# The "Dome Phenomenon" Associated with Maxillary Sinus Augmentation

Dan Mahler, DMD;\* Liran Levin, DMD;<sup>†</sup> Hadar Zigdon, DMD;<sup>‡</sup> Eli E. Machtei, DMD<sup>§</sup>

### ABSTRACT

Aim: This case series is aimed to report a new phenomenon, the "dome phenomenon," which was observed in infected augmented sinuses over several years.

*Methods:* Five patients are presented in whom sinus lift augmentation resulted in postoperative infection with inflammation and suppuration. The patients received aggressive anti-inflammatory treatment and surgical debridement of the inflamed tissue, including some grafted material performed through the lateral window of the primary procedure.

*Results:* The inflammatory condition was reversed, and the site healed clinically. Radiographically, a dome-shaped, radioopaque tissue was observed at the superiormost aspect of the grafted sinus. This "dome phenomenon" was further confirmed during dental implant placement, which indicates healing potential adjacent to the maxillary sinus membrane.

*Conclusions:* The current report, as well as other studies and case series, suggests that there is great potential for healing and bone formation in the maxillary sinus membrane. The precise mechanism is not known. Further clinical and histologic studies are needed to understand the regenerative potential of the Schneiderian membrane.

KEY WORDS: bone augmentation, contamination, dental implantation, implants, sinus elevation

# INTRODUCTION

The residual alveolar ridge is often reduced following tooth loss in the posterior maxilla, and placement of dental implants in patients with pneumatized of atrophic maxilla could be difficult.<sup>1–9</sup> The so-called lateral wall "sinus lift" procedure with bone grafting was first reported by Tatum in 1975<sup>1</sup> and published for the first time by Boyne and James<sup>1,8</sup> in 1980. This method for attaining sufficient bone height for posterior maxillary

© 2009, Copyright the Authors Journal Compilation © 2009, Wiley Periodicals, Inc.

DOI 10.1111/j.1708-8208.2009.00178.x

implant placement has proved highly successful and predictable,<sup>2–5,10</sup> with an implant survival rate of over 90% for 3 to 5 years.<sup>11–13</sup>

A low incidence of surgical and postsurgical complications has been reported in this procedure.<sup>11</sup> Perforation of the Schneiderian membrane is the most common surgical complication,<sup>4,5,9,11-15</sup> occurring in 7 to 35% of sinus floor elevation procedures.<sup>2,7,11,13</sup> According to the literature, membrane perforations are associated with greater postoperative complications, such as acute or chronic sinus infection, bacterial invasion, swelling, bleeding, wound dehiscence, loss of the graft material, and disruption of normal sinus physiologic function.<sup>1,4–7,10–14</sup> Most studies, however, failed to find an association between membrane perforations or postoperative complications and implant survival.<sup>7,11,13,16</sup>

Postoperative complications, such as chronic sinus infection, bacterial invasion, swelling, and suppuration, are usually treated with antibiotics and lavage, when appropriate. A reentry surgical debridement is performed to resolve the infection. However, the fate of the grafted site remains uncertain.

This case series reports a new phenomenon, the "dome phenomenon," which was observed in infected augmented sinuses of five patients over several years.

<sup>\*</sup>Clinical instructor, Department of Periodontology, the Rambam Health Care Campus School of Graduate Dentistry; <sup>†</sup>clinical instructor, Department of Oral Rehabilitation, The Maurice and Gabriela Goldschleger School of Dental Medicine, Tel-Aviv University, Tel-Aviv, Israel, and Department of Periodontology, the Rambam Health Care Campus School of Graduate Dentistry; <sup>†</sup>clinical instructor, Department of Periodontology, the Rambam Health Care Campus School of Graduate Dentistry; <sup>§</sup>Head of Rambam Health Care Campus School of Graduate Dentistry, chairman of the Department of Periodontology, and associate professor, Faculty of Medicine, Technion, Israel Institute of Technology, Haifa, Israel

Reprint requests: Dr. Liran Levin, Department of Periodontology, the Rambam Health Care Campus School of Graduate Dentistry, Haifa, Israel; e-mail: liranl@post.tau.ac.il

The patients had had reentry and surgical debridement. During the "emergency" operation, a dome of dense, solid material could be palped using a blunt instrument; this solid material was also evident radiographically. After soft tissue healing and resolution of the inflammation, implants could be installed without further augmentation because of complete bone fill.

