after 12 months of loading, respectively.

Conclusions: The study showed that there is great potential for healing and bone formation in the maxillary sinus without the use of additional bone grafts or bone substitutes. The secluded compartment created by the elevated sinus membrane, implants, and replaceable bone window allowed bone formation according to the principle of guided tissue regeneration. The precise mechanisms are not known, and further histologic studies are needed. Sinus membrane elevation without the use of additional graft material was found to be a predictable technique for bone augmentation of the maxillary sinus floor.

KEY WORDS: augmentation, bone formation, bone reformation, implants, maxillary sinus

*Department of Oral and Maxillofacial Surgery, Umeå University, Umeå, Sweden; †private practice, Bergamo, Italy; ‡Department of Biomaterials, Gothenburg University, Gothenburg, Sweden

Reprint requests: Stefan Lundgren, Department of Oral and Maxillofacial Surgery, Umeå University, SE- 90187 Umeå, Sweden; e-mail: stefan.lundgren@odont.umu.se

©2004 BC Decker Inc

Endosseous implants are frequently used for prosthetic reconstruction in the edentulous patient. Sufficient volume and density of the alveolar bone for implant integration and load bearing are prerequisites for good results. Bone resorption following the extraction of posterior maxillary teeth sometimes results in severe loss of bone in vertical and/or horizontal dimen-

sions, which may preclude the use of dental implants. Various grafting procedures to reestablish an adequate bone volume to enable the placement of endosseous implants in the posterior maxilla have been described. The most commonly used technique is augmentation of the maxillary sinus floor, a technique introduced by Tatum[1] and modified by Boyne and James[2] and by Wood and Moore.[3] With this technique the maxillary sinus is accessed by creating a bone window in the lateral sinus wall with a small round bur, with the aim of leaving the sinus membrane intact. The sinus membrane is then carefully elevated and the bone window is rotated medially. Several studies have evaluated maxillary sinus elevation surgery using a variety of bone grafting materials (autogenous bone grafts from the iliac crest,[4] mandibular chin,[5] mandibular ramus,[6] or calvarium,[7] as well as bone substitutes alone[8] or in combination with autogenous bone[9]).

An alternative technique for increasing the available bone volume in the posterior maxilla was described by Summers.[10] With this technique access to the maxillary sinus floor was obtained through the alveolar ridge. A variety of osteotomes were used to form and shape a socket. The sinus membrane was then pushed up, and a bone graft was placed prior to the immediate insertion of the titanium implant.

Even if new bone will be obtained after placement of bone grafts in the maxillary sinus, such placement might not be a prerequisite for bone formation per se. The mere lifting of the sinus membrane, creation of a void space, and blood clot formation may result in new bone owing to the principles of guided tissue regeneration.[11] This was indicated in an earlier study.[12] Spontaneous bone reformation in the floor of the maxillary sinus has also been found 3 months after the removal of an intrasinusal cyst.[13]

The aim of the present study was to investigate the clinical and radiologic results of a new surgical technique by which endosseous implants are inserted in a void space created by elevating the sinus membrane without adding any graft material.

MATERIALS AND METHODS

Patients

Eleven subjects (9 women and 2 men, with a mean age of 51 years) who were recruited from a group of patients referred to the Department of Oral and Maxillofacial Surgery of Umeå University for maxillary sinus floor grafting to enable dental implant treatment and who met the inclusion criteria and consented to the research protocol were included in the study. Three patients were subjected to bilateral sinus surgery, and 8 patients underwent unilateral sinus surgery. The presurgical evaluation included clinical examination and radiographic analysis of the edentulous posterior maxilla with conventional or computed tomography (CT).

Inclusion criteria were as follows:

- Need of implant treatment in the posterior maxilla
- Residual bone height of ≤ 7 mm and marginal bone width of at least 4 mm in estimated implant positions
- Healthy sinuses as judged from radiographic and clinical examinations

Exclusion criteria were as follows:

- Maxillary sinus pathology
- Achievement of adequate primary stability of the implant in the residual bone not possible
- Creation of a closed compartment not possible (ie, impossible to repair or close extensive sinus membrane perforation by lifting the sinus membrane)
- Replacement of the bone window not possible

Maxillary Sinus Membrane Elevation and Implant Placement

The surgical procedure was performed with the patient under local anesthesia and conscious sedation. With a midcrestal incision and vertical releasing incisions, a mucoperiosteal flap was elevated to expose the sinus wall. The extension of a bone window was marked with a small round bur, and the window was cut with a reciprocating microsaw (Aesculap®, B. Braun Melsungen AG, Melsungen, Germany) (Figure 1). The saw was tilted to make a tapered osteotomy to ensure the stability of the window when the window was replaced after surgery (Figure 2). The bone flap was dissected free from the sinus membrane with a dissector and kept in saline (Figure 3). The sinus membrane was dissected to create a secluded compartment for the implants (Figures 4 and 5). If the dissected membrane moved during the patient's respiration or if the membrane fell down into the area where the implants were to be inserted, two holes were made in the sinus wall above the window. The sinus membrane was then sutured to the holes in a superior

