Clinical Evaluation of a Minimally Invasive Surgical Technique for Maxillary Sinus Floor Augmentation

Mitsuhiko Igarashi,1,2,4 Masanori Saito,3 Hiroyuki Okada,2 and Takao Kato4

1Igarashi Dental Clinic, Utsunomiya, Tochigi 329–1104, Japan
Departments of 2Histology, and 3Microbiology and Immunology, Nihon University School of Dentistry at Matsudo, Matsudo, Chiba 271–8587, Japan
4Department of Oral Implant, Nihon University Hospital at Matsudo, Matsudo, Chiba 271–8587, Japan

Article History
Received 1 June 2017
Accepted 10 August 2017

Keywords:
maxillary sinus, sinus augmentation, minimally invasive surgical technique, bone graft

Abstract
The purpose of this study, conducted at a private dental clinic, was to clinically evaluate the outcome of a minimally invasive surgical technique for sinus augmentation that carries lower risks of intra- and postoperative complications.

We modified the usual steps performed in the sinus augmentation procedure, and discuss the major modifications and resultant improvements, along with a literature review of the original technique in this paper. The modifications and improvements we made in each step are highlighted, and the major modifications are discussed along with a literature review. The biggest improvement most likely resulted from creation of a small fenestration, thereby creating a bag-like structure to keep the graft material in a stable state, which would facilitate better bone formation. In addition, maxillary sinus floor resorption was observed in most cases 2–3 years after surgery, with the resorption reaching the level of or below the tip of the implant. These results suggest that there is no need to take the risk involved in detaching and elevating a large area of mu cosa from the inner wall, and that minimal mucosal detachment or augmentation is sufficient and leads to a stable outcome.

Our results suggest that minimal-intervention maxillary sinus augmentation is an effective procedure from both patient and bibliographic viewpoints.

Introduction
Reduced alveolar bone width between the maxillary sinus floor and the maxillary posterior teeth is caused by loss of the maxillary molar teeth and pneumatization of the maxillary sinus and subsequent activation of osteoclasts originating from the maxillary sinus mucosa (1). Implant placement in the bone deficient area requires additional maxillary sinus floor augmentation. However, this technique is challenging as it involves anatomically modifying and restoring the degenerated, fragile alveolar bone (2). The technique was developed by Tatum in the 1970s and was published about 10 years later (3).

Sinus augmentation is achieved either by simultaneous bone grafting and implant placement (one-stage method), or, if the initial anchorage is difficult to achieve, by waiting for the bone tissue to mature before implant placement (two-stage method). Both these surgical techniques are well established and generally accepted (4), with stable outcomes reported in the literature (5–7).

However, a previous study reported that long-term implant survival is poorer in those in whom sinus augmentation is performed than in those in whom it is not performed (8).

The purpose of this study, which was conducted at a private dental clinic, was to clinically evaluate the outcomes of a minimally invasive surgical technique for sinus augmentation that avoids complications during and after surgery.

Materials and Methods
Forty-five patients (age, 57 ± 8.6) of this study, examined
and treated in Igarashi Dental Clinic, were selected from a pool of subjects requiring maxillary sinus augmentation for the placement of implants. All patients were partially edentulous and needing either unilateral or bilateral maxillary sinus augmentation. All patients signed their informed consent in which all procedures of the treatment were detailed.

The steps involved in the usual sinus augmentation procedure and our modifications of these steps are described below.

Normal surgical technique:
The general sinus augmentation technique (9–11) involves:
1. Local anesthesia or general anesthesia
2. Fenestration of the lateral sinus wall
3. Detachment and elevation of the maxillary sinus membrane
4. Bone grafting
5. Protection of the fenestration opening

Improved surgical technique
The modified sinus augmentation technique evaluated in this study is performed as follows:

1. Preoperative treatment
All patients receive intravenous sedation (midazolam and propofol) and local anesthesia (2% xylocaine, 1:50,000) before the sinus augmentation technique, with standard physical status monitoring.

2. Bone fenestration of the lateral sinus wall
Although many reports describe the use of an engine-powered round bur at a low velocity (9–11) for fenestration, we use the Siffradent piezoelectric bone surgery system (Surgerybone®, Siffradent Srl. Italy (Piezo)). Next, a 10 × 20-mm oval-shaped fenestration, which is the minimum possible size that is adequate to allow a sinus lifter to be inserted, is created in the anterior wall of the maxillary sinus.