# **CASE REPORTS**

## Case 1

A 53-year-old woman was referred for left lateral wall sinus augmentation with simultaneous implant placement. The sinus was grafted by using autogenous bone combined with  $\beta$ -tri-calcium-phosphate (Cerasorb<sup>®</sup>, Curasan AG, Kleinostheim, Germany) and covered with a collagen membrane (Bio-Guide®, Geistlich Pharma AG, Wolhusen, Switzerland). Perforation of the Schneiderian membrane was not observed. The patient received antibiotics (Amoxicillin, Novopharm, Toronto, Ontario, Canada; 1.5 g/day starting 1 day preoperation) for 10 days and was instructed to gargle with 0.2% chlorhexidine mouthwash. Surgery included simultaneus implant placement and was uneventful. However, 2 weeks postoperation, when the patient returned for suture removal, suppuration was evident in the flap's marginal area, which included bone particles. The area was thoroughly lavaged with saline, and the patient received an additional antibiotic course of 1.5 g/day Amoxicyline clavulanate (SmithKline Beecham, Brentford, Middlesex, U.K.) and 1 g/day Metronidazole (Haupt Pharma, Livron-Sur-Drôme, France). After 2 weeks, the pain had subsided, and clinical symptoms



**Figure 1** Panoramic radiograph 4 months postoperation revealed a gap between the implant and grafted material in its mesial side.



Maxillary Sinus Augmentation – "Dome Phenomenon"

e47

**Figure 2** After the area was surgically exposed and the implant was removed, together with the granulation and inflammatory tissue around it, the superior border of the augmentation site was intact with solid, dense tissue separating the surgical compartment from the maxillary sinus above it.

improved. The patient was further monitored and reported some discomfort and minor swelling. At 4 months postoperatively, the patient presented with acute abscess at the surgical site. Panoramic radiograph revealed a gap between the implant and the grafted material in its mesial aspect (Figure 1). The area was surgically exposed, and the implant was removed together with the granulation and inflammatory tissue around it. The superior border of the augmentation site was intact with dense, solid tissue separating the surgical compartment from the maxillary sinus above it (Figure 2). Postoperative panoramic radiograph showed the radiopaque dome at the most superior aspect of the augmented sinus (Figure 3). The area was left to heal for



**Figure 3** Postoperative panoramic radiograph showed the radiopaque dome at the most posterior portion of the augmented sinus.



**Figure 4** Two follow-up radiographs taken 6 months (A) and 5 years (B) following implant placement. Note that the left maxillary premolars were extracted along the way.

7 months, at which time new implants were inserted. During implant surgery, the void that was present at the time of debridement was now completely filled with bone. Implants were later loaded and are still in function 5 years postoperatively (Figure 4).

#### Case 2

A 45-year-old man, and a heavy smoker, was scheduled for left lateral wall sinus lift operation. A preoperative computed tomography (CT) scan revealed a residual ridge, 2 to 3 mm in height, in the upper left posterior region and thickening of the Schneiderian membrane (Figure 5). After a consultation with an otolaryngologist, Amoxicyline clavulanate (SmithKline Beecham), 875 mg (twice daily), was administered 2 days preoperatively continuing for 8 days postoperatively. The sinus was grafted with autogenous bone combined with bovine bone material (Bio-oss<sup>®</sup>, Geistlich Pharma AG, Wolhusen, Switzerland) and  $\beta$ -tri-calcium-phosphate



**Figure 5** Computed tomography scan taken before surgery revealed a residual ridge of 2–3 mm in the upper left posterior region and thickening of the Schneiderian membrane.

and covered with a collagen membrane (Bio-Guide), which was also inserted in the superior wall of the grafted area (even though the Schneiderian membrane was intact) (Figure 6). The operation and healing were



Figure 6 The sinus was grafted with autogenous bone combined with bovine bone material and  $\beta$ -tri-calcium-phosphate and covered with a collagen membrane inserted in the superior wall of the grafted area (though the Schneiderian membrane was intact).



