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Research Article

Immediate Function of Anodically Oxidized Surface Implants (TiUnite™) for Fixed Prosthetic Rehabilitation: Retrospective Study with 10 Years of Follow-Up

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Purpose. To report the long-term outcome at 10 years of fixed prosthetic rehabilitation supported by dental implants with anodically oxidized surfaces in immediate function. *Materials and Methods*. This retrospective cohort study included 75 consecutive patients (44 females and 31 males; 14 bruxers; 21 smokers; 14 systemic compromised), with average age of 60 years, rehabilitated with 264 implants. Outcome measures were implant cumulative survival rates (calculated through life tables) and marginal bone level at 10 years. *Results*. Twenty-one patients with 66 implants (25%) were lost to follow-up. Six patients lost 12 implants (MkIII implants: $n = 9$; MkIV implants: $n = 3$). The overall implant cumulative survival rate at 10 years was 95.2% (maxilla: 95.6%; mandible: 94.7%). The average (standard deviation) marginal bone level at 10 years was 1.96 mm (1.50 mm), with 1.92 mm (1.31 mm) for the maxilla and 2.00 mm (1.71 mm) for the mandible, with a significant difference between nonsmokers (average = 1.60 mm) and smokers (average = 2.95 mm). *Conclusions*. Within the limitations of this study, it can be concluded that fixed prosthetic rehabilitation supported by implants with anodically oxidized surface in immediate function is a viable and safe treatment option for both jaws.

1. Introduction

Insertion of dental implants exhibits an increasing trend over the years on a global scale, becoming the best treatment option in terms of long-term success for replacing missing teeth [1]. Dental implant success/failure is related to various factors, namely, the surgeons' skill, surgical procedures, prosthetic and biomechanical factors, patient's overall general health, oral hygiene, and the dental implants' surface, among others [2].

Dental implant surface plays an important role in tissue interaction as well as in the rate and quality of osseointegration, as the design of the surface will influence the implant integration with the surrounding bone. Surface properties, chemical composition, hydrophilicity, and roughness are parameters that are crucial for the short- and long-term success of an implant [2, 3]. That is the reason for the development of variety of surfaces with different characteristics, compositions, and degrees of roughness in implant industry [2]. This roughness can be created by coatings, blasting by various substances, acidic treatments, or treatment combinations [2].

Since its launch in 2000, more than 15 million implants with TiUnite surface (Nobel Biocare, Gothenburg, Sweden) have been used. The TiUnite surface (Nobel Biocare, Gothenburg) consists of a moderately rough thickened titanium oxide layer [4–9], with a roughness of 1.35 microns [6]. It is obtained through spark anodization in an electrolytic solution containing phosphoric acid resulting in a duplex oxide structure: an inner barrier layer without pores and an outer porous layer featuring numerous pores with diameters and depths between ≤ 4 microns and ≤ 10 microns [5–9]. This surface also displays a high crystallinity and phosphorus content (11% P) in its oxide layer [6] as well as a surface morphology that aims for high osteoconductivity and fast anchorage to the collagen matrix.

The advantages of this anodically oxidized surface include a higher osteoconductivity and a shortened healing phase [4, 5, 10]. A higher osteoconductivity for this anodically oxidized surface was found when compared to the machined surface which favours an enhanced and faster osseointegration, maintaining a high implant stability immediately after placement and during the healing phase [4, 5]. This aspect may be significant when considering the insertion of implants in critical bone conditions in both low quantity bone (allowing the insertion of short implants) and low density bone (maintaining a high implant stability) [10]. Furthermore, the anodically oxidized surface enabled a shortened healing phase by reducing the time required to achieve secondary stability through the acceleration of bone formation at the implant-abutment interface [5, 10]. Given these advantages, the clinical applications of the anodically oxidized surface implants comprise immediate function protocols, with previous clinical research registered successful long-term outcomes (≥5 years of follow-up) irrespective of the arch (maxilla: 88.5%–100%; mandible: 94.8%–100%) [7, 11–18], the area (anterior regions: 100%; posterior regions: 96.7%–100%) [14], and the type of rehabilitation (single elements: 96.5%–100% [14, 17]; partial rehabilitation: 88.5%–99.2% [12, 14, 18]; or more complex full-arch rehabilitation: 94.8%–100% [7, 11, 13–16]). Moreover, favourable marginal bone response and soft tissue conditions of implants with anodically oxidized surface have also been reported, with an average bone loss at 10 years of 0.7 mm [9], 1.93–1.98 mm [13], and 1.67 mm at 11 years [14], in addition to average probing pocket depths of 1.65 ± 0.84 mm [12] to 2.54–2.63 mm [13]. A possible disadvantage of the anodically oxidized surface retrieved from studies in the animal model may stand in the resolution of peri-implant pathology where previous clinical studies registered no signs of resolution when analysing the effect of surgical treatment without the use of systemic antibiotics [19] and a more pronounced bone loss, vertical dimensions of the inflammatory lesion, and apical extension of the biofilm at 1-year postintervention [20] when compared to machined surface implants.

Nevertheless, relatively few studies exist on the long-term outcome (with at least 10 years of follow-up) of implants with anodically oxidized surfaces inserted with immediate loading protocols: these studies registered cumulative survival rates over 96.5% at 10 years of follow-up [12–14].

There is a necessity of more studies investigating the long-term outcome (with at least 10 years) of implants with anodically oxidized surface inserted in immediate function.

