Accepted: 16 March 2018
DOI: 10.1111/clr.13153

ORIGINAL RESEARCH

WILEY CLINICAL ORAL IMPLANTS RESEARCH

A retrospective study on the crestal bone loss associated with different implant surfaces in chronic periodontitis patients under maintenance

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Abstract

Objective: To analyze retrospectively interproximal crestal bone loss (CBL) on external-hex "non-identical" (NI) dental implants with different surface topography, when placed in the same intra-oral location in patients with a history of chronic periodontitis following maintenance care.

Material and methods: The patient population consisted of 206 consecutive patients with a history of chronic periodontitis who underwent implant surgery between 2007 and 2010; 755 NI implants with different implant surfaces were placed at posterior mandibular sites: 72 machined, 145 acid-etched/machined (hybrid), and 538 anodized. Crestal bone loss measurements were carried out analyzing the calibrated digital X-rays taken at 1-year intervals as part of the maintenance program, being the time of this retrospective examination from 1 to 3 years.

Results: At 3 years (51 patients), the mean CBL was 1.36/1.35 mm at implant/patient level (range: 0–6 mm). A higher CBL was observed at anodized surface implants, when compared to machined and hybrid implants, being the mean CBL 1.48, 0.96, and 0.77 mm, respectively (p = .005). CBL between 2 and 3.9 mm was found in 10.6% of the implants at 3 years (95% CI: 6%–15%), ≥4 mm in 5% (95% CI: 2%–8%). Anodized surface implants had CBL >2 mm at 2 years of 9% (95% CI: 6%–12%) and at 3 years of 18% (95% CI: 12%–24%), which were 2.5 times higher than hybrid implants with 3.6% (95% CI: 0.8%–4%) and 7.4% (95% CI: 0%–17%), respectively.

Conclusions: A higher CBL was observed in the anodized surface implants group, when compared to the hybrid implants group in patients with a history of chronic periodontitis followed during 1–3 years.

KEYWORDS
chronic periodontitis, dental implants, peri-implantitis, retrospective studies, X-rays

1 | INTRODUCTION

Over the past decades, the placement of dental implants has become a routine procedure in the oral rehabilitation of fully and partially edentulous patients and there is well-established evidence supported by long-term (more than 10 years) studies that different implant systems may attain high success and survival rates (Buser et al., 2012; Gotfredsen, 2012; Ostman, Hellman, & Sennerby, 2012). In spite of these figures, however, osseointegrated implants are susceptible to crestal bone loss through physiological remodeling or due to pathological processes, such as peri-implantitis (Laurell & Lundgren, 2011). Indeed, the number of patients/implants affected by peri-implant diseases is increasing, although there is still controversy on the real prevalence of these conditions (Derks et al., 2015, 2016).

Definitions of peri-implant diseases have been agreed upon at previous European Workshops of Periodontology (Lang & Berglundh, 2011), being the key parameter to define then the inflammatory process within the peri-implant tissues. When inflammation is restricted to the mucosa, it will be diagnosed by bleeding upon gentle probing of the peri-implant mucosa (BOP), and this condition is defined as mucositis. When the inflammatory process is accompanied by significant peri-implant bone loss, the condition is defined as peri-implantitis. Using these definitions, recent systematic reviews have evaluated the prevalence, extent, and severity of peri-implant diseases (Derks et al., 2015), reporting a weighted mean prevalence of peri-implantitis of 22% (CI: 32%–54%) in 1,196 patients and 4,209 implants. Most of the existing studies, however, have used convenience samples, which may not be representative of the population. Furthermore, the methodological inconsistencies among the studies and the application of different case definitions have resulted in a high variability of the reported prevalence figures (Sanz & Chapple, 2012). A recent cross-sectional analysis of a randomly selected Swedish population sample has reported a 45% patient-based prevalence for peri-implantitis after 9 years of loading when the case definition was based on the presence of BOP and crestal bone loss >0.5 mm. However, when the threshold of bone loss was established at >2 mm, the prevalence was 14.5% (Derks et al., 2016).

