A Retrospective Analysis of Early and Immediately Loaded Osseotite Implants in Cross-Arch Rehabilitations in Edentulous Maxillas and Mandibles Up to 7 Years

Hilde Browaeys, MD, DDS;[*] Joel Defrancq, MD, DDS;[†] Melissa C.A. Dierens, DDS, MSc;[‡] Resa Miremadi, DDS, MSc;[§] Stefan Vandeweghe, DDS, PhD;[¶,**] Tommie Van de Velde, DDS, MSc, PhD;[††] Hugo De Bruyn, DDS, MSc, PhD[‡‡,§§]

ABSTRACT

Background: Immediate loading of full-arch restorations yields good results in selected cases, but long-term follow-up and the outcome in compromised bone are scarcely evaluated.

Purpose: To evaluate immediately loaded Osseotite implants (Biomet 3i, Palm Beach, FL, USA) installed in healed or grafted bone, with regard to implant survival and peri-implant bone loss up to 7 years in function.

Materials and Methods: Information was retrospectively retrieved from 83 patients' records with 749 Osseotite implants supporting immediately loaded semipermanent full-arch acrylic restorations. Five hundred sixty-eight (75.8%) implants were placed in healed bone and 181 (24.2%) in augmented bone, regenerated with sinus lifting and/or onlay/inlay grafts with/without biomaterials and membranes. Implant survival and success based on radiological peri-implant bone loss were registered. Wilcoxon rank sum tests evaluated peri-implant bone loss in compromised versus healed bone or between jaws or time intervals with $p < .05$ as statistically significant.

Results: Sixteen of 749 implants failed (2.1%), 11/343 in maxilla (3.2%) and 5/406 (1.2%) in mandible. After 7 years, the cumulative failure rate was 9%. Mean peri-implant bone loss increased to 1.2 mm (SD 1.0) during the first 2 years but remained unchanged thereafter. Around implants in grafted bone, on average, 0.3 mm more bone loss was found.

Conclusion: The Osseotite implants offer a predictable long-term outcome in terms of implant survival and stable peri-implant bone under immediate loading even in grafted bone. However, the high incidence of technical repair because of fractures of the semipermanent provisionals requires attention because it may be negative from a cost-benefit perspective. Implants in grafted bone show a tendency to a more pronounced initial bone remodeling without clinical consequence in the long term.

KEY WORDS: bone remodeling, dental implant, grafting, immediate loading, implant survival, one-stage surgery, Osseotite surface, posterior hip graft, prosthetic complications, sinus lift

[*]Maxillofacial surgeon, PhD student, and clinic head, Department of Oral and Maxillofacial Surgery, Dental School, Faculty of Medicine and Health Sciences, University of Ghent, University Hospital Ghent, Ghent, Belgium; [†]maxillofacial surgeon, Department of Oral and Maxillofacial Surgery, Eeuwfeestkliniek of Antwerp, Antwerp, Belgium; [‡]specialist in periodontics and PhD student, Department of Periodontology and Oral Implantology, Dental School, Faculty of Medicine and Health Sciences, University of Ghent, Ghent, Belgium; [§]specialist in periodontics and PhD student, Department of Periodontology and Oral Implantology, Dental School, Faculty of Medicine and Health Sciences, University of Ghent, Ghent, Belgium; [¶]postdoctoral researcher, Department of Periodontology and Oral Implantology, Dental School, Faculty of Medicine and Health Sciences, University of Ghent, Ghent, Belgium; [**]prosthodontist, Department of Prosthodontics, School of Dentistry, Malmö University, Malmö, Sweden; [††]assistant head of clinic, Department of Periodontology and Oral Implantology, Dental School, Faculty of Medicine and Health Sciences, University of Ghent, Ghent, Belgium; [‡‡]specialist in periodontics, Department of Periodontology and Oral Implantology, Dental School, Faculty of Medicine and Health Sciences, University of Ghent, Ghent, Belgium; [§§]professor and clinic head, and visiting professor, Department of Prosthodontics, School of Dentistry, Malmö University, Malmö, Sweden

Reprint requests: Professor Dr. Hugo De Bruyn, Department of Periodontology and Oral Implantology, University Hospital Ghent-P8, De Pintelaan 185, B-9000 Ghent, Belgium; e-mail: hugo.debruyn@Ugent.be

DOI 10.1111/j.1708-8208.2011.00367.x

INTRODUCTION

The traditional two-stage and delayed loading protocols are gradually replaced by immediate loading protocols. Immediate loading of oral implants has been reported as a beneficial treatment option in implant dentistry that increases the comfort of the patient. Besides less discomfort for the patient, a gain of time, and a reduction in postoperative care, immediate loading has a remarkable, positive psychological impact on the patient.[1] For patients, the immediate loading protocol is the first treatment choice in fully edentulous jaws.[2] Several review papers documented good implant survival rates of 96 to 100% irrespective of the implant system used, albeit after relatively short time evaluation.[3–5] Only two clinical studies available in the English literature have evaluated immediately loaded implants up to 7 years and longer. Schnitman and co-workers[6] were the first to report 10-year survival of 85% for machined surface implants initially used to support a provisional bridge in the mandible. Unfortunately, they did not report on the peri-implant bone loss. Degidi and Piattelli[7] reported on 93 immediately loaded dental implants in seven full and nine partially edentulous arches with a cumulative survival rate of 93.5% after 7 years. The reported peri-implant bone loss was 0.6 mm after the first year and 1.1 mm at the 7-year evaluation. Sennerby and Gottlow[8] reviewed prospective studies comparing immediate loading with delayed loading procedures and concluded that various designs of dental implants can be loaded shortly after placement in both maxilla and mandible. However, most studies specify rather strict inclusion criteria to avoid possible risk factors such as soft bone, bruxism, and short implants. Additionally, they mentioned that most clinical studies lack sufficient power and include too few cases and implants.

