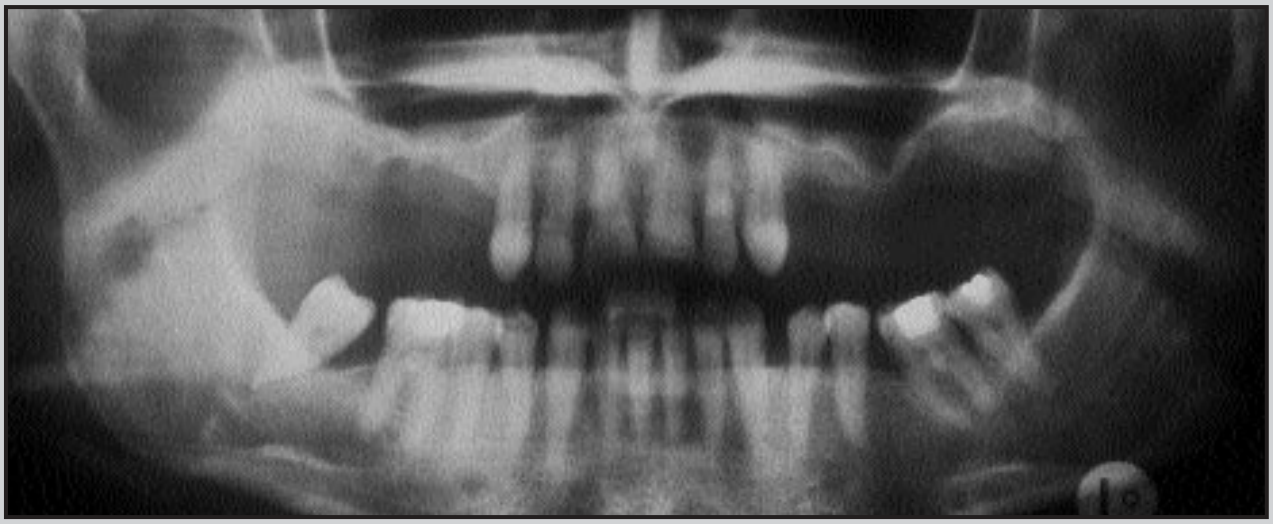
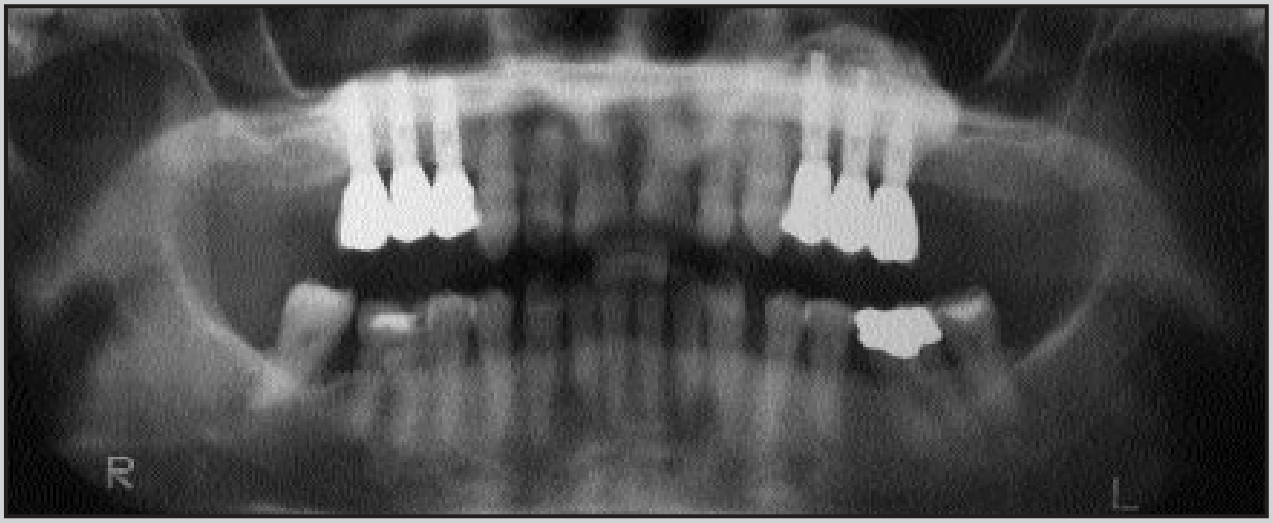
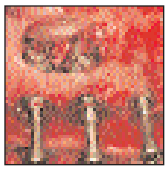