The aim of this study was to evaluate the 10-year survival and marginal bone level outcomes of dental implants with anodically oxidized surface for support of fixed prosthetic rehabilitation in immediate function on both jaws.

2. Materials and Methods

This retrospective study was performed in Malo Clinic Lisbon (a private clinic in Portugal) from January 2001 (first implant insertion) to December 2012 (last follow-up appointment) and was approved by an independent ethical committee (Ethical Committee for Health, authorization number 004/2012).

The inclusion criteria for patient selection were the need for rehabilitation of single, partial, or full-arch maxilla or mandible through dental implants with anodically oxidized surface inserted with an immediate function protocol between January 2001 and January 2003. Exclusion criteria were patients rehabilitated through dental implants inserted in one-stage or two-stage surgical approaches, patients that underwent bone grafting procedures in the position of the implants, and patients rehabilitated with machined surface dental implants. These patients were identified from the medical records.

The rehabilitation procedure was divided into 2 treatment stages as per protocol: the first stage comprising the treatment planning, surgical intervention, immediate provisional prosthesis manufacture, and the maintenance appointments during the first 6 postoperative months and the second stage comprising the definitive prosthesis manufacture and the long-term maintenance.

2.1. Surgical Protocol. A clinical examination with a preoperative panoramic radiograph and a computed tomography (CT) scan were used to plan the surgeries. The medication protocol was as follows: antibiotics before surgery and 15 days after surgery (Oraminax® 1 g, Wyeth Laboratories, Azevedos, Algés, Portugal); cortisone medication (prednisone 5 mg; Meticorten®, Schering-Plough Farma, Agualva-Cacém, Portugal), given daily in a regression mode (15 mg to 5 mg) from the day of surgery until 4 days postoperatively; anti-inflammatory medication (Nimed®, Rhône-Poulenc Rorer, Mem Martins, Portugal), administered for 2 days postoperatively starting on day 4; analgesics (clonixin 300 mg; Clonix®, Janssen-Cilag Farmaceutica, Barcarena, Portugal), given on the day of surgery and postoperatively for the first 3 days if needed; and antacid medication (omeprazole 20 mg; Generis, Lisbon, Portugal), given on the day of surgery and daily for 6 days postoperatively. The surgery was performed under local anesthesia (lidocaine hydrochloride 2% with epinephrine 1 : 100,000; Rapicaine®, Unipharm, Veracruz, Mexico). One operator (PM) performed the surgical procedures.

The insertion of the anodically oxidized surface implants followed the manufacturer's standard procedures [21] with the following modifications: for single elements [17] and partial rehabilitation [18], the incision was performed (blade number 15, ref. P305, Lance Paragon, Ltd., Sheffield, England) on the palatal aspect of the crest for maximum tissue repositioning on the buccal aspect and the flaps were kept as small as possible to maximize the blood supply to the implant site after surgery. A direction indicator pin (Nobel Biocare) was used for optimal implant positioning.

For full-arch edentulous rehabilitation [11], a mucoperiosteal flap was raised at the ridge crest with relieving incisions on the buccal aspect in the molar area (blade number 15, ref. P305, Lance Paragon, Ltd., Sheffield, England).

Common to all types of rehabilitation, the drilling sequence was modified by employing underpreparation in order to secure a final torque of at least 30 Ncm before the final seating of the implant. Countersinking was used only when required to create space for the tilted implants' head (n = 9 patients and 18 implants) in full-arch edentulous

rehabilitation or to secure both buccal and lingual cortical bone contact at the implant head in thin bone crests. All the implants were positioned with the implant platform at 0.8 mm above bone level, corresponding to the lower corner of the cylindrical part of the implant flange at bone level and bicortical anchorage was established whenever possible. No membranes or biomaterials were used. After closing and suturing the flap with 3-0 nonresorbable sutures (Silkam, B. Braun Surgical SA, Rubi, Spain), the access to the abutments was opened by a punch and impression copings were placed. Postoperative radiographs were performed for control of the dental implant rehabilitation (Kodak 8000C, Carestream Health Inc., Rochester, New York, USA).

2.2. Immediate and Final Prosthetic Protocol. All implants underwent immediate loading. For single teeth or fixed partial prostheses, the intended final abutment (ranging from CeraOne, MirusCone, EsthetiCone, or Multiunit Abutments; Nobel Biocare AB) was inserted on the day of surgery and a provisional acrylic-resin crown/fixed partial prosthesis was connected (screw-retained). The occlusion was adjusted to eliminate direct contact to the prosthesis. After 6 months the patients received their permanent prosthetic reconstruction consisting of full-ceramic crowns (Procera Alumina or Zirconia; Nobel Biocare AB) or metal-ceramic fixed partial prostheses.

For full-arch rehabilitation, based on the impression, provisional full-arch acrylic-resin prostheses (PalaXpress Ultra, Heraeus Kulzer GmbH, Hanau, Germany) with titanium cylinders (Nobel Biocare AB) were manufactured at the laboratory and delivered on the day of surgery. Final acrylic-resin prostheses of the same type, metal-acrylic-resin prosthesis with a titanium framework (Procera® titanium framework; Nobel Biocare AB) and acrylic-resin teeth (PalaXpress Ultra, Heraeus Kulzer GmbH), or metal-ceramic prostheses with a titanium framework (Procera titanium framework; Nobel Biocare AB) and ceramic crowns (Procera Alumina crowns; Nobel Biocare AB) were delivered, respectively, at the earliest, 6 months after surgery.