The aim of the present retrospective study was therefore to report the long-term clinical outcome of immediately loaded acid-etched surface implants with a complete mandibular or maxillary fixed screw-retained bridge for a large group of implants and consecutively treated cases. The clinical outcome is defined both as implant survival as well as peri-implant bone loss, and this for implants placed in healed as well as in grafted bone.

MATERIALS AND METHODS

Patient Selection

All patients selected in the study were referred to the Eeuwfeest Clinic, Antwerp, Belgium, for implant placement in an edentulous jaw. Patients were diagnosed and treated by one and the same surgeon (D.J.). The patients were in a good general health and able to tolerate a surgical procedure. They were proposed a fixed, immediately functionally loaded, prosthetic construction in the lower or upper jaw. Patients were included based on clinical examination and additional standard radiographs such as orthopantomograms or computed tomography scans. In those patients who lacked sufficient crestal bone height or width, a bone grafting procedure was performed under general anesthesia in the 4 to 6 months prior to dental implant placement. No direct crestal augmentations were performed, but sinus lifting was performed to allow implant placement in the posterior zones. Crestal width was increased with corticocancellous bone plates fixed onto the crest with fixation microscrews in order to cover all implants or, in addition, create a midface augmentation for aesthetic purpose. In brief, the pre-implant procedure was performed using different onlay or inlay techniques with autologous bone and/or additional bone substitutes. Platelet-rich plasma was added in the sinus lifted bone graft. Bone was harvested in the majority of the cases from the posterior hip area where sufficient cortical and cancellous bone is available. This procedure has minimal postoperative discomfort for the patients, and the patients were dismissed from the hospital after 1 day. Heavy smokers and diabetic patients were not excluded, and the opposing dentition was natural teeth, complete or partial removable dentures, or implant-supported restorations.

Planning and Surgical Procedure

All implant surgeries were performed according to a single-stage surgical protocol by one operator (D.J.) under local or general anesthesia. None of the patients were premedicated with antibiotics or sedatives when treated under local anesthesia. A crestal incision was made, and a full-thickness mucoperiosteal flap was raised prior to implant placement to fully visualize the bony crest. In case of augmentation, the fixation microscrews of the grafts were removed. All implant sites were prepared according to the standard drilling protocol

with sterile saline irrigation. The number, length, and diameter of the implants (Osseotite®, Biomet 3i, Palm Beach, FL, USA) placed were decided by the surgeon at the time of implant placement, depending on the total number of teeth needed and bone condition appraised during implant surgery. For safety reasons, enough implants were foreseen because, at the time of operation, the immediate loading protocol was a relative new procedure. Implants had to achieve insertion torque values of at least 15 Ncm to be accepted as initially stable. In case of decreased implant stability, the surgeon had the option to alter the drilling procedure or choose a wider implant. The implant choice was dependent on the amount of available bone quantity and quality, and decided by the surgeon after preoperative planning using orthopantomograms. The bone status of the recipient bone was described in the patient's records and given a notation of dense, normal, or soft bone. This quotation was based on the perception of the surgeon during the surgery and on the cutting force resistance during the drilling procedure. The appropriate impression copings were connected onto the implants. The mucosal tissue was sutured, and an impression was taken with the previously fabricated guiding denture. In some cases, the existing denture was modified to be used as surgical guide and impression tray, and could be used for occlusal bite registration simultaneous with implant placement. The procedure was similar to the one described previously.[9] After impression healing, abutments were screwed on the implants, and the patients were dismissed with the advice to rinse with a 0.12% chlorhexidine solution for 2 weeks. Postoperative analgesics, ibuprofen 600 mg or paracetamol 500 mg, for pain relief as well as antibiotics, clindamycin 3 × 300 mg for 5 days, were prescribed. Sutures were removed 4 to 10 days after surgery. Based on the guide denture, the provisional acrylic bridge was made at the dental laboratory. The provisional acrylic prosthesis was made from customized acrylic teeth bonded in the glass fiber or metal-reinforced acrylic framework. The provisional prosthetic appliance could be classified as semipermanent because the patients were advised to wait at least 6 months before final prosthetics were made. The provisional bridge was torqued at 25 Ncm according to the manufacturer's guidelines, and occlusal adjustments were made to allow an even distribution of loading on all implants. The patients were informed to attend the clinic in the event of technical or medical complication, and were encouraged to participate in a recall program, either at the clinic or with their referring dentist.

