Long-Term Success of Sinus Augmentation Using Various Surgical Approaches and Grafting Materials

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Two hundred twenty-two sinus augmentation procedures were performed using one of three techniques: crestal approach; lateral approach; or lateral approach with simultaneous implant placement. Forty-one of these sinus augmentation procedures were performed in conjunction with buccolingual ridge augmentation. Of the 222 procedures, 217 (97.7%) were successful. Of 510 implants placed in augmented sinus areas, 495 (97.0%) were deemed successful by the criteria of Albrektsson et al for up to 73 months in function. Clinical considerations in the execution of such therapy are discussed.
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Key words: buccolingual ridge augmentation, crestal approach, grafting materials, guided bone regeneration, simultaneous implant placement, sinus augmentation procedures

The clinician contemplating reconstruction of the posterior maxilla with osseointegrated implants must overcome a number of anatomic challenges.[1] Buccolingual and/or apico-occlusal atrophy of the edentulous ridge and pneumatization of the maxillary sinus often limit the volume of bone available for implant placement. In addition, the residual alveolar ridge may be of such morphology and position in relation to the opposing arch as to preclude ideal positioning of implants for reception of subsequent restorations. Finally, the residual bone in the posterior maxilla is often type IV in quality. Such sparsely trabeculated, poor-quality bone has been cited as a significant contributing factor to greater implant failure in a number of studies.[2–5]

Regenerative techniques have been employed in an attempt to obviate a number of these concerns. The use of guided bone regeneration (GBR), utilizing a variety of materials to rebuild the atrophied edentulous ridge, has been the subject of a number of animal and clinical studies.[6–10] While this technique has been shown to result in significant regeneration of lost bone, the factors that contribute to optimal success and the absolute limitations of the technique are still the subject of much discussion.

Le Fort I osteotomies with interpositional bone grafts, or bone onlays, have also been used to increase the amount of available bone for implant placement.[11–14] However, these techniques are only applicable when there is sufficient interarch space to allow the subsequent restoration of the implants that have been placed in the downfractured bone. In addition, significant postoperative morbidity is associated with this approach.

Many clinicians advocate augmentation of the maxillary sinus to increase the dimension of available bone for implant placement. This procedure was popularized by Tatum[15] in the mid-1970s; his results were reported in 1986. Over the last three decades, a number of authors have documented the anatomic concerns, technical considerations, and clinical and histologic results of the sinus augmentation procedure using a number of clinical approaches and grafting materials.[16–18] Particulate and block grafts include autogenous bone (from the iliac crest or a variety of intraoral sites),[19–24] freeze-dried bone allografts (mineralized or demineralized),[25,26] xenografts, hydroxyapatite (resorbable or nonresorbable),[27,28] resorbable tricalcium phosphate,[17,29] or various combinations of these materials.[30,31] To better idealize subsequent implant positioning, concomitant buccolingual ridge augmentation procedures are also advocated by some authors.[1]

However, many of the published reports have limitations. Some present the results of only a small patient population. Statistical analysis often varies

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from article to article. The differentiation between a surviving implant and a successful implant is made in only a limited number of the reports. Finally, many of the studies were carried out in a controlled environment, with a select number of highly adept clinicians carrying out all surgical, restorative, and maintenance procedures. The results of such ideal therapeutic conditions are not necessarily transferrable to the clinical milieu of the everyday practitioner.

The purpose of this study was to evaluate the outcome of placing 510 implants in 222 maxillary sinuses augmented with a variety of bone substitutes. Specific criteria were used to assess the success of the augmentations and implants.

Materials and Methods

Patient Selection. Following a thorough review of medical histories, patients were deemed unsuitable to receive sinus augmentation therapy based on the following criteria:

- The presence of uncontrolled diabetes, immune diseases, or other contraindicating systemic conditions
- Radiation therapy to the head and neck region in the 12 months prior to proposed therapy
- Chemotherapy in the 12-month period prior to proposed therapy
- Uncontrolled periodontal disease, or an unwillingness to undergo needed periodontal therapy, around remaining teeth
- An active sinus infection, or a history of persistent sinus infections
- A smoking habit of one pack or more per day
- A psychological problem, which, in the opinion of the authors, would render the delivery of comprehensive therapy untenable. Such concerns range from severe manic depression for which a patient is under professional care, to extreme nervousness or agitation, which precludes the patient from undergoing numerous, lengthy treatment visits.
- An unwillingness to commit to a long-term, post-therapy maintenance program

A complete examination of oral hard and soft tissues was conducted for each patient, and an overall dental treatment plan was formulated in conjunction with the treating restorative dentists. Panoramic radiographs were taken of all patients, as were formatted computed tomography (CT) scans, when they were deemed clinically necessary. Diagnostic casts, wax-ups, and surgical templates were also utilized as needed.