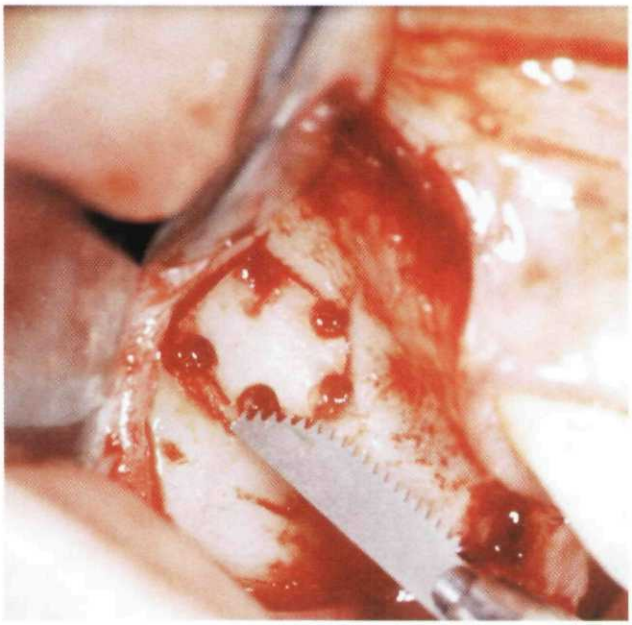


Figure 1 Bone window created in the lateral wall of the maxillary sinus.

position to prevent the membrane from falling down onto the implants (Figure 6). The same procedure was done when the membrane was perforated during dissection (Figure 7). The membrane was elevated by the suture, and the perforation was closed (Figure 8).

A periosteal elevator was inserted into the prepared cavity to protect the elevated membrane during the insertion of the implants (see Figure 4). The implant positions were marked with a guide bur, and the holes

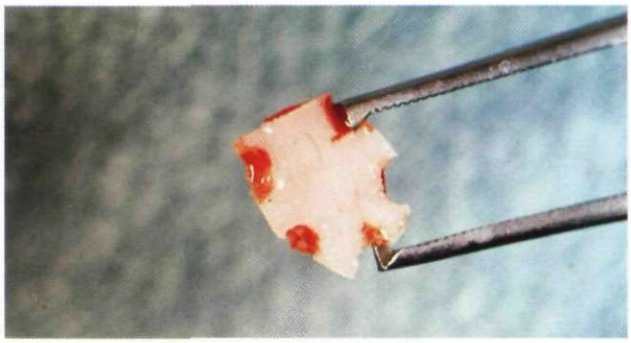


Figure 3 The removed bone window.

for the implants were prepared with a 2 mm twist drill. A 3 mm pilot drill was used just to remove the cortical 2 to 3 mm to facilitate the entry of a 2.85 mm twist drill, the final drill used. In the case of dense bone, a short countersink drill was used in the marginal 2 to 3 mm. If the bone had a low density, no countersinking was done. In the case of extremely soft bone, the implants were placed after preparation with the 2 mm twist drill.

A total of 19 Brånemark System® implants (Ti-Unite™, Mk III, Nobel Biocare AB, Gothenburg, Sweden) were placed. All implants were 3.75 mm in diameter and 10 to 15 mm in length. All implants protruded a minimum of 5 mm into the sinus cavity (Figure 9). After insertion of the implants, the periosteal elevator was removed and the position of the elevated sinus membrane was controlled. The bone window was then replaced and secured by closure of the oral mucosal flap

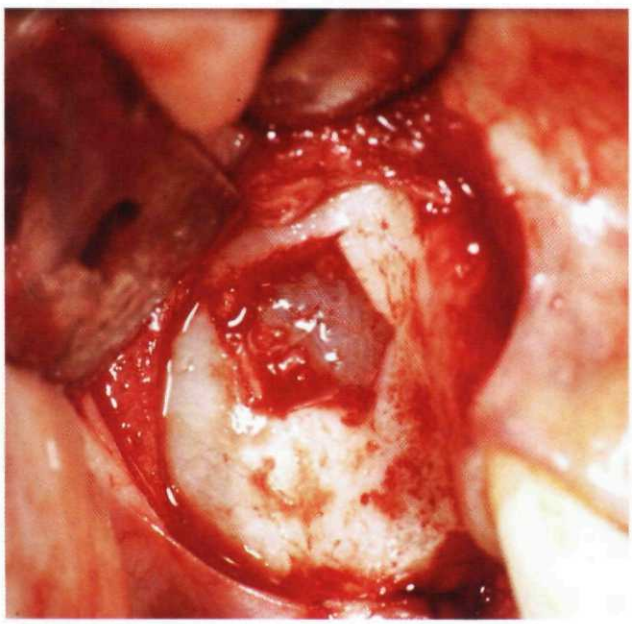


Figure 2 The intact sinus membrane after removal of the bone window.

