# A Review of Survival Rates for Implants Placed in Grafted Maxillary Sinuses Using Meta-analysis

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A variety of materials and procedures are used to create adequate bone volume in the maxillary sinus for placement of endosseous implants in the posterior atrophic maxilla. This review used the structured method of meta-analysis to evaluate the survival of the implants placed into various materials that have been used in the maxillary sinus with the sinus lift procedure. A MEDLINE computer search of the English literature yielded 28 studies that reported using the maxillary sinus augmentation procedure to increase bone volume for placement of endosseous implants; only 10 of these met the inclusion criteria for meta-analysis. Data regarding immediate or delayed placement of implants were combined to simplify analysis. Implant survival was 90% for autogenous bone (484 implants in 130 patients followed for 6 to 60 months), 94% for the combination of hydroxyapatite (HA) and autogenous bone (363 implants in 104 patients followed for 18 months), 98% for the combination of demineralized freeze-dried bone (DFDB) and HA (215 implants in 50 patients followed for 7 to 60 months), and 87% for HA alone (30 implants in 11 patients followed for 18 months). The results for autogenous bone were based on six reports, for the combination of autogenous bone and HA on three reports, and for DFDB/HA and HA alone on one study each. The results of single studies cannot be weighted as heavily as the results combining several studies; however, the analysis of these studies suggests that implant survival rates were similar for autogenous bone, HA/autogenous bone mix, HA/DFDB, and HA alone.
(INT J ORAL MAXILLOFAC IMPLANTS 1998;13:175–182)

**Key words:** implants, maxillary sinus augmentation, meta-analysis, review, sinus lift

The edentulous posterior maxillary ridge with a large pneumatized maxillary sinus poses a difficult challenge for the placement of endosseous implants. Recently, clinicians have recommended augmenting the maxillary sinus to facilitate placement of endosseous implants in the severely atrophic posterior maxilla.[1] While various surgical techniques and materials have been used to augment the maxillary sinus, data examining short-term and long-term outcomes have been scarce and have been reported for only a limited number of patients.

The objective of this review was to compare the survival of implants placed in the different materials used to increase bone volume in the maxillary sinus. Meta-analysis offers a structured method to systematically identify, review, and analyze all published reports examining the outcome of implants placed in maxillary sinuses augmented using the sinus lift procedure.[2] Using meta-analysis, the data available from different studies were reviewed, statistically compared, and used to form opinions and draw conclusions.

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**Table 1** Studies Included in the Meta-analysis

| Study | Material* | No. of implants | Delayed vs immediate | No. of patients | Follow-up (mo) | Overall survival (%) |
|---|---|---|---|---|---|---|
| Wheeler et al[28] | HA alone | 30 | Immediate/delayed | 11 | 12–60 | 87 |
| | HA/autogenous bone | 36 | Immediate/delayed | 13 | 12–60 | 97 |
| Chiapasco and Ronchi[5] | HA/autogenous bone | 124 | Delayed | 43 | 12–24 | 93.5 |
| Tidwell et al[26] | HA/autogenous bone | 203 | Delayed | 48 | 12–32 | 93 |
| Lundgren et al[18] | Autogenous bone | 30 | Delayed | 10 | 12–46 | 100 |
| Zinner and Small[30] | HA/DFDB | 215 | Immediate | 50 | 7–60 | 98 |
| Kent and Block[15] | Autogenous bone | 54 | Immediate | 11 | 12–48 | 100 |
| Bloomqvist et al[3] | Autogenous bone | 171 | Immediate | 49 | 14–58 | 83 |
| Hall and McKenna[8] | Autogenous bone | 70 | Delayed | 15 | 6–12 | 91 |
| Raghoebar et al[22] | Autogenous bone | 93 | Immediate/delayed | 25 | 6–36 | 93 |
| Keller et al[14] | Autogenous bone | 66 | Immediate | 20 | 12–60 | 92 |

*HA = hydroxyapatite; DFDB = demineralized freeze-dried bone.