One hundred eighty-one patients were treated. Of these patients, 104 (57.5%) were women and 77 (42.5%) were men. Patient age ranged from 31 to 72 years. All surgical therapy and preoperative and postoperative measurements were recorded by the authors.

Surgical Technique. Following a supracrestal incision, with mesial and distal releasing incisions extending well up into the buccal fold, a full-thickness mucoperiosteal flap was reflected. A sinus augmentation procedure was then carried out utilizing one of three clinical approaches:

Crestal Approach. A rectangular-shaped osteotomy was prepared on the crest of the alveolar ridge under copious sterile water irrigation. The detached "window" was elevated apically while simultaneously reflecting the sinus membrane. Following adequate reflection, the sinus membrane was inspected for tears. If a tear was encountered, it was repaired, and the augmentation procedure was completed according to its classification.[32] If no tears were found, the grafting material was placed. The area was then sutured. This approach was used when less than 2 mm of bone was evident between the floor of the sinus and the crest of the residual ridge. Twenty-eight procedures were performed in this manner.

Lateral Approach. A rectangular- or oval-shaped osteotomy was prepared on the lateral aspect of the alveolar ridge under copious sterile water irrigation. The detached "window" was elevated medially and apically while simultaneously reflecting the sinus membrane. Following adequate reflection, the sinus membrane was inspected for tears. If a tear was encountered, it was repaired, and the augmentation procedure was completed according to its classification.[32] If no tears were found, the grafting material was placed. The area was then sutured. This approach was used when more than 2 mm but less than 5 mm of bone was evident between the floor of the sinus and the crest of the residual ridge. One hundred thirteen procedures were performed in this manner.

Lateral Approach With Simultaneous Implant Placement. A rectangular- or oval-shaped osteotomy was prepared on the lateral aspect of the alveolar ridge under copious sterile water irrigation. The detached "window" was elevated medially and apically while simultaneously reflecting the sinus membrane. Following adequate reflection, the sinus membrane was inspected for tears. If a tear was found, it was repaired according to its classification. The extent and classification of the perforation determined whether simultaneous implant placement could still be performed as anticipated.[32] If not, the augmentation procedure was completed and classified as a lateral approach without simultaneous

implant placement for the purpose of this study. If no tears were found, the implant sites were prepared, with care taken not to damage the reflected membrane. The mesial, medial, and distal aspects of the created subantral space were filled with the grafting material, and the implants were placed. The remaining subantral space was then filled with the grafting material, and the area was sutured. This approach was used when more than 5 mm of bone was evident between the floor of the sinus and the crest of the residual ridge. Eighty-one procedures were performed in this manner.

The dimensions and shapes of the individual osteotomies varied from patient to patient, and depending on local anatomic considerations.

Particulate grafting materials were placed in the following combinations (Table 1):

1. Equal parts of demineralized freeze-dried bone allograft (DFDBA), 500 to 800 μm in diameter (Musculoskeletal Foundation, Holmoel, NJ), and resorbable tricalcium phosphate (TCP) (Augmen, Miter & Co, Warsau, IN): 84 patients
2. Equal parts of DFDBA, 1200 to 1500 μm in diameter, and TCP: 21 patients
3. Equal parts of freeze-dried bone allograft (FDBA), 500 to 800 μm in diameter (Musculoskeletal Foundation), and TCP: 13 patients
4. Equal parts of FDBA and DFDBA, 500 to 800 μm in diameter: 11 patients
5. Bovine bone matrix (Bio-Oss, Osteohealth, Shirley, NY): 53 patients
6. A mixture of equal parts DFDBA and Osteogen (Stryker, Kalamazoo, MI): 40 patients