# Systematic Review of Survival Rates for Implants Placed in the Grafted Maxillary Sinus



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*Based on a systematic review of the literature from 1986 to 2002, this study sought to determine the survival rate of root-form dental implants placed in the grafted maxillary sinus. Secondary goals were to determine the effects of graft material, implant surface characteristics, and simultaneous versus delayed placement on survival rate. A search of the main electronic databases was performed in addition to a hand search of the most relevant journals. All relevant articles were screened according to specific inclusion criteria. Selected papers were reviewed for data extraction. The search yielded 252 articles applicable to sinus grafts associated with implant treatment. Of these, 39 met the inclusion criteria for qualitative data analysis. Only 3 of the articles were randomized controlled trials. The overall implant survival rate for the 39 included studies was 91.49%. The database included 6,913 implants placed in 2,046 subjects with loaded follow-up time ranging from 12 to 75 months. Implant survival was 87.70% with grafts of 100% autogenous bone, 94.88% when combining autogenous bone with various bone substitutes, and 95.98% with bone grafts consisting of bone substitutes alone. The survival rate for implants having smooth and rough surfaces was 85.64% and 95.98%, respectively. Simultaneous and delayed procedures displayed similar survival rates of 92.17% and 92.93%, respectively. When implants are placed in grafted maxillary sinuses, the performance of rough implants is superior to that of smooth implants. Bone-substitute materials are as effective as autogenous bone when used alone or in combination with autogenous bone. Studies using a split-mouth design with one variable are needed to further validate the findings.* (Int J Periodontics Restorative Dent 2004;24:565–577.)

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The placement of endosseous implants in the edentulous posterior maxilla may become a challenging procedure in the presence of reduced maxillary bone height. Bone grafting to the maxillary sinus floor is a well-accepted surgical procedure for increasing bone volume in the posterior maxilla. The sinus floor elevation procedure to facilitate implant placement in the severely atrophic posterior maxilla was first presented in the late 1970s,[1] and the first article on this subject was published in 1980.[2] The latter study used autogenous cancellous bone and marrow from the lateral iliac crest as the graft material and adopted a modified Caldwell-Luc procedure to enter the maxillary sinus. Since the publication of that article, other sinus grafting techniques have been reported, and several bone-substitute materials have been used to reduce the morbidity of treatment while maintaining high levels of success. Many variables may have an influence on the outcome of the sinus graft procedure in combination with implant treatment; following are the most relevant.

Autogenous bone has long been considered the gold standard graft material because of its osteoinductive and osteoconductive properties; however, many allografts, xenografts, and alloplastic graft materials have also been used, alone or in combination with autogenous bone, for the sinus augmentation procedure. The use of bone substitutes can result in reduced treatment morbidity by eliminating the need for harvesting autogenous bone from secondary surgical sites. Most of these materials form a scaffold for bone growth but have no osteoinductive potential. One objective of this review was to evaluate the effect of graft material on the implant survival rate and thereby determine if autogenous bone is, in fact, the gold standard.

Implant surface texture may qualitatively influence the process of early bone formation around implants. There is histologic and clinical evidence that a more favorable implant-bone interface is established on rough-surfaced implants than on implants with a smooth surface.[3–8] As the bone quality in maxillary sinus grafts may be comparable to that of the ungrafted posterior maxilla (type III or IV bone), the comparative survival rates of textured and smooth-surfaced implants placed in grafted maxillary sinuses were analyzed to determine if a statistical difference was present.

Sinus grafting and implant placement can be accomplished as either a one-stage (simultaneous) or two-stage (delayed) procedure. This decision is often dictated by the amount of residual crestal bone height. Crestal bone measuring less than 5 mm in height is usually considered insufficient to provide adequate mechanical stability for simultaneous placement of an endosseous implant. If less than 5 mm is present, it is generally preferred to delay implant placement by several months after the grafting phase, with this time dependent on the type of graft material, to allow for adequate graft maturation. More recent evidence, however, challenges this concept, showing that it is possible to successfully use the one-stage approach when residual crestal bone height is limited to as little as 1 mm.[9,10] One objective of the present review was to evaluate the reported outcomes for these two procedures to determine if specific recommendations relative to implant placement timing could be made.

The surgical approach used to enter the maxillary sinus is another variable that may influence the treatment outcome. The classic Caldwell-Luc lateral approach is today the most widely used surgical procedure for sinus elevation, but less invasive alternatives have been introduced, the most relevant being the osteotome technique.[11]

The 1996 Sinus Consensus Conference (SCC) presented a review based on a wide database of patients treated by the sinus graft procedure.[12] One purpose of the SCC was to examine the influence of parameters such as the graft material used and implant placement timing on the success of treatment. After the SCC, the number of patients treated by the sinus graft technique in combination with implant placement increased dramatically, as has the number of clinical reports.