Even though these diseases are clearly defined as chronic inflammatory diseases, their etiology is complex, with multiple factors intervening (Klinge et al., 2015). These factors have been investigated in multiple studies, although as described earlier, most of them are cross-sectional and with limited samples. There is good evidence from prospective studies that poor plaque control, pre-existing periodontal disease, and smoking can be considered as clear risk factors for the onset and progression of peri-implantitis, although with regard to other possible risk indicators, such as diabetes, genetic markers, and local issues as the need of minimal amount of keratinized tissue, the presence of limited bone availability, or the impact of the implant's surface micro-topography, this evidence is unclear (Heitz-Mayfield, 2008; Klinge & Meyle, 2012; Klinge et al., 2015; Mombelli, Muller, & Cionca, 2012; Renvert & Quirynen, 2015).

As for being the implant surface a potential risk factor for crestal bone loss, several experimental studies have shown that moderate rough surfaces, in particular, surfaces treated with sandblasting-acid etching and anodizing techniques, may increase the progression of bone loss once experimental ligature-induced peri-implantitis has been developed (Albouy, Abrahamsson, & Berglundh, 2012; Albouy, Abrahamsson, Persson, & Berglundh, 2008, 2009; Berglundh, Gotfredsen, Zitzmann, Lang, & Lindhe, 2007). This evidence, however, has not been validated in human studies with naturally developed peri-implantitis.

If we take a look at long-term (5–20 years) studies—often involving implants placed between 1965 and 1990—we realize that turned surface implants exhibit an initial bone loss, during their first year of usage, of 0.38–1.8 mm (Adell, Lekholm, Rockler, & Branemark, 1981; Attard & Zarb, 2004; Friberg, Nilson, Olsson, & Palmquist, 1997; Jemt, 1994; Jemt & Johansson, 2006; Jemt et al., 2002; Lindquist, Carlsson, & Jemt, 1996; Ortorp & Jemt, 2012), observing afterward and in the medium run (1–5 years) a bone loss of 0.1–0.4 mm (Adell et al., 1981; Friberg et al., 1997; Jemt, 1994; Jemt & Johansson, 2006; Lindquist et al., 1996; Ortorp & Jemt, 2012). Also, long-term studies found a limited bone loss of 0.05–0.1 mm yearly, from first year to 10, 15, or 20 years (Adell et al., 1981; Friberg et al., 1997; Jemt, 1994; Jemt & Johansson, 2006; Lindquist et al., 1996; Ortorp & Jemt, 2012). It is important to note that in the long run, the frequency distribution analysis indicates that the amount of implants with an overall bone loss exceeding the 3.7–4 mm threshold ranges from 3.3% to 5.8% (Ekelund, Lindquist, Carlsson, & Jemt, 2003; Jemt & Johansson, 2006; Ortorp & Jemt, 2012). On the other hand, implants with highly rough surfaces (titanium plasma sprayed) have reported higher and more significant crestal bone loss (Arlin, 2007; Becker et al., 2000; Roynesdal, Ambjornsen, & Haanaes, 1999; Roynesdal, Ambjornsen, Stovne, & Haanaes, 1998). Currently, however, most of the commercially available implants have "moderately rough" surfaces, with Sa values between 1 and 2 μm (Wennerberg & Albrektsson, 2011). These surfaces have shown improved results in reducing the rates of early failures, mainly in complex cases and compromised sites (Friberg & Jemt, 2008; Pinholt, 2003; Rocci, Martignoni, & Gottlow, 2003).

However, generally comparing this type of implants and turned surface implants is quite complex. When assessing cumulative survival through a comparative study, turned implants and anodized implants show similar results (Balshe, Assad, Eckert, Koka, & Weaver, 2009). But if we analyze radiographically the evolution of bone loss, the information withdrawn at medium term (5 years) is not currently enough to identify a common behavioral pattern. Also, in cohort studies assessing one single implant type, crestal bone loss (CBL) values at 5 years range from 0.15 mm (average CBL), for sandblasted and acid-etched implants with a tissue level design (Bornstein, Schmid, Belser, Lussi, & Buser, 2005), to 1.07 mm and 1.5 mm CBL for titanium dioxide sandblasted surface implants and anodized surface implants, respectively, using in both cases a transmucosal protocol design (Glauser, 2013; Glauser, Zembic, Ruhstaller, & Windisch, 2007; Rasmusson, Roos, & Bystedt, 2005). On the other hand, studies considering two types of implants—turned surface implants and titanium dioxide sandblasted implants (Vroom et al., 2009) or turned implants and anodized implants (Friberg & Jemt, 2010)—show similar CBL in the different groups at 5 years. It should be highlighted that the starting point in these studies is the placement of a final prosthesis. As for the second study, CBL is not easy to read and the author suggests they are remarkably low when compared to high benchmark CBL of 1.4 mm upon prosthesis placement, where 4.3% of implants yielded CBL baseline higher or equal to 4.3 mm (Friberg & Jemt, 2010). Most of these studies, however, were carried out in edentulous patients or in subjects without a periodontal disease. Moreover, these studies mainly have reported average figures of crestal bone level changes and have not analyzed data of frequency distributions, which may provide additional information.

