Comparative Clinical Results After Implant Placement in the Posterior Maxilla With and Without Sinus Augmentation

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Purpose: *The objective was to compare implants in the posterior maxilla with or without sinus floor augmentation.* ***Materials and Methods:*** *A retrospective study was conducted of patients who received implants in the posterior maxilla. All patients received solitary, implant-retained fixed partial dentures or crowns. A standardized form for implant treatment was used to document the follow-up examination. The different parameters were initially analyzed descriptively by frequency distribution, measure of central tendency, and statistical spread. A 95% level of significance was set for all tests.* ***Results:*** *A total of 76 patients with 141 dental implants in the posterior region of the maxilla were evaluated. Fifty-one patients with 71 implants received prior no augmentation (sinus floor elevation) and composed the control group. Twenty-five patients with 70 implants received an additional bone transfer prior to implant placement. The mean age of the patients at time of the follow-up examination was 49.7 years in the overall group, 52.6 years for men and 46.7 years for women. The implants inserted in an augmented area had similar implant stability and implant loss results after a mean functional observation period of 1.6 years (range, 0.5 to 4.7 years) compared to those inserted without augmentation. Augmented implants exhibited less peri-implant bone resorption.* ***Conclusions:*** *The outcomes for implants with augmentation were similar to those without augmentation.* (Comparative Cohort Study) Int J Oral Maxillofac Implants 2008;23:289–298

Key words: *comparative study, peri-implant bone resorption, posterior maxillary region, sinus floor elevation*

Implant insertion in the posterior maxilla can be problematic due to insufficient vertical and horizontal bone volume and the proximity to the maxillary sinus.[1,2] In addition, the bone quality is often unfavorable. The cancellous bone is often of low density.[3,4] The technique of sinus floor augmentation was developed to increase the vertical bone level to accomplish primary stability of endosseous implants.[5] Sinus augmentation has proven to be a safe procedure with predictable outcomes.[6,7]

With only thin cortical bone and low-density cancellous bone, the posterior maxilla offers low mechanical resistance.[8] In the posterior maxillary region, vertical resorption of the jawbone and pneumatic enlargement of the maxillary sinus may leave only a thin bone lamella.[9]

With respect to such difficulties, autologous bone transplantation or artificial bone grafting materials may be used to produce a satisfactory implant site.[10–15] The maxillomandibular distance has to be considered with respect to the intended prosthetic restoration. Graft fixation can be obtained by direct fixation with immediately inserted dental implants or by osteosynthesis of the bone graft, with implantation performed after complete integration of the bone graft.[16,17]

In the classical sinus augmentation, an implant site is created by perforating the buccal osseous margin of the antrum, lifting the mucous membrane of the antrum, and inserting bone or grafting material into the created antrum lumen. This treatment was first described by Boyne and James in 1980. The

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internal sinus lift is advantageous compared to external augmentation in cases where the interocclusal distance should not be affected.[11]

Bone at least 4 to 5 mm thick is necessary to sufficiently secure implant stability in the unaugmented maxilla.[16] If there is not enough remaining local bone, only augmentation can be accomplished initially. After 4 to 6 months of osseous integration of the grafting material, dental implants can be placed.

The advantage of entrance through the lateral antral septum is the protection of tissue integrity in the region of the implants.[18] With this combination of augmentation and implant insertion, the spectrum of indications for osseous implants can be expanded to allow adequate treatment even under unfavorable circumstances. Schliephake and Neukam ascertained the statistically significant effect of implant length and retention in a clinical trial including 399 dental implants.[8] Implants with a length of at least 7 mm had a better prognosis than shorter implants.

Based on the demonstrated scientific standard of knowledge, it was hypothesized that implant placement in clinical areas affects the clinical and radiologic results. The purpose of the present study was to compare the clinical and radiologic peri-implant parameters for implants placed in the augmented or nonaugmented posterior maxilla.

MATERIALS AND METHODS

All patients were treated with fixed dentures, such as implant-supported single and splinted crowns. All patients were treated at the Department of Oral and Maxillofacial Surgery and the Department of Prosthodontics of the University of Erlangen-Nuremberg and gave their written consent to participate in the study. The patients were restored with fixed implant-borne restorations in the posterior maxilla. Augmentative procedures and implant placement were performed by 2 different maxillofacial surgeons. The follow-up examinations were accomplished following a standardized study protocol. Implant insertion was performed after a standardized healing period of 6 months after sinus floor augmentation. The implants were loaded 6 months after their insertion.

Besides general patient information, such as name, gender, and age, the patient's medical history, implantation, exposure, and prosthetic treatment were recorded. Furthermore, throughout the period for prosthetic loading, the level of bone resorption, stability, and the periodontal conditions were evaluated annually. The subjective judgment of the patients regarding their treatment was recorded. Vertical bone resorption was assessed based on orthopantographs. To minimize radiation exposure standardized periapical radiographs were not made.

