A Long-term Retrospective Study of Two Different Implant Surfaces Placed After Reconstruction of the Severely Resorbed Maxilla Using Le Fort I Osteotomy and Interpositional Bone Grafting

Claudio Marchetti, MD, DDS[1]/Francesco Pieri, DDS[2]/
Giuseppe Corinaldesi, MD, DDS[3]/Marco Degidi, MD, DDS[4]

Purpose: *In this retrospective study, the long-term survival and success rates of implants with 2 different surfaces placed in extremely atrophic maxillae augmented with Le Fort I osteotomy and interpositional bone grafts were assessed.* ***Materials and Methods:*** *In 12 consecutive patients (7 female, 5 male; average age, 55 years; age range, 47 to 63 years), the resorbed maxilla was reconstructed using Le Fort I osteotomy in combination with interpositional iliac bone grafts. After 5 to 6 months, machined or titanium plasma-sprayed implants were inserted. The patients were followed clinically and radiographically for 6 to 12 years (mean 102 ± 24.42 months) after prosthetic loading. Implant outcome in terms of survival and success using Albrektsson's criteria was analyzed.* ***Results:*** *In all cases, the bone-grafting procedures allowed implant placement. Of the 104 implants placed (53 machined and 51 titanium plasma-sprayed), 11 failed, resulting in an overall cumulative survival rate of 89.4%. When the success rate was calculated using the defined criteria, the cumulative success rate was 67.3%. The respective survival and success rates were 86.8% and 66.0% for the machined implants and 92.2% and 68.7% for the titanium plasma-sprayed implants. The mean marginal bone resorption was 2.91 ± 0.77 mm (range, 0.6 to 4.9 mm) around machined implants and 2.72 ± 0.84 mm (range, 0.7 to 5.3 mm) around titanium plasma-sprayed implants. No significant differences in survival, success rate, or marginal bone resorption were found between the 2 implant groups.* ***Conclusions:*** *Le Fort I osteotomy combined with bone grafts and delayed implant placement gave predictable long-term results. There was a distinct relationship between implant survival and the long-term success rate. The implant surface had no significant effect on the survival, success rate, or marginal bone resorption.* Int J Oral Maxillofac Implants 2008;23:911–918

Key words: *alveolar bone augmentation, atrophic maxilla, autogenous bone graft, dental implants, follow-up study, Le Fort I osteotomy*

Severe atrophy of the maxilla combined with a reversed jaws relationship (Class VI, according to the Cawood and Howell classification[1]) requires extensive maxillary bone reconstruction using Le Fort I osteotomy in combination with interpositional bone grafts and implant placement.[2–5] This augmentation technique allows repositioning of the maxilla in both the vertical and horizontal directions, thereby correcting the unfavorable maxillomandibular relationship. Moreover, it offers predictable integration of the inlay bone grafts. Some studies have reported on the use of Le Fort I osteotomy in combination with interpositional bone grafts with either simultaneous[6–8] or delayed implant placement,[9–14] but little is known of the long-term stability and bone resorption pattern of implants inserted in grafted maxillae.[9,11]

Different implant systems with machined or rough surfaces have been placed in reconstructed maxillae, and recent clinical and review studies[15–17] have suggested that differences in implant design and surface affect the survival and success rates. A

[1]Professor and Chief, Department of Oral and Maxillofacial Surgery, School of Dentistry, University of Bologna, Italy.
[2]Resident, Department of Oral and Maxillofacial Surgery, School of Dentistry, University of Bologna, Italy.
[3]Assistant Professor, Department of Oral and Maxillofacial Surgery, School of Dentistry, University of Bologna, Italy.
[4]Visiting Professor, Department of Oral and Maxillofacial Surgery, School of Dentistry, University of Bologna, Italy.