**Table 2** Studies Excluded From the Meta-analysis and the Basis for Exclusion

| Study | Inadequate no. of patients | Inadequate reporting | Not a root-form implant | Duplicate patient data* |
|---|---|---|---|---|
| Misch and Dietsh[19] | | X | | |
| Jensen et al[10] | X | | | |
| Jensen and Greer[13] | X | | | |
| Wagner[27] | X | | X | |
| GaRey et al[7] | X | | | |
| Jensen and Sindet-Petersen[11] | | X | | |
| Smiler et al[25] | | X | | |
| Moy et al[20] | X | | | |
| Nishibori et al[21] | X | | | |
| Jensen et al[12] | | X | | |
| Fugazzotto[6] | X | | | |
| Smiler and Holmes[24] | X | | | |
| Boyne and James[4] | X | X | | |
| Leder et al[16] | X | | | |
| Wood and Moore[29] | X | | | |
| Small et al[23] | | | | X |
| Loukota et al[17] | X | X | | X |
| Hürzeler et al[9] | X | X | | |

*See Table 1.

## Materials and Methods

An exhaustive MEDLINE computer search was undertaken to identify all studies in the English literature reporting the outcomes of implants placed in the augmented maxillary sinus between 1980 and 1996. Multiple strategies to identify key words, such as sinus lift, implants, and augmentation, were used to search the database. A total of 28 studies was identified for consideration.[3–30] Four examiners screened and selected articles according to the following criteria: *(1)* at least 10 patients participated in the study; *(2)* all patients received root-form endosseous implants; *(3)* less than 5% of the patients were lost to follow-up over a 6-month period; *(4)* patient follow-up was no less than 6 months; and *(5)* data regarding survival of implants were reported.

A log of excluded studies and the reasons for their exclusion was kept, while the identified reports were evaluated in detail. The key variables were abstracted and placed in tabular form. A variety of outcome measures was reported. Because it was consistently reported in the articles, implant survival was the outcome measure used for analysis.

The proportion of surviving implants was calculated by dividing the number of surviving implants by the total number of implants placed into grafted maxillary sinuses. A Kaplan-Meier (life table) analysis *could not be done* because most of the reports did not provide the precise follow-up period for each patient. Instead, 95% confidence intervals were calculated using the normal approximation to the binomial probability distribution.[31] Confidence intervals were also calculated using the length of follow-up when

**Table 3** Mean Survival Rates and Confidence Intervals for the 10 Studies Included in the Meta-analysis†

| Graft material | No. of studies | Total no. of implants | No. of implant failures | Rate of survival (%)* | 95% Confidence interval |
|---|---|---|---|---|---|
| Autogenous bone | 6 | 484 | 47 | 90 | 87–93 |
| HA alone | 1 | 30 | 4 | 87 | 68–95 |
| HA/autogenous bone | 3 | 363 | 22 | 94 | 90–97 |
| HA/DFDB | 1 | 215 | 3 | 98 | 96–100 |

*Survival rate calculated by combining the data at the longest follow-up evaluation reported in each article.
†The study by Wheeler et al[28] used both HA alone and in combination with autogenous bone.

the data were included in the report. Chi-square analysis was used to test statistical significance.[31]