**Figure 7** Computed tomography scan taken 9 months postoperatively for guided implant placement. Note the radiolucency in the area of the grafted maxillary sinus with a dome-shaped radiopacity at the most superior portion of the grafted region.

uneventful. However, at 9 months postoperatively, a CT scan taken to guide implant placement showed a radiolucent area in the center of the grafted area with a dome-shaped radiopacity at the most superior portion of the grafted region (Figure 7). The area was surgically exposed for implant placement, and a void was evident in the lateral wall area. The superior border of the augmentation site was intact with solid, dense tissue separating the surgical compartment from the maxillary sinus above it (Figure 8). Implants were inserted and the gap was filled with additional bovine bone material (Bio-Oss). The patient received antibiotics for a week (Amoxicyline clavulanate, 875 mg twice daily) with no



**Figure 8** The void that was discovered in the lateral wall area with the superior border of the augmentation site intact with solid dense tissue separating the surgical compartment from the maxillary sinus above it.





**Figure 9** Clinical/radiographic view of the loaded implants 1 year post–implant placement.

further complications. Implants were loaded 6 months after insertion and have been in function for 1 year (Figure 9).

This phenomenon was seen following infected sinus maxillary augmentations in another three patients treated with the same protocol.

#### DISCUSSION

This study presents a phenomenon where, in spite of an inflammatory complication that warranted further surgical intervention, a dense, solid, hard tissue was maintained in the superiormost aspect of the grafted area. This tissue might represent a solidification of the  $\beta$ -tricalcium-phosphate that was previously grafted in the sinus<sup>17</sup> together with initial bone formation originating in the Schneiderian membrane. This dome provided a 3-to 4-wall defect inside the maxillary sinus, which was

completely filled with bone and enabled the insertion of dental implants without the need for additional sinus augmentation.

Grafting of the maxillary sinus is a method used to achieve sufficient bone height for posterior maxillary implant placement and has proved highly successful.<sup>1,4–6,7,9,13</sup> Sinus floor augmentation procedures are routinely performed, although the function of the maxillary sinus is not fully understood. Several of its functions might be adding resonance to the voice and some degree of olfactory function, warming and humidifying inspired air and reducing the weight of the skull.<sup>4,5,7</sup> Nevertheless, there are no reports on functional or voice-related impairments following sinus augmentation.

The long-term success rate of dental implants in grafted sinuses is increased when grafting materials are replaced or encompassed by newly formed bone, which starts growing from local host bone into the augmented area.<sup>18</sup> Bone formation requires osteoblasts derived from progenitor cells of the mesenchymal lineage.<sup>19-21</sup> Mesenchymal progenitor cells originate from various sources, for example, bone marrow, the cambium layer of periosteum, and pericytes surrounding blood capillaries.<sup>19,22</sup> The question of whether the sinus mucosa, which covers approximately half of the augmentation material, contains cells with an osteogenic potential remains a matter of debate.<sup>22-24</sup> Gruber and colleagues,<sup>24</sup> in an in vitro study, support the hypothesis that the sinus mucosa is a potential source of cells that can differentiate toward the osteogenic lineage. The presently described phenomenon also supports these findings.

Artzi and colleagues<sup>25–27</sup> report the rate change of grafted versus new bone along the depth of the augmented site in sinus grafting procedures. The amount of newly regenerated tissue is dependent not only on time but also on augmentation location and depth. The recipient osseous site and walls and the proximity of the Schneiderian membrane, as vascular nourishment sources, probably influence the amount of tissue generation. In human histomorphometric analysis, areas in proximity to the Schneiderian membrane exhibited higher new bone formation than areas adjacent to the residual crest. Thus, the potential source for the above-described dome is likely to be the Schneiderian membrane.