Clinical and Radiographic Follow-Up

Implants reported as removed or registered as mobile were called failures. All others were called survivals up to their last recall visit. Because not all implants have been followed during the whole period, it was furthermore chosen to examine the cumulative failure rate. All radiographs available in the patient's records were analyzed under magnification by a calibrated investigator from the University of Ghent, appointed as a neutral evaluator (R.M.). The peri-implant bone level was measured as the distance from the implant–abutment borderline to the most coronal point of contact between marginal bone and implant surface. The marginal bone level was measured mesially and distally using the known distances from implant top to the respective threads, and using the 0.6-mm pitch thread as a reference for calibration. The mean of both values was calculated as the implant value. This was done using orthopantomograms under 10 times magnification. It was decided to analyze peri-implant bone loss over time on implant level and not patient level because implants within the same mouth were not always allocated to the same treatment modality. Therefore, implants were allocated to a healed bone group, meaning implants inserted in natural bone, and a compromised bone group, when implants were inserted in augmented bone irrespective of the procedure used. Hence, each individual implant was analyzed for bone level changes. Given the retrospective nature of the study, not all radiographs were taken at the same time after surgery. Additionally, some implants had no readable or available baseline radiograph taken shortly after surgery. From other implants, there was an orthopantomogram immediately after surgery, but the follow-up radiographic data are missing because the patient returned to their own dentist for follow-up. The lack of baseline radiographs in a majority of the implants is a serious drawback related to the retrospective design of the study. Consequently, it does not allow bone loss calculation from time of insertion to the given time interval. Therefore, mean bone levels were calculated using the abutment–implant interface as reference point. To overcome the problem of non-standardized follow-up, the bone loss at a certain follow-up time was grouped into time intervals. In case more than one set of measurements was available during the given interval, the

TABLE 1 Distribution of Implants with Their Respective Length and Width

	8.5 mm	10 mm	11.5 mm	13 mm	15 mm	18 mm	Total
3.25 mm	0	2	0	4	7	1	14
3.75 mm	0	5	5	25	55	33	123
4.0 mm	13 (2)	25	30	125 (2)	310 (3)	122 (5)	625 (12)
5.0 mm	4	6	2 (1)	5	14 (3)	3	34 (4)
6.0 mm	0	0	1	1	0	0	2
	17 (2)	38	38 (1)	160 (2)	386 (6)	159 (5)	798 (16)

The number of failed implants is indicated between brackets.

longest time frame was chosen, and the other was discarded in order to avoid double measurements.

Nonparametric Wilcoxon rank sum test was used to analyze peri-implant bone level changes between healed or grafted bone groups, or time intervals. $p < .05$ was considered as statistically significant.

RESULTS

Patient and Implant Selection

Clinical and radiographic information was retrieved from 83 patients, 32 women and 51 men, with a mean age of 58.2 years old (range 28–89). In total, 23% of the patients reported that they were smokers, although the daily amount of cigarettes was not registered. All 83 patients were treated consecutively with 4 to 10 endosseous implants (Osseotite®, Biomet 3i) from November 1997 to October 2003.

In total, 798 implants were inserted. Implant length and width related to jaw location is given in Table 1. Less than 6% of the implants were smaller than 4 mm, and 7% were 10 mm or shorter. Of the total group, 49 sleeping implants, 27 in the maxilla and 22 in the mandible, were not exposed and kept unloaded because initial stability was doubtful. Hence, 749 implants (Osseotite®, Biomet 3i) supported immediately loaded, complete cross-arch, fixed bridgework on four to nine implants, and were analyzed in detail for implant survival and success. Three hundred forty-three implants (46%) were placed in 41 maxillae and 406 (54%) in 74 mandibles. The number of loaded implants with respect to tooth location is given in Table 2. The average number of loaded implants per case was 5.5 in the mandible and 8.4 in the maxilla. One hundred forty-one out of 749 loaded implants (19%) were located in molar positions.

Five hundred sixty-eight of the loaded implants were placed in healed non-grafted bone (75.8%), and

TABLE 2 Total Number and Proportion of Loaded Implants with Their Respective Tooth Position

Teeth Number	Count	Proportion (%)
18	4	0.5
17	9	1.1
16	33	4.1
15	36	4.5
14	33	4.2
13	41	5.1
12	19	2.4
11	10	1.3
21	13	1.6
22	17	2.1
23	40	5.0
24	35	4.4
25	37	4.6
26	32	4.0
27	8	1.0
28	3	0.4
48	0	0.0
47	1	0.1
46	27	3.4
45	14	1.8
44	56	7.0
43	47	5.9
42	42	5.3
41	35	4.4
31	20	2.5
32	46	5.8
33	45	5.7
34	54	6.7
35	17	2.1
36	22	2.8
37	2	0.2
38	0	0.0

TABLE 3 Total Number of Loaded Implant Related to Bone Condition and Pre-Implant Augmentation Procedure

Bone Condition/ Treatment	Number of Implants	Proportion (%)
Healed non-grafted bone	568	75.8
Sinus lift	46	6.1
Onlay graft	35	6.7
Le Fort I osteotomy + sinus lift + onlay graft	14	1.9
Sinus lift + onlay graft	86	11.5
Total material	749	100

181 implants (24.2%) were placed in bone previously treated with sinus lifts, onlay grafts, or regenerated bone, which was augmented with autologous bone, biomaterials, and/or membranes in an additional procedure 4 to 6 months prior to implant surgery. The frequency distribution of the various surgical modalities is given in Table 3. Because of the disparities between these surgical groups, they were combined in one group called the compromised bone group to allow comparison with healed bone.