3. Detachment and elevation of the maxillary sinus membrane
First, a piezo chip is used for detachment of the membrane. Next, a mucosal sinus elevator is used for detachment of the inner wall of the maxillary sinus. The amount of detachment is kept to the minimum that allows sufficient space to be secured for embedding the implant. The sinus membrane is carefully elevated so as to avoid applying pressure at an acute angle. A resorbable membrane (GC-Membrane®, GC Corporation, Tokyo, Japan) and autologous fibrin are used to protect the maxillary sinus mucosa.

4. Bone graft
The use of autogenous bone is recommended for bone grafting. However, anorganic bovine bone (Bio-Oss®, Geistlich Switzerland) is used when patient consent is not obtained due to the risk of possible postoperative complications. Graft materials are also not used for patients with more than 5 mm of maxillary alveolar bone height prior to grafting or in those with satisfactory bone substance.

5. Protection of the fenestration opening
The fenestration opening is covered with a resorbable membrane (GC-Membrane®, GC Corporation) and sutured. The opening and wound are protected with a periodontal dressing (Coe-Pak®, Coe Laboratories, Alsip, IL). A splint is also made when deemed necessary.

Results and Discussion
1. Preoperative treatment
In private dentistry, intraoperative patient monitoring is given as much importance as in university hospitals. Intravenous sedation using a combination of midazolam and propofol is effective for maintenance of stable blood pressure, which allows smooth performance of surgery and prevents the postoperative complications arising from extreme increases in blood pressure (12). Hence, periodontists in the USA routinely perform periodontal surgery under intravenous sedation (13).

2. Bone fenestration
Reportedly, the perforation rate decreased to 7% from 30% with the use of Piezo (14). Further, the cause of perforation in the 7% of patients was likely from the hand instruments used after making the lateral window. In our clinical study, the perforation rate during fenestration was 6.4% with the use of Piezo (15). Vercellotti et al. (16) also stated that the clinical significance of a piezoelectric system lies not only in its ability to cut bone while protecting soft tissue, but also that it favors the regeneration of bone tissue.
while minimizing tissue damage (as compared with the use of rotating tools). Blood vessels often exist around the fenestration area, as shown in Fig. 1. Most of the posterior superior alveolar artery (80%) is located more than 15 mm above the alveolar crest. However, this distance decreases with alveolar bone resorption (17). Previously, we often encountered cases in which the surgical field was obscured by bleeding during fenestration using cutting instruments, as shown in Fig. 2. Use of Piezo allows fenestration without injury to blood vessels, thus reducing intraoperative bleeding (Fig. 3). In our study, the size of the maxillary sinus fenestration was limited to the minimum possible size (approximately 10 × 20 mm) that the mucosal sinus elevator was able to achieve. As shown in Fig. 4, since breathing excursions exert pressure toward the alveolar crest, keeping the size of the fenestration as small as possible that would still allow creation of a bag-like structure will prevent leakage of the graft material through the opening, thereby facilitating stable bone formation. Reportedly, bone graft cells serve as scaffolding, encouraging pre-existing bone cells to form new bone by the process of osteoconduction (18). Based on these findings, creating a small fenestration through which a bag-like structure is created for graft placement allows the graft to be maintained in a stable state, facilitating better bone formation.