The length of the implant was used as a reference for the measurement of bone resorption, which was expressed as a percentage of the implant length. Appraisal of bone quality was performed according to the classification of Lekholm and Zarb.[19] The stability of the implant was evaluated subjectively by the examiner and objectively by Periotest measurement (Gulden, Laurertal, Germany).[20] The rigidity of the implants was assessed with the usual scale for natural teeth.

For the evaluation of the peri-implant conditions in the area of the emergence profile, the sulcus fluid flow rate and the papillary bleeding index were measured. The sulcus fluid flow rate was measured with the Periotron 600 measuring device (Harco, New York, NY).[20]

The contexts of the various variables were analyzed using contingence tables and the test for independence. A significance level of 95% was chosen. The retention period was descriptively analyzed using the Kaplan-Meier method. All evaluations were performed using SPSS software version 6.1.2. for Windows (SPSS, Chicago, IL).

RESULTS

Seventy-six patients with 141 implants were included in the present study. Seventy implants were inserted after preliminary sinus floor elevation. These 70 implants were distributed over 25 patients (12 women; 13 men). No patient dropouts were observed during the follow-up evaluation. The overall mean age of the patients at the time of re-evaluation was 49.7 years (52.6 years in men and 46.7 years in women). Five (20%) of the 25 patients were smokers. Of these 70 implants, 33 (47.1%) were placed in women and 37 (52.9%) in men. Six patients received only 1 implant, 8 received 2 implants, and 4 had either 3 or 4 implants. One patient received 5 implants, 3 received 6 implants, and 1 received 9 implants.

Augmentation Material

In all 70 implant regions, both augmentation and implantation were performed with a temporal offset. Augmentation was achieved with autologous bone or a bone substitute material (Bio-Oss; Geistlich Biomaterials, Wolhusen, Switzerland). In addition to cancellous bone chips, autologous bone was extracted from the retromolar region, interforaminal region, or the iliac crest (Table 1). No combinations of the aforementioned graft materials were used.

Table 1 Distribution of Donor Regions

Donor region for bone grafts	Frequency	Percentage
Spina iliaca	34	48.6
Regio interforaminalis	17	24.3
Retromolar region	8	11.4
Cancellous bone	5	7.1
Bio-Oss	6	8.6
Total	70	100.0

Table 2 Distribution of Reasons for Tooth Loss

	Frequency	
Cause	Sinus augmentation group	Control group
Periodontitis	67.1	50.7
Caries	14.3	26.8
Genetically missing teeth	4.3	8.5
Trauma	4.3	4.2
Unknown	10.0	9.0
Total	100.0	100.0

Control Group

For a comparative assessment, a control group of patients who received dental implants without augmentation in the maxillary molar region restored with single or splinted crowns was selected. With the exception of this basic criterion, the control group was randomly chosen. The control group contained 51 patients (27 women, 24 men) with 71 implants.

Thirty-three patients (64.7%) in the control group received only 1 implant. The mean age of the control group was 54 years (55.3 years in male patients and 52.9 years for female patients). The peak age and the mean age were slightly higher than those of the sinus augmentation patients. Nine patients (17.6%) in the control group were smokers compared to 5 (20.0%) smokers in the sinus augmentation group.

Comparison of the Test and Control Groups

The control group had more patients who received a single implant than the sinus augmentation group, in spite of similar numbers of total implants. All inductive standard methods used for comparisons between 2 groups emanate from independent observance; this criterion is not fulfilled in cases of multiple implantation. Therefore, all of the following findings of standard tests should be interpreted as trend statements when *P* is near the critical value.

Patient Population. The 2 groups were quite similar with respect to mean age (49.7 years in the sinus floor augmented group and 54 years in the control group). The proportions of men and women were similar. Neither group had a significant number of patients with risk factors such as primary diseases or radiation of the augmented or implanted areas. The sinus augmentation group contained a higher percentage of smokers (20.0%, compared with 17.6% in the control group).

Causes of Tooth Loss. The most frequent cause of tooth loss was periodontal disease; the second most frequent cause was caries (Table 2).

Implant Database. There were 70 implants in the sinus augmentation group and 71 implants in the control group. In the sinus augmentation patients, sufficient primary stability was achieved after all implant insertions, and the implants were judged to be clinically stable. Two implants in the control group did not achieve sufficient primary stability. Postoperative antibiotic prophylaxis was used in 94.3% of the sinus augmentation patients and in 70.4% of the control group. No implant losses occurred in the sinus augmentation group. In the control group, the loss of 1 implant occurred in a patient where primary stability could not be achieved.

Period of Function. To critically assess the long-term success rates of the 2 groups, subjects in the sinus augmentation group and the control group with similar placement periods were chosen. The placement period was defined as the period between implant insertion and the day of the follow-up examination. If the period of function, defined as the period between prosthetic rehabilitation and the follow-up examination, is completely accomplished, the success of the implant was assumed. Figures 1 and 2 show the periods of function in the 2 groups. To verify possible differences in the idle period and the period of function between the 2 groups, the Kolmogorov-Smirnov test for the distribution of the 2 groups was used. For an examination of consistency of median idle periods and periods of function, the Mann-Whitney test was used. The Kolmogorov-Smirnov test declined consistency regarding idle periods ($P = .003$) as well as periods of function ($P < .001$). The Mann-Whitney test declined both cases for consistency concerning the median ($P = .0001$ in the period of function and $P = .0014$ for the idle period).