The goal of this article is to review the survival rates of implants placed in grafted maxillary sinuses, based on clinical reports from 1986 to 2002. Attention was focused on the influence of the following variables: graft material, implant surface, and simultaneous versus delayed procedure. The influence of follow-up duration on implant survival rate was also evaluated.

## Method and materials

### *Search protocol*

A computer search of electronic databases (MEDLINE 1986 to 2002, Embase 1988 to 2002, and The Cochrane Central Register of Controlled Trials) was performed. Keywords such as "maxillary sinus," "sinus lift," "sinus augmentation," "sinus elevation," "sinus graft," "bone grafting," "dental implants," and "endosseous implants" were used, alone and in combination, to search the databases. Non–English language publications were included. The search was limited to studies involving human subjects. Restrictions were not placed regarding the type of study design. Clinical papers were classified as randomized controlled trials, controlled trials, case series, and retrospective studies. Additionally, a hand search of the following journals from 1986 to December 2002 was performed: *The International Journal of Oral & Maxillofacial Implants, Clinical Oral Implants Research, The International Journal of Periodontics & Restorative Dentistry, Implant Dentistry,* and *The Journal of Oral & Maxillofacial Surgery.* A further search was performed through the bibliographies of all relevant papers and review articles.

### *Selection and data abstraction*

The review of the articles obtained from the above search was accomplished in two consecutive screenings. In the first screening, two independent examiners reviewed the titles and abstracts according to the following inclusion criteria: *(1)* the article was a clinical report; *(2)* root-form implants were used; *(3)* mean follow-up was at least 6 months from implant placement; and *(4)* implant survival rate was either clearly indicated or calculable from data reported in the paper. When necessary, the complete text of the article was obtained and reviewed to find the required information. Multiple publications of the same pool of patients, when ascertained, were excluded from the database. Disagreements between the examiners were resolved by discussion. Inter-examiner agreement scores were calculated as kappa statistics on a 2 $\times$ 2 contingency table.

The second screening served to select those papers that provided sufficient data for a quantitative analysis of the influence of various factors on the implant survival rate. The complete text of all articles that passed the first screening was reviewed by the same examiners using a data extraction form. The inclusion criteria were modified to become more selective: *(1)* at least 20 sinus elevations were performed; *(2)* mean follow-up was no less than 12 months of implant loading, or the follow-up range exceeded 2 years; *(3)* fewer than 5% of the patients were lost to follow-up without explanation; *(4)* multiple interventions (eg, simultaneous ridge augmentation) were not performed; *(5)* access to the antrum occurred by the lateral window procedure; *(6)* graft material and implant placement timing (simultaneous or delayed procedure) were clearly reported; and *(7)* type of implants used was indicated. All studies excluded at this time were listed, along with the main reason for exclusion. When an article failed to meet more than one inclusion criterion, the reviewers were asked to indicate one as the most important reason for exclusion.

All types of clinical papers, independent of overall quality, were included if they met the above inclusion criteria. If sufficient information was available, the data were subgrouped. To fill in missing or inadequately reported data that would make the study more acceptable for inclusion, we attempted to obtain information by contacting the authors.

The primary outcome measurement chosen for this review was implant survival rate. An analysis using the patient as the analysis unit was also attempted. The data extracted from the articles were allocated to subgroups according to the following variables:

- *Type of graft material.* This group was divided into three subgroups: *(1)* autogenous bone alone; *(2)* autogenous bone in combination with bone substitutes; or *(3)* bone substitutes alone. Within the first subgroup, block and particulate grafts were further compared.

- *Type of implant surface.* This group consisted of two subgroups: *(1)* smooth surface; or *(2)* textured surface, regardless of degree and type of roughness.
- *Implant placement timing.* This group comprised two subgroups: *(1)* simultaneous procedure; or *(2)* delayed procedure.

A further evaluation was performed by combining a given graft material with different implant surfaces.

Those articles reporting on more than one subgroup were included in the specific subgroup analysis if it was possible to completely split data, thereby obtaining separate implant survival rates. The survival data of each subgroup were further divided according to the mean follow-up duration: *(1)* shorter than 3 years; or *(2)* equal to or longer than 3 years.

Studies at each level of evidence were analyzed separately as well as in a combined database. Heterogeneity between articles of similar study design was evaluated, considering the clinical characteristics of participants, the study protocol, the methodology, and the outcomes.

## Results

The literature search provided a total of 252 articles concerning the maxillary sinus graft procedure in association with implant placement. Of the 252 articles retrieved, 108 met the inclusion criteria of the first screening, whereas 39 articles met the inclusion criteria for quantitative data analysis.[9,13–50] The kappa scores for agreement between examiners for the first and second screenings were 0.81 and 0.78, respectively, indicating an excellent degree of accordance.