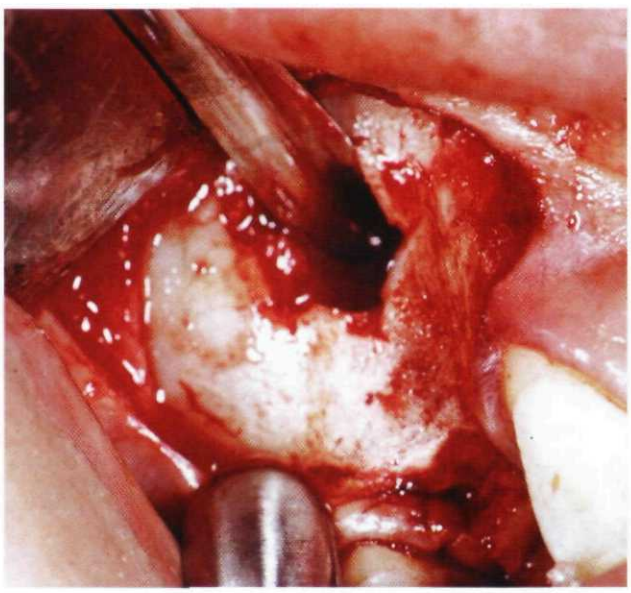


Figure 4 The sinus membrane is dissected free from the bone walls, creating a space. A periosteal elevator is placed to protect the sinus membrane during the placement of implants.

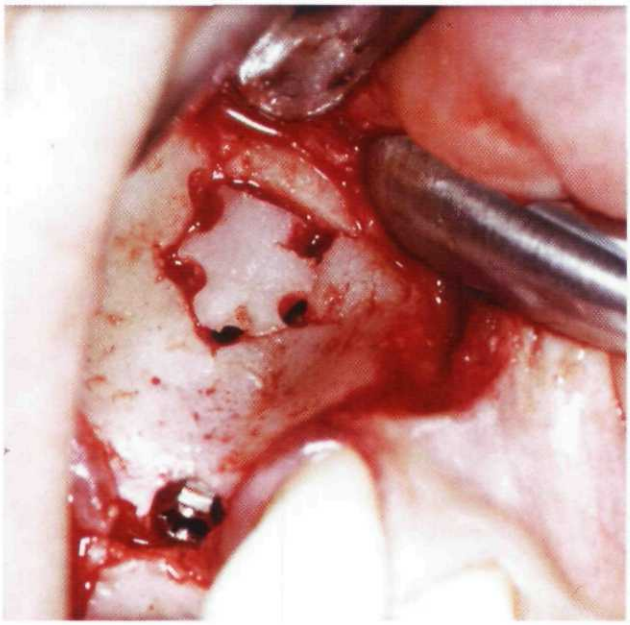


Figure 5 The removed bone window is replaced, closing the created compartment.

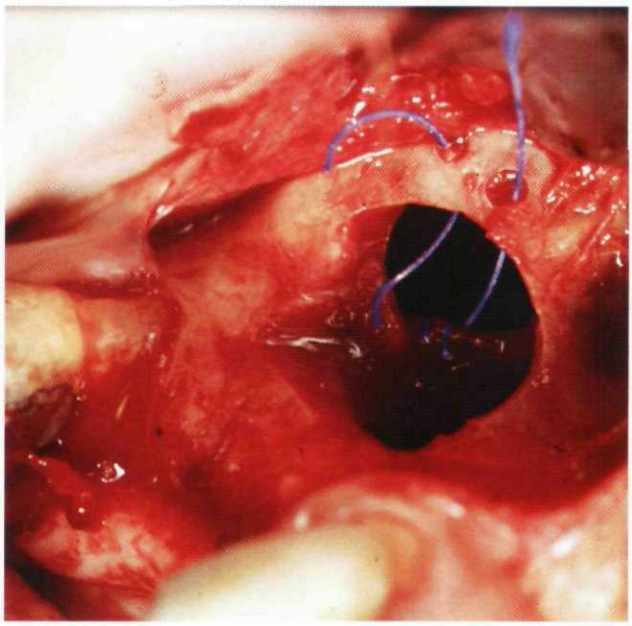


Figure 7 Perforation of the sinus membrane. Two holes are drilled in the sinus wall above the window, and a suture is inserted through one of the holes and attached to the sinus membrane. The suture needle is inserted through the other hole in a reversed way.

(Figure 10). The patients were given an antibiotic (penicillin V, 1 g three times a day for 7 days) and were advised to avoid sneezing and to use a nasal spray for 1 week.

Radiographic Follow-Up

Axial maxillary CT was performed to check the position of the bone window and coagulum formation 2 weeks after surgery (Figure 11A). Six months later, prior to abutment surgery, the CT investigation was repeated. Intraoral periapical radiography was performed after placement of the final abutments and after 12 months of loading.