## Results

Of the 28 identified by the literature search, 10 studies[3,5,8,14,15,18,22,26,28,30] met the inclusion criteria for meta-analysis (Table 1). The reasons for excluding the other 18 studies from the analysis are reported in Table 2. The studies that were included in the analysis represented a 7-year period from 1989 to 1996 and consisted of both retrospective and prospective follow-up reports of implants placed into augmented maxillary sinuses. No randomized controlled trials were identified. Six of the 10 studies reported using autogenous bone alone.[3,8,13,14,18,22] Bone was harvested from the anterior iliac crest in five studies[3,8,13,14,22] and from the mandibular symphysis in one study.[18] A total of 484 implants were placed in 130 patients followed for 6 to 60 months. The combined average implant survival rate for autogenous bone alone at 18 months of follow-up was 90%. Three studies reported using a combination of hydroxyapatite (HA) autogenous bone in 61 patients followed for 12 to 60 months.[5,25,28] The compiled mean survival rate for 363 implants in 104 patients using HA/autogenous bone was 94% at 18 months. One study used a 1:1 ratio of HA demineralized freeze-dried bone (DFDB) to augment the maxillae of 50 patients, and reported 98% implant survival for 215 implants with 7 to 60 months of follow-up.[30] In addition to the patients who received HA/autogenous bone, Wheeler et al[28] described 11 patients who had 30 implants placed in sinuses augmented with HA alone; the survival rate was 87% at 18 months. The mean survival rates, along with confidence intervals for each of the 10 studies, are reported in Table 3 and Fig 1.

These studies could not be statistically compared in detail because the augmentation and implant techniques used were significantly different and the outcomes were reported at different follow-up times.

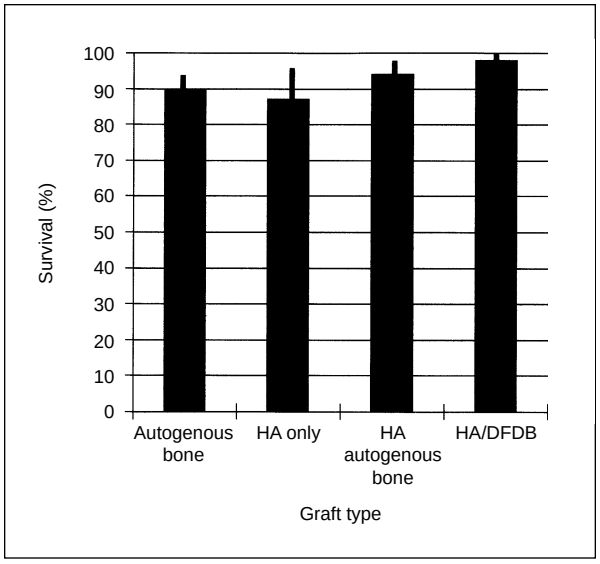


**Fig 1** Mean implant survival at 18 months of follow-up. Survival is reported as the percent of the total number of implants surviving after 18 months. Bars represent the 95% confidence intervals.

Delayed placement of implants was reported in four studies,[5,8,18,25] immediate implant placement was reported in four studies,[3,13,14,30] and both immediate and delayed implant placement were reported in two studies[22,28] (Table 1). Some studies used cortical block grafts, while others used particulate grafts. Some clinicians used press-fit implants, while others used screw-fit implants. Some implants were titanium, while others were coated with HA. Although implant survival rates for the various types of materials were not identical, the differences were not great, and the confidence intervals overlapped each other (Fig 1).

The effect of inconsistent follow-up in the 10 studies was examined by calculating confidence limits for each study. The 95% confidence limits for implant survival were examined relative to the length of follow-up for each study (Table 4 and Fig 2). There were no statistically significant differences in

the survival rates ($P > .05$). Most implant failures occurred in the first 6 months after placement, while only a few losses occurred after the initial healing period.

## Discussion

Several surgical techniques, including onlay grafts and Le Fort I osteotomies, have been described for augmenting the atrophic maxilla.[1,32,33] Recently, augmentation of the maxillary sinus floor through the lateral sinus wall has been recommended for augmenting the atrophic posterior maxilla. The technique has had only minor modifications[1] since it was described by Boyne and James[4] in 1980. Initially, a vestibular incision is made approximately 6 mm superior to the attached gingival margin, extending from the canine to the zygomatic buttress. The incision is carried to the bone, and soft tissue and periosteum are reflected to expose the lateral wall of the maxillary sinus, which can be extremely thin (Fig 3). If implants are placed simultaneously with the graft, the incision is made from the tuberosity to the canine 2 to 5 mm palatal to the crest of the alveolar ridge, and