In 2003, Lundgren and colleagues<sup>28</sup> reported spontaneous bone formation in the maxillary sinus after the removal of a cyst without any bone graft, and, in 2004, they described a new surgical technique for maxillary sinus augmentation with only sinus membrane elevation and replacement of the bony window.<sup>29</sup>

Similarly, Jung and colleagues<sup>30</sup> report a case of spontaneous bone formation in the maxillary sinus floor associated with the extraction socket of a maxillary impacted tooth. At 5 months post extraction, the space between the sinus floor and the socket was filled with new bone. Later, implant placement was successfully carried out in this site without any sinus augmentation. It was concluded that the osteogenic activity of sinus mucosa and the blood clot in the extraction socket beneath the elevated sinus would have been important factors in this spontaneous bone formation.<sup>30</sup>

It is noteworthy that there are alternative treatments for cases of acute sinus infection. These include removal of the infected or grafted materials as well as regrafting the defects or placing a membrane over the window to prevent soft tissue ingrowths. Further studies are warranted in order to reveal the preferred way of treatment.

#### CONCLUSIONS

The current report, as well as other studies and case series, suggests that there is great potential for healing and bone formation in the maxillary sinus membrane. The precise mechanism is not known. Further clinical and histologic studies are needed to understand the regenerative potential of the Schneiderian membrane.

# CONFLICTS OF INTEREST STATEMENT

The authors have declared no conflicts of interest. [Correction added after online publication 23 October 2009: Conflicts of Interest Statement added.]

## REFERENCES

- Chanavaz M. Maxillary sinus: anatomy, physiology, surgery, and bone grafting related to implantology – eleven years of surgical experience (1979–1990). J Oral Implantol 1990; 16:199–209.
- Khoury F. Augmentation of the sinus floor with mandibular bone blocks and simultaneous implantation: a 6-year clinical investigation. Int J Oral Maxillofac Implants 1999; 14:557– 564.
- 3. Vlassis JM, Fugazzotto PA. A classification system for sinus membrane perforations during augmentation procedures with options for repair. J Periodontol 1999; 70:692–699.
- 4. Bergh van den JPA, ten Bruggenkate CM, Disch FJM, Tuinzing DB. Anatomical aspects of sinus floor elevations. Clin Oral Implants Res 2000; 11:256–265.

- Bergh van den JPA, ten Bruggenkate CM, Groeneveld HHJ, Burger EH, Tuinzing DB. Recombinant human bone morphogenetic protein-7 in maxillary sinus floor elevation surgery in 3 patients compared to autogenous bone grafts. A clinical pilot study. J Clin Periodontol 2000; 27:627–636.
- Aimetti M, Romagnoli R, Ricci G, Massei G. Maxillary sinus elevation: the effect of macrolacerations and microlacerations of the sinus membrane as determined by endoscopy. Int J Periodontics Restorative Dent 2001; 21:581–589.
- Nkenke E, Schlegel A, Schultze-Mosgau S, Neukam FW, Wiltfang J. The endoscopically controlled osteotome sinus floor elevation: a preliminary prospective study. Int J Oral Maxillofac Implants 2002; 17:557–566.
- Boyne PJ, James RA. Grafting of the maxillary sinus floor with autogenous marrow and bone. J Oral Surg 1980; 38:613–616.
- Sorní M, Guarinós J, García O, Peñarrocha M. Implant rehabilitation of the atrophic upper jaw: a review of the literature since 1999. Med Oral Patol Oral Cir Bucal 2005; 10:E45–E56.
- Browaeys H, Bouvry P, De Bruyn H. A literature review on biomaterials in sinus augmentation procedures. Clin Implant Dent Relat Res 2007; 9:166–177.
- Schwartz-Arad D, Herzberg R, Dolev E. The prevalence of surgical complications of the sinus graft procedure and their impact on implant survival. J Periodontol 2004; 75:511–516.
- 12. Levin L, Herzberg R, Dolev E, Schwartz-Arad D. Smoking and complications of onlay bone grafts and sinus lift operations. Int J Oral Maxillofac Implants 2004; 19:369–373.
- Shlomi B, Horowitz I, Kahn A, Dobriyan A, Chaushu G. The effect of sinus membrane perforation and repair with Lambone on the outcome of maxillary sinus floor augmentation: a radiographic assessment. Int J Oral Maxillofac Implants 2004; 19:559–562.
- Proussaefs P, Lozada J, Kim J, Rohrer M. Repair of the perforated sinus membrane with a resorbable collagen membrane: a human study. Int J Oral Maxillofac Implants 2004; 19:413–420.
- Hernández-Alfaro F, Torradeflot MM, Marti C. Prevalence and management of Schneiderian membrane perforations during sinus-lift procedures. Clin Oral Implants Res 2008; 19:91–98. Epub Oct 23, 2007.
- 16. Fugazzotto PA, Vlassis J. A simplified classification and repair system for sinus membrane perforations. J Periodontol 2003; 74:1534–1541.
- Kikuchi M, Koyama Y, Yamada T, et al. Development of guided bone regeneration membrane composed of betatricalcium phosphate and poly (L-lactide-co-glycolide-coepsilon-caprolactone) composites. Biomaterials 2004; 25:5979–5986.
- 18. Schlegel KA, Fichtner G, Schultze-Mosgau S, Wiltfang J. Histologic findings in sinus augmentation with autogenous