2.3. Postoperative Care and Follow-Up. The patients were instructed to have a soft food diet for the first four months after surgery. Ten days after surgery, the sutures were removed, and hygiene and implant stability (clinical mobility and suppuration by finger pressure) were checked. The occlusion was rechecked according to the initial protocol, a procedure that was repeated after 2 and 4 months. Usually, at around 4 months, the prostheses were again removed, jet-cleaned (using Air-Flow Powder, EMS, Nyon, Switzerland), and disinfected (using 0.2% chlorhexidine; Elugel, Pierre Fabre Dermo-Cosmetique), and the implants were checked for anchorage (clinical mobility), suppuration, and pain.

The patients were evaluated at 6 months after surgery, one-year after surgery, and thereafter every 6 months. The prosthesis was removed in every clinical appointment (except for single crowns) and the implants were evaluated in terms of stability.

2.4. Outcome Measures. Primary outcome measure was implant survival evaluated based on function and using the implant as unit of analysis. The implants survival was evaluated based on function and determined by fulfillment of the following criteria [11]: implant fulfilling its purported function as support for reconstruction; clinical stability; no signs of persistent infection observed; no radiolucent areas around the implants; demonstrating good esthetic outcome in the rehabilitation; and patient reported function without any discomfort. All implants that were removed were classified as failures. The same operator performed the evaluation of postsurgical stability at 6 months.

Secondary outcome measures were marginal bone level evaluated at 10 years of function using the implant as unit of analysis. A conventional radiographic holder (super-bite; Hawe Neos, Bioggio, Switzerland) was used, and its position was manually adjusted for an estimated orthognathic position of the film. An outcome assessor examined all implant radiographs. Each periapical radiograph was scanned at 300 dpi with a scanner (HP Scanjet 4890, HP Portugal, Paço de Arcos, Portugal), and the marginal bone level was assessed with image analysis software (Image J version 1.40 g for Windows, National Institutes of Health, Bethesda, MD, USA). The reference point for the reading was the implant platform (the horizontal interface between the implant and the abutment), and the marginal bone level was assessed and defined as the most apical contact between bone and implant. The measurements were performed on the mesial and distal sites, and average values were calculated. The radiographs were calibrated using the implant platform diameter. The radiographs were accepted or rejected for evaluation based on the clarity of the implant threads; a clear thread guaranteed both sharpness and an orthogonal direction of the radiographic beam towards the implant axis.

2.5. Statistical Analysis. Survival was calculated using life table analysis. Descriptive statistics were computed for the variables of interest (marginal bone level). Cumulative implant survival rates were computed through life table analysis considering the overall, the implant site (maxilla, mandible), the type of restoration (single tooth, partial restoration, and full-arch restoration), the patients' smoking status (smoker, nonsmoker), systemic status (healthy, systemic compromised), and parafunctional habits status (nonbruxer, bruxer). The average marginal bone level with corresponding 95% confidence interval (95% CI) was calculated overall and implant site specific and further evaluated according to the patients' smoking, systemic, and parafunctional status. The data was analysed using the software SPSS for Windows version 17 (IBM SPSS, New York, USA).

3. Results

3.1. Patients. The study included 75 patients (44 females and 31 males), with an age range of 29 to 88 years (mean age of 60 years). The medical status of the patients was established at implant insertion: fourteen patients with 57 implants were bruxers; twenty-one patients with a total of 69 implants were

Table 1: Patient characteristics, number of implants per group, and number of failed implants according to the presence or absence of comorbidities, smoking habits, and bruxism habits.

Condition	Number of patients	Number of implants (implants failed)
Hepatitis	1	8
Cardiovascular condition	8	31
Thyroid condition	2	4 (1)*
Diabetes	2	8
Rheumatologic condition	0	0
Smokers	21	69 (2)*
HIV	1	8
Oncological condition	4	20
Neurologic condition	2	13
One or more of the abovementioned conditions	4	23
Heavy bruxers	14	57 (0)
Healthy patients	37	126 (10)
Total	75	264 (12)

*One patient presented concurrently a thyroid condition and smoking habits.

Table 2: Dental implants with external implant-abutment connection distribution by type of implant, diameter, and length.

Type of implants	Number of implants (implants failed)
Mk III 3.3 mm diameter: 10 mm of length	2
Mk III 3.3 mm diameter: 11.5 mm of length	1
Mk III 3.3 mm diameter: 13 mm of length	6
Mk III 3.75 mm diameter: 15 mm of length	7 (1)
Mk III 3.75 mm diameter: 8.5 mm of length	2
Mk III 3.75 mm diameter: 10 mm of length	9
Mk III 3.75 mm diameter: 11.5 mm of length	10
Mk III 3.75 mm diameter: 13 mm of length	19
Mk III 3.75 mm diameter: 15 mm of length	70 (8)
Total number of Mk III implants	126 (9)
Mk IV 3.3 mm diameter: 8.5 mm of length	6
Mk IV 4.0 mm diameter: 8.5 mm of length	17 (1)
Mk IV 4.0 mm diameter: 10 mm of length	19
Mk IV 4.0 mm diameter: 11.5 mm of length	9
Mk IV 4.0 mm diameter: 13 mm of length	31 (1)
Mk IV 4.0 mm diameter: 15 mm of length	56 (1)
Total number of Mk IV implants	138 (3)
Total number of implants	264 (12)

smokers; fourteen patients with a total of 56 implants had systemic conditions such as hepatitis, cardiovascular condition, thyroid condition, diabetes, rheumatologic condition, HIV, oncologic condition, and neurologic condition as presented in Table 1.