Bone Situation. The evaluation of bone quantity and bone quality was conducted with panoramic radiographs generated at the time of implant placement. All radiographs were evaluated by a single individual.

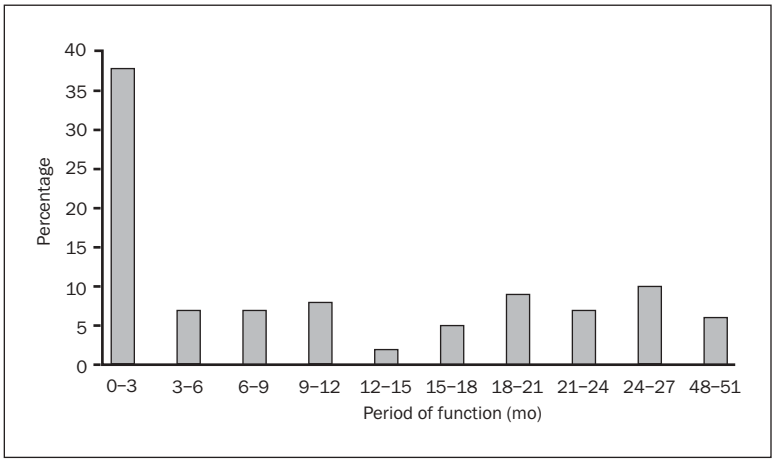
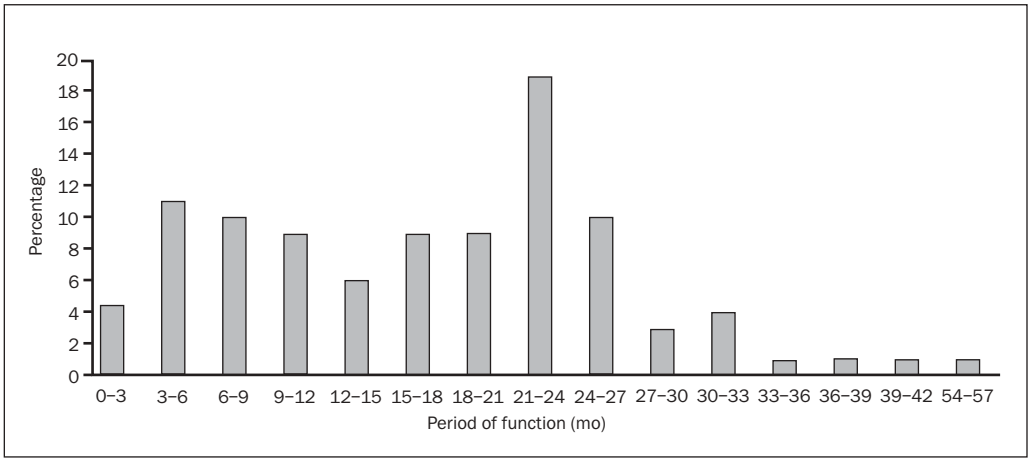


Fig 1 Period of function of implants of sinus augmentation patients.

Fig 2 *(Below)* Period of function of implants of control-group patients.



Bone Quantity. Initial bone quantity was measured preoperatively in both groups. A higher percentage of advanced or severe resorption was seen in the later sinus augmentation group (Table 3). Statistical comparison of the 2 groups was carried out using the Fisher exact test for the comparison of 2 probabilities. Therefore, the criteria had to be reduced to 2 statements. The grades "no resorption" and "moderate jaw bone resorption" were pooled in 1 group, and the remaining grades were pooled in another. The test suggested significant differences in bone quantity ($P < .001$), with the control group having better bone quantity.

Bone Quality. The bone quality of the 2 groups was compared based on the panoramic radiographs using the classification system of Lekolm and Zarb[19] (Table 4). Twice as much unfavorable bone quality (class 4) was found in the group with sinus floor augmentation compared to the control group. However, when classes 1 and 2 and classes 3 and 4, respectively, were pooled for a Fisher statistical comparison, the difference between the 2 groups was not significant ($P = .2075$).

Implant Length. In the sinus augmentation group, 57 (81.4%) of the inserted implants had a minimal length of 12 mm (Fig 3) compared to 23 (32.4%) in the control group (Fig 4). Shorter implants were used more often in the control group than in the sinus augmentation group. Therefore, 20 implants in the control group were shorter than 10 mm compared to only 5 in the sinus augmentation group.

Bone Loss. Bone resorption in the 2 groups during the idle period was determined by comparing the postoperative radiographs with radiographs made on the day of the follow-up examination. The implant was used as a reference parameter for the evaluation of bone loss. Twenty-nine (41.4%) of the implants in the sinus augmentation group exhibited bone loss. Of these, 26 implants showed 25% bone loss and 3 showed 50% loss. In the control group, 50 (70.4%) cases of bone loss were recognized, while in 21 cases no bone loss was observed (29.6%). Thirty-nine of the 50 cases with bone loss showed a bone loss of 25%, 7 had bone loss of 50%, and 4 had bone loss of up to 75% (Figs 5 and 6).