Correspondence to: Professor Claudio Marchetti, Via San Vitale 59, 40139 Bologna, Italy. Fax: +39 051 225208. E-mail: claudio.marchetti@unibo.it

Table 1 Patient Population Data

Patient	Age (y)	Sex	Reconstructive surgery date	Implant insertion date	Implant loading date	No. and type of implants	Follow-up (y)
1	48	M	Sep 1999	Jan 2000	Aug 2000	7 Brånemark	6
2	51	F	Oct 1999	Feb 2000	Aug 2000	8 Brånemark	6
3	52	F	Nov 1999	Mar 2000	Sep 2000	9 Frialit	6
4	57	F	Feb 1997	Jun 1997	Jan 1998	12 Brånemark	8
5	47	M	May 1997	Sep 1997	Mar 1998	5 Frialit	8
6	63	M	Sep 1997	Jan 1998	Aug 1998	10 Frialit	8
7	52	F	Dec 1997	May 1998	Nov 1998	6 Frialit	8
8	59	M	Feb 1995	Jun 1995	Jan 1996	10 Brånemark	10
9	55	M	Mar 1995	Aug 1995	Feb 1996	8 Brånemark	10
10	61	F	May 1995	Sep 1995	Mar 1996	11 Frialit	10
11	59	M	Jun 1995	Nov 1995	Apr 1996	10 Frialit	10
12	57	F	May 1993	Oct 1993	Mar 1994	8 Brånemark	12

number of histologic studies[18,19] have found a better rate of osseointegration of roughened implants compared with machined implants. Nevertheless, the effect of these surface modifications on the long-term clinical outcome of dental implants is still not clear. The long-term success depends on reducing the amount of marginal bone resorption after several years of functional loading.[20] Long-term studies have documented the results using machined implants and titanium plasma-sprayed (TPS) implants in native bone.[21–24] However, only 2 comparative clinical studies of machined and roughened implants inserted in bone-grafted maxillae have been published.[13,25] Therefore, the present study was carried out to assess the long-term success and survival rates of implants inserted into severely resorbed maxillae reconstructed using Le Fort I osteotomy and interpositional iliac bone grafts and to evaluate the effect of implant surface characteristics on implant success over a 6- to 12-year observation period.

MATERIALS AND METHODS

From 1994 to 1999, 12 consecutive patients (7 women and 5 men) presenting with total edentulism of the maxilla with an average age of 55.08 ± 5.10 years (range, 47 to 63 years) were treated (Table 1). The patients were referred to the Department of Oral and Maxillofacial Surgery of the University of Bologna, Italy, for maxillary bone reconstruction because of insufficient alveolar bone volume to allow dental implant placement. The inclusion criterion was a need for major bone augmentation before implant insertion in an extremely atrophic maxilla with an altered maxillomandibular relationship, judged clinically and radiographically to belong to Cawood and Howell Class VI (Fig 1).[1] Patients were excluded from this surgical procedure if they had systemic pathologies affecting immune system function, uncontrolled non–insulin-dependent diabetes mellitus, chronic liver or renal disease, or blood disorders. They were also excluded if they were undergoing chemotherapy or radiotherapy of 5,000 rads or higher, had poor oral hygiene and motivation, or were smokers. The initial clinical and radiographic examination included panoramic and cephalometric radiographs and computerized tomography in conjunction with casts of the alveolar processes to evaluate the sagittal relationships and plan the subsequent prosthodontic rehabilitation. The procedure was explained to the patients in detail, including the expected prognosis,[9,11] and all of the patients signed informed consent.

Surgical Technique

All surgeries were performed under general anesthesia with nasal endotracheal intubation. Le Fort I osteotomy was performed according to the orthognathic surgical concept, with careful removal of the maxillary sinus mucosa from the down-fractured part of the maxilla. Iliac bone grafts were modeled to fit in the sinus recesses, one on each side. In the areas of buccal atrophy in the premaxilla, veneer grafts were placed and stabilized firmly in place with titanium microscrews (Martin, Tuttlingen, Germany; Fig 2). The maxilla was then repositioned into the planned position (4 to 8 mm anterior and 2 to 4 mm inferior to its original position) and stabilized with 2 miniplates on each side (Fig 3). The incision of the passively mobilized mucosa was closed with single loop and a running, resorbable 4-0 suture (Vicryl/Johnson & Johnson, Somerville, NJ). The patients were given intravenous penicillin preoperatively and twice daily postoperatively and were discharged 4 days later. On discharge, they were prescribed peni-

Fig 1 Preoperative lateral radiograph showing the retrognathic position of the maxilla after severe resorption of the maxillary alveolar process.