Gore-Tex membranes (WL Gore & Associates, Flagstaff, AZ) were used in a number of cases for different reasons:

1. If simultaneous implant placement resulted in the development of fenestration and/or dehiscences: 19 patients, 26 implants
2. If a concomitant ridge augmentation procedure was performed: 41 patients

A total of 510 IMZ implants (Interpore International, Irvine, CA) of varying lengths, with widths of 3.3, 4.0, or 4.25 mm, were placed in 219 of the grafted subantral areas (Table 2). Two hundred ten of these implants were placed at the time of subantral augmentation, and 300 were placed following successful grafting. Implant placement followed standard IMZ protocol, with one exception. Site preparation for simultaneous sinus augmentation and implant placement never included the final drill size. Sites for 4.25-mm-wide implants were widened to 4.0 mm; sites for 4.0-mm-wide implants were widened to 3.7 mm; and sites for 3.3-mm-wide implants were widened to 2.8 mm. This ensured a firm fit of the implant into the prepared site, to help anchor the implant in the surrounding bone for primary stability.

All flaps were sutured with Gore-Tex sutures (WL Gore & Associates). Every attempt was made to achieve passive primary closure, including the utilization of a number of flap design modifications.

Postoperative Management. Medication prescribed included Peridex rinses (Proctor & Gamble, Cincinnati, OH) twice a day for 21 days, amoxicillin

Table 1 Sinus Augmentation Procedures by Materials Placed

Materials placed	No. of cases No. of patients/No. successful (%)
DFDBA (500 to 800 μm) and TCP	84/81 (96.4)
DFDBA (1200 to 1500 μm) and TCP	21/21 (100)
FDBA (500 to 800 μm) and TCP	13/13 (100)
DFDBA (1200 to 1500 μm) and FDBA (500 to 800 μm)	11/10 (90.9)
Bio-Oss	53/53 (100)
Osteogen and DFDBA (500 to 800 μm)	40/39 (97.5)

Table 2 Sinus Augmentation Procedures by Technique

Surgical approach	No. of sinuses augmented	No. successful (%)	No. of implants placed
Crestal	28	28 (100%)	77
Lateral	113	110 (97.3%)	252
Lateral with simultaneous implant placement	81	79 (97.5%)	181
Total	222	217 (97.7%)	510

500 × 40 four times a day (enteric-coated erythromycin 400 × 30 three times a day was used for penicillin-sensitive patients), ibuprofen 600 × 20 four times a day, unless medically contraindicated, and pain medication (Tylenol with Codeine III [McNeill Pharmaceutical, Fort Washington, PA] or Percocet [DuPont Pharma, Wilmington, DE]) as necessary.

Patients were not allowed to use any removable prostheses before the suture removal visit 10 to 12 days postoperatively. At that time, removable prostheses were adjusted, relined, and placed for cosmetic purposes only. Throughout the regenerative phase, patients were not allowed to function with these restorations. Patients undergoing concomitant ridge augmentation procedures were never allowed to use removable prostheses over operated sites until regeneration had been deemed complete. Peridex rinses were continued for the total course of membrane retention if membrane exposure occurred. Gore-Tex membrane exposure occurred in 1 of 81 patients with simultaneous implant placement, and in 5 of 31 patients with concomitant ridge augmentation. Exposed membranes were only removed before 12 weeks if persistent clinical signs of infection were noted, which occurred in two of the five patients with premature membrane exposure.

Healing Time. In patients having sinus grafting alone, implants were placed 7 to 10 months postoperatively, depending on radiographic analysis. If a concomitant ridge augmentation was performed, healing was allowed to occur for 8 to 10 months, depending on radiographic analysis and the extent of the ridge augmentation sought. Implants were then allowed to osseointegrate for 5 to 6 months before they were uncovered. If implants had been placed at the time of the sinus augmentation, they were allowed to osseointegrate for 6 to 8 months before they were uncovered, depending on radiographic analysis.

Progressive Loading. No attempts were made to accomplish progressive loading of the newly regenerated bone, other than the time that would pass as the restorative dentist proceeded from temporization to placement of the final prosthesis. This interval routinely ranged from 6 weeks to 4 months.