**Table 4** Proportion of Implants Surviving at Various Periods of Follow-Up*

| | Period of follow-up | | | |
|---|---|---|---|---|
| Graft material/study† | 0 to 6 Months | 7 to 12 Months | 13 to 18 Months | > 18 Months |
| Autogenous bone alone | | | | |
| Keller et al[14] (66) | 100.0 (93.1–100) | 98.5 (90.7–100) | 98.5 (90.7–100) | 92.4 (86.0–98.8) |
| Hall and McKenna[8] (70) | | | 90.0 (80.0–95.5) | |
| Raghoebar et al[22] (93) | 94.6 (87.3–98.0) | 94.6 (87.3–98.0) | 94.6 (87.3–98.0) | |
| Bloomqvist et al[3] (171) | | | 82.5 (75.7–87.7) | |
| Lundgren et al[18] (30) | | | 100 (85.9–100.0) | |
| Kent and Block[15] (54) | 100.0 (91.7–100.0) | 100.0 (91.7–100.0) | | |
| Mean survival | 97.6 (96.6–98.6) | 97.2 (96.1–98.3) | 90.0 (87.2–92.8) | |
| HA/autogenous bone | | | | |
| Tidwell et al[26] (203) | | 93.5 (87.6–96.8) | 93.8 (84.2–98.0) | 93.8 (84.2–96.8) |
| Chiapasco and Ronchi[5] (124) | 98.4 (93.7–100.0) | | 93.5 (87.3–97.0) | |
| Wheeler et al[28] (36) | 100.0 (87.4–100.0) | 97.1 (82.9–100.0) | 97.1 (82.9–100.0) | |
| Mean survival | 98.7 (95.0–99.9) | 94.2 (89.3–97.0) | 94.2 (90.0–96.7) | |
| HA/DFDB | | | | |
| Zinner and Small[30] (215) | 99.1 (96.3–100.0) | 98.1 (95.0–99.5) | 97.2 (93.7–98.9) | 97.2 (93.7–98.9) |
| HA alone | | | | |
| Wheeler et al[28] (30) | 93.1 (75.8–98.9) | 89.7 (71.5–97.3) | 89.7 (71.5–97.3) | 86.2 (67.4–95.5) |

*Data reported as percentage survival, followed by the 95% confidence interval in parentheses.
†Number in parentheses is the total number of implants in the study.

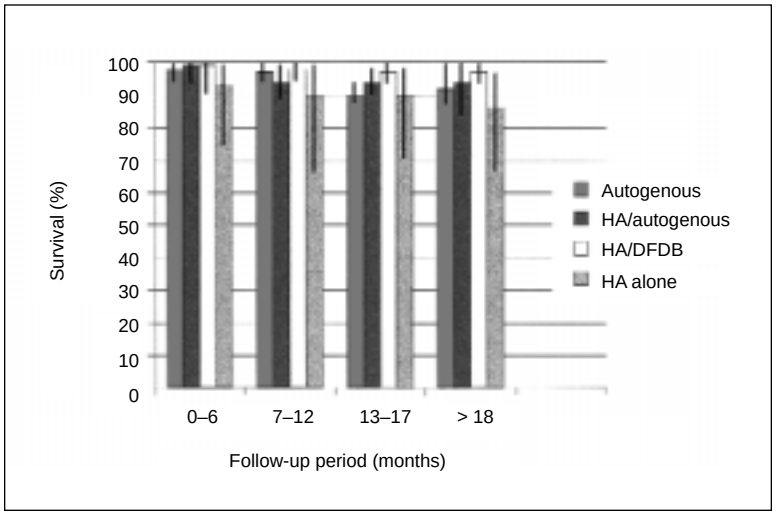


**Fig 2** Mean implant survival at various lengths of follow-up. Survival is reported as the percent of the total number of implants surviving at each follow-up period. Bars represent the 95% confidence intervals for the number of studies reporting data for the time period (see Table 4).

the lateral maxillary sinus wall is exposed by elevating the flap to the buccal (Figs 4 and 5).