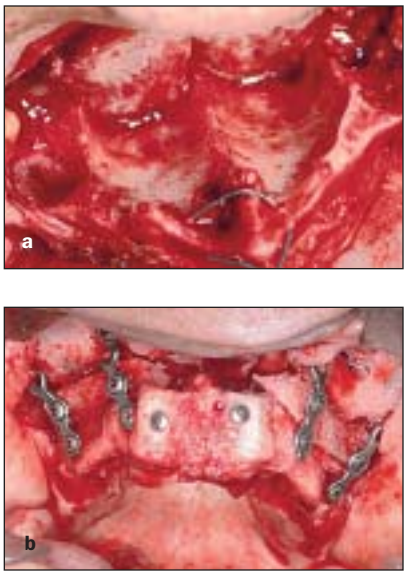

Fig 2 Surgical photos showing *(a)* downfracturing of the maxilla and *(b)* rigid fixation of the osteotomized maxilla with titanium miniplates after downward and forward repositioning in association with inlay and veneer buccal iliac bone grafts.

Fig 3 Postoperative lateral radiograph showing the maxillary advancement with the bone grafts fixed in place.

cillin 1 g twice daily for 3 days. Seven to 10 days later, the sutures were removed. The patients were not allowed to wear a provisional removable prosthesis for 3 weeks; after this period, prostheses relined with soft material were permitted.

After 4 to 5 months of healing, dental implants were inserted under local anesthesia. The implants were placed by the 2 clinicians who had referred the patients. One operator used machined-surface MK II implants (Nobel Biocare, Göteborg, Sweden), and the other used Frialit-2 System implants with a TPS surface (Dentsply Friadent, Mannheim, Germany). The 12 patients were assigned to 2 different groups according to the type of implant inserted: machined implants were placed in 6 patients, whereas TPS implants were placed in the other 6 patients. The patients were given amoxicillin 2 g per day for 5 days, starting 1 hour before implant placement. Following an incision at the top of the alveolar crest, the bone plates and screws that did not allow correct implant placement based on a guide splint were removed and dental implants were inserted. The healing abutments were placed 6 to 7 months after implant insertion under local anesthesia. A temporary fixed acrylic resin prosthesis was used in all patients for the first 6 to 8 months for gradual loading purposes. After 6 to 8 months, gold–acrylic resin or ceramic fixed restorations were fabricated for all patients.

Clinical and Radiologic Follow-up

After the final restoration had been placed, the patients were assessed 1, 3, and 6 months after implant insertion and yearly thereafter. At each visit, the patient was examined for gingival health, adequate oral hygiene, occlusal relationship, implant stability, prosthesis integrity, and areas of excessive wear. The restorations were not routinely removed to test the implant mobility after loading because this evaluation would be difficult with cemented restorations. Only if radiographically significant bone loss was observed were the definitive prostheses removed and the integration of each implant evaluated.

A panoramic radiographic examination was performed when the definitive prosthesis was delivered (year 0) and subsequently at the 1-, 2-, 3-, 4-, 6-, 8-, 10-, and 12-year assessments (Fig 4). A specialist in oral radiology measured the marginal bone resorption of each implant in all of the panoramic radiographs to avoid interobserver differences. The implant-abutment connection was used as a reference point because the implants were normally inserted with the implant–abutment connection at the level of the alveolar crest according to the surgical protocol. The images were digitized, and for each implant, the marginal bone resorption (MBR) was measured from the implant-abutment interface to the first visible bone-implant contact. The known length of the implants served as an internal standard to establish the MBR

Fig 4 The machined implants after 6 years of functional loading.

for both the mesial and distal sides, and the mean MBR was determined for each implant.[26] The MBR was measured by comparing the radiographs obtained just after delivery of the definitive prosthetic restoration with those obtained at the last follow-up. The MBR could not be measured for 8 implants because of artifacts in the panoramic radiographs. To prevent bias there was no sequence in measuring the radiographs, and the measurements were not made per patient.