A total of 70.5% of the implants were placed in normal bone, meaning that the normal drilling protocol was used. In 9.2% of the implant sites, all located in the mandible, the bone was dense, and pretapping was necessary. A total of 14.7% of the implants were placed in soft bone, and the site was underprepared. From 6% of the implants, the registration of bone quality was missing.

A total of 9.5% of the implants were loaded at the day of surgery; 65.0% was loaded within 2 days. As a consequence, 74.5% can be classified as immediate loading. Respectively, 12.5% and 13% were loaded within 3 days or within 10 days, and should be regarded as early loaded.

Implant Failure

Sixteen implants were removed because of infection or mobility. Another initially mobile implant became integrated, and was followed up to 3 years and counted as a survival. The absolute failure rate is therefore 16/749 (2.1%). Failures were encountered in 11/343 (3.2%) of maxillary implants in 4/41 (9.8%) patients and 5/406 (1.2%) of mandibular implants in 4/74 (5.4%) patients.

Taking into account that not all implants are followed during the study period, the cumulative failure rate is depicted in Table 4. The clinical survival reported after 7 years, being 9%, should be interpreted with care because of the large dropout of the material after 5 years.

Peri-Implant Bone Loss

From 339 implants, peri-implant bone loss was calculated based on radiographs taken within 10 days after surgery (Table 5). Based on these implants, it clearly shows that 79% were installed with the implant–abutment border equal with the bone crest. Ten percent had the implant up to 1 mm above the crest, corresponding with the non-threaded smooth coronal part. The mean initial bone level at the time of loading was 0.26 mm (SD 0.40; range 0–3.4) above the crest.

TABLE 4 Number of Implants, Failures, Cumulative Failure Rate (%), and Peri-Implant Bone Level (Mean, SD, and Maximal Value) Based on Available Implants in a Respective Time Interval

Interval Time (Months)	Implants in Interval	Lost Implants	Cumulative Failure %	Bone Mean (SD; Range)
0–3	501		0	0.48 (0.7; 0–3.4)
4–6	260	4	1.54	1.25 (1.3; 0–11.2)
7–12	233		1.54	1.40 (1.0; 0–4.3)
13–18	249	1	1.94	1.42 (0.9; 0–4.0)
19–24	160	5	5.00	1.73 (1.1; 0–4.6)
25–36	349	2	5.54	1.57 (1.1; 0–6.1)
37–48	203	3	6.94	1.63 (1.1; 0–4.0)
49–60	106		6.94	1.57 (1.1; 0–5.8)
61–72	44	1	9.05	1.86 (0.8; 0–3.4)
73–84	39		9.05	1.75 (1.1; 0–4.3)
85–96	24		9.05	1.48 (0.9; 0–3.1)

TABLE 5 Peri-Implant Bone Level Measured at Baseline within 10 Days after Surgery Based on 339 Implants

Bone Level (mm)	Number of Implants	Proportion %
0.0	269	79.4
0.8	30	8.8
1.1	5	1.5
1.4	1	0.3
1.6	31	9.1
1.9	2	0.6
3.4	1	0.3
Total material	339	100

There was no statistically significant difference between peri-implant bone loss measured on the implants placed in women or men. The mean peri-implant bone loss during the first 3 months (allocated to period 1) is 0.64 mm (SD = 0.98; range 0.0–6.1; $n = 406$ implants) in women versus 0.63 mm (SD = 1.01; range 0.0–11.2; $n = 343$ implants) in men. Bone loss increased significantly between 3 and 6 months ($p < .001$), and between 6 and 12 months ($p = .04$), but reached a steady state thereafter ($p > .05$). Statistically reliable changes in peri-implant bone level after 5 years are not reliable based on the current study because too few implants could be examined, and hence, the reported figures should be interpreted cautiously. For this reason, analysis of subgroups within the material was only performed up to 4 years.

Table 6 summarized the peri-implant bone level values per interval up to 4 years for the total material as well as for mandibular and maxillary implants. After 4 years, too few implant numbers were analyzed in the various groups, giving an unreliable statistical power. Figure 1 shows bone loss after 1, 2, 3, 4, and 5 years for 100 implants (irrespective of jaw, native, or grafted bone) where radiographic information at all time intervals, including baseline immediately after surgery, was available for pairwise analysis. Observe the large range of initial bone remodeling during the first year of loading. A statistically significant peri-implant bone loss occurred during the first 2 years, but afterward, a steady state was obtained.