The 108 articles selected in the first screening constitute a database of clinical papers that may be useful to estimate the overall number of published cases treated by the sinus graft procedure in combination with implant therapy. More than 12,000 implants placed in the grafted sinuses of more than 4,000 patients are documented in the literature. These data show an overall implant survival rate of more than 92%. The 39 studies included after the final screening are listed in Table 1, along with the main characteristics of each study. They represent a 10-year period, from 1993 to 2002, and consist of 3 randomized controlled trials, 7 controlled trials, 10 case series reports, and 19 retrospective studies.

A total of 213 articles were excluded. The main reasons for exclusion of articles were inadequate number of cases (n = 57), paper not clinical in nature (n = 51), inadequate reporting of data (n = 47), alternate grafting technique (n = 24), inadequate follow-up (n = 22), and multiple publications of data from a single study (n = 12). Many of the excluded articles did not meet multiple inclusion criteria.

The 39 selected articles showed considerable differences in residual crestal bone height, implants placed, graft materials used, success and survival criteria, and follow-up time. Additionally, there were differences in study design, data reporting, outcome measures, and methods of statistical analysis. Because of such heterogeneity, no attempt was made to apply a formal meta-analytic technique to the material for a quantitative evaluation of the abstracted data.

All of the articles included in the final analysis provided data that considered the implant as the unit of analysis. Only a few papers specifically considered the graft (n = 3) and the prosthesis (n = 4) as the unit of analysis. In 24 articles, it was possible to determine the number of patients who experienced the failure of one or more implants. When considering the patient as the analysis unit, an overall success rate of 98% was estimated (31 cases, of 1,529 patients, failed). Because of the limited data available, no further analysis was possible using the patient, as opposed to the implant, as the unit of analysis.