Definition of Survival and Success

Implants that failed to establish or maintain osseointegration and were removed were considered failures. As suggested by Albrektsson et al,[27] implant success was based on the following criteria: *(1)* the implant was clinically stable with no signs of pathologic reaction, pain, or infection; *(2)* the implant was surrounded by compact or trabecular bone without radiolucency; and *(3)* the marginal bone resorption was no greater than 1.5 mm for the first year after loading and 0.2 mm/year in subsequent years. Implants that met all of these criteria but showed peri-implant bone resorption greater than the parameters established were considered surviving implants.

Statistical Analysis

The Kaplan-Meier estimation method was used to calculate the cumulative survival and success rate. The χ^2 test was used to assess the statistical significance of differences between machined and TPS implants according to the survival and success criteria. The Kruskal-Wallis test was used to examine the significance of differences between machined and TPS implants according to the mean MBR data. $P < .05$ was considered statistically significant. The SAS System version 8.02 (SAS Institute, Cary, NC) was used to perform these analyses.

RESULTS

The patient follow-up ranged from 72 to 144 months after prosthetic loading. The machined implant group was followed up for a mean period of 104 ± 26.53 months (range, 72 to 144 months). The TPS implant group was followed up for a mean period of 100 ± 18.06 months (range, 72 to 120 months).

Postoperative Complications

All of the patients were discharged from the hospital between 3 and 5 days after the bone-grafting procedure. The immediate postoperative healing was uneventful in all patients. Two patients (patients 4 and 9) had late infections in the maxilla after 4 to 6 weeks, which resolved with the removal of 1 mini-plate under local anesthesia. At the time of implant insertion, the grafts showed some resorption where the mini-plates had been removed, but this did not interfere with implant placement. No patients reported pain, discomfort, or difficulties in walking after 6 weeks postoperatively.

Implant Survival and Success

In all, 104 implants placed in the bone-grafted maxillae were evaluated: 53 machined and 51 TPS implants. Of the 104 implants, 8 (7.7%) were found to be mobile at the time of implant exposure. Two more of the 96 remaining implants (9.6%) were lost between loading and the end of the first year; 1 implant failed between 1 and 3 years after loading, and none failed subsequently, for an overall cumulative survival rate of 89.4% after 12 years. There were

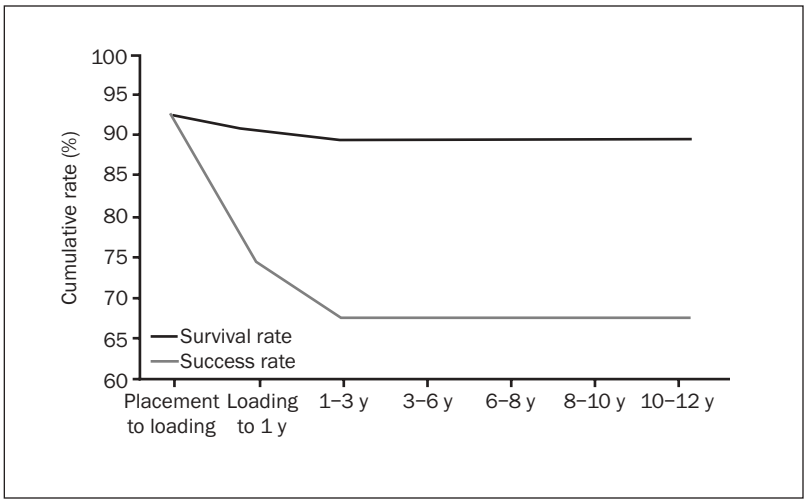

Fig 5 Life table analysis showing the cumulative survival and success rates of implants placed in grafted maxillae.