3. Detachment and elevation of the maxillary sinus membrane

First, the piezo tip is used for detachment (Fig. 5A) of the mucosa around the fenestration (Fig. 5B). This reduces the risk of perforation during the first step of detachment up to the depth reached with a sinus lifter. Extra caution is required when performing this step, due to the small size of the fenestration and the resultant increased risk of perforation during the first detachment step. In addition to the posterior superior alveolar artery that is an important feeding artery to be considered during maxillary mucosal detachment, branches of the orbital artery and the posterior lateral nasal artery should also be taken into consideration. Although these vessels are mostly located in the bone, vigorous abrasion may cause bleeding from these vessels (19). Chan et al. (20) have reported that the mean angle formed by the palatal and nasal inner walls of the maxillary sinus (Fig. 6) is 109.8° ± 25.3° in the premolar region, 121.6° ± 22.1° in the first molar region, and 144.9° ± 23.1° in the second molar region, and that the corresponding angles are ≤ 90° in 15%, 8.2%, and 2.4% of the patients. They suggest that the risk of perforation during mucosal detachment
increases as the acuteness of the angle increases, more so in the premolar region (Fig. 7). In other words, the risk of perforation is particularly high in the premolar part. The presence of a septum is a risk factor for perforation, and they are found in 21.3% of patients (21). Morphologically, the width of the inner and lateral walls was divided into narrow type and wide type, and it was suggested that the former should pay attention to perforation of exfoliation of inner wall membrane, and the latter should give attention to perforation of detachment of lower wall membrane and spreading of the bone supplement material at the time of mucosal elevation. Reportedly, a computed tomography study that evaluated cases 8 to 10 months after one-time sinus augmentation surgery showed that 49 of 57 implants
demonstrated bone resorption up to the tip of the implant at the maxillary sinus floor, and that 29 of 57 implants revealed bone resorption below the top of the implant on the buccal and palatal sides (22). Hatano et al. (23) also reported that maxillary sinus floor resorption was observed in most cases 2–3 years after surgery, and that resorption reached the level of or below the tip of the implant. These results suggest that there is no need to take the risk of detaching and elevating a large area of mucosa from the inner wall, and that minimal mucosal detachment or augmentation is sufficient and leads to a stable outcome. A representative case is presented in Fig. 8.
4. Bone graft

Generally, we recommend that most patients should undergo autogenous bone grafting. However, anorganic bovine bone (Bio-Oss®) is used when the patient refuses an autogenous graft after being informed of the potential risks of the procedure, namely infection secondary to injury, enlargement, external bleeding and internal bleeding from the graft site of the mandibular ramus. In patients who do not consent for autogenous bone and in whom the height of the alveolar bone is more than 5 mm, or when there is adequate healthy bone, graft material is not used. The sinus consensus conference on sinus lift surgery held in 1996 concluded that autogenous bone graft is the most effective graft material (24). However, due to significant risk of damage to the donor site, efforts have been made to develop graft materials that can overcome these shortcomings. Apart from autogenous bone grafts, we also use xenogeneic bone (anorganic bovine bone; Bio-Oss®). Our search of Medline using the search terms “sinus, augmentation, bone substitute” identified xenogeneic bone (including demineralized freeze-dried bone), hydroxyapatite, β-tricalcium phosphate (β-TCP), autogenous blood components, and bone morphogenetic protein (BMP) as graft materials. We will therefore focus this next part of the discussion on a comparison of autogenous bone graft (as mainly used in the present study), Bio-Oss®, and implant placement without any graft material.

Hallman et al. (25) compared the clinical and histological outcomes of using three graft materials (autogenous bone graft, Bio-Oss®, alone, and a 2:8 mixture of autogenous bone and Bio-Oss®) in sinus lift surgery at evaluated the 6-9 months after surgery and found no significant difference. There was also no significant difference in outcome even after 2 and 5 years of follow-up (26, 27). A systematic review also showed no significant difference in outcomes between these three graft materials (28). Another systematic review by Nkenke et al. (29) indicated the efficacy of autogenous bone, but also cautioned about the risk of a higher-than-expected degree of resorption of the maxillary sinus floor, in addition to damage to the donor site. As for using a mixture of autogenous bone and Bio-Oss®, except for a report by Bosshardt et al. (30) and we could not find significant difference from other studies. It was revealed that the bone-implant contact (BIC) ratio using autogenous bone alone was significantly higher that of both Bio-Oss® alone and the mixture, 9 months after the operation (31). This suggests the efficacy of autogenous bone in maxillary sinus augmentation and simultaneous implant placement (single-stage/concurrent method). However, there are no reports available on the incidence of complications at the donor site after autogenous bone collection. Further, sufficient consideration should also be given to the financial burden of this procedure for patients (32).

As mentioned above, we do not use graft materials if the patient does not consent to bone grafting, provided that the alveolar bone height is ≥ 5 mm or the bone is of good quality. Augmenting the alveolar bone height above the tip of the implant is technically demanding, but provides a stable outcome (33).