Abutment Connection and Prosthetics

Abutment connection surgery was performed after 6 months of healing. The implants were exposed via

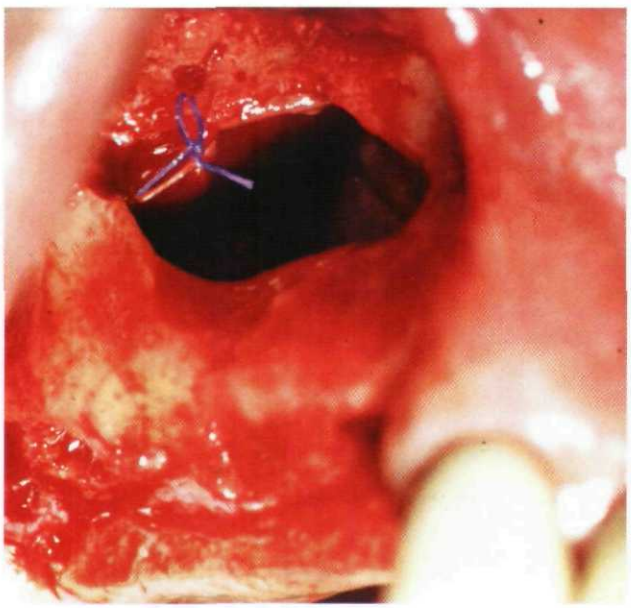


Figure 6 The sinus membrane is kept in place by a suture connected to the lateral sinus wall above the window.

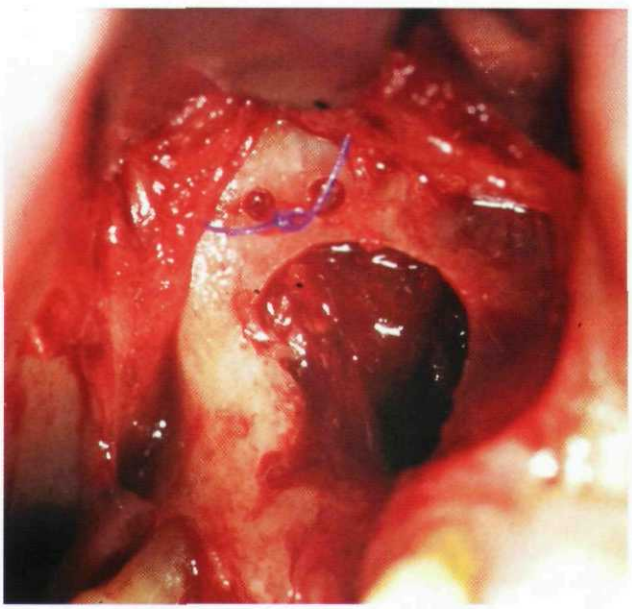


Figure 8 The sinus membrane perforation is closed by elevation of the membrane and is secured with the suture knot.

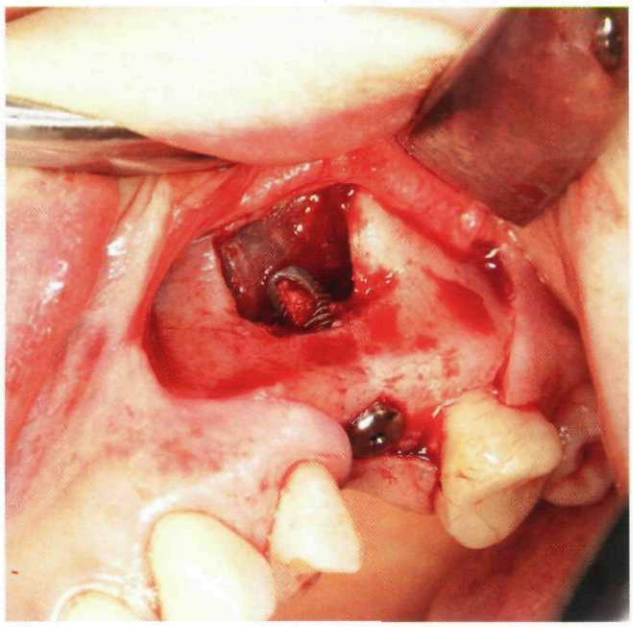


Figure 9 The inserted implant (TiUnite) protruding into the prepared compartment separated from the sinus cavity by the intact sinus membrane.

crestal incisions, and healing abutments (Nobel Biocare AB) were connected. After approximately 2 weeks, the healing abutments were replaced with CeraOne® abutments (Nobel Biocare AB) for single-tooth replacements and with Multi-Unit® abutments (Nobel Biocare AB) for bridges. Following routine prosthetic procedures eight single-tooth replacements and four bridges were connected to the implants within 3 to 5 weeks. All

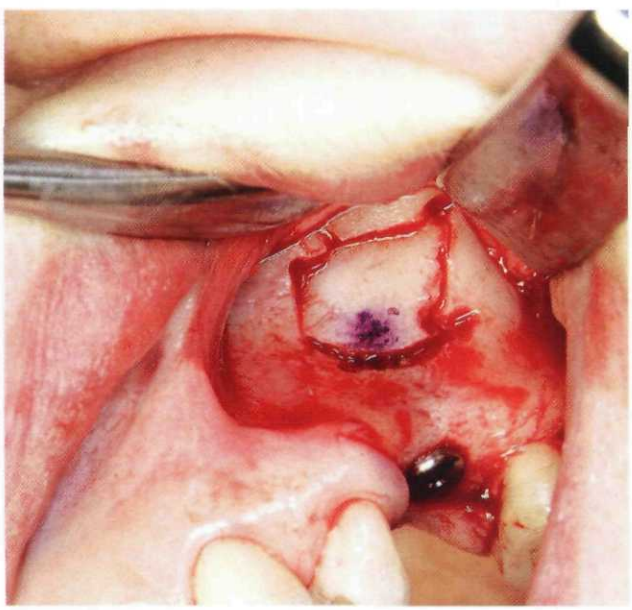


Figure 10 The compartment is closed by the replaced bone window, which is kept in place by the sutured oral mucosal flap.