Prosthetic Therapy. Of 217 fixed prostheses, 213 were restored following standard IMZ protocol, using either an intramobile element (IME) or an intramobile connector (IMC). As a result, implants were often attached to natural teeth with the use of screw-fixed rigid attachments. Four patients were restored by substituting titanium components for the resilient elements, and these were not connected to natural teeth. Most superstructures were composed of a precious metal substructure veneered with porcelain. Five patients in whom significant parafunction was noted were restored via a gold framework and porcelain veneers. Prosthesis classification followed that of Hurzeler et al.[34]

Postoperative Maintenance. Ideally, all patients underwent maintenance visits at 3-month intervals consisting of plaque control instruction, scaling, and selected curettage. Realistically, not all patients conformed to this schedule, although all patients were seen at least three times per year, and the mean number of maintenance visits per year per patient was 3.7. All implant-supported portions of the prostheses were removed every 6 months, or sooner if clinical judgment warranted. IMEs and IMCs were replaced as necessary (for fracture, bending, or severe discoloration). Titanium abutments were removed, cleaned, and replaced upon removal of the prostheses. The following measurements were taken upon removal of the prostheses:

1. Implant immobility, assessed through the placement of the carrying head into the implant and the manual application of lateral forces
2. Clinical attachment level (the distance from the most coronal portion of the implant to the base of the sulcus) as measured by probe on the midbuccal, middistal, midmesial, and midpalatal aspects of the implant
3. Tissue margin height (the distance from the most coronal aspect of the implant to the gingival margin on all four aspects of the implant) as measured by probe
4. Gingival Index, assessed on the buccal aspect of the implant

Panoramic radiographs were taken preoperatively, following regeneration, and at yearly intervals following prosthesis placement. Individual periapical films were taken at 3-year intervals, or as clinical symptoms warranted. Every attempt was made to standardize the angulation of the periapical films, and all films were taken by one of two dental assistants. Such films were not used to assess absolutely the continued success of the implants, but rather as diagnostic tools (in the face of clinical symptoms) or as possible harbingers of problems.

Assessment of Success. A sinus augmentation was deemed successful if sufficient bone was generated to allow placement entirely in bone of an implant of at least 11 mm in length. Such regeneration was assessed with panoramic radiographs that had been calibrated to account for the magnification factor of the individual machines, and confirmed clinically at the time of implant placement.

Table 3   Rate of Success of Implants Placed in Function

Implant width (mm)	No. placed	No. successful	Percentage success
4.0	448	436	97.3
4.25	36	36	100
3.3	26	23	88.5
Total	510	495	97.0

Table 4   Implant Function Over Time

Months in function	No. of patients	No. of implants*
73+	2	5
61–72	4	9
49–60	9	21
37–48	50	106
25–36	48	109
13–24	50	120
0–12	59	125

*Numbers do not include the 15 failed implants.

Ridge augmentation procedures were considered successful if sufficient width of bone was regenerated to allow the placement of implants of at least 4 mm in width, without the development of any fenestrations/dehiscences. An implant was deemed successful if it met the criteria of Albrektsson et al.[35]

Panoramic radiographs were used to calculate the stability of the bone crest in relation to the most coronal aspect of the implant by utilizing the known dimensions of the implants to accurately calculate radiographic distortion/enlargement factors.

Results

Two hundred twenty-two sinus augmentation procedures were performed, using a crestal, lateral, or lateral with simultaneous implant placement approach (Table 1). Of these, 217 were deemed successful (97.7%). Criterion for success of the augmentation was sufficient bone regeneration for placement entirely in bone of implants 11 mm or more in length. In patients who underwent simultaneous implant placement, success required both generation of sufficient bone to completely surround the implants, and clinically immobile implants upon uncovering. All 28 of the crestal approach sinus augmentations were successful, while 97.3% (110 of 113) of the lateral approach and 97.5% (79 of 81) of the lateral approach with simultaneous implant placement sinus augmentations were successful.

Concomitant buccolingual ridge augmentation procedures were performed in 41 patients (all lateral approach sinus augmentations). All of these procedures were judged successful with regard to both the sinus augmentation (classified as such if regeneration allowed for placement of implants at least 11 mm in length) and the ridge augmentation (classified as regeneration of sufficient bone for placement of at least a 4-mm-wide implant without development of any fenestration/dehiscence).