5. Protection of the fenestration opening

It is vital to prevent exposure of the bone graft at the site of the fenestration. Moreover, the bone graft materials at the graft site should be stable in order to allow successful bone formation (18).

If the fenestration opening becomes larger than the planned size during surgery, we use a protective splint for a month after surgery, in which case the fenestration region is sufficiently covered with the splint, which is made from a self-curing or heat-curing resin.

Conclusion

Our results suggest that maxillary sinus augmentation with minimal intervention is an effective surgery from both patient and bibliographic viewpoints. Future studies evaluating the validity of autologous bone extraction and its long-term prognosis are necessary for further improvement of the sinus augmentation procedure.

References

1. Tallgren A: The continuing reduction of the residual alveolar ridges in complete denture wearers: A mixed-longitudinal study covering 25 years. J Prosthet Dent, 27: 120–132, 1972.
2. Del Fabbro M, Rosano G, Taschieri S: Implant survival rates after maxillary sinus augmentation. Eur J Oral Sci, 116: 497-506, 2008.
3. Tatum H Jr.: Maxillary and sinus implant reconstructions. Dent Clin North Am, 30: 207–229, 1986.
4. Barone A, Santini S, Sbordone L, Crespi R, Covani U: A clinical study of the outcomes and complications associated with maxillary sinus augmentation. Int J Oral Maxillofac Implants, 21: 81–85, 2006.
5. Blomqvist JE, Alberius P, Isaksson S: Two-stage maxillary
sinus reconstruction with endosseous implants: A prospective study. Int J Oral Maxillofac Implants, 13: 758–766, 1998.
6. Valentini P, Abensur DJ: Maxillary sinus grafting with anorganic bovine bone: A clinical report of long-term results. Int J Oral Maxillofac Implants, 18: 556–560, 2003.
7. Tong DC, Rioux K, Drangsholt M, Beirne OR: A review of survival rates for implants placed in grafted maxillary sinuses using meta-analysis. Int J Oral Maxillofac Implants, 13: 175–182, 1998.
8. Barone A, Orlando B, Tonelli P, Covani U: Survival rate for implants placed in the posterior maxilla with and without sinus augmentation: A comparative cohort study. J Periodontol, 82: 219–226, 2011.
9. Barone A, Santini S, Sbordone L, Crespi R, Covani U: A clinical study of the outcomes and complications associated with maxillary sinus augmentation. Int J Oral Maxillofac Implants, 21: 81–85, 2006.
10. Fugazotto PA, Vlassis J: Long-term success of sinus augmentation using various surgical approaches and grafting materials. Int J Oral Maxillofac Implants, 13: 52–58, 1998.
11. Mardinger O, Nissan J, Chaushu G. Sinus floor augmentation with simultaneous implant placement in the severely atrophic maxilla: Technical problems and complications. J Periodontol, 78: 1872–1877, 2007.
12. Taguchi T, Fukuda K, Sekine H, Kakizawa T: Intravenous sedation and hemodynamic changes during dental implant surgery. Int J Oral Maxillofac Implants, 26: 1303–1308, 2011.
13. Holtzclaw DJ, Hinze F, Burnham JK, Toscano NJ, Shumaker N. Intravenous moderate sedation as an adjunct for periodontal surgery: A retrospective analysis of 964 cases. Clin Adv Periodontics, 4: 88–93, 2014.
14. Wallace SS, Mazor Z, Froum SJ, Cho SC, Tarnow DP: Schneiderian membrane perforation rate during sinus elevation using piezosurgery: clinical results of 100 consecutive cases. Int J Periodontics Restorative Dent, 27: 413–419, 2007.
15. Igarashi M, Igarashi N, Toyoda R, Sakurai H, Okada H, Kato T: A clinical study of thickness of maxillary sinus mucous membrane after maxillary sinus floor elevation using dental cone-bean CT. J Jpn Oral Impl. Dent, 29: 20–28, 2016.