A total of 21 patients (28%) with 66 implants (25%) were lost to follow-up: fifteen patients became unreachable and 6 patients passed away due to causes unrelated to implant treatment.

3.2. Inserted Implants. Seventy-five patients received 264 dental implants, 167 in the maxilla and 97 in the mandible. One hundred and nine of the inserted implants supported full-arch rehabilitation, 80 implants supported fixed partial prostheses, and 75 implants supported single tooth rehabilitation. From these 264 implants with moderately rough surfaces, 126 were Brånemark System MkIII (Nobel Biocare AB) implants (68 placed in the maxilla and 58 in the mandible) and 138 were Brånemark System MkIV (Nobel Biocare AB) implants (99 in the maxilla and 39 in the mandible) (Tables 2 and 3).

3.3. Implant Failures. A total of 12 implant failures were registered in 6 patients: 9 Brånemark system MkIII implants and 3 Brånemark system MkIV implants. There were five implant failures in the first year, two implant failures in the second year, three implant failures in the fourth year, one implant failure after five years, and one implant failure after 9 years of follow-up. Five implant failures occurred in two patients with full-arch prostheses (4 implant failures and 1 implant failure occurred in mandibular full-arch prostheses supported by 6 implants and 4 implants, resp.) and with implant-supported prosthesis as opposing dentition: the first patient (healthy) with 4 implant failures due to infection (exhibiting probing pocket depths over 9 mm, with concurrent presence of bleeding on probing, suppuration, and marginal bone loss extending to the apical third of the implant) between 23 and 36 months (positions 31, 41, 42, and 45) in a full-arch prosthesis supported by 6 implants, had new implants inserted after 6 months (uneventful). One patient (smoker) with 1 implant failure after 53 months (position 45) due to infection (exhibiting probing pocket depths of 6 mm, with concurrent presence of bleeding on probing, suppuration, and marginal bone loss extending to the apical third of the implant) in a full-arch prosthesis supported by four implants had the prostheses adapted to be supported by the remaining three implants. One implant (position 14) failed after 8 years due to infection (exhibiting probing pocket depths of 6 mm, with concurrent presence of bleeding on probing, suppuration, and marginal bone loss extending to the apical third of the implant) in a healthy patient with a maxillary fixed partial prosthesis (supported by two implants) with natural teeth as opposing dentition: the failed implant was not reinserted and the patient had the prostheses adapted to be supported by the remaining implant. Six implants failed in 3 patients with maxillary single tooth rehabilitation: one healthy patient, with implant-supported fixed prosthesis as opposing dentition, lost 4 implants due to loss of osseointegration (positions 11, 12, 21, and 22) after one month and no implants were reinserted (the rehabilitation was transformed into a fixed prosthesis over natural teeth);

Table 3: Implant type, position in the maxilla/mandible, and implant failures after 10 years' follow-up.

Implant positions in the maxilla (number of implant failures)																	
Implant position→*	18	17	16	15	14	13	12	11	21	22	23	24	25	26	27	28	Total
MKIII implants	1	0	4	1	10	4	12 (2)	7 (1)	9 (1)	7 (1)	3	5	3	1	1	0	68 (5)
MKIV implants	0	2	18	17	6 (1)	1	5	7	4	3	4	6 (1)	11	12	2	1	99 (2)
Implant positions in the mandible (number of implant failures)																	
Implant position→*	48	47	46	45	44	43	42	41	31	32	33	34	35	36	37	38	Total
MKIII implants	0	2	2	7 (1)	2	1	11 (1)	1 (1)	2 (1)	12	2	4	6	4	2	0	58 (4)
MKIV implants	0	3	7	5 (1)	0	0	1	1	0	3	0	0	6	6	6	1	39 (1)

*Implant position according to the FDI World Dental Federation two-digit notation.

another patient (smoker and with thyroid condition), with natural teeth as opposing dentition, lost 1 implant after one year due to loss of osseointegration (position 24) with the prostheses adapted to be supported by implants on positions 23 and 25; a third patient (healthy), with natural teeth as opposing dentition, lost one implant after 5 months due to loss of osseointegration (position 12) that was reinserted after 6 months (uneventful).

3.4. Implant Cumulative Survival Rate. The overall implant cumulative survival rate (CSR) registered in this study was 95.2% at 10 years, with 95.6% for the maxilla and 94.7% for the mandible (Table 4). Concerning the distribution of surviving implants by type of rehabilitation, the CSR registered at 10 years of follow-up was 95.2%, 98.4%, and 92.3% for implants in full-arch, partial, and single tooth rehabilitation, respectively (Table 5). The implant CSR distribution according to the patients' smoking habits and systemic and parafunctional habits status is illustrated on Figures 1–3.

3.5. Average Marginal Bone Level. The average (95% confidence interval) marginal bone level for the anodically oxidized surface implants at 10 years of follow-up was 1.96 mm (1.71; 2.22), with 1.92 mm (1.61; 2.23) for the maxilla and 2.00 mm (1.58; 2.44) for the mandible (Table 6). The 27 implants with more than 3.0 mm of marginal bone level clustered in 15 patients, whose characteristics are detailed in Table 6. Representative radiographs of single tooth and fixed partial rehabilitation supported by implants with anodically oxidized surface at 10 years of follow-up are presented in Figures 4 and 5. Considering the patients' status, the average (95% CI) bone level around the implants at 10 years is illustrated in Figures 6–8, with significant overlap in the 95% confidence intervals for healthy versus systemic compromised and nonbruxer versus bruxer, but an absence of overlap in the 95% confidence interval for nonsmoker versus smoker.