Table 3 Distribution of Bone Resorption Levels

Level of resorption	Sinus augmentation group		Control group	
	n	%	n	%
No resorption	0	0.0	8	11.3
Moderate resorption	10	14.3	36	50.7
Advanced resorption	24	34.3	23	32.4
Resorption of cancellous bone	27	38.5	3	4.2
Extreme resorption of cancellous bone	9	12.9	1	1.4
Total	70	100.0	71	100.0

Table 4 Distribution of Bone Quality

Level	Sinus augmentation group		Control group	
	n	%	n	%
Class 1	1	1.4	2	2.8
Class 2	15	21.4	11	15.5
Class 3	27	41.4	47	66.2
Class 4	25	35.7	11	15.5

Fig 3 Implant length of sinus augmentation patients.

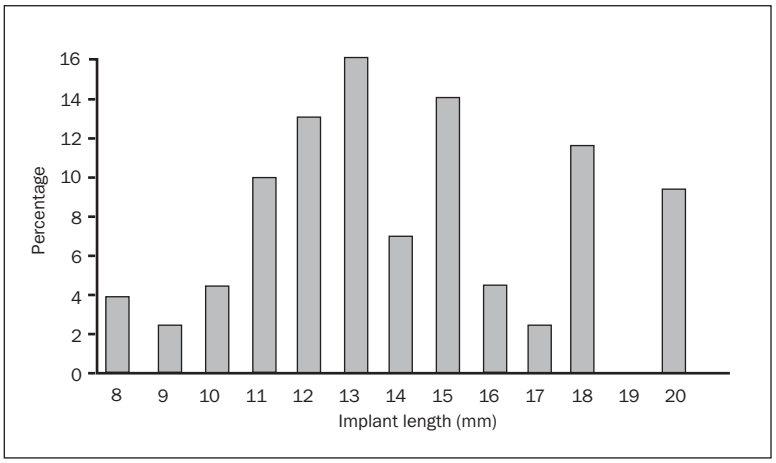
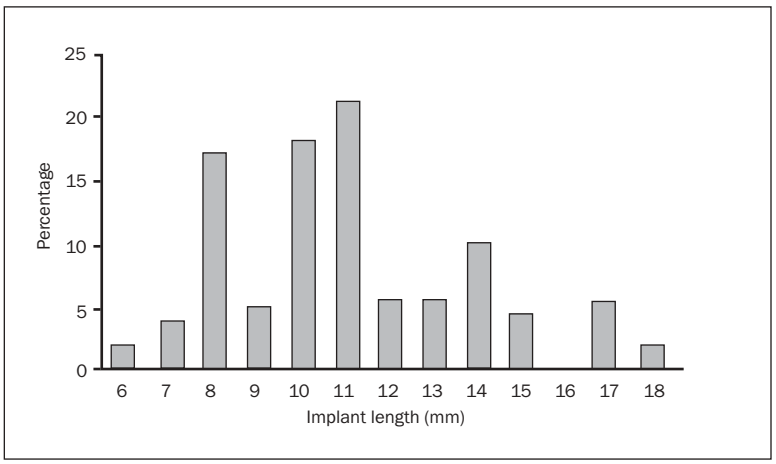


Fig 4 Implant length of control-group patients.



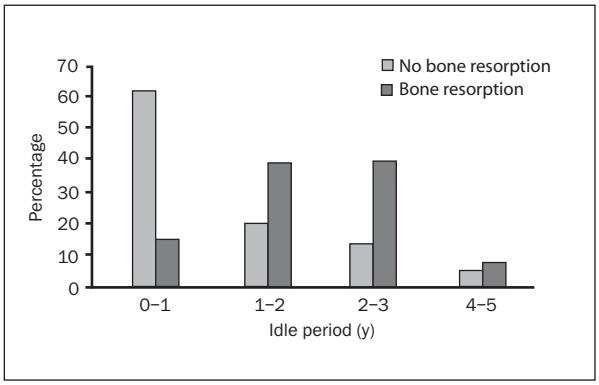


Fig 5 Idle periods of sinus augmentation patients divided into "bone resorption" and "no bone resorption" groups.

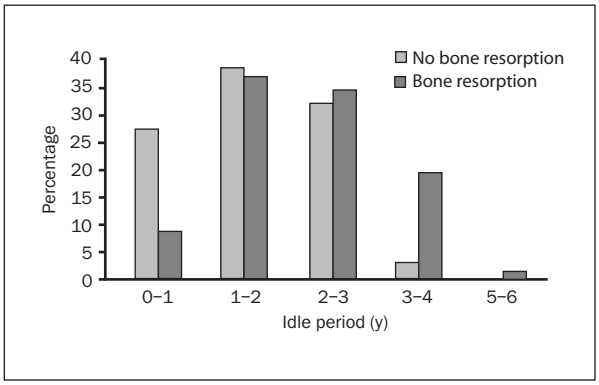


Fig 6 Idle periods of implants of the control group divided into "bone resorption" and "no bone resorption" groups.