**Table 1 Studies included in the final review**

| Study | Graft material | Implant surface | Simultaneous (1) or delayed (2) placement | No. of patients | No. of implants in graft | Overall survival (%) | Follow-up range (mean), in mo | Residual ridge height range (mean), in mm |
|---|---|---|---|---|---|---|---|---|
| **Randomized controlled trials** | | | | | | | | |
| Olson et al[13] | A/B/D/B+D/A+D | R | 1/2 | 29 | 120 | 97.5 | ≤ 71 (38.2) | NR |
| Tarnow et al[14] | Various types | R/S | 2 | 12 | 55 | 96.4 | 0–60 | NR |
| Wannfors et al[15] | A(b/p) | S | 1/2 | 40 | 150 | 84 | 12 | 2–7 |
| Total | | | | 81 | 325 | 91.08 | | |
| **Controlled trials** | | | | | | | | |
| Lozada et al[16] | Composite | R | 1/2 | 60 | 158 | 92 | ≤ 60 | < 3/≥ 3 |
| Valentini and Abensur[17] | E+C | R/S | 1/2 | 20 | 60 | 93.3 | (34.6) | < 5/> 5 |
| Blomqvist et al[18] | A(b+p) | S | 2 | 50 | 202 | 84.2 | 9–48 (34.1) | NR |
| Froum et al[19] | F/F+A/F+D/ F+A+D | R/S | 1/2 | 78 | 215 | 98.2 | 0–48 | NR |
| Buchmann et al[20] | A(b) | R/S | 1 | 50 | 167 | 100 | > 36 to > 60 | < 5 |
| De Leonardis and Pecora[21] | H | R | 1/2 | 57 | 130 | 98.5 | 12 | 1–7 |
| Tawil and Mawla[22] | C | S | 1/2 | 29 | 61 | 85.2 | 12–40 (22.4) | 4–8 |
| Total | | | | 344 | 993 | 93.55 | | |
| **Case series** | | | | | | | | |
| Keller et al[23] | A(b) | S | 1 | 20 | 66 | 92.4 | 12–72 | NR |
| Zinner and Small[24] | A+B/E | R | 1 | 50 | 215 | 98 | 7 to > 60 | — |
| Peleg et al[9] | A+D | R | 1 | 20 | 55 | 100 | 15–39 (26.4) | 1–2 |
| van den Bergh et al[25] | A | R | 2 | 42 | 161 | 100 | 12–72 (38.2) | < 4 to 8 |
| Valentini et al[26] | C | R | 2 | 15 | 57 | 98.2 | 38–58 (48) | 1–3.1 |
| van den Bergh et al[27] | E | R | 2 | 24 | 69 | 100 | 12–72 (34.6) | 4–8 |
| Bahat and Fontanessi[28] | A+B/A+C | S | 1/2 | 62 | 313 | 93 | 12–96 (37.3) | NR |
| Kahnberg et al[29] | A(b+p) | S | 1 | 26 | 91 | 61.2 | 12 to > 60 (39.8) | 1–5.5 (2.5) |
| Hallman et al[30] | A(b/p)/A+C/C | S | 2 | 21 | 111 | 91 | 12 | < 5 |
| Hallman et al[31] | A(b/p)/C | S | 2 | 20 | 79 | 92.4 | 12 | 1–3 (1.6)/2–5 (3.8) |
| Total | | | | 300 | 1,217 | 93.18 | | |
| **Retrospective studies** | | | | | | | | |
| Blomqvist et al[32] | A(b) | S | 1 | 49 | 171 | 82.5 | 14–58 (30) | NR |
| Hürzeler et al[33] | B/C/B+C/A+B | R | 1/2 | 133 | 340 | 98.8 | 12–60 (34.3) | < 4 to > 8 |
| Triplett and Schow[34] | A(b) | S | 1/2 | 50 | 145 | 86.9 | > 12 | NR |
| Wheeler et al[35] | A+B/B | R/S | 1/2 | 24 | 64 | 95.3 | 12–60 | < 5/5–7 |
| Block and Kent[36] | A(b) | R | 1 | 33 | 173 | 88.4 | 36–132 (70) | NR |
| Daelemans et al[37] | A(b+p) | S | 1 | 33 | 121 | 93.4 | ≤ 80 (40.2) | NR |
| Block et al[38] | A(b/p) | R | 1 | 16 | 73 | 95.9 | 63–126 (75) | NR |
| Fugazzotto and Vlassis[39] | C/D/E/G | R | 1/2 | 153 | 433 | 97 | 6–73 (32) | 2–5/> 5 |
| Kaptein et al[40] | A+B | R | 1/2 | 88 | 388 | 88.1 | ≤ 70 (55) | < 5/> 5 |
| Watzek et al[41] | A/A+B | R | 2 | 20 | 145 | 95.4 | 12–72 (38.8) | (2.1)/(2.3) |
| Johansson et al[42] | A(b) | S | 1 | 39 | 131 | 75.3 | 36 | < 5 |
| Keller et al[43] | A(b/p) | S | 1/2 | 37 | 139 | 85.6 | ≤ 144 (57.1) | NR |
| Khoury[44] | A(b+p) | R/S | 1 | 216 | 467 | 94 | 24–72 (49) | 1–5 |
| Lekholm et al[45] | A(b/p) | S | 1/2 | 55 | 280 | 81 | 36 | NR |
| Peleg et al[46] | A/D | R | 1 | 63 | 160 | 100 | 23–48 (31) | 3–5 |
| Lorenzoni et al[47] | C | R | 1/2 | 32 | 98 | 92.7 | ≤ 60 (40.4) | < 4/4–8/> 8 |
| Geurs et al[48] | Various types | R/S | 1/2 | 100 | 329 | 93.9 | (38) | < 4/4–8/> 8 |
| Raghoebar et al[49] | A(b/p) | S | 1/2 | 99 | 392 | 91.8 | 12–124 (59.6) | 1–7 (3) |
| Becktor et al[50] | A(b) | S | 1/2 | 81 | 329 | 79.6 | 22–105 (64.2) | NR |
| Total | | | | 1,321 | 4,378 | 90.59 | | |
| **Overall total** | | | | 2,046 | 6,913 | 91.49 | | |

A = autogenous bone (b = block; p = particulate); B = hydroxyapatite (HA); C = Bio-Oss (anorganic bovine bone); D = demineralized freeze-dried bone allograft; E = freeze-dried bone allograft; F = Osteograf/N; G = tricalcium phosphate; H = calcium sulfate; S = smooth; R = rough (eg, HA coated, titanium plasma sprayed, acid etched); NR = not reported.

**Table 2** Overall implant survival rates according to graft material

| Subgroup | No. of studies | No. of patients | No. of implants | % of implants | No. of implant failures | Survival rate (%) |
|---|---|---|---|---|---|---|
| **Autogenous** | 20 | 968 | 3,398 | 49.15 | 418 | 87.70 |
| < 36 mo | 6 | 220 | 767 | 11.10 | 116 | 84.88 |
| > 36 mo | 14 | 748 | 2,631 | 38.06 | 302 | 88.52 |
| **Combined** | 13 | 575 | 2,011 | 29.09 | 103 | 94.88 |
| < 36 mo | 10 | 422 | 1,298 | 18.78 | 34 | 97.38 |
| > 36 mo | 3 | 153 | 713 | 10.31 | 69 | 90.32 |
| **Bone substitutes** | 12 | 391 | 1,120 | 16.20 | 45 | 95.98 |
| < 36 mo | 9 | 332 | 915 | 13.24 | 36 | 96.07 |
| > 36 mo | 3 | 59 | 205 | 2.97 | 9 | 95.61 |
| **Not classified** | 2 | 112 | 384 | 5.55 | 22 | |
| **Total** | | 2,046 | 6,913 | 100.00 | 588 | |