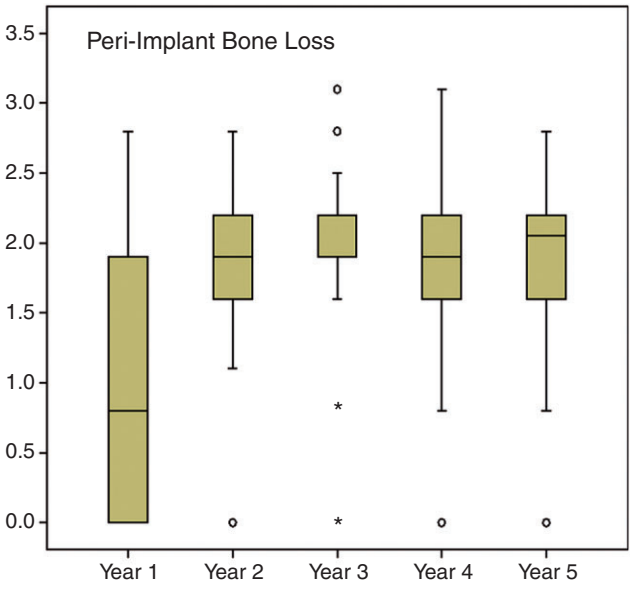

Figure 1 Changes in actual peri-implant bone loss from baseline (after surgery). One hundred implants were selected on the availability of readable radiographs at all reported time intervals. The distribution of data is shown in 25% percentiles and the median. Statistically significant changes are found for baseline to 1 year and 1 to 2 years, but no further changes occurred later (Kruskal-Wallis test and Wilcoxon signed ranks test).

In the maxilla, bone loss was on average 0.3 mm more pronounced than in the mandible (see Table 6). The cumulative percentage of implants and the corresponding peri-implant bone loss after 1 year in relation to the jaw is shown in Figure 2 and demonstrates this

TABLE 6 Peri-Implant Bone Level in mm (Mean, SD, and Range) Based on Available Radiographs [between Brackets] in a Respective Time Interval in Months for the Total Material, and Mandible and Maxilla

Interval	Mean (SD; Range) [N] Total Material	Mean (SD; Range) [N] Mandible	Mean (SD; Range) [N] Maxilla	*p* Value
0–3	0.36 (0.7; 0–3.4) [497]	0.34 (0.6; 0–3.4) [286]	0.39 (0.7; 0–2.5) [211]	
4–12	1.25 (1.2; 0–11.2) [462]	1.17 (1.2; 0–11.2) [257]	1.41 (1.1; 0–6.1) [205]	$p < .05$
13–24	1.53 (1.1; 0–6.1) [406]	1.45 (1.1; 0–4.6) [201]	1.61 (1.0; 0–6.1) [205]	
25–36	1.57 (1.0; 0–5.8) [363]	1.43 (1.1; 0–5.8) [188]	1.72 (0.9; 0–3.7) [175]	$p < .01$
37–48	1.69 (1.1; 0–5.8) [233]	1.54 (1.1; 0–5.8) [140]	1.92 (1.0; 0–4.0) [93]	$p < .01$

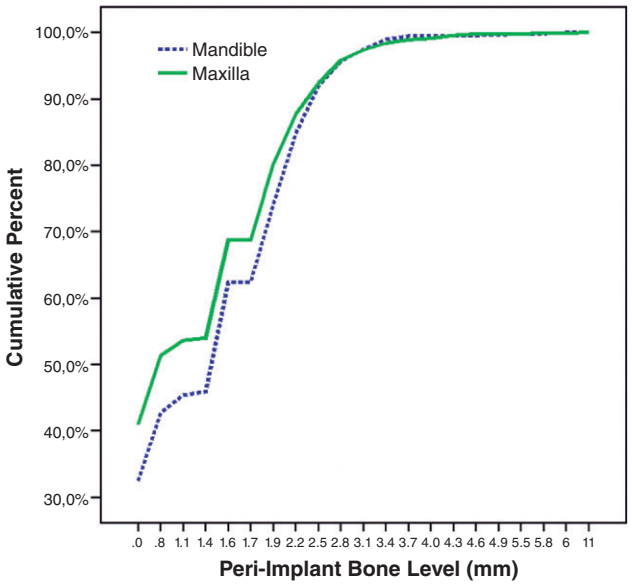

Figure 2 Cumulative percentage of implants and the corresponding peri-implant bone loss after 1 year in relation to the jaw.

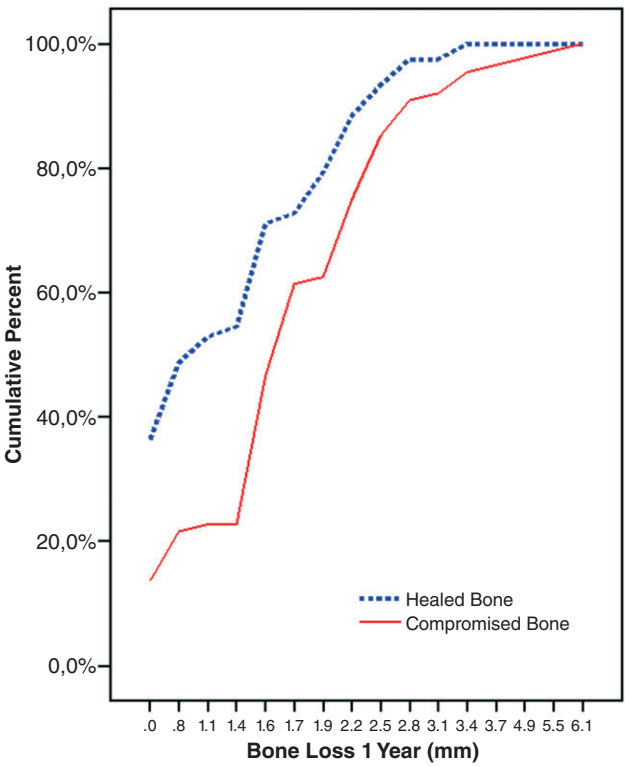

Figure 3 Cumulative percentage of implants and the corresponding peri-implant bone loss after 1 year in relation to the bone condition.

difference. More than 60% of the implants have peri-implant bone loss below 1.5 mm, the latter being the first implant thread.