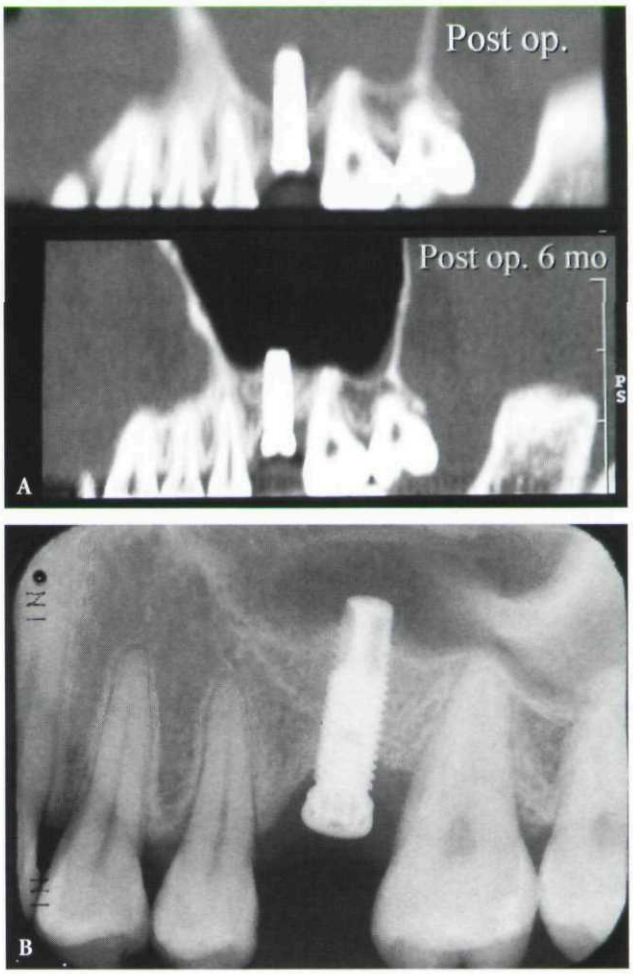


Figure 11 *A*, Top shows postoperative computed tomography (CT) scan taken 2 weeks after surgery, at removal of sutures. Bottom shows corresponding CT scan taken 6 months after surgery. *B*, Corresponding intraoral radiograph taken 6 months after surgery.

constructions were screw retained. The access holes were closed with composite fillings.

Resonance Frequency Analysis

Implant stability measurements were made after placement, at abutment connection, and after 12 months of healing, with the aid of resonance frequency analysis (Osstell™ instrument, Integration Diagnostics AB, Gothenburg, Sweden). On these occasions a transducer was attached to each implant, and measurements were recorded in implant stability quotient (ISQ) units.

RESULTS

One patient subjected to unilateral surgery was excluded because of insufficient density of the residual bone and the possibility of reaching primary stability for the planned implants. For another patient a bilateral

sinus elevation procedure had been planned. On one side surgery was uneventful, but on the other side primary implant stability could not be achieved owing to soft bone; this side was excluded from the study.

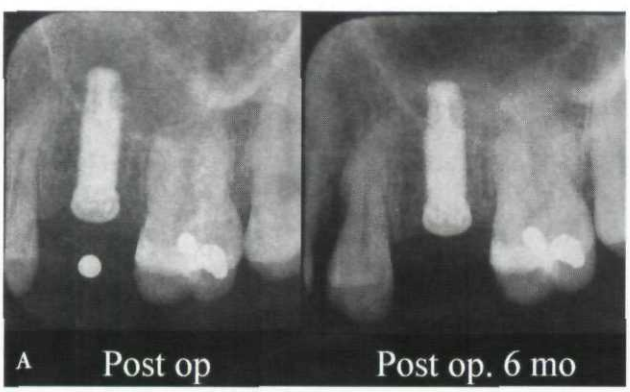
All remaining 10 patients and 12 treated sinuses could be observed throughout the study period. All 19 implants remained stable. In all 10 patients radiographic evidence of ossification of the coagulum in the elevated sinus area was seen (Figures 12–14; see also Figure 11B). At the 12-months postloading follow-up examination, radiographic and clinical investigations and resonance frequency analysis (RFA) showed a status quo situation (Table 1).

DISCUSSION

The present study of 10 consecutive patients showed radiographic evidence of bone formation in all maxillary sinuses after sinus membrane elevation and placement of dental implants. CT performed 2 weeks after surgery revealed that a blood clot had formed around the implants and occupied a large part of the maxillary sinus. Follow-up examinations after 6 to 12 months showed ossification and shrinkage of the blood clot, which formed a new sinus floor. As measured with RFA all 19 implants remained stable during the study period.