**Table 3** Overall implant survival rates according to implant surface texture

| Subgroup | No. of studies | No. of patients | No. of implants | % of implants | No. of implant failures | Survival rate (%) |
|---|---|---|---|---|---|---|
| **Smooth** | 19 | 726 | 2,827 | 40.89 | 406 | 85.64 |
| < 36 mo | 9 | 281 | 991 | 14.34 | 135 | 86.38 |
| > 36 mo | 10 | 445 | 1,836 | 26.56 | 271 | 85.24 |
| **Rough** | 18 | 854 | 2,862 | 41.40 | 115 | 95.98 |
| < 36 mo | 9 | 540 | 1,516 | 21.93 | 29 | 98.09 |
| > 36 mo | 9 | 314 | 1,346 | 19.47 | 86 | 93.61 |
| **Not classified** | 5 | 466 | 1,224 | 17.71 | 67 | |
| **Total** | | 2,046 | 6,913 | 100.00 | 588 | |

**Table 4** Overall implant survival rates according to implant placement timing

| Subgroup | No. of studies | No. of patients | No. of implants | % of implants | No. of implant failures | Survival rate (%) |
|---|---|---|---|---|---|---|
| **Delayed** | 23 | 773 | 2,871 | 41.53 | 203 | 92.93 |
| < 36 mo | 14 | 424 | 1,331 | 19.25 | 93 | 93.01 |
| > 36 mo | 9 | 349 | 1,540 | 22.28 | 110 | 92.86 |
| **Simultaneous** | 27 | 1,022 | 3,079 | 44.54 | 241 | 92.17 |
| < 36 mo | 14 | 471 | 1,393 | 20.15 | 88 | 93.68 |
| > 36 mo | 13 | 551 | 1,686 | 24.14 | 153 | 90.93 |
| **Not classified** | 4 | 251 | 963 | 13.93 | 144 | |
| **Total** | | 2,046 | 6,913 | 100.00 | 588 | |

### *Graft material*

Data from all included studies, except for 2 papers (accounting for 112 patients and 384 implants), could be allocated to at least one of the three subgroups. In the subgroup using combination grafts, seven different graft materials were used in combination with autogenous bone: demineralized freeze-dried bone allograft (DFDBA; 6 studies), hydroxyapatite (HA; 4 studies), Bio-Oss (Geistlich; 4 studies), OsteoGraf/N (Dentsply/Ceramed; 3 studies), Int-200 (Interpore; 2 studies), OsteoGraf/N + DFDBA (1 study), and OsteoGraf/N + freeze-dried bone allograft (1 study). In the subgroup using only bone substitutes, twelve different graft materials were used: Bio-Oss (6 studies), DFDBA (5 studies), HA (3 studies), OsteoGraf/N + DFDBA (2 studies), FDBA (1 study), OsteoGraf/N (1 study), β-tricalcium phosphate (1 study), calcium sulphate (1 study), HA + DFDBA (1 study), DFDBA + Bio-Oss (1 study), HA + Bio-Oss (1 study), and DFDBA + Int-200 (1 study). An analysis of the survival rates for each type of material was beyond the aim of the present study. A recent systematic review of histologic data in the literature highlights the performance of all the anorganic bone additives used in the sinus floor augmentation procedure.[51]

Table 2 shows the distribution of data in the subgroups. The overall survival rate for 100% autogenous bone grafts was lower with respect to composite grafts containing autogenous bone and 100% bone-replacement grafts. Within the autogenous graft subgroup, the influence of using the graft either as a block or in particulate form was examined. When considered separately, block grafts, block plus particulate grafts, and particulate grafts alone had survival rates of 82.9% (384 patients, 1,458 implants), 89.4% (407 patients, 1,225 implants), and 92.5% (113 patients, 490 implants), respectively. This suggests that either the addition of particulate graft or the use of particulate grafts alone would improve implant survival rates, as opposed to using autogenous block grafts alone. Long-term reports are more numerous for autogenous bone than for other subgroups; conversely, long-term studies using bone substitutes alone are still scarce.

Minimal data come from studies with a high level of evidence, such as randomized controlled trials. It can be noted, however, that similar results are reported at all study evidence levels.