4. Discussion

The results registered in this study demonstrated a successful long-term outcome for implants with anodically oxidized surface placed exclusively in immediate function, with high cumulative survival rates at 5 and 10 years of follow-up and considering the high prevalence of patients with smoking habits (1/4 of the patients), systemic conditions (1/5 of the patients), and parafunctional habits (1/5 of the patients).

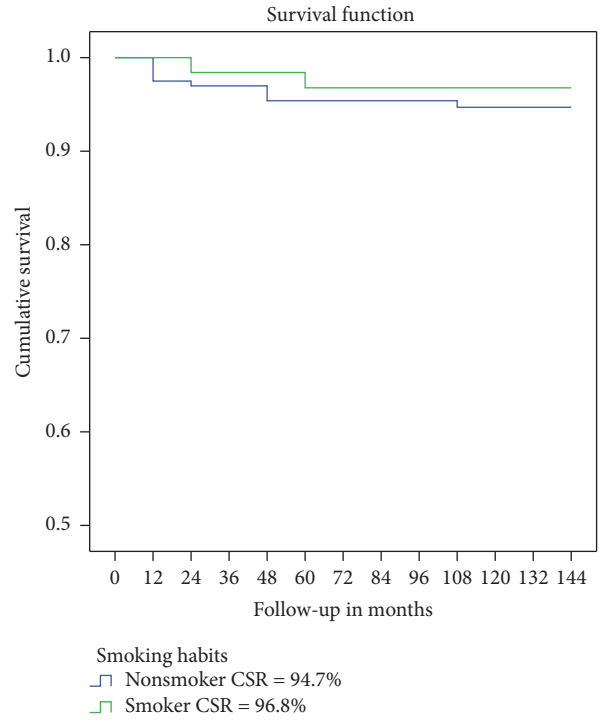

Figure 1: Implant survival curves according to the patients' smoking status.

Concerning the type of prosthetic rehabilitation, cumulative implant survival rates around 98% were registered for full-arch rehabilitation performed with immediate loading in the mandible [7] and in the maxilla [11] at 5 years of follow-up, while cumulative implant survival rates of 95% and 100% were registered for immediately loaded single lower molars [22] and immediately loaded implants inserted in postextraction sockets [23], respectively.

At 10 years of follow-up, the number of studies is scarce. Concerning studies with at least 10 years of function, Östman et al. [12] in a prospective study evaluating 46 patients with 121 oxidized Brånemark system implants registered a cumulative survival rate of 99.2% in a combination of immediate loading and two-stage surgical procedure implants to support single, partial, and total prostheses. Degidi et al. [13] in

Table 4: Cumulative survival rates for implants with anodically oxidized surface by total and per arch of rehabilitation.

Time	Total number of implants	Implant failures	Lost to follow-up	Follow-up not completed	Survival rate%	Cumulative survival rate%
			Total number of implants			
0-1 year	264	5	1	0	98.1%	98.1%
1-2 years	258	2	10	0	99.2%	97.3%
2-3 years	246	0	0	0	100%	97,3%
3-4 years	246	3	5	0	98.8%	96.1%
4-5 years	238	1	0	0	99.6%	95.7%
5-6 years	237	0	6	0	100%	95.7%
6-7 years	231	0	30	0	100%	95.7%
7-8 years	201	0	12	0	100%	95.7%
8-9 years	189	1	1	0	99.5%	95.2%
9-10 years	187	0	1	0	100%	95.2%
10-11 years	186	0	0	136	100%	95.2%
11-12 years	50	0	0	45	100%	95.2%
			Maxilla			
0-1 year	169	5	1	0	97.0%	97.0%
1-2 years	163	1	10	0	99.4%	96.4%
2-3 years	152	0	0	0	100%	96.4%
3-4 years	152	0	5	0	100%	96.4%
4-5 years	147	0	0	0	100%	96.4%
5-6 years	147	0	3	0	100%	96.4%
6-7 years	144	0	17	0	100%	96.4%
7-8 years	127	0	11	0	100%	96.4%
8-9 years	116	1	1	0	99.1%	95.6%
9-10 years	114	0	0	0	100%	95.6%
10-11 years	114	0	0	78	100%	95.6%
11-12 years	36	0	0	34	100%	95.6%
			Mandible			
0-1 year	95	0	0	0	100%	100%
1-2 years	95	1	0	0	98.9%	98.9%
2-3 years	94	0	0	0	100%	98.9%
3-4 years	94	3	0	0	96.8%	95.8%
4-5 years	91	1	0	0	98.9%	94.7%
5-6 years	90	0	3	0	100%	94.7%
6-7 years	87	0	13	0	100%	94.7%
7-8 years	74	0	1	0	100%	94.7%
8-9 years	73	0	0	0	100%	94.7%
9-10 years	73	0	1	0	100%	94.7%
10-11 years	72	0	0	58	100%	94.7%
11-12 years	14	0	0	11	100%	94.7%

a prospective study evaluating the 10-year outcome of 210 anodically oxidized implants in immediate loading inserted in 59 patients registered cumulative survival rates between 96.5% (for postextractive sites) and 98.1% (for healed sites). Glauser [14] in a clinical study with 11 years of follow-up evaluating 66 immediately loaded anodically oxidized implants in 26 patients reported an implant cumulative survival rate of 97.1%. Mozzati et al. [15] performed a retrospective investigation on 209 implants (81 immediately loaded) supporting mostly single tooth and partial rehabilitation in 90 patients, from which 181 implants (90.5%) reached at least 10 years. The cumulative survival rate registered for this sample was 97.1%.