Although the proper identification of risk factors in diseases of multifactorial etiology requires well-designed long-term prospective cohort studies (Abrahamsson & Berglundh, 2009), these are difficult to perform and often they are conducted under ideal research conditions and small samples, limiting their external validity and statistical power (von Elm et al., 2007). The workshop from the European Federation of Periodontology emphasized the need to carry out studies under different clinical scenarios: academic university vs. private practice settings, or specialized vs. general practice settings (Sanz & Chapple, 2012). Therefore, the purpose of this retrospective study carried out in a specialized periodontal private practice was to evaluate the interproximal crestal bone loss (CBL) on dental implants placed in a cohort of patients with a history of periodontitis, where non-identical implants with three different micro-surface topographies have been inserted in the posterior mandible.

2 | MATERIAL AND METHODS

The sample consisted of 206 consecutive partially edentulous patients with a history of periodontitis undergoing a periodontal maintenance program. Patients with uncontrolled systemic diseases (ASA III) or in need of bone regenerative interventions were excluded. The protocol for this clinical study was approved by the Research Ethical Committee of the Principality of Asturias (Spain), and the requirement of an informed consent from participants was waived due to the retrospective nature of the study (protocol # 174/17). STROBE guidelines have been reviewed and followed.

From 2007 and 2010, a total of 755 external-hex 4.1-mm platform “non-identical” implants (NI), with three different surface micro-topographies, were placed in the posterior mandible in a specialized clinic (Clínica Sicilia, Oviedo, Spain). Group 1 consisted of 72 implants placed in 27 patients. These implants had a machined titanium surface with Sa values between 0.2 and 0.4 (Lifecore Biomedical, Chaska, MN, USA). Group 2 included 145 implants placed in 74 patients. These implants had a hybrid micro-surface topography (machined surface at the most coronal aspect and dual acid-etched surface on the remainder of the implant body) with Sa values ranging from 0.6 to 0.8 (Osseotite®; Zimmer Biomet, Warsaw, IN, USA). Group 3 included 538 implants placed in 167 patients. These implants had a moderately rough anodized surface with Sa values ranging from 1.1 to 1.3 (Ti-Unite®; Nobel Biocare, Zurich, Switzerland). Table 1 describes the sizes and diameters of all implants in each group.

All maintenance patients at the study clinic are requested to follow the clinical protocol described in Figure 1. An experienced specialist in periodontology (AS) performed all implant surgeries using a surgical microscope (MSX2001, Leica Microsystems AG, Wetzlar, Germany). All implants were placed in the posterior mandible in sites with enough bone availability after raising mucoperiostal flaps through a crestal incision. All implants were intended to be placed using an implant platform leveled with the bone crest. After implant placement, titanium-healing abutments were installed and the surgical wound was sutured with 6/0 absorbable monofilament (Monocryl®; Ethicon, New Brunswick, NJ, USA). Patients were prescribed with antibiotics (amoxicillin 500 mgrs every 8 hr during 7 days) and anti-inflammatory medication (ibuprofen 600 mgr every 12 hr while pain or inflammation persisted). Patients were instructed to control the plaque in the operated area with an ultra-soft toothbrush and chlorhexidine gel (Perio Aid gel & Vitis Cirugía toothbrush. Dentaid, Barcelona. Spain) immediately after the surgery and normal oral hygiene was usually reinstituted once the sutures were removed 1 week postoperatively. All implants were allowed to heal during 8–10 weeks without functional loading. At this time, a periodontist (A.S.) evaluated the health of the peri-implant tissues and whether implants were osseointegrated. The absence of inflammation, bleeding, or exudate in the peri-implant tissues and the absence of implant mobility were a pre-requisite for performing a first periapical radiograph (baseline) and the referral to the restorative dentist who would produce the final implant-supported prosthetic restoration. These prostheses were screw-retained and direct-to-implant