Table 2 Distribution of Placed and Failed Implants in Terms of Surface and Length

Length (mm)	No. placed	No. failed
Machined		
10	13	1
13	25	4
15	14	2
18	1	0
Total	53	7
TPS		
11	22	2
13	23	2
15	6	0
Total	51	4

too few implants for a statistical analysis. Considering successful implants as those with marginal bone resorption no greater than 1.5 mm for the first year after loading plus 0.2 mm/year in subsequent years, the cumulative success rate was 67.3% after 6 to 12 years (Fig 5). Cross tabulation between the survival and success rates showed that 23 surviving implants (22.1%) were considered failures. The majority of the implants were 13 mm long; 6 of these 48 implants failed. One of thirteen 10-mm implants failed, 2 of twenty 15-mm implants failed, and 0 of six 15-mm and one 18-mm implant failed (Table 2).

In the machined-surface group, 7 to 12 implants were inserted in each patient. Of 53 implants placed in 6 patients, 7 were lost (5 before functional loading, 1 after 1 year, and 1 after 3 years), resulting in a cumulative survival rate of 86.8%. In the TPS group, 5 to 11 implants were inserted in each patient. Of the 51 implants placed in 6 patients, 4 implants were lost up to the time of the last recall (3 before functional loading and 1 after 1 year) for a cumulative survival rate of 92.2%. There was no statistical difference in implant survival between the 2 groups (Fig 6). In the machined-surface group, the success rate was 66%, whereas in the TPS-surface group it was 68.7%. There was no significant difference in the success rate between the implants with different surface topographies ($P = .82$; Fig 7).

Marginal Bone Resorption

The mean MBR was 2.91 ± 0.77 mm (± standard deviation; range, 0.6–4.9 mm) in the machined-surface group and 2.72 ± 0.84 mm (range, 0.7–5.3 mm) in the TPS group during the 6- to 12-year observation period. No significant difference in the MBR was recorded between the implants with machined and TPS surfaces ($P = .06$; Fig 8). However, such comparisons were complicated by the considerable variability inherent in measuring MBR levels from nonstandardized radiographs.

DISCUSSION

The objective of this 6- to 12-year retrospective study was to evaluate the survival and success rates of dental implants with different surfaces inserted in extremely atrophic maxillae after reconstruction using Le Fort I osteotomy and interpositional bone grafts. The cumulative implant survival rate was 89.4% (11 of 104 implants failed). Of the implant failures, the majority (72.7%) were discovered at the moment of implant exposure, and 90.9% of the implant losses occurred within the first year of functional loading. Only 1 of the 11 failures occurred between 1 and 3 years after loading, and none failed thereafter. The survival and success rates and pattern of implant failure were similar to those in other long-term studies evaluating implants placed in bone-grafted maxillae,[9,11,14] which suggests that we may expect a low frequency of additional implant failures with long-term follow-up. Comparable clinical reports exceeding 5 years are rare. In 1999, Keller et al[9] reported on 54 consecutive patients treated with