It is important to notice that compared to the previously cited studies [12–14] our study had a significantly higher

Table 5: Cumulative survival rates for implants with anodically oxidized surface by total and type of reconstruction.

Time	Total number of implants	Implant failures	Lost to follow-up	Follow-up not completed	Survival rate%	Cumulative survival rate%
			Full-arch			
0-1 year	105	0	0	0	100%	100%
1-2 years	105	1	0	0	99.0%	99.0%
2-3 years	104	0	0	0	100%	99.0%
3-4 years	104	3	0	0	97.1%	96.2%
4-5 years	101	1	0	0	99.0%	95.2%
5-6 years	100	0	0	0	100%	95.2%
6-7 years	100	0	14	0	100%	95.2%
7-8 years	86	0	8	0	100%	95.2%
8-9 years	78	0	0	0	100%	95.2%
9-10 years	78	0	1	0	100%	95.2%
10-11 years	77	0	0	63	100%	95.2%
11-12 years	14	0	0	14	100%	95.2%
			Fixed partial prostheses			
0-1 year	80	0	0	0	100%	100%
1-2 years	80	0	3	0	100%	100%
2-3 years	77	0	0	0	100%	100%
3-4 years	77	0	0	0	100%	100%
4-5 years	77	0	0	0	100%	100%
5-6 years	77	0	0	0	100%	100%
6-7 years	73	0	11	0	100%	100%
7-8 years	62	0	1	0	100%	100%
8-9 years	61	1	0	0	98.4%	98.4%
9-10 years	60	0	0	0	100%	98.4%
10-11 years	60	0	0	43	100%	98.4%
11-12 years	17	0	0	14	100%	98.4%
			Single teeth			
0-1 year	79	5	1	0	93.6%	93.6%
1-2 years	73	1	7	0	98.6%	92.3%
2-3 years	65	0	0	0	100%	92.3%
3-4 years	65	0	5	0	100%	92.3%
4-5 years	60	0	0	0	100%	92.3%
5-6 years	60	0	2	0	100%	92.3%
6-7 years	58	0	5	0	100%	92.3%
7-8 years	53	0	3	0	100%	92.3%
8-9 years	50	0	1	0	100%	92.3%
9-10 years	49	0	0	0	100%	92.3%
10-11 years	49	0	0	30	100%	92.3%
11-12 years	19	0	0	17	100%	92.3%

overall percentage of patients included with systemically compromised situations (~20%), smoking habits (~25%), or bruxism (~19%): Östman et al. [12] reported the inclusion of only 2 patients who were smokers (4.4%), while Degidi et al. [13] excluded patients presenting systemic disease that could compromise osseointegration and reported only on one patient (1.7%) who was a smoker; Glauser [14] included in the initial sample 11 patients who were smokers but excluded patients with ongoing signs of parafunctional habits and systemically compromised.

The marginal bone level registered in this study at 10 years (1.96 mm) was higher compared to the 1.6 mm of marginal bone level reported by Östman et al. [12] or the 1.65 mm marginal bone loss reported by Glauser [14] and potentially

Table 6: Marginal bone level at 10 years for anodically oxidized implants in immediate function.

(a) Descriptive statistics, number, and frequencies by total and distributed by arch of rehabilitation

	Maxilla		Mandible		Total	
Average (mm) [95% confidence interval]	1.92 [1.61; 2.23]		2.00 [1.58; 2.44]		1.96 [1.71; 2.22]	
Standard deviation (mm)	1.31		1.71		1.50	
Number	73		63		136	
Frequencies	*N*	%	*N*	%	*N*	%
0 mm	3	4.1%	0	0.0%	3	2.2%
0.1 to −1.0 mm	19	26.0%	21	33.3%	40	29.4%
1.1 to −2.0 mm	25	34.2%	23	36.5%	48	35.3%
2.1 to −3.0 mm	10	13.7%	8	12.7%	18	13.2%
>3.0 mm	16	21.9%	11	17.5%	27	19.9%

(b) Discrimination of patients with implants with a marginal bone level (MBL) > 3.0 mm at 10 years