TABLE 1 Implants included in the study

	Type 1	Type 2	Type 3	Total
Implant length	*n*	*n*	*n*	*n*
4 × 7	0	0	57	57
4 × 8.5	14	14	92	120
4 × 10	55	81	282	418
4 × 13	1	28	73	102
4 × 15	2	22	34	58
Total	72	145	538	755
Implant connection				
4.1 platform 2.7 × 0.7 external-hex	72	145	538	
Implant type				
LB machined	72			
ZB Osseotite PW		65		
ZB Osseotite NT		80		
NB MKIII			92	
NB MKIV			79	
NB speedy			367	

Type 1: LB: Lifecore Biomedical machined surface screw implant with external connection (Lifecore Biomedical, Chaska, Minnesota, USA). Type 2: ZB: Zimmer-Biomet hybrid micro-surface topography (machined surface at the most coronal aspect and dual acid-etched surface on the remainder of the implant body) (Osseotite®, Zimmer Biomet, Warsaw, Indiana, USA). PW: parallel walled: NT: tapered. Type 3: NB: Nobel Biocare anodized surface (Ti-Unite®, Nobel Biocare, Zurich, Suiza).

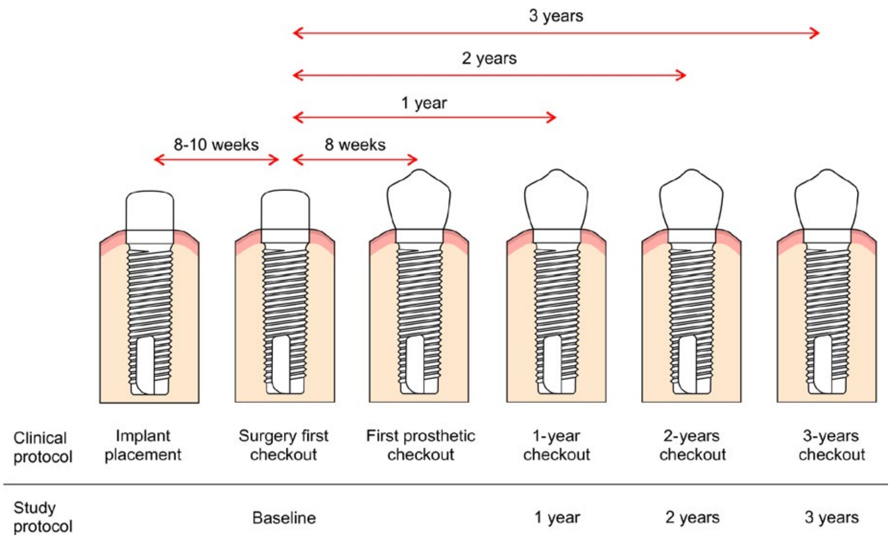

FIGURE 1 Clinical and study protocols

(without abutments), using only original components on a platform of 4.1 mm and a design that assures a proper plaque control. After the completion of the restorative phase (2–3 months), all patients were re-examined by the periodontist (A.S.) for a clinical and radiographic evaluation, evaluating the prosthesis adjustment, occlusion, and patient's oral hygiene. At this point, patients were offered to continue their periodontal maintenance program, including maintenance visits every 3, 4, or 6 months, depending on their periodontal risk assessment (Tonetti, Muller-Campanile, & Lang, 1998), and yearly clinical examinations, which included a periodontal evaluation and a radiographic examination.

Digital periapical radiographs (Digora®; Soredex, Tuusula, Finland) were taken with a parallel technique (Rinn® XCP film holder, Dentsplay, USA) at 8 weeks, 1, 2, and 3 years in the patients following the maintenance protocol. Interproximal peri-implant crestal bone loss (CBL) was measured in calibrated digital X-rays and was used as the primary outcome variable of this retrospective study. Figure 2 depicts the method of calibration. The implant length was used as a reference for the calibration, and in each implant, the distance from the implant's platform to the most coronal level of bone was measured at both the mesial and distal aspects. After preparation and calibration of the images, all measurements were performed by the same experienced examiner (LG), using a proprietary software and a mouse-driven caliper (Digora®; Soredex, Tuusula, Finland).