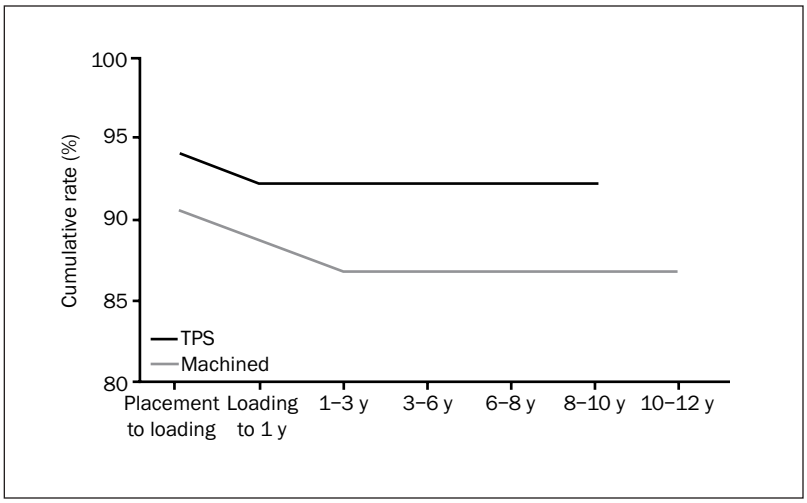

Fig 6 Life table analysis showing the cumulative survival rates for machined and TPS implants.

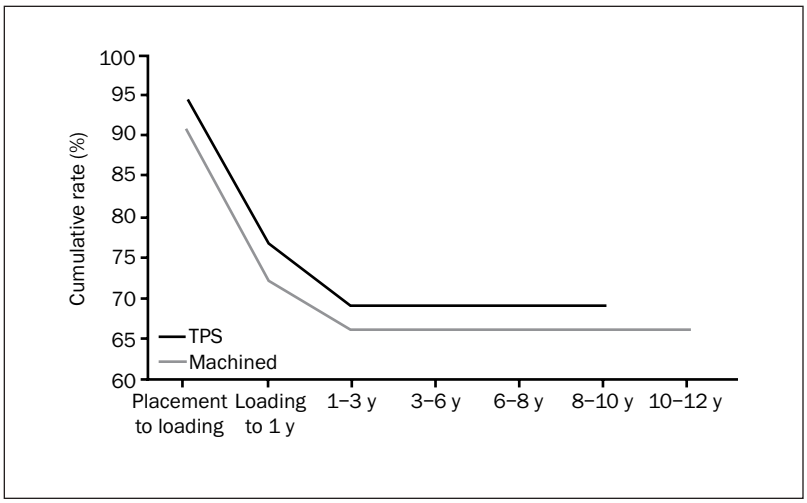

Fig 7 Life table analysis showing the cumulative success rates for machined and TPS implants.

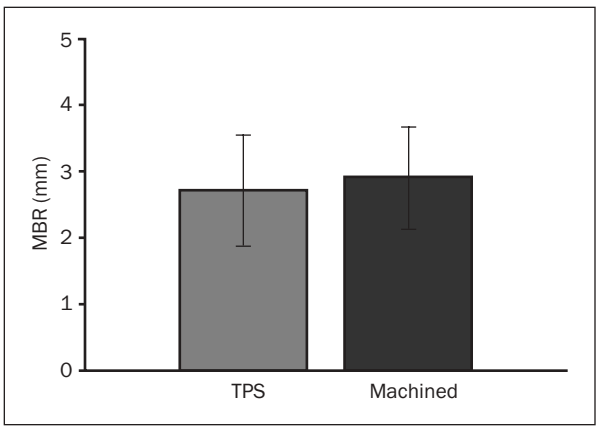

Fig 8 Comparison of marginal bone resorption between machined and TPS implants.

maxillary inlay autogenous bone grafts with 248 implants placed in delayed procedures. Of these, 33 implants were lost during the mean follow-up period of 57.1 months (range, 6 to 139 months) with a cumulative survival rate of 87%. Yerit et al[11] followed 35 patients for up to 12 years after bone reconstruction using horseshoe Le Fort I osteotomy, interposed bone grafts, and implant placement; implant survival was 91.1%. In 2005, Kahnberg et al[12] reported a 5-year cumulative implant survival rate of 97% in 22 consecutive patients after reconstructing severely resorbed maxillae with inlay bone grafts and delayed implant placement. Chiapasco et al[14] reported a cumulative survival rate of 94.5% in 39 patients and 281 implants, with a mean follow-up after prosthetic loading of 45.9 months (range, 12 to 108 months). The long-term survival rate presented here compares favorably with these reports and shows a successful outcome over a 6- to 12-year observation period.