Using a rotary instrument and a large round bur, or a combination of a rotary instrument and osteotomes, a bony window is created through the lateral sinus wall, and care is taken to leave the underlying Schneiderian mucosal membrane intact. Boyne and James[4] recommended removing the bone from the window; however, recent reports describe scoring a series of perforations along the superior margin of the bony window and infracturing the bone medially into the sinus (Fig 3).[1] In either case, the underlying mucosa is lifted intact from the sinus floor. Augmentation material is packed into the space created by infracturing the bone and elevating the mucous membrane (Fig 5). If the sinus membrane is torn during the procedure, clinicians have recommended various techniques to repair the defect, including suturing, no treatment, and guided tissue regeneration.[1,34] The soft tissues incisions are closed over bone.

Both immediate and delayed placement of implants have been reported.[3–30] Immediate implant placement into single corticocancellous bone blocks,[14] into corticocancellous struts placed superiorly[35] to sandwich the augmentation material, and into areas that have adequate residual bone to stabilize the implants, have been described.

Various augmentation materials have been used to augment the maxillary sinus.[1,3–30] Autogenous bone can be harvested from many areas, eg, the anterior iliac crest, the symphysis of the mandible, the maxillary tuberosity, the calvarium, and the external oblique ridge of the mandible (Fig 6).[36] The advantages of using autogenous bone are that it is not immunogenic, it is both osteoinductive and osteoconductive, and it is a source of osteoprogenitor cells. The disadvantage is the need for a second surgical site (with the increased morbidity and surgical time). In addition, a short hospital stay, which adds to the overall cost and inconvenience to the patient, may be required.

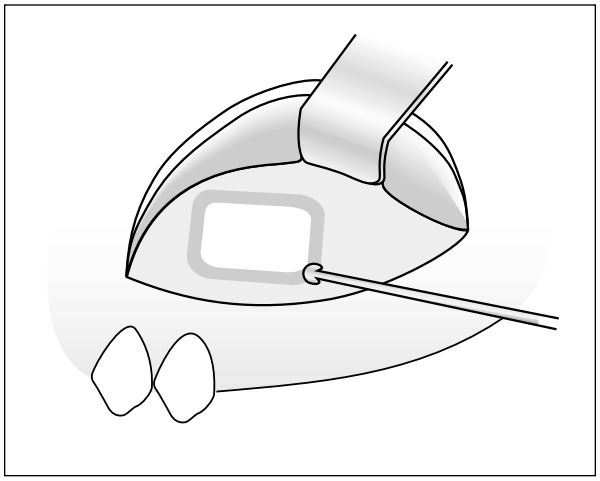

**Fig 3** A vestibular incision is made and a buccal window outlined with a rotary instrument prior to infracture and elevation of the sinus membrane.