The exact mechanisms behind the bone formation observed in the maxillary sinus are presently not well understood. The general knowledge about bone healing has mainly been gained from studies of fracture healing and regeneration of bone defects. The maxillary sinus situation is unique in this respect since bone ought to be formed beyond the skeletal contour and not in a fracture or defect. Irrespective of situation, bone formation and healing require the recruitment, migration, and differentiation of osteogenic cells into osteoblasts, a process that starts to synthesize and deposit a collagenous extracellular matrix for mineralization. Bone marrow tissue constitutes the most potent source of such cells,[14] and it is likely that mesenchymal stem cells migrated from the bone marrow in the underlying alveolar bone and possibly from tissue fragments displaced during surgery into the blood-filled sinus, using the fibrin network as a scaffold. The lifting of the periosteum may have initiated a resorption process, exposure of the bone marrow, and access of stem cells to the sinus cavity, which have been observed in experimental studies.[15,16] Another theoretical source of bone-forming cells is the periosteum of the lifted sinus membrane, which may have contributed to bone formation. Finally, it is possible that circulating cells arrested in the blood clot played a role in the observed bone formation. Experimental studies using histology are obviously needed to better understand the bone formation mechanisms in maxillary sinus membrane elevation.

Care was taken to ensure high primary implant stability. This was achieved by using a thinner final drill (2.85 mm) than that usually used (3.00 mm) for Brånemark System regular-platform implants. RFA measurements confirmed that sufficient primary stability had been reached in all patients. One patient in whom it was not possible to achieve good primary stability was excluded from the study. The titanium implants used in the study had been subjected to anodic oxidation, which results in the growth of the native titanium oxide layer and the formation of a porous surface structure. Previous studies have shown that this surface facilitates



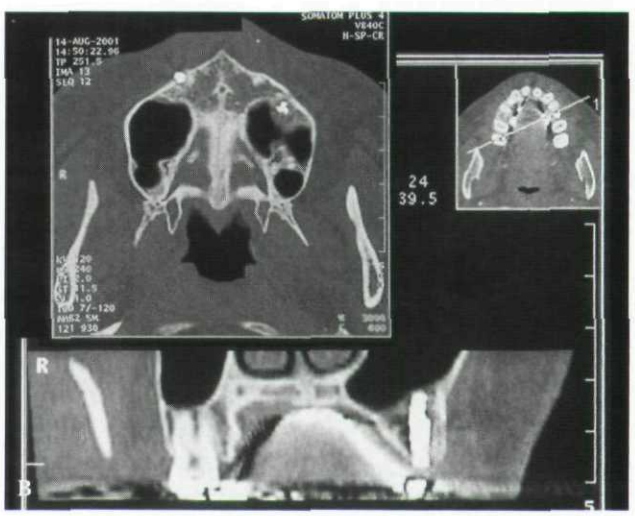


Figure 12 *A*, Intraoral radiographs: direct postoperative radiograph and corresponding radiograph after 6 months of healing. *B*, Slides of computed tomography scans from the same patient as in *A*.

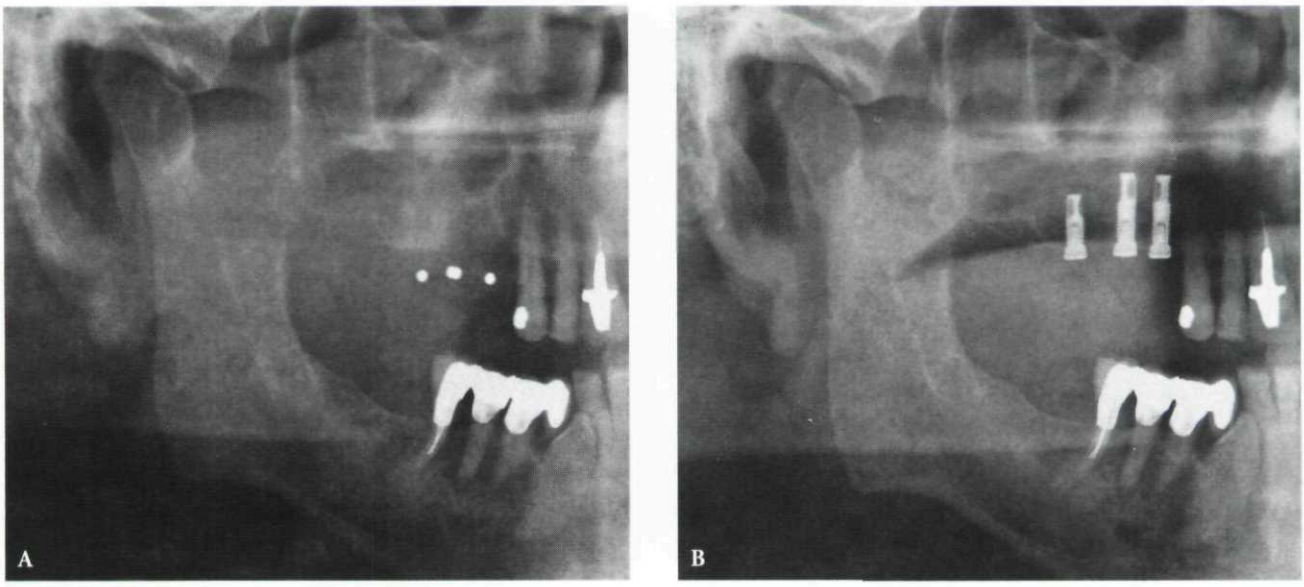


Figure 13 *A,* Preoperative panoramic radiograph. *B,* Radiograph made after placement of three implants at the same time as the sinus elevation procedure.