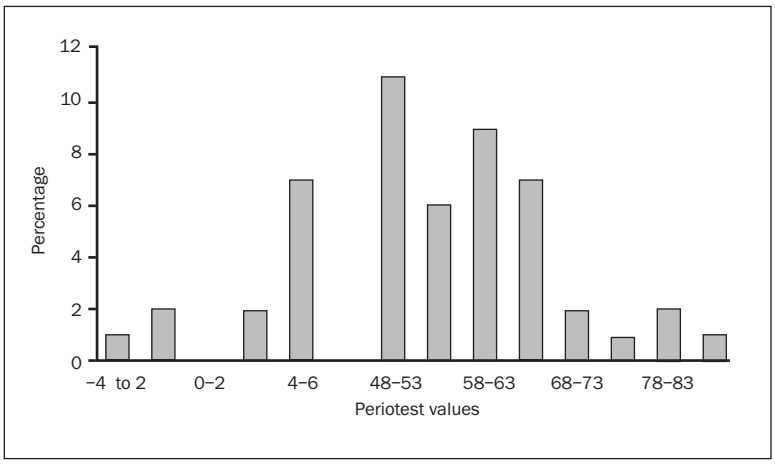


Fig 7 Periotest values in the sinus augmentation group.

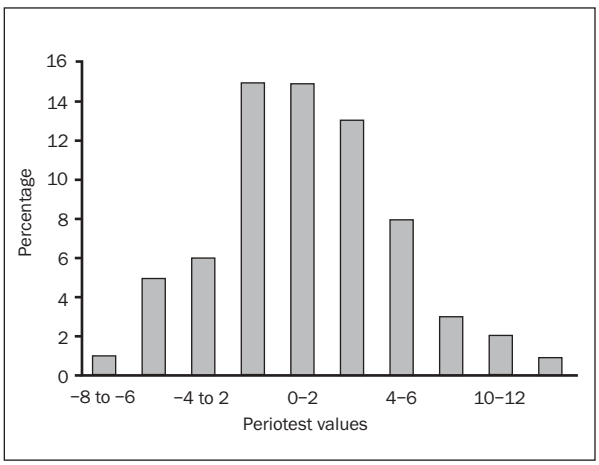


Fig 8 Periotest values in the control group.

For statistical analysis, bone loss was dichotomized as "existing" and "not existing" in both groups. The Fisher exact test comparison declined consistency ($P < .001$). Bone loss was more frequent in the control group. Furthermore, bone loss in both groups was compared with respect to the different idle periods and implant lengths. Group differences were evaluated by marginal regression models and calculated with the Mareg & Win Mareg software. Bone resorption was classified as "yes" or "no." In both groups there was a significant difference between "yes" and "no."

Implant Stability. In the sinus augmentation group, 69 of 70 implants were stable at the follow-up examination. One implant was palpably mobile. In the control group, implant mobility was palpable in 4 cases, while the remaining 67 implants were clinically stable. As a result of the different idle periods and the low fold number, no trend could be detected.

The results of the Periotest examination are shown in Figs 7 and 8. The variable "Periotest value" was regarded as consistent in the statistical analysis for both groups. Therefore, the Kolmogorov-Smirnov test for the examination of consistency of distribution and the Mann-Whitney test for verification of the consistency of the medians were applied to the data. Although the Kolmogorov-Smirnov test declined consistency ($P = .033$), the Mann-Whitney test did not decline consistency of the medians.

Sulcus Fluid Flow Rate. The sulcus fluid flow rate was compared in both groups as a measure of cur-

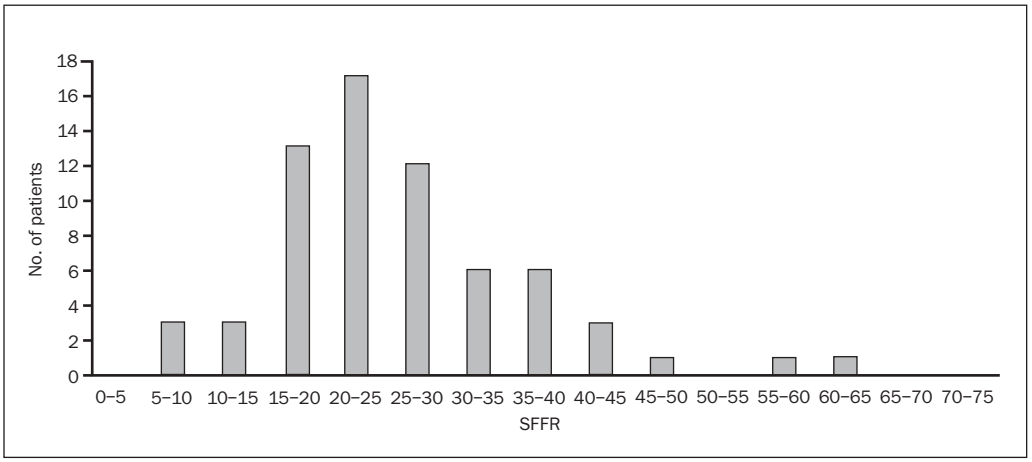


Fig 9 Sulcus fluid flow rates for the sinus augmentation group.