### *Implant surface*

The survival rates of smooth-surfaced implants were compared to rough-surfaced implants, without taking into consideration the degree of roughness, type of coating, or procedure adopted to roughen the implant surface (Table 3). Based on the above classification, implants with a smooth surface displayed a mean survival rate of 85.64%; implants with textured surfaces displayed a mean survival rate of 95.98%. Five articles accounting for 1,224 implants could not be classified. In all of these articles, more than one implant type was used, but separate survival rates for each type were not reported. The differences in implant survival rates observed between studies of differing evidence levels were minimal.

### *Combining graft material and implant surface*

A further analysis showed that 69.5% of all implants placed in autogenous bone had a smooth surface, and they accounted for 87.8% of the total failures reported for autogenous bone. All implants used in combination with autogenous block grafts had a smooth surface. In comparison, the combination of rough-surfaced implants with particulate autogenous grafts achieved an implant survival rate of 94%. Ninety percent of the implants placed in materials other than autogenous bone (the subgroup displaying the highest implant survival rate, 95.98%) had a rough surface. Smooth-surfaced implants placed in the latter subgroup had only an 87.96% survival rate.

### *Implant placement timing*

Table 4 presents the survival rates of implants placed according to either the simultaneous or delayed protocol. The overall implant survival rates

were similar for the two subgroups. Four articles that reported on both simultaneous and delayed procedures were not classifiable because separate survival rates could not be estimated. Similar survival rates were also observed between delayed and immediate placement when the data were evaluated according to study design.

## Discussion

The number of published reports on the sinus graft procedure has rapidly increased since the SCC. A large percentage of the articles consist of histologic studies and case reports with a low level of evidence. The present review isolated studies of similar design and found no difference in overall implant survival rate with regard to level of evidence. A similar finding was reported in a recent systematic review.[52]

Published human data pertaining to the sinus elevation procedure have been generally reported either in the form of clinical reports on implant survival over a given period using one or more grafting materials and one or more implant types and/or as histologic/histomorphometric analyses of the performance of a sinus graft material. Survival rates relative to a low sample size may be misleading. We chose to include those studies that treated at least 20 cases (grafted sinuses) followed up for no less than 1 year after loading, for which the lateral window technique was used to enter the maxillary sinus. After the initial screening, it was evident that reports concerning other techniques (eg, osteotome sinus elevation) are still scarce. A different surgical procedure constitutes a further source of variability. Because of the strict inclusion criteria of the final screening, we had to exclude many excellent and detailed papers because the low number of cases reported did not contribute significantly to the data analysis in terms of implant survival rate.

The overall implant survival rate found in the present review (91.49%) is similar to that reported by the SCC (90.0% for implants with at least 3 years of function).[12] In that conference, 38 clinicians were asked to fill out a form listing all the parameters useful for a detailed analysis of survival rates, especially the graft material used. Many life tables (Kaplan-Meier statistics) were compiled for each parameter considered, as this is the ideal type of analysis when using implant survival rate as the primary outcome. This was not possible in the present study because only a few of the selected articles describe implant survival rate in the form of a life table analysis.

Another source of heterogeneity is the criteria used for reporting implant survival/success, which differ from paper to paper. Furthermore, some articles do not clearly report those criteria in the text. The number of reported failures was extracted from the data, without attempting to unify the success criteria, and overall implant survival data were calculated.

From its inception, the sinus grafting technique has relied mostly on autogenous bone as the graft material. Autogenous bone is considered the gold standard for intraoral bone grafting because of its osteoinductive and osteoconductive properties; however, it has some shortcomings, including the possible requirement for hospitalization for an extraoral harvesting procedure or the need for a second intraoral site and increased morbidity. Furthermore, autogenous bone grafts

have been reported to have a history of greater than average resorption,[53,54] leading to subsequent sinus repneumatization and/or implant failure.

These limitations may be overcome by using autogenous bone as part of a composite bone-replacement graft. The use of bone-substitute materials has been advocated to replace or minimize the use of autogenous bone in the sinus graft procedure. Many allogeneic, xenogeneic, and alloplastic materials have been developed for use alone or in combination with autogenous bone in sinus grafting procedures. The present review supports the statement that bone-substitute materials, used alone or in combination with autogenous bone, may be at least as effective as autogenous bone alone. Autogenous bone in particulate form seems to provide better outcomes compared to block grafts and therefore may be the preferred choice. These findings are confirmed in the systematic review by Wallace and Froum[52] that reports an 80.40% implant survival rate for iliac block grafts, compared to 94.83% for particulate grafts.