As secondary variables, patient-related characteristics that could affect the primary outcome were evaluated before the start of the implant surgeries: age, gender, smoking habits, severity of periodontitis (Armitage, 1999; Lang & Lindhe, 2015), frequency of maintenance visits, type of opposing dentition, oral hygiene by the plaque index (O'Leary, Drake, & Naylor, 1972), and local inflammation by the gingival bleeding index (Joss, Adler, & Lang, 1994).

2.1 | Statistical analysis

The Kolmogorov–Smirnov test was used to analyze the normality of the numerical variables. The relation between the numerical and

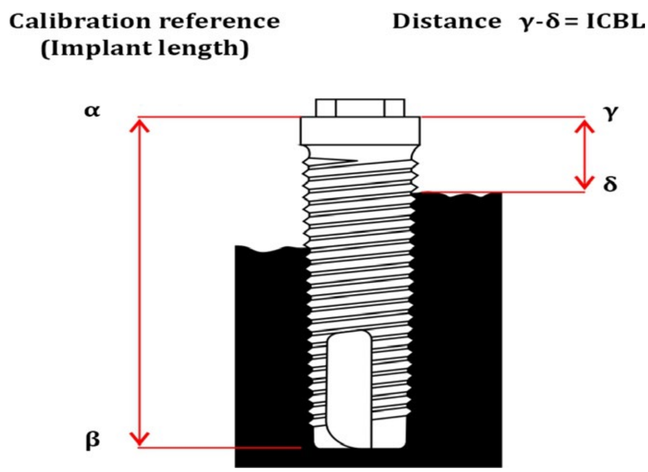

FIGURE 2 Calibration method and measurements. After image calibration using the known implant length as the baseline measurement and α-β distance as the real measurement, the Diagora software was used to measure the interproximal crestal bone loss (CBL). To do this, a fixed reference at the angle between the platform and the lateral wall of the implant γ was used as baseline (all implants had identical 4.1-mm platforms), and a parallel line to the implant's axis was drawn up to the most coronal site of the crestal bone touching the implant's wall δ as identified by the examiner

qualitative variables was assessed using the analysis of variance in independent samples. Post hoc analysis was achieved by means of the Tukey HSD test. The size of the effect for the analysis of variance was calculated using Cohen's *f* statistic (Cohen, 1988; Turturean, 2015). Finally, frequency distributions were generated and the prevalence for the different CBL levels was calculated and expressed in mean percentages with 95% of confidence intervals.

Intra-examiner variability was assessed using the kappa statistics after repeated measurements were taken on randomly selected baseline radiographs of the same set of patients. The values of bone loss were divided into the following categories: from 0 to 0.25 mm, larger than 0.25 and up to 0.50 mm, and larger than 0.5 mm. The resulting *k*: 0.9213 showed an excellent intra-examiner agreement.

3 | RESULTS

The sample population consisted of 206 patients evaluated at baseline, with 755 implants placed. This study reports on the 3-year data of 51 patients and 179 implants. Their mean age was 60.6, being 65.5% women and 34.5% men. Twenty-eight percent of patients were smokers with a mean consumption of 12.17 cigarettes per day. All patients had been previously diagnosed of chronic periodontitis, being most of them moderate and advanced chronic periodontitis (49.5% and 48.1%, respectively), with only five patients exhibiting mild chronic periodontitis. All patients were periodontally treated before implants were placed and were immediately enrolled in a periodontal maintenance program with recall periods according to their individual risk assessment, with an average recall interval of 3.58 (*SD* = 1.01) months.

When starting their maintenance program, patients exhibited good oral hygiene with visible plaque index of 19.43% (*SD* = 15.11%) and good control of local inflammation with a mean gingival bleeding index of 13.08% (*SD* = 12.18%). Eleven patients presented controlled diabetes (5.3%). Table 2 depicts the patient characteristics of the sample distributed according to the type of implant placed, taking the implant as a unit of analysis (*n* = 755). These patient characteristics were equally distributed among the three types of implants evaluated in this investigation.