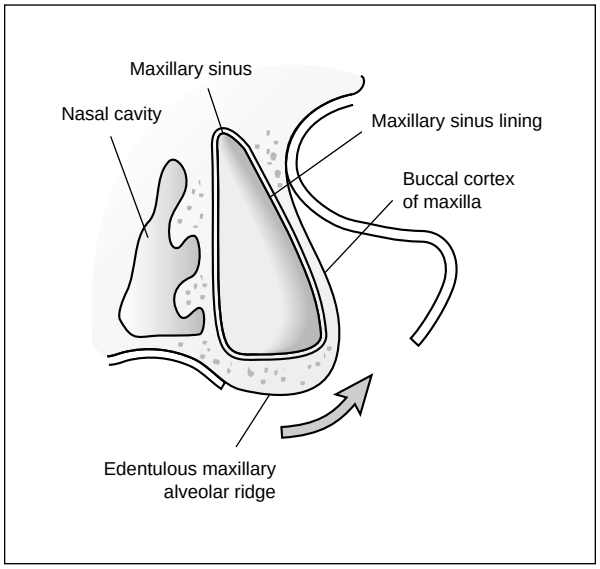


**Fig 4** Periosteal flap used to expose the maxillary alveolar ridge and buccal cortex.

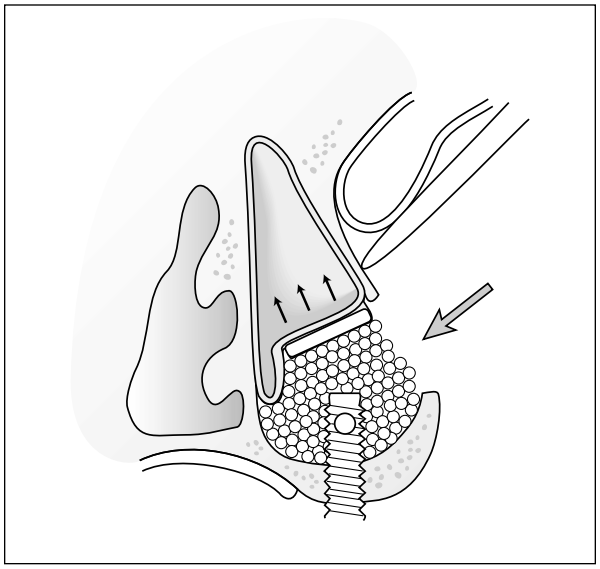

**Fig 5** The buccal cortex is elevated intact with the sinus membrane, and the augmentation material is placed into the maxillary sinus.

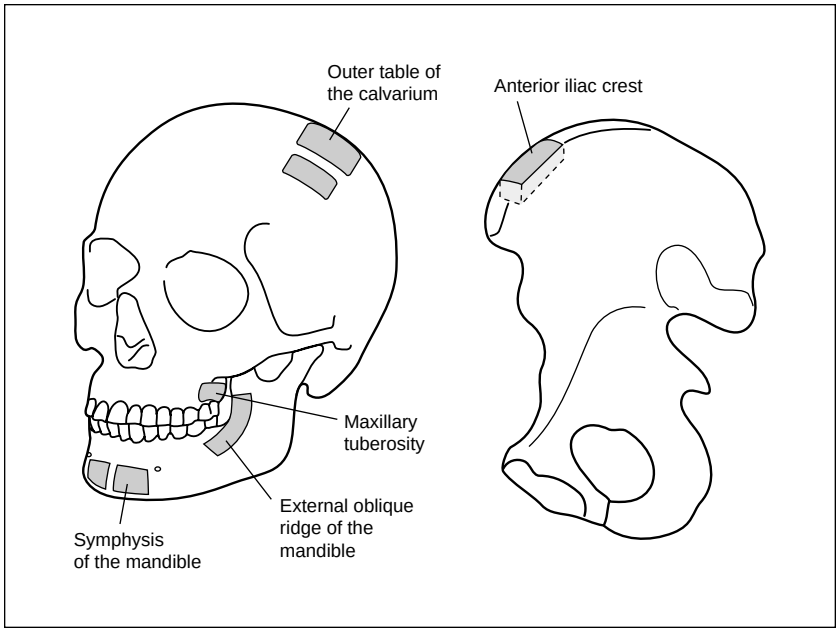


**Fig 6** Autogenous bone can be harvested from many sites, eg, symphysis of the mandible; outer table of the calvarium; maxillary tuberosity; external oblique ridge of the mandible; anterior iliac crest.

Hydroxyapatite alone and in combination with other materials has been used to augment the maxillary sinus.[5,9,24–26] Various forms of hydroxyapatite are available, including resorbable and nonresorbable and particulate or block material; moreover, the particles and blocks can be solid or porous. The advantages of using HA are that a second surgical site is not needed and HA is biocompatible and forms a direct bond with bone.[3] The disadvantages of HA are that it is not osteoinductive and does not contain osteoprogenitor cells.