The SCC drafted two consensus statements pertaining to bone grafting materials: *(1)* autogenous bone is appropriate for sinus grafting; and *(2)* allografts, alloplasts, and xenografts alone or in combination may be effective as graft materials in selected clinical situations.[12] This distinction was in part due to a lack of evidence regarding the performance of bone substitutes. Since that conference, the number of articles showing successful use of bone graft substitutes has rapidly increased. This reported success is based on both the histologic evidence of matured sinus grafts and the excellent survival rates of implants placed in these grafts. Bone-replacement grafts can be successful in the absence of autogenous bone.[12,52,55] It is difficult, if not impossible, to make a definitive statement concerning the superiority of bone substitutes compared to 100% autogenous bone. While the existing data are compelling, there is as yet not a significant number of randomized controlled trials reporting on this subject; therefore, conclusions have to be based on the results of study designs of a lower level of evidence (eg, case reports, longitudinal studies).

It may be difficult to determine whether the implant survival rate is due to the graft material used or to the surface characteristics of the implants placed in these grafts. A textured implant surface may retain the blood clot in direct contact with the surface, whereas the clot may retract away from a smooth surface.[56] In the former case, so-called contact osteogenesis (bone apposition starting from the implant surface) occurs. This process leads to a more favorable implant-bone interface compared to distance osteogenesis, which usually occurs with smooth surfaces and results in bone formation close to, but not in direct contact with, the implant surface. Clinical and histologic studies show the superiority of implants with textured as opposed to smooth surfaces in the

human posterior maxilla.[5,6] The ability of a textured surface to enhance the process of bone formation around implants may become more evident when implants are placed in poor-quality bone or high-risk patients such as smokers[7] or diabetics.[57] The results of the present analysis are similar to those reported by Wallace and Froum[52] and confirm that in the sinus graft procedure, the survival of implants with textured surfaces is greater than that of implants with a machined surface. A further analysis in the present review combined graft material and implant surface data and demonstrated that the low implant survival rate calculated for 100% autogenous bone grafts could be at least in part explained by the fact that most of the implants placed in them (69.5%) had a smooth surface.

The ability of an implant surface to form a stable implant-bone interface in the type III or IV bone that normally results from sinus augmentation surgery should be considered a modulating factor. The choice of implant surface, as well as graft material, may be critical, as they are the most important variables under the control of the clinician.

The present analysis showed that the survival rate of implants placed in the grafted sinus is substantially independent of the adoption of either the simultaneous or delayed protocol. Similar implant survival rates were reported with both procedures, in agreement with other studies.[12,52] The choice of procedure is often dictated by the amount of residual crestal bone in the posterior maxilla: If it is insufficient to guarantee adequate mechanical (primary) stability to implants, the delayed protocol should be adopted, and the implants can be placed after maturation and consolidation of the graft. When the matured bone graft is predominantly responsible for both mechanical and biologic implant stability, the use of a composite graft with an autogenous component should be considered. The increased volume of mineralized bone that results from such a graft[19,26] may ultimately lead to a more stable graft with greater implant-bone contact and therefore provide a more favorable prognosis for implant survival.

Ideally, multiple implants placed in a single patient should not be treated as independent units. An analysis for clustered survival observations should be performed, as this may provide more reliable statistical inference.[58,59] Such analysis is impractical in a review of the literature, as most papers report results in terms of implant survival rate, and it is not feasible to access all clinical records of each patient to identify the existence of cluster failures.

Many additional confounding variables may influence the outcome of the sinus graft procedure. Examples are the use or nonuse of a membrane to cover the bone window, amount of residual bone height between the sinus floor and alveolar crest, graft maturation time (in the two-stage procedure), other concomitant oral bone grafts, implant macrogeometry (shape, length, and width), patient age and gender, smoking habits, kind of prosthetic reconstruction, and type of occlusal antagonist. It was not possible to isolate these variables in the present analysis, as data reporting was heterogeneous between papers and complete information on each patient was rarely provided.

Follow-up duration is a factor considered of importance for an implant survival analysis. To combine results from different studies, it is important that the follow-up duration be the same or that a standard reference follow-up length be adopted (eg, 1 or 3 years of function). However, the evidence indicates that after a minimum of 1 year of loading, there is not a significant difference in implant survival over time.[52]

## Conclusions

Sinus grafting is now considered a safe and well-documented procedure to prepare an environment in which dental implants may have an excellent prognosis. Appropriate patient selection, careful evaluation of presurgical anatomy and oral health, sound surgical technique, and proper postoperative care represent key factors for the success of the procedure. The choice of the type of graft material and the implant micromorphology may significantly influence the outcome of the treatment. Within the limits of this systematic review, the following conclusions can be drawn:

1. The performance of rough-surfaced implants is superior to that of smooth-surfaced implants.
2. Grafts using bone-substitute materials are as effective as autogenous bone, either when used alone or in combination with autogenous bone.

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