implant integration since bone-to-implant contacts are formed more quickly and to a higher extent with implants with this surface than with machined-surfaced implants.[17,18] Bone formation has been reported to occur directly on the oxidized surface, something that generally is not seen with machined implants.[19] This has been described as *contact osteogenesis,* in contrast to *distance osteogenesis,* in which bone is formed from the surrounding tissues toward the implant surface. It is believed that the difference is due to the surface's ability to form a stable connection with the blood clot fibrin network, which facilitates the migration of osteogenic cells to the implant surface.[20] It is not known if bone contacts were established at the implant surfaces protruding into the maxillary sinus, but it is possible that the use of surface-modified implants contributed to the successful outcome of this study.

One factor contributing to the successful outcome of the membrane elevation procedure was probably the use of a technique with a replaced bone window. This was made technically possible by using a reciprocating saw with a thin blade. The extension of the window was

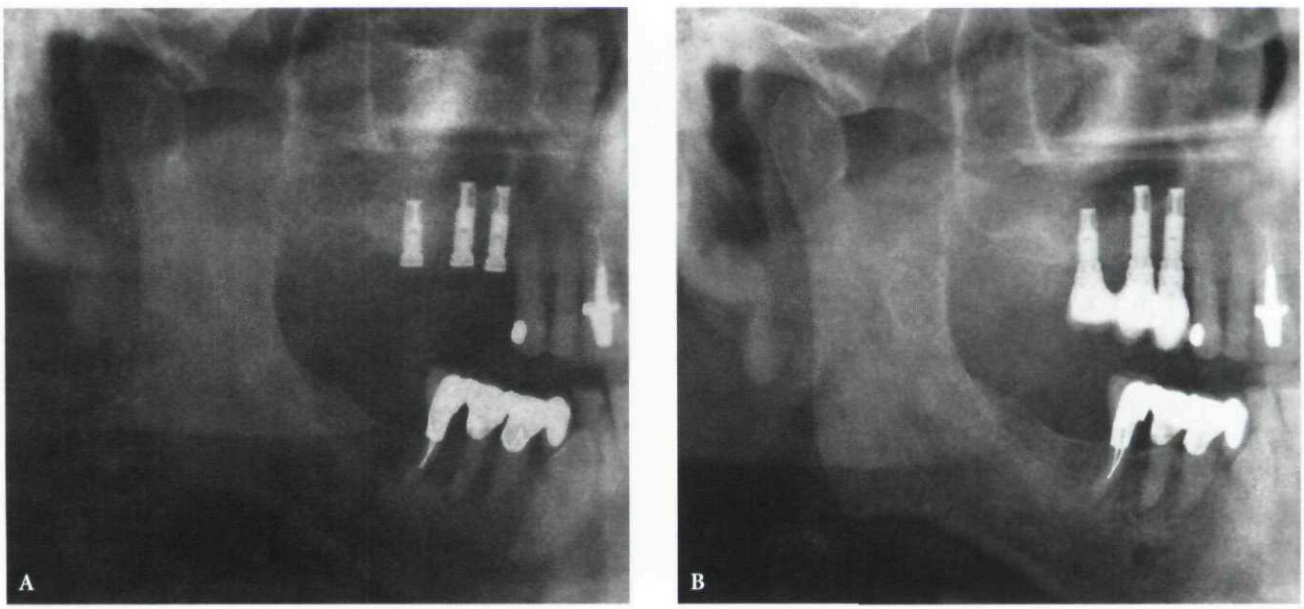


Figure 14 *A,* The same patient as shown in Figure 13, after 6 months of healing. *B,* The same patient after 12 months of bridge loading.

TABLE 1 Summary of Individual Patient Results

Patient	Implants		Bone Height (mm)	Healing Time (mo)	Follow-Up (mo)	RFA (ISQ)		
	Length (mm)	Number				Placement	Abutment	12 Months
1	13	1	7	12	51	—	—	*
2	13	3	7	12	49	—	74	—
	13		7	12		—	71	—
	13		7	12		—	61	—
3	13	2	7	11	48	68	74	68
	10		5	11		71	74	69
4	15	3	9	11	44	63	62	63
	13		7	11		65	66	63
	10		4	11		54	68	66
5	15	2	10	10	43	70	74	*
	13		6	10		72	74	*
6	15	3	15	6	43	58	49	55
	13		10	6		62	59	63
	10		5	6		—	63	65
7	13	1	5	6	43	68	75	*
8	13	2	7	6	39	67	63	*
	13		5			54	53	*
9	13	1	6	6	39	72	63	*
10	13	1	4	6	38	65	61	*
Average	13	—	6	9	44	65	66	64
Range	(10–15)	—	(4–10)	(6–12)	(38–51)	(54–72)	(49–75)	(55–69)

ISQ = implant stability quotient; RFA = resonance frequency analysis.
*Single implants with cemented crowns.

first marked by four to five drill holes; cutting with the reciprocating saw was then performed in an oblique direction. This resulted in a flanged bone window that could be replaced in a stable position. There are several advantages to using a replaceable bone window. First, soft tissue from the overlying intraoral mucosa does not have access to the sinus space. Second, the replaced bone window reestablishes the pneumatic conditions since air cannot pass through the bone window, which reduces the risk of disturbing the sinus membrane and the underlying blood clot. Third, it is possible that the surface of the bone window contributes to healing, passively by serving as a stabilizing surface for the blood clot and actively by bone formation into the space, at least after initial healing.