A detailed analysis of the peri-implant loss in the maxilla shows that this overall higher bone loss is largely explained by the substantial number of implants installed in compromised bone. Fifty-two percent of the maxillary implants are installed in grafted bone. Table 7 gives the bone level values only for the maxillary implants, split up in healed and compromised bone. In the latter group, no distinction was made between the grafting procedures used. At baseline, there was no significant difference between the mean bone level in healed versus compromised bone ($p = .904$). However, on average, 0.4 to 0.8 mm more bone loss was seen at the 1 to 4 years interval in the compromised bone. Statistically higher bone loss was observed in the compromised bone group up to 4 years. Figure 3 visualizes this difference after 1 year for the total material (combined maxilla and mandible).

DISCUSSION

The present study reports on the implant survival and peri-implant bone loss of implants subjected to immediate loading or loading within 3 to 10 days after surgery.

TABLE 7 Peri-Implant Bone Level in mm (Mean, SD, and Range) Based on Available Radiographs [between Brackets] in a Respective Time Interval in Months for the Total Material from the Maxilla and Split Up for Healed versus Compromised Bone

Interval	Mean (SD; Range) [N] Total Maxilla	Mean (SD; Range) [N] Healed Bone	Mean (SD; Range) [N] Compromised Bone	*p* Value
0–3	0.39 (0.7; 0–2.5) [211]	0.38 (0.7; 0–2.5) [134]	0.46 (0.8; 0–2.2) [77]	
4–12	1.41 (1.1; 0–6.1) [205]	1.11 (1.0; 0–3.4) [123]	1.87 (1.2; 0–6.1) [82]	$p < .001$
13–24	1.61 (1.0; 0–6.1) [205]	1.44 (0.9; 0–3.7) [114]	1.87 (1.0; 0–6.1) [91]	$p < .01$
25–36	1.72 (0.9; 0–3.7) [175]	1.55 (1.0; 0–3.7) [97]	1.92 (0.9; 0–3.4) [78]	$p < .02$
37–48	1.92 (1.0; 0–4.0) [93]	1.52 (1.0; 0–3.1) [47]	2.32 (0.9; 0–4.0) [46]	$p < .001$

These later time points do not exactly fall within the 2-day period classified as immediate loading. The intention to treat was clearly to have immediate loading; however, practical problems related to opening hours of the clinic, patients' desire to combine prosthetic loading with suture removal, or technical aspects forced us to follow this approach. Despite this, the remaining 25.5% are indeed semantically early loaded; it seems justified to classify this study predominantly as an immediate loading study, and given the short time frame, the whole material was considered irrespective of the exact loading time. The clinical cases were treated in an era where this treatment protocol was innovative and only considered applicable in cross-arch rehabilitations supported by a sufficient number of implants. The present study furthermore overcomes the problem of stringent selection of treatment indication often encountered in clinical prospective trials.[8] There were no specific exclusion criteria, and all consecutively included cases were reported, among them 23% smokers and 3% diabetes patients. Nearly 20% of the implants were inserted in posterior molar areas, and 24% were placed in previously grafted bone, all in the maxilla. The disadvantage of this approach is clearly the retrospective nature of the study. However, sufficient cases are followed over a long-term period. To our knowledge, this study is the first to analyze such a large group of cases treated by one surgeon with the same implant system and above 5 years of follow-up.

With a 2.1% absolute failure rate and 9.1% cumulative failure rate after 7 years, the applied immediate loading protocol yielded a similar outcome as with delayed loading procedures. In a systematic review,[10] it was concluded that dental implants can be immediately loaded after their placement in selected patients, though not all clinicians may achieve optimal results. It has to be mentioned that the surgeon has more than 20 years of clinical experience with dental implants, which may add to the positive result. In a recent review paper, a high degree of primary implant stability reflected by high value of insertion torque was described as one of the prerequisites for a successful immediate/early loading procedure.[11] In the current patients, the torque values were ranging between 15 and 40 Ncm, and only occasionally higher. Whenever torque values of below 15 were recorded, the surgeon either removed the implant and replaced it by a wider one, or chooses another location to optimize clinical stability. The aspect of initial implant stability reflected by the insertion torque has been discussed previously, and it is obvious that proper stability has shown to be beneficial in immediate loading of fully edentulous jaws irrespective of the implant system used[9,12–14]

It is worthwhile to consider that the implant treatment protocol described in the current study was developed in an era where immediate loading procedures were not considered as state of the art. This may explain why the implant number was maximalized, and sometimes, sleeping implants were present. Although the surgeon (D.J.) had more than 20 years of experience, a learning curve cannot be excluded, especially in the maxilla, given the innovative treatment protocol at that time.