Patients	*N* implants MBL > 3.0 mm	Age	Gender	Patient characteristics
1	4	55	Male	Smoker, HIV+, bruxer
2	4	72	Female	—
3	3	56	Male	Smoker
4	2	50	Female	Smoker
5	2	52	Male	Smoker
6	2	57	Female	Cancer
7	2	60	Female	Bruxer
8	1	46	Female	Smoker
9	1	61	Female	—
10	1	61	Female	Cancer
11	1	60	Female	Smoker
12	1	51	Male	Smoker
13	1	87	Female	—
14	1	32	Female	Smoker
15	1	62	Male	Smoker

lower than the 1.93 mm (for healed sites) and 1.98 mm (for postextractive sites) marginal bone loss reported by Degidi et al. [13]. The marginal bone levels of a given implant constitute an overestimation of the marginal bone loss in the absence of baseline bone levels. This principle was based on the fact that the implant neck was positioned at bone level on the day of surgery, and therefore the marginal bone level at 10 years of a given implant represents the highest possible marginal bone resorption. Nevertheless, it constitutes a limitation of our study. The 27 implants with marginal bone levels over 3 mm reported in this study seemed to be significantly influenced by smoking habits, with a considerable ~60% (16/27 implants) of the implants. Furthermore, the difference between smokers and nonsmokers was significant, considering the absence of overlap for the 95% confidence intervals of the average bone level between both groups, a result that was not registered when analysing the systemic or parafunctional habits status judging by the significant overlaps [24, 25]. This translated in an average increase of 1.35 mm in marginal bone level for smokers compared to nonsmokers. The deleterious effect of smoking on the marginal bone level outcome of anodically oxidized implants was previously reported by Östman et al. [12] where all implants with more than 3 mm of marginal bone level were inserted in patients who were smokers. Furthermore, previous studies have confirmed the higher probability of implant loss and biological complications in smokers when compared to nonsmokers [26–28].

The limitations of this study include the retrospective design, the single center, and more than 20% of loss to follow-up rate. Nevertheless, it is important to note the common correlation between long-term studies and a higher probability for loss to follow-up as previously reported [14, 29, 30], a situation that is considerably related to a low number of long-term studies over 10 years for any implant system.

Future investigations should focus on the long-term evaluation of these implants taking into consideration the soft tissue outcomes and the stratification according to different populations (healthy versus systemically compromised and smokers versus nonsmokers).

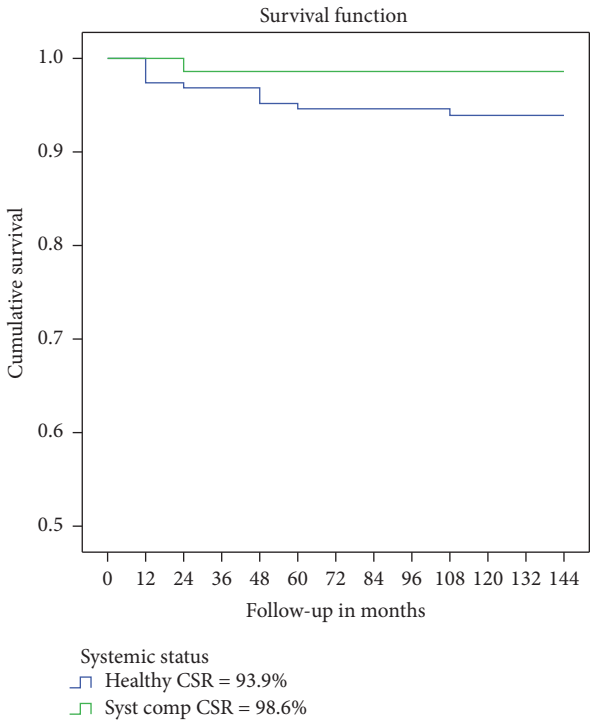

Figure 2: Implant survival curves according to the patients' systemic status.

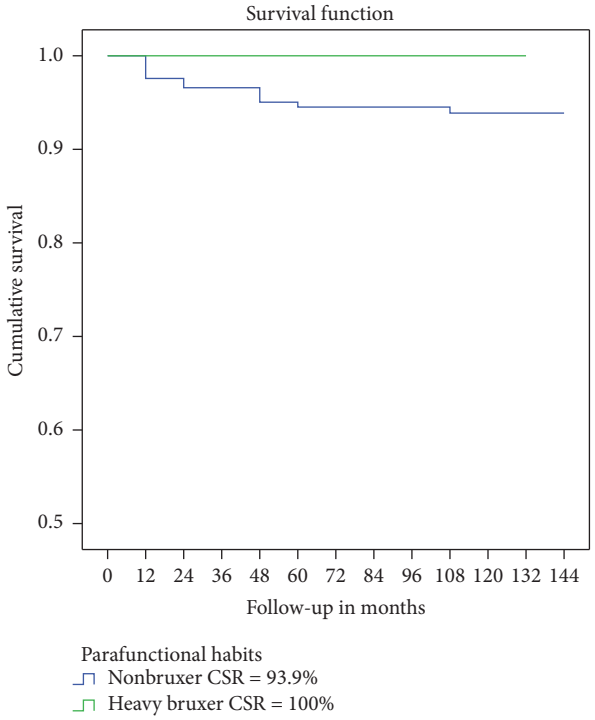

Figure 3: Implant survival curves according to the patients' parafunctional habits status.

5. Conclusions

Within the limitations of this study and based on the 10 years' outcome results, it is possible to conclude that fixed

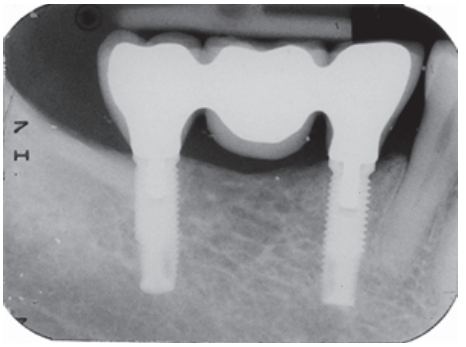

Figure 4: Patient with a fixed partial rehabilitation (implant positions #45 and #47) supported by two MkIII implants with anodically oxidized surface at 10 years of follow-up.