A variety of materials were placed in the newly created subantral space to stimulate bone regeneration (Table 2). Success rate for the various materials ranged from 90.9% to 100%. However, since no material experienced more than three failures in its group, these differences were not statistically significant, and should therefore be noted with caution.

Although a purely subjective impression, the regenerated bone, when combinations of FDBA and/or DFDBA were used, did not appear to be as dense as when other materials were incorporated into the mixture or placed by themselves.

Of the 510 implants placed into augmented sinus areas, 2 failed as a result of a healing complication (loss of primary closure and development of marked purulent drainage); 2 were removed at the time of uncovering in connection with failed augmentation; and 2 were removed at the time of uncovering in spite of successful augmentation (this augmentation procedure was classified as a failure in our statistical analysis). Nine implants in three patients failed while functioning under provisional acrylic resin restorations within 6 months of loading. All three of these patients demonstrated heavy parafunctional habits and severe and rapid wear of the provisional restorations.

The remaining 495 implants (97.0%) (Table 3) were deemed successful when judged by the criteria of Albrektsson et al.[35] Of 448 4.0-mm-wide implants, 436 were successful (98.0%); of 36 4.25-mm-wide implants, 36 were successful (100%); and of 26 3.3-mm-wide implants, 23 were deemed successful (88.5%).

Successful implants were followed for a period of 73+ months (Table 4). Because all implant loss occurred within the first 6 months of loading, life table analysis was not carried out. The results would have been identical to the absolute success rate analysis because no implants had been lost beyond the first segment of observation. It should also be noted that implant function over time was assessed beginning when the implants were placed in function in provisional restorations. This point in time is denoted as time 0. The time prior to loading of the implants is not considered in the statistical analysis.

Discussion

The results of the present study concur with many published reports documenting both the predictability of the subantral augmentation procedure, and the capacity of implants placed in the augmented bone to function successfully over time.[15–18,20,27,29,34] The success rates for both the augmentation procedure (97.7%) and the implants placed in function in regenerated bone (97.0%) are at least comparable to documented survival rates of implants placed in areas where regeneration was not necessary.[34–38]

While the findings are in agreement with many other published reports regarding sinus augmentation procedures, this study does offer some differences. Implant retention alone is not sufficient in this study to warrant classification as success. Rather, all implants considered successful meet the Albrektsson et al success criteria. In addition, the sinus augmentation procedures themselves were only deemed successful if implants of at least 11 mm in length could be placed without further augmentation. Finally, when a buccolingual ridge augmentation was performed at the time of sinus augmentation, the procedure was only deemed successful if at least 4-mm-wide implants could be subsequently placed without generation of any fenestrations and/or dehiscences. To our knowledge, no other papers published on the topic of sinus augmentation have imposed such strict success criteria.

Statistical analysis did not reveal any significant differences with regard to success when evaluating the clinical approach used or the type of material placed in the area to be augmented. This was to be expected considering the very small number of failures encountered, both with regard to sinus augmentation success and implant success in function.

Of the 15 implants that did fail, two failed during the early stages of healing of a failed augmentation procedure, and four were removed at the time of uncovering. All 9 remaining failures occurred within the first 6 months of function under provisional restorations, in three patients subjected to heavy parafunctional forces. This was evident by the severe and rapid wear on the provisional restoration. Such a finding leads the authors to hypothesize that the failures of these implants were a function of inadequate diagnosis of heavy parafunction, thus subjecting the implants to excessive forces immediately upon uncovering. It is of note that no implants failed after the initial 6 months of loading, for a period of 73+ months. Furthermore, all of the implants in this study were restored with the conventional IMZ protocol, using a resilient element between the implants and the restorations. While the use of such a compo-

nent in implant restorations is still considered controversial,[39–41] it is possible that the documented dampening effect of such a resilient element may have helped reduce the load on the regenerated bone, both initially and over time.

Finally, this study differs from other reports in that patients were not treated in a highly controlled institutional environment, nor were they restored by only a select group of superbly qualified clinicians. While it is true that all surgical therapy was performed by the two authors, the restorations were fabricated by literally dozens of restorative dentists with varying degrees of training and expertise. This in itself helps to underscore the potential for a high rate of success when using sinus augmentation procedures and subsequent implant placement.

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