Another aspect that counts for the high survival is probably related to the surface modification of the acid-etched titanium implant (Osseotite) used. Hence, better results were obtained than with machined surface implants, yielding an 85% survival after 10 years.[6] The outcome is comparable with the 7-year survival of 93% also using surface-modified implants.[7] Histomorphometric analysis has proven that the Osseotite surface induces a high level of 78 to 85% bone-to-implant contact under immediate loading.[15] In a comparative study, greater bone-to-implant contact compared with machined surface implants was shown and appears to exert a positive effect on the amount of bone approaching the implant surface, and is considered as osseoconductive.[16]

Compared with other studies using Osseotite implants in two-stage delayed loading conditions, the outcome is somewhat lower than expected. Davarpanah and collegues[17] evaluated Osseotite implants supporting short-span bridges in various indications and reported a 3-year survival rate of 96%. After 3 years, the cumulative survival in the present study was 93%, which is obviously smaller. Testori and coworkers[18] reported a 3-year survival of 99% of Osseotite implants installed in the posterior zone with a one-stage delayed loading protocol. It is tempting to suggest that the smaller survival rate is because of a substantial number of implants in the present study being placed in compromised bone normally not considered for immediate loading procedures such as grafted bone (24%), smokers (24%), or posterior bone (14%) with hampered bone quality.

Del Fabbro and coworkers[19] systematically reviewed literature from 1986 to 2007 to determine the survival rate of dental implants in the grafted maxillary sinus.

Based on more than 13,000 implants placed in over 4,000 patients, they calculated implant survival rate of 88.9% in sinus areas augmented with autogenous bone grafts, 94.7% when combining autogenous bone with various bone substitutes, and 96.1% with bone grafts consisting of bone substitutes alone. Simultaneous and delayed procedures displayed similar survival rates of 92% and 93%. In accordance with the latter study, Cosyn and coworkers[20] also observed no significant difference in the incidence of failure between implants placed in native and grafted bone. Vandeweghe and De Bruyn[21] reported the effect of smoking on early bone remodeling and early implant failure around rough dental implants. Their study concluded a threefold higher failure rate in smokers versus nonsmokers. The maxilla appears to be more prone to bone loss compared with the mandible. So, although smokers are not more susceptible to implant loss, more peri-implant bone loss was observed. Whether this observation may affect future biological complications remains to be investigated.

One of the difficulties in retrospective long-term follow-up is the fact that radiographs are available at irregular, non-standardized time points. Hence, an estimation had to be performed by grouping the radiographic data in time intervals. Additionally, not all implants have a baseline radiograph available. In the current report, this was only the case for 339 of the 749 evaluated implants (45%). As a consequence, it was impossible to calculate the exact changes in peri-implant bone level from the day of surgery, but mean changes were calculated using all radiographs available in a given time interval (see Figure 1). Additionally, conclusions on peri-implant bone level changes after 5 years should be interpreted with care given the substantial dropout. Because patients had implants inserted in grafted bone and healed bone, and given the statistically significant differences between compromised and healed bone, it was impossible to do an analysis with the patient as a unit. Furthermore, analysis on the implant level allows to discriminate better between high losses and is of clinical relevance whenever the prevalence of peri-implantitis is discussed.[22]

Fractures of the provisional reconstructions were often reported in immediate loading studies with implant failures as a consequence.[9,13,23,24] The presented study protocol did advocate a final reconstruction, but the patients had the freedom to choose when and how the final prosthesis was made. Hence, for practical and economical reasons, semi-provisional acrylic bridges were constructed. Especially in the maxilla, a final suprastructure is not recommended as an immediately loaded solution given the risk for soft tissue changes during the first months after surgery. The latter affects aesthetics and phonetics, and may hamper patient's satisfaction. In the mandible, however, the semi-provisional often suffices for aesthetics and phonation. The patients were warned to attend to the clinic whenever complications such as visible damage to the teeth occurred. Twenty-seven percent of the semipermanent reconstruction showed fractures of the acrylic teeth, although this seldom affected the basic structure. This points to the extreme bite forces that are imposed on the implants. This technical complication ratio can be considered high and causes unexpected chair time and sometimes unhappy feelings and stress among the patient as well as clinician. One may suggest a possibly higher risk for implant failures because of uncontrolled loading, but this was not encountered in the current study. Nevertheless, the fracture rate seems negligible or absent when the reconstructions are permanent.[13,14,25] Patients should therefore be informed properly of the risk for complications when the provisionals are not replaced in time to avoid liability problems. Additionally, the cost-benefit calculation should be taken into account.

In conclusion, the acid-etched implants subjected to immediate loading in cross-arch rehabilitations of both mandible and maxilla offer a predictable long-term outcome in terms of implant survival and stable peri-implant bone. This is explained by several factors: (i) the good primary stability obtained by modification of the drilling protocol and adapting the drill diameter to the encountered cutting resistance in the recipient bone; (ii) a sufficient healing time after additional bone grafting or regenerative procedures were required; (iii) an immediate cross-arch splinting of the implants with a rigid and provisional framework minimizing micromobility; and (iv) an even occlusal load distribution on a sufficient number of implants. Whether this semipermanent provisionalization is cost beneficial in the long run remains to be investigated in prospective clinical trials with a randomized controlled design.