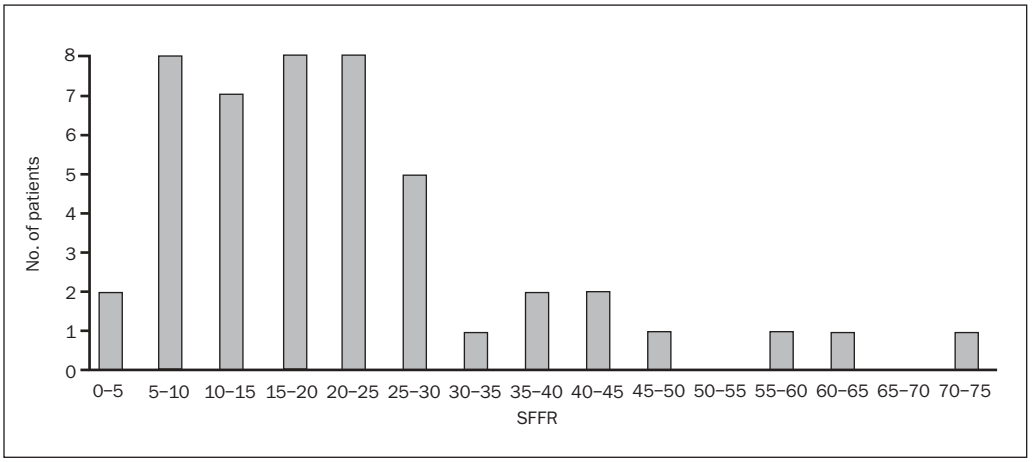


Fig 10 Sulcus fluid flow rates for the control group.

rent inflammation status. The sulcus fluid flow rates for both groups are shown in Figs 9 and 10. The sulcus fluid flow rate of both groups were considered consistent variables; thus, the Kolmogorov-Smirnov test and the Mann-Whitney test were applied. Both tests declined consistency ($P = .0035$ and $P = .007$). The peak value of the distribution for the sinus augmentation group was between 15 and 30; it was between 5 and 25 for the control group. The rates for the 2 groups did not differ significantly.

DISCUSSION

In the present study, 141 implants in 76 patients given fixed implant-borne restorations were evaluated. Twenty-five patients with a total of 70 implants received sinus floor augmentation prior to implantation. Although implant losses did not occur in these 70 implants, no conclusion for the long-term success of this method could be determined because the average idle period for these implants of 1.6 years was too short. However, several trends were noted.

The control and sinus augmentation groups contained similar numbers of implants. As it was not possible to obtain an appropriate control group, there were differences in idle periods, time of function, and the number of patients in the 2 groups. The mean implant length was longer in the sinus augmentation group (14.3 mm) than in the control group (11 mm). With augmentation of the sinus, a more favorable initial situation was created, which made the insertion of longer implants possible in this group. In contrast, this was not possible in the control group due to preliminary atrophic changes in the jawbones. In a study concerning 732 implants in the maxilla, Bahat[21] verified that the probability of loss depends significantly on the implant length,

with shorter implants being associated with a higher risk of loss.

Because of the more favorable leverage between the implant and denture and improved osseointegration because of a higher proportion of bone in the mating surface of the implant, it is generally preferable to insert longer implants. There is a tendency toward greater implant length in augmented areas of the sinus floor. However, whether sinus floor augmentation is preferable to implantation in the unaugmented posterior maxilla has not yet been completely determined. When there is unfavorable bone quality in the posterior maxilla, a higher loss rate may result, and some authors postulate that a minimal implant length of 10 mm is required in this region, a length which was achieved in all cases in the control group in the present study.[22]

No significant difference in bone quality was noted between the 2 groups, although the bone quantity was significantly higher in the control group. This was, of course, expected, since augmentative procedures are only indicated in cases where there is an insufficient amount of bone. Following the classification of Atwood, Watzek et al[23] recommended sinus floor augmentation for resorption class 4. Bone resorption was observed in 29 cases (41.4%) in the augmented patients during the observation period. In 26 cases, the resorption was less than 25%. In only 3 (4.3%) cases, the resorption was between 25% and 50%. No bone resorption was noted in the 41 remaining implants. In the control group (71 implants), 50 implants exhibited bone resorption, with up to 25% resorption in 39 implants and more than 50% in the remaining 11. Bone resorption rate in the control group was significantly greater. In a study by Adell et al,[6] 124 successfully inserted implants in the posterior maxilla showed a mean bone resorption of 1.5 mm. This represents an average description of an augmentation height of 10 mm. The majority of sinus floor augmentation patients in the present study had bone resorption in a similar range after 1 year. The relatively low bone resorption in the patients evaluated in the present study corresponds to the findings of Raghoebar et al,[24] who evaluated 93 implants with a mean bone resorption of less than 1 mm after 6 months in a group of 47 patients with sinus floor augmentation. In only 1 case was more resorption evident, but it was less than 25%.