16. Vercellotti T, Nevins ML, Kim DM, Nevins M, Wada K, Schenk RK, Fiorellini JP: Osseous response following resective therapy with piezosurgery. Int J Periodontics Restorative Dent. 25: 543–549, 2005.
17. Elian N, Wallace SS, Cho SC, Jablout, ZN, Froum S: Distribution of the maxillary artery as it relates to sinus floor augmentation. Int J Oral Maxillofac Implants, 20: 784–787, 2005.
18. Tadjoeedin ES, de Lange GL, Bronckers AL, Lyaruu DM, Burger EH: Deproteinized cancellous bovine bone (Bio-Oss) as bone substitute for sinus floor elevation: A retrospective, histomorphometrical study of five cases. J Clin Periodontol, 30: 261–270, 2003.
19. Flanagan D: Arterial supply of maxillary sinus and potential for bleeding complication during lateral approach sinus elevation. Implant Dent, 14: 336–338, 2005.
20. Chan HL, Monje A, Suarez F, Benavides E, Wang HL: Palatonasal recess on medial wall of the maxillary sinus and clinical implications for sinus augmentation via lateral window approach. J Periodontol, 84: 1087–1093, 2013.
21. Krennmair G, Ulm C, Lugmayr H: Maxillary sinus septa: Incidence, morphology and clinical implications. J Craniomaxillofac Surg, 25: 261–265, 1997.
22. Peleg M, ChauShu G, Mazor Z, Ardekan L, Bakoon M: Radiological findings of the post-sinus lift maxillary sinus: A computerized tomography follow-up. J Periodontol, 70: 1564–1573, 1999.
23. Hatano N, Shimizu Y, Ooya K: A clinical long-term radiographic evaluation of graft height changes after maxillary sinus floor augmentation with a 2:1 autogenous bone/xeno-graft mixture and simultaneous placement of dental implants. Clin Oral Implants Res, 15: 339–345, 2004.
24. Jensen OT, Shulman LB, Block MS, lacono VJ: Report of the sinus consensus conference of 1996. Int J Oral Maxillofac Implants, 13: 11–45, 1998.
25. Hallman M, Sennerby L, Lundgren S: A clinical and histologic evaluation of implant integration in the posterior maxilla after sinus floor augmentation with autogenous bone, bovine hydroxyapatite, or a 20:80 mixture. Int J Oral Maxillofac Implants, 17: 635–643, 2002.
26. Hallman M, Hedin M, Sennerby L, Lundgren S: A prospective 1-year clinical and radiographic study of implants placed after maxillary sinus floor augmentation with bovine hydroxyapatite and autogenous bone. J Oral Maxillofac Surg, 60: 277–284, 2002.
27. Hallman M, Zetterqvist L: A 5-year prospective follow-up of implant-supported fixed prostheses in patients subjected to maxillary sinus floor augmentation with an 80:20 mixture of bovine hydroxyapatite and autogenous bone. Clin Implant Dent Relat Res, 6: 82–89, 2004.
28. Jensen T, Schou S, Stavropoulos A, Terheyden H, Holmstrup P: Maxillary sinus floor augmentation with Bio-Oss or Bio-Oss mixed with autogenous bone as graft: A systematic review. Clin Oral Implants Res, 23: 263–273, 2012.
29. Nkenke E, Stelze F: Clinical outcomes of sinus floor augmentation for implant placement using autogenous bone or bone substitutes: a systematic review. Clin Oral Implants Res, 20: 124–133, 2009.
30. Boshhardt DD, Schenk RK. Biologic basis of bone regeneration. In: Buser D, editor. 20 Years of guided bone regeneration in implant dentistry. 2nd edition, Berlin: Quintessence Publishing: 2009. p.15–45.
31. Handsche J, Simonowska M, Naujoks C, Depprich RA,
Ommerborn, MA, Meyer U, Kübler NR: A histomorphometric meta-analysis of sinus elevation with various grafting materials. Head Face Med. 5: 1-10, 2009.

32. Aludden HC, Mordenfeld A, Hallman M, Dahlin C, Jensen T: Lateral ridge augmentation with Bio-Oss alone or Bio-Oss mixed with particulate autogenous bone graft: A systematic review. Int J Oral Maxillofac Surg, 46: 1030–1038, 2017.

33. Riben C, Thor A: Follow-up of the sinus membrane elevation technique for maxillary sinus implants without the use of graft material. Clin Implant Dent Relat Res, 18: 895–905, 2016.