Demineralized freeze-dried bone has been used for sinus augmentation because of its osteoinductive as well as osteoconductive potential.[32] In addition, like HA, DFDB eliminates the need for a second surgical site. However, the osteoinductive properties of DFDB may be altered by harvesting, sterilization, and storage techniques.[37]

While many different materials are used to augment the maxillary sinus for the placement of endosseous implants, it is not clear whether the various materials are equally capable of supporting implants. This review attempted to systematically identify all of the published studies reporting survival rates for implants placed in augmented maxillary sinuses. Because most reports include only a small number of patients and implants, the authors had hoped that data could be combined for analysis and comparison of the different augmentation materials. However, no clinical studies comparing the different augmentation materials were identified. Therefore, data analysis was done using studies that met simple criteria.

Meta-analysis has *significant* limitations. The validity of the analysis depends on the quality and the similarity of the studies. None of the studies analyzed was a randomized clinical trial, and the patient populations in the reports were probably dissimilar with respect to age, gender, medical problems, and so forth. The outcome measures, criteria for success, and surgical techniques varied from study to study, and included such uncontrolled variables as different survival criteria and implant type, delayed versus immediate implant placement, variable healing time before loading, and disparate management of the autogenous graft.

Meta-analyses are affected not only by the quality of the reported data, but also by "publication bias." If investigators are unwilling to submit studies reporting implant failures, or if the publisher rejects articles that report negative results, only favorable studies will be identified for analysis. Such "publication bias" would distort the results of this review toward favorable as opposed to unfavorable outcomes.

Because of the limitations of the meta-analysis, *very conservative* conclusions can be drawn. Hypothesis testing *cannot* be done because of the limitations of the analysis and the quality of the reports that were identified.

However, even with its limitations, this review shows that implant survival in maxillary sinuses augmented with autogenous bone, HA/autogenous bone, HA/DFDB, and HA alone appears to be relatively stable after a period of 6 months (Table 4, Fig 2). Tidwell et al[26] and Bloomqvist et al[3] observed that

implant survival in adjacent nongrafted bone was similar to implant survival in grafted maxillary sinuses. In addition, the survival rates identified in this review were greater than those identified for implants placed in the posterior maxilla with poor-quality bone. Jaffin and Berman[38] reported a 40% implant failure rate in the posterior maxilla with poor-quality bone. The highest failure rate in the maxillary sinus grafted with autogenous bone alone, 17.5%, was reported by Bloomqvist et al.[3] The failure rates for autogenous bone/HA and DFDB/HA were also much lower than reported for the posterior maxilla with poor-quality bone.

Some clinicians have harvested core biopsy specimens when placing implants several months after augmenting the maxillary sinus.[13,18,20,24,28] It is encouraging that all of the specimens, including the ones harvested from sites grafted with HA alone, contained new bone, and that the amount of bone appears to increase with time. Wheeler et al[28] reported, however, that implant survival did not correlate with the quantity of bone in the graft site.

## Conclusions

This review reveals that implants placed in maxillary sinuses augmented with autogenous bone alone, HA/autogenous bone, HA/DFDB, and HA alone had similar survival rates. However, only one study each demonstrated the efficacy of HA alone and HA/DFDB. From this analysis of the literature, it is reasonable to say that the "gold standard" for bone graft material remains autogenous bone; however, with sound surgical technique, appropriate patient selection, and proper postoperative care, the survival rates identified in this review indicate that HA alone or in combination with DFDB or autogenous bone can be placed in the maxillary sinus to create support for endosseous implants. It is also interesting to note that the rate of implant survival in the augmented posterior maxillary sinus appears to be better than that in the posterior maxilla with bone of poor quality, but adequate quantity for implant placement. However, additional randomized clinical trials and/or follow-up studies are needed before final conclusions can be drawn concerning the long-term safety and efficacy of these augmentation materials.

## Acknowledgments

This study was supported in part by the National Institute of Dental Research Grant No. T35 DE07150.

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