Although the observation period was relatively short, the majority of resorption of augmented material occurred in the initial 6 months after augmentation. The proximate resorption is usually equivalent to atrophic changes in unaugmented areas. It appears that transplants in sinus floor augmentations show the usual resorption rates for augmentative procedures.[25,26] As mentioned earlier, the control group showed significantly greater bone resorption in the follow-up examinations. In a follow-up examination of 219 implants, increased bone resorption in the posterior maxilla was reported.[27] Capacity overload of the remaining bone by means of induced loading forces via implants may explain this phenomenon.

The comparison of the implant stability of the augmentation and control groups showed no significant differences between the clinical evaluation and the evaluation with the Periotest system. In both groups, more than 94% of the implants were clinically stable. As more than 90% of the implants showed clinical stability (98.6% in the sinus floor augmented group and 94.3% in the control group), no clinically relevant difference between the 2 groups was found.

In sum, the sinus floor augmentation group was at least equal to the control group with respect to implant stability and peri-implant bone resorption. The treatment can be considered successful during the observation period. Certainly no prognosis can be derived from these findings, because the observation period was relatively short, and not all the patients treated at the authors' clinic with sinus floor augmentation were evaluated. Nevertheless, there was no significant difference between implantation in augmented sinus floors and implantation in unaugmented tissue.

The peak sulcus fluid flow rates in the 2 groups were similar; the statistical analysis showed no consistency. Most of the values in the sinus floor group ranged between 15 and 30 and between 5 and 25 in the control group. In both groups, only a few explicitly higher values were found.

Sinus floor augmentation is a successful therapeutic procedure to improve the implant bed. Smiler et al[28] concluded that sinus floor augmentation is a good operative procedure in cases of atrophic jaw bone in the posterior maxilla. Jensen et al[29] achieved a success rate of 93.5% after 5 years for their sinus floor augmentations. Tidwell et al[9] achieved similar results in 48 patients who had received 203 implants.

Measurement of the amount of bone remaining in the posterior maxilla as an indicator by which to compare implantation in augmented bone with implantation in unaugmented bone is controversial, as is using the minimum implant length required in the posterior maxilla. Some authors postulate that a minimum of 10 mm of remaining bone is required for successful implantation without augmentative procedures in the maxilla.[30] Raghoebar et al[7] defines the limit at 8 mm, while the benchmark of Neukam et al[31] was between 8 and 10 mm. With the inevitable distortion of radiographic methods, no accurate

assessment of the remaining bone level can be conducted, leaving the implant length more or less a theoretical issue.

CONCLUSION

Due to its bone structure, the maxilla is less favorable for implantation, which leads to higher loss rates. A minimal implant length of 10 mm in the maxilla is postulated to improve the success rate. Therefore, favorable loading forces for the remaining bone are expected. In cases of advanced atrophy in the posterior maxillary region, only razor-thin bone levels remain, and in these cases the sinus floor augmentation can increase the bone level. This was demonstrated in the present study, where the implant length in the augmented group averaged 13.5 mm compared to 11 mm in the control group.

After a mean functional observation period of 1.6 years (range, 0.5 to 4.7 years), implants placed in regions with sinus floor augmentation were similar to those in a control group with single implantation in the posterior maxilla with respect to implant rigidity and implant loss. The augmented group appeared to be superior in terms of peri-implant bone resorption. With the observation period being relatively short in this study, no general statistical differences between implants placed in augmented regions and in the remaining alveolar crest could be drawn concerning clinical and radiographic parameters. Long-term success of sinus floor augmentation must be proven in studies with a longer observation periods.