bone chips vs. a bovine bone substitute. Int J Oral Maxillofac Implants 2003; 18:53–58.

- Bianco P, Riminucci M, Gronthos S, Robey PG. Bone marrow stromal stem cells: nature, biology, and potential applications. Stem Cells 2001; 19:180–192.
- Ducy P, Schinke T, Karsenty G. The osteoblast: a sophisticated fibroblast under central surveillance. Science 2000; 289:1501–1504.
- 21. Doherty MJ, Ashton BA, Walsh S, Beresford JN, Grant ME, Canfield AE. Vascular pericytes express osteogenic potential in vitro and in vivo. J Bone Miner Res 1998; 13:828–838.
- 22. Terheyden H, Jepsen S, Moller B, Tucker MM, Rueger DC. Sinus floor augmentation with simultaneous placement of dental implants using a combination of deproteinized bone xenografts and recombinant human osteogenic protein-1. A histometric study in miniature pigs. Clin Oral Implants Res 1999; 10:510–521.
- 23. Watzek G, Haas R. Internal augmentation of the alveolar crest with the sinus membrane for guided bone regeneration. An experimental study in sheep. Oral Maxillofac Surg Clin North Am 2001; 13:511–520.
- Gruber R, Kandler B, Fuerst G, Fischer MB, Watzek G. Porcine sinus mucosa holds cells that respond to bone morphogenetic protein (BMP)-6 and BMP-7 with increased osteogenic differentiation in vitro. Clin Oral Implants Res 2004; 15:575–580.
- Artzi Z, Nemcovsky CE, Dayan D. Bovine-HA spongiosa blocks and immediate implant placement in sinus augmentation procedures. Histopathological and histomorphometric observations on different histological stainings in 10 consecutive patients. Clin Oral Implants Res 2002; 13:420– 427.
- Artzi Z, Nemcovsky CE, Tal H, Dayan D. Histopathological morphometric evaluation of 2 different hydroxyapatitebone derivatives in sinus augmentation procedures: a comparative study in humans. J Periodontol 2001; 72:911–920.
- 27. Artzi Z, Kozlovsky A, Nemcovsky CE, Weinreb M. The amount of newly formed bone in sinus grafting procedures depends on tissue depth as well as the type and residual amount of the grafted material. J Clin Periodontol 2005; 32:193–199.
- Lundgren S, Andersson S, Sennerby L. Spontaneous bone formation in the maxillary sinus after removal of a cyst: coincidence or consequence? Clin Implant Dent Relat Res 2003; 5:78–81.
- 29. Lundgren S, Andersson S, Gualini F, Sennerby L. Bone reformation with sinus membrane elevation: a new surgical technique for maxillary sinus floor augmentation. Clin Implant Dent Relat Res 2004; 6:165–173.
- Jung YS, Chung SW, Nam W, Cho IH, Cha IH, Park HS. Spontaneous bone formation on the maxillary sinus floor in association with an extraction socket. Int J Oral Maxillofac Surg 2007; 36:656–657.

Copyright of Clinical Implant Dentistry & Related Research is the property of Blackwell Publishing Limited 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.