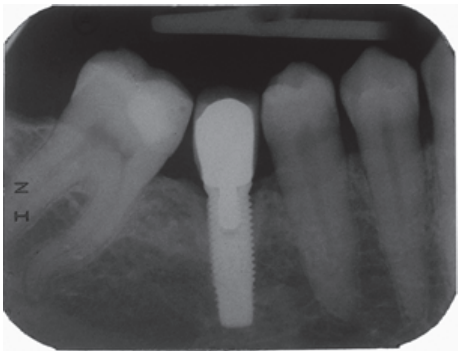

Figure 5: Patient with a single tooth rehabilitation (position #46) supported by an MkIV implant with anodically oxidized surface at 10 years of follow-up.

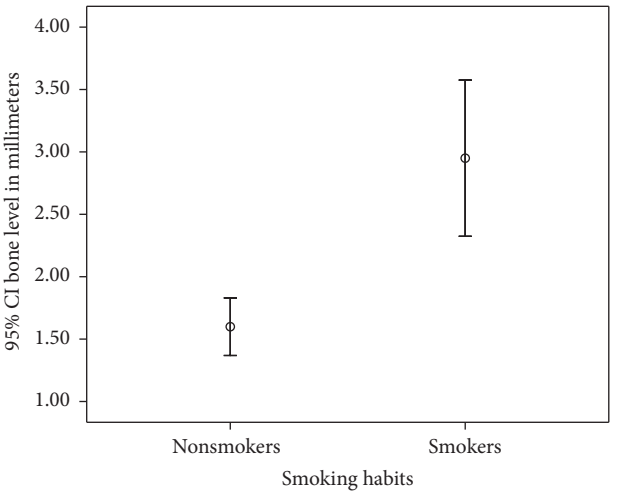

Figure 6: Error-bar plot illustrating the bone level at 10 years according to the patients' smoking status. The average (95% confidence interval) bone level was 1.60 mm (1.37; 1.83) for nonsmokers and 2.95 mm (2.32; 3.58) for smokers. Note that the 95% confidence interval of the average (represented by the error bars) does not overlap, indicating a significant difference between both groups.

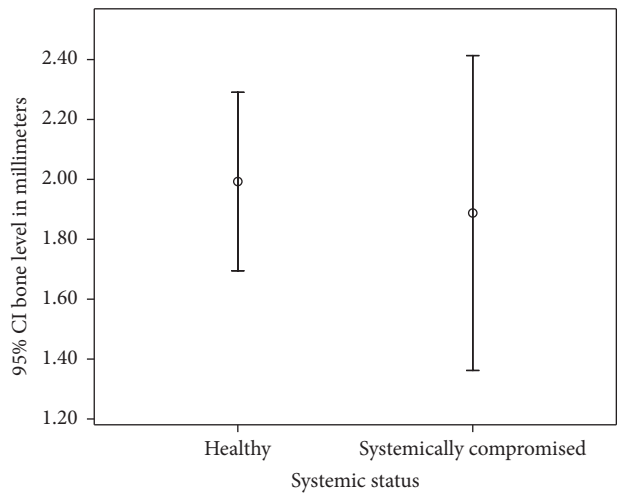

Figure 7: Error-bar plot illustrating the bone level at 10 years according to the patients' systemic status. The average (95% confidence interval) bone level was 1.99 mm (1.70; 2.29) for healthy patients and 1.89 mm (1.36; 2.41) for systemic compromised patients. Note that the 95% confidence interval of the average (represented by the error bars) significantly overlaps indicating a nonsignificant difference between both groups.

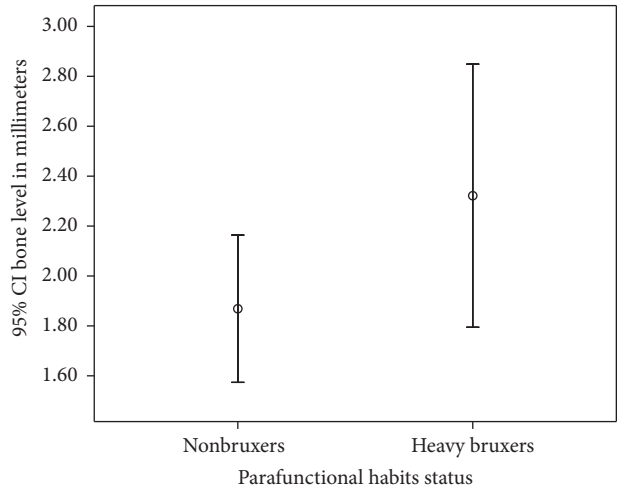

Figure 8: Error-bar plot illustrating the bone level at 10 years according to the patients' parafunctional habit status. The average (95% confidence interval) bone level was 1.87 mm (1.57; 2.16) for nonbruxers and 2.32 mm (1.80; 2.85) for bruxers. Note that the 95% confidence interval of the average (represented by the error bars) significantly overlaps indicating a nonsignificant difference between both groups.

prosthetic rehabilitation supported by implants anodically oxidized surfaces in immediate function represents a valid treatment procedure.

Competing Interests

This study was supported by Nobel Biocare Services AG, Grant 2014-1260. Paulo Maló is currently a consultant for Nobel Biocare. Miguel de Araújo Nobre, Yolande Gonçalves, Armando Lopes, and Ana Ferro have no conflict of interests.

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