Implants placed in poor-quality and grafted bone are considered less likely to integrate and more likely to fail after loading.[28,29] Long-term clinical results show that the cumulative survival rates of machined implants placed in severely resorbed and bone-grafted maxillae were 71.3% and 80.7%, respectively, versus 92.1% for those placed in better-quality bone after 5 years of clinical function.[30] Despite some literature on implant treatment in combination with bone grafts in atrophic maxillae, only a few controlled clinical studies provide long-term data on the survival and success rates of implants inserted in maxillary grafted bone according to implant surface morphology.[13,25] A clinical study by Pinholt[25] showed that it was possible to increase the survival rate from 81% to 98% by using roughened implants, compared with the use of machined implants, in bone-grafted maxillae, with follow-up ranging from 20 to 67 months postimplantation. The present investigators found that the cumulative implant survival rate was 92.2% for the TPS implants and 86.8% for the machined implants, with no statistically significant difference after 6 to 12 years of prosthetic loading. This finding closely reflects the results of a previous study documenting the longitudinal outcomes of machined-surface and titanium blasted-surface implants inserted after maxillary osteotomy and interpositional bone grafting,[13] and it would appear to indicate that the 2 types of implants performed equally well in these very demanding reconstructive surgeries.

Because survival criteria do not include the level of alveolar bone support, the survival percentages over 6 to 12 years decreased only slightly. Considering the mean MBR, the success rate of implants tends to decline significantly over a 12-year period, with most of the decline occurring between 1 and 3 years of function. The present results implied that bone stabilization occurred for both types of implant surface after 3 years of functional loading. Machined and roughened implants followed a similar MBR pattern: rapid bone loss for up to 3 years after loading, followed by almost insignificant MBR (ie, less than 0.2 mm/year), which is considered acceptable in non-grafted patients.[31,32] This is in agreement with previous studies reporting the MBR of implants placed in reconstructed maxillae,[13,33] which showed initial continuous marginal bone loss during the first 3 years and no significant changes between the 3- and 10-year follow-ups. In the present study, it was found that greater peri-implant bone resorption and consequent lower implant success rates may occur for implants inserted in bone-grafted maxillae compared to those placed in native, nonregenerated bone.[20,21,31,32] This resorption was probably caused by the effect of the reconstructive surgery on the vascularity of the remaining poor-quality native bone and the supplementary surgical procedure for implant placement. This important MBR may be considered when selecting implant length, which should be the maximum allowed for the reconstructed bone. In this study, the implant length varied from 10 to 18 mm, with only 13 10-mm implants.

Regarding the implant surface, the success rates for roughened and machined implants were similar (68.7% and 66.0%, respectively). In addition, no significant differences were detected between machined- and rough-surface implants in terms of the MBR. These values concur with MBR levels observed in studies documenting the longitudinal outcomes of implants placed in augmented maxillae.[8,10,12–14] In contrast with Halmann et al,[13] there was no trend toward a greater risk of MBR and consequent higher risk of future losses over time for implants with roughened surfaces. The slight difference in bone resorption between machined and roughened implants could be a result of the type of radiographic examination, and it did not have any clinical significance for long-term implant survival. The rotational panoramic radiograph is widely used to evaluate the bone around dental implants in edentulous jaws.[26] However, this technique suffers from a lack of sharpness and image distortion and has problems with reproducibility. The paralleling technique, using intraoral radiographs, is preferable.[31] Because panoramic radiographs were used at the beginning of the study, this technique was continued and bone changes were evaluated relative to implant length in millimeters.

CONCLUSIONS

Implants placed in extremely resorbed maxillae treated using Le Fort I osteotomy and interpositional bone grafting have an acceptable long-term survival rate (6 to 12 years). Although the success rate decreased significantly over time, this did not compromise the functional and esthetic outcome of the implant-supported prosthetic rehabilitation. No significant differences were found in the survival or success rates or the MBR around implants with machined or TPS surfaces. Careful patient selection is necessary before performing this reconstructive surgery, and patients must be given detailed information on the expected results.

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