CONCLUSION

This study shows that the maxillary sinus has great potential for healing and bone formation and indicates that bone grafts or bone substitutes may not be needed to achieve augmentation of the maxillary sinus floor. Our findings can in fact explain the generally good results reported from sinus lift procedures using bone grafts and bone substitutes. We thus concluded that sinus membrane elevation without the use of bone grafts or bone substitutes predictably results in bone formation at the maxillary sinus floor.

REFERENCES

1. Tatum OH. Maxillary and sinus implant reconstructions. Dent Clin North Am 1986; 30:207–229.
2. Boyne PJ, James RA. Grafting of the maxillary sinus floor with autogenous marrow and bone. J Oral Surg 1980; 38:613–616.
3. Wood RM, Moore DL. Grafting of the maxillary sinus with intraorally harvested autogenous bone prior to implant placement. Int J Oral Maxillofac Implants 1988; 3:209–214.
4. Raghoebar GM, Louwerse C, Kalk WI, Vissink A. Morbidity of chin bone harvesting. Clin Oral Implants Res 2001; 12:503–507.
5. Lundgren S, Moy P, Johansson C, Nilsson H. Augmentation of the maxillary sinus floor with particulated mandible: a histologic and histomorphometric study. Int J Oral Maxillofac Implants 1996; 11:760–766.

6. Clavero J, Lundgren S. Ramus or chin grafts for maxillary sinus inlay and local onlay augmentation. Comparison of donor site morbidity and complications. Clin Implant Dent Relat Res 2003; 5:154–160.
7. Tulasne JF. Sinus grafting with calvarial bone. In: Jensen OT, ed. The sinus bone graft. Chicago: Quintessence, 1999: 107–116.
8. Hallman M, Sennerby L, Lundgren S. A clinical and histological evaluation of implant integration in the posterior maxilla after sinus floor augmentation with autogenous bone or bovine hydroxyapatite, or with a 20:80 mixture. Int J Oral Maxillofac Implants 2002; 17:635–643.
9. Yildirim M, Spiekermann H, Handt S, Edelhoff D. Maxillary sinus augmentation with the xenograft Bio-Oss and autogenous intraoral bone for qualitative improvement of the implant site: a histological and histomorphometric clinical study in humans. Int J Oral Maxillofac Implants 2001; 16:23–33.
10. Summers RB. The osteotome technique: Part 3—Less invasive methods of elevating the sinus floor. Compend Contin Educ Dent 1994; 15:698–708.
11. Dahlin C, Linde A, Gottlow J, Nyman S. Healing of bone defects by guided tissue regeneration. Plast Reconstr Surg 1988; 81:672–676.
12. Ellegaard B, Kølsen-Petersen J, Baelum V. Implant therapy involving maxillary sinus lift in periodontally compromised patients. Clin Oral Implants Res 1997; 8:305–315.
13. Lundgren S, Andersson S, Sennerby L. Spontaneous bone formation in the maxillary sinus after removal of a cyst: coincidental or expected reaction? Clin Implant Dent Relat Res 2003; 5:78–81.
14. Owen M. Marrow stromal stem cells. J Cell Sci Suppl 1988; 10:63–76.
15. Lundgren AK, Lundgren D, Hämmerle CH, Nyman S, Sennerby L. Influence of decortication of the donor bone on guided bone augmentation. An experimental study in the rabbit skull bone. Clin Oral Implants Res 2000; 11:99–106.
16. Slotte C, Lundgren D. Impact of cortical perforations on contiguous donor bone in a guided bone augmentation procedure: an experimental study in the rabbit skull. Clin Implant Dent Relat Res 2002; 4:1–10.
17. Albrektsson T, Johansson C, Lundgren AK, Sul Y, Gottlow J. Experimental studies on oxidized implants. A histomorphometrical and biomechanical analysis. Appl Osseointegration Res 2001; 1:21–24.
18. Ivanoff CJ, Widmark G, Johansson C, Wennerberg A. Histological evaluation of the bone response to oxidized and turned titanium microimplants in human jawbone. Int J Oral Maxillofac Implants 2003; 18:341–348.
19. Rocci A, Martignoni M, Miranda Burgos P, Gottlow J, Sennerby L. Histology of retrieved immediately and early loaded oxidized implants: light microscopic observations after 5 to 9 months of loading in the posterior mandible. Clin Implant Dent Relat Res 2003; 5(Suppl 1):88–98.
20. Davies JE. Mechanisms of endosseous integration. Int J Prosthodont 1998; 11:391–401.

Copyright of Clinical Implant Dentistry & Related Research is the property of B.C. Decker Inc. and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.