REFERENCES

1. Razavi R, Zena RB, Khan Z, Gould A. Anatomic site evaluation of edentulous maxillae for dental implant placement. J Prosthodont 1995;4:90–94.
2. Ulm CW, Solar P, Gsellmann B, Matejka M, Watzek G. The edentulous maxillary alveolar process in the region of the maxillary sinus—A study of physical dimension. Int J Oral Maxillofac Surg 1995;24:459–467.
3. Misch CE. Density of bone: Effect on treatment plans, surgical approach, healing and progressive bone loading. Int J Oral Implantol 1990;6:23–31.
4. Wheeler SL, Holmes RE, Calhoun CJ. Six-year clinical and histologic study of sinus-lift grafts. Int J Oral Maxillofac Implants 1996;11:26–34.
5. Tatum H. Maxillary and sinus implant reconstructions. Dent Clin North Am 1986;30:207–229.
6. Adell R, Lekholm U, Grondahl K, Brånemark P-I, Lindstrom J, Jacobsson M. Reconstruction of severely resorbed edentulous maxillae using osseointegrated fixtures in immediate autogenous bone grafts. Int J Oral Maxillofac Implants 1990;5:233–246.
7. Raghoebar GM, Vissink A, Reintsema H, Batenburg RH. Bone grafting of the sinus floor of the maxillary sinus for the placement of endosseous implants. Br J Oral Surg 1997;35:119–125.
8. Graziani F, Donos N, Needleman I, Gabriele M, Tonetti M. Comparison of implant survival following sinus floor augmentation procedures with implants placed in pristine posterior maxillary bone: A systematic review. Clin Oral Implants Res 2004;15:677–682.
9. Tidwell JK, Blijdorp PA, Stoelinga PJ, Brouns JB, Hinderks F. Composite grafting of endosteal implants. A preliminary report of 48 patients. Int J Oral Maxillofac Surg 1992;21:204–209.
10. Saglam AA. The vertical heights of maxillary and mandibular bone in panoramic radiographs of dentate and edentulous subjects. Quintessence Int 2002;33:433–438.
11. Boyne PJ, James RA. Grafting of the maxillary sinus floor with autogenous marrow and bone. J Oral Surg 1980;38:613–616.
12. Black MS, Kent JN. Sinus augmentation for dental implants: The use of autogenous bone. J Oral Maxillofac Surg 1997;55:1281–1286.
13. Chan MF, Howell RA, Cawood JI. Prosthetic rehabilitation of the atrophic maxilla using pre-implant surgery and endosseous implants. Br Dent J 1996;181:51–58.
14. Cordioli G, Mazzocco C, Schepers E, Brugnolo E, Majzoub Z. Maxillary sinus floor augmentation using bioactive glass granules and autogenous bone with simultaneous implant placement. Clinical and histological findings. Clin Oral Implant Res 2001;12:270–278.
15. 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.
16. Wiltfang J, Schultze-Mosgau S, Merten HA, Kessler P, Ludwig A, Engelke W. X-ray, endoscopic and ultrasound evaluation of maxillary sinus following combined sinus floor augmentation and implant insertion. Oral Surg Oral Med Oral Pathol Oral Rad 2000;89:288–291.
17. Sailer HF. A new method of inserting endosseous implants in totally atrophic maxillae. J Craniomaxillofac Surg 1989;17:299–305.
18. Schlegel KA, Donath K. Bio-Oss—A reasonable bone substitute? Int J Biomater Med Implants 1998;8:201–209.
19. Lekholm U, Zarb A. Patient selection and preparation. In: Brånemark P-I, Zarb GA, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985:199–210.
20. Syrjanen SM, Alakuijala P, Markkanen SO, Markkanen H. Gingival fluid, beta 2-microglobulin and protein level as indicators periodontal disease. Scand J Dent Res 1989;97:500–504.
21. Bahat O. Brånemark system implants in the posterior maxilla: Clinical study of 660 implants followed for 5 to 12 years. Int J Oral Maxillofac Implants 2000;15:646–653.
22. Curtis TA, Ware WH. Autogenous bone graft procedures for atrophic edentulous mandibles. J Prosthet Dent 1977;38:366–379.
23. Watzek G, Weber R, Bernhart T, Ulm C, Haas R. Treatment of patients with extreme maxillary atrophy using sinus floor augmentation and implants: Preliminary results. Int J Oral Maxillofac Surg 1998;27:428–434.
24. Raghoebar GM, Brouwer TJ, Reintsema H, van Oort RP. Augmentation of the maxillary sinus floor with autogenous bone for the placement of endosseous implants: A preliminary report. J Oral Maxillofac Surg 1993;51:1198–1203.

25. Schlegel KA, Schultze-Mosgau S, Wiltfang J, Neukam FW, Ruprecht S, Thorwarth M. Changes of mineralization of free autogenous bone grafts used for sinus floor elevation. Clin Oral Implants Res 2006;17:673–678.
26. Schlegel KA, Fichtner G, Schultze-Mosgau S, Wiltfang J. Histologic findings in sinus augmentation with autogenous bone chips versus a bonine bone substitute. Int J Oral Maxillofac Implants 2003;18:53–58.
27. Schlegel KA, Hubbertz S, Kastner C. Verlustrate von Brånemark-Fixturen mit unterschiedlicher prothetischer Nutzung. Dent Implantol 1998;2:86–99.
28. Smiler DG, Johanson PW, Lozada JL, Misch C, Rosenlicht JL, Tatum OH Jr. Sinus lift grafts and endosseous implants. Treatment of the atrophic posterior maxilla. Dent Clin North Am 1992;36:151–186.
29. Jensen J, Sindet-Pedersen S, Oliver AJ. Varying treatment strategies for reconstruction of maxillary atrophy with implants: Results in 98 patients. J Oral Maxillofac Surg 1994;52:210–216.
30. Breine U, Brånemark PI. Reconstruction of alveolar jaw bone. An experimental and clinical study of immediate and preformed autologous bone grafts in combination with osseointegrated implants. Scand J Plast Reconstr Surg 1980;14:23–48.
31. Neukam FW, Hausamen JE, Scheller H. Knochentransplantation in Kombination mit enossalen Implantaten. Z Stomatol 1990; 87:125–138.