REFERENCES

1. Schropp L, Isidor F, Kostopoulos L, Wenzel A. Patient experience of, and satisfaction with, delayed-immediate vs.

delayed single-tooth implant placement. Clin Oral Implants Res 2004; 15:498–503.
2. Dierens M, Collaert B, Deschepper E, et al. Patient-centered outcome of immediately loaded implants in the rehabilitation of fully edentulous jaws. Clin Oral Implants Res 2009; 20:1070–1077.
3. Nkenke E, Fenner M. Indications for immediate loading of implants and implant success. Clin Oral Implants Res 2006; 17(Suppl 2):19–34.
4. Attard NJ, David LA, Zarb GA. Immediate loading of implants with mandibular overdentures: one-year clinical results of a prospective study. Int J Prosthodont 2005; 18:463–470.
5. Romanos G, Froum S, Hery C, Cho SC, Tarnow D. Survival rate of immediately vs delayed loaded implants: analysis of the current literature. J Oral Implantol 2010; 36:315–324.
6. Schnitman PA, Wohrle PS, Rubenstein JE, DaSilva JD, Wang NH. Ten-year results for Branemark implants immediately loaded with fixed prostheses at implant placement. Int J Oral Maxillofac Implants 1997; 12:495–503.
7. Degidi M, Piattelli A. 7-year follow-up of 93 immediately loaded titanium dental implants. J Oral Implantol 2005; 31:25–31.
8. Sennerby L, Gottlow J. Clinical outcomes of immediate/early loading of dental implants. A literature review of recent controlled prospective clinical studies. Aust Dent J 2008; 53(Suppl 1):S82–S88.
9. Van de Velde T, Collaert B, De Bruyn H. Immediate loading in the completely edentulous mandible: technical procedure and clinical results up to 3 years of functional loading. Clin Oral Implants Res 2007; 18:295–303.
10. Esposito M, Grusovin MG, Achille H, Coulthard P, Worthington HV. Interventions for replacing missing teeth: different times for loading dental implants. Cochrane Database Syst Rev 2009; CD003878.
11. Javed F, Romanos GE. The role of primary stability for successful immediate loading of dental implants. A literature review. J Dent 2010; 38:612–620.
12. Collaert B, De Bruyn H. Early loading of four or five Astra Tech fixtures with a fixed cross-arch restoration in the mandible. Clin Implant Dent Relat Res 2002; 4:133–135.
13. Collaert B, De Bruyn H. Immediate functional loading of TiOblast dental implants in full-arch edentulous maxillae: a 3-year prospective study. Clin Oral Implants Res 2008; 19:1254–1260.
14. De Bruyn H, Van de Velde T, Collaert B. Immediate functional loading of TiOblast dental implants in full-arch edentulous mandibles: a 3-year prospective study. Clin Oral Implants Res 2008; 19:717–723.
15. Testori T, Szmukler-Moncler S, Francetti L, et al. Immediate loading of Osseotite implants: a case report and histologic analysis after 4 months of occlusal loading. Int J Periodontics Restorative Dent 2001; 21:451–459.
16. Trisi P, Lazzara R, Rao W, Rebaudi A. Bone-implant contact and bone quality: evaluation of expected and actual bone contact on machined and osseotite implant surfaces. Int J Periodontics Restorative Dent 2002; 22:535–545.
17. Davarpanah M, Martinez H, Celletti R, et al. Osseotite implant: 3-year prospective multicenter evaluation. Clin Implant Dent Relat Res 2001; 3:111–118.
18. Testori T, Del Fabbro M, Feldman S, et al. A multicenter prospective evaluation of 2-months loaded Osseotite implants placed in the posterior jaws: 3-year follow-up results. Clin Oral Implants Res 2002; 13:154–161.
19. Del Fabbro M, Rosano G, Taschiere S. Implant survival rates after maxillary sinus augmentation. Eur J Oral Sci 2008; 116:497–506.
20. Cosyn J, Vandenbulcke E, Browaeys H, Van Maele G, De Bruyn H. Factors associated with failure of surface-modified implants up to four years of function. Clin Implant Dent Relat Res 2010. DOI: 10.1111/j.1708-8208.2010.00282.x [Epub ahead of print].
21. Vandeweghe S, De Bruyn H. The effect of smoking on early bone remodeling on surface modified Southern Implants(R). Clin Implant Dent Relat Res 2009. DOI: 10.1111/j.1708-8208.2009.00198.x [Epub ahead of print].
22. De Bruyn H, Collaert B. Effect of Microthread design on preservation of marginal bone loss. Appl Osseointegration Res 2008; 7:38–47.
23. De Bruyn H, Kisch J, Collaert B, et al. Fixed mandibular restorations on three early-loaded regular platform Branemark implants. Clin Implant Dent Relat Res 2001; 3:176–184.
24. Malo P, Rangert B, Nobre M. All-on-4 immediate-function concept with Branemark System implants for completely edentulous maxillae: a 1-year retrospective clinical study. Clin Implant Dent Relat Res 2005; 7(Suppl 1):S88–S94.
25. Testori T, Del Fabbro M, Szmukler-Moncler S, Francetti L, Weinstein RL. Immediate occlusal loading of Osseotite implants in the completely edentulous mandible. Int J Oral Maxillofac Implants 2003; 18:544–551.