3.1 | Interproximal crestal bone loss (CBL)

During evaluation (1–3 years), no implants were lost. Table 3 depicts the mean interproximal crestal bone loss at the different study visits at implant and patient level. At 8 weeks, CBL was 0.44 mm, both at patient and implant level of analysis. This parameter increased significantly at the following evaluation time points (1, 2, and 3 years) reaching 1.35 mm (0.11) at 3 years at implant's level, and 1.36 mm (1.04) at patient's level, which represents a difference of 0.91 mm and 0.92 mm, respectively, from baseline. The higher value of CBL detected at 3 years, when using the implant as the unit of analysis, was 6.7 mm and 5 mm when the analysis was made at patient's level.

TABLE 2 Patient-related characteristics according to the types of implants (implant as a unit of analysis *n* = 755)

	Turned	Hybrid/Double acid etched	Anodized	*p*	Total
Age—mean (*SD*)	60.93 (10.75)	61.17 (10.24)	61.07 (8.96)	.985 (*F* = 0.02)	61.07 (9.39)
Gender *n* (%)	Male 27 (37.50%)	Male 178 (33.09%)	Male 53 (36.55%)	.6065 (χ^2 = 1.0019)	Male 258 (34.17%)
	Female 45 (62.50%)	Female 360 (66.91%)	Female 92 (63.45%)		Female: 497 (65.83%)
Smoking (*n* cig)	Smokers 50 (69.44%)	Smokers 100 (68.97%)	Smokers 401 (74.53%)	.3164 (χ^2 = 2.3015)	Smokers 551 (72.98%)
	Non-smokers 22 (30.56%)	Non-smokers 45 (31.03%)	Non-smokers 137 (25.47%)		Non-smokers 204 (27.02%)
Periodontitis	Mild; 0 (0%)	Mild; 3 (2.07%)	Mild; 9 (1.68%)	.1384 (χ^2 = 6.9528)	Mild; 12 (1.59%)
	Moderate: 41 (56.94%)	Moderate: 58 (40.00%)	Moderate: 261 (48.51%)		Moderate: 360 (47.68%)
	Advanced: 31 (43.06%)	Advanced: 84 (57.93%)	Advanced: 268 (49.81%)		Advanced: 383 (50.73%)
Diabetes	No: 70	No: 137	No: 512	.6669	No: 719
	Yes: 2	Yes: 8	Yes: 26	(χ^2 = 0.81)	Yes: 36
Frequency of Maintenance	3.50 (0.65)	3.34 (0.92)	3.63 (1.04)	.008 (*F* = 4.91)	3.56 (0.99)
Opposite dentition	Natural teeth: 35 (48.61%)	Natural teeth: 302 (56.13%)	Natural teeth: 63 (43.45%)	.081 (χ^2 = 11.257)	Natural teeth: 400 (52.98%)
	Combined: 0 (0%)	Combined: 12 (2.23%)	Combined: 3 (2.07%)		Combined: 15 (1.99%)
	Implants: 35 (48.61%)	Implants: 218 (40.52%)	Implants: 77 (53.10%)		Implants: 330 (43.70%)
	Dentures: 2 (2.78%)	Dentures: 6 (1.12%)	Dentures: 2 (1.38%)		Dentures: 10 (1.33%)
Bleeding Index—mean (*SD*)	9.58 (8.05)	13.52 (15.52)	13.01 (11.91)	.017 (*F* = 4.09)	12.79 (12.45)
Plaque Index—mean (*SD*)	16.54 (12.69)	18.63 (16.57)	18.54 (14.83)	.555 (*F* = 0.59)	18.36 (14.98)

TABLE 3 Interproximal Crestal bone loss (CBL) observed at the different stages

	8 weeks	1 year	2 years	3 years	Dif. 8 weeks–3 years
Interproximal crestal bone loss (CBL) (patient as unit of analysis)					
Mean (*SD*)	0.44 (0.34)	0.78 (0.47)	0.99 (0.60)	1.36 (1.04)	0.92 (0.94)
Median	0.42	0.72	0.88	1.05	0.58
Range	0–2.1	0–2.7	0–2.94	0–5.04	0–4.62
ANOVA of CBL and time, F: 50.24 $p < .001$.					
Interproximal crestal bone loss (CBL) (implant as unit of analysis)					
Mean (*SD*)	0.44 (0.42)	0.79 (0.58)	0.99 (0.73)	1.35 (0.11)	0.91 (0.86)
Median	0.39	0.71	0.87	1.03	0.58
Range	0–2.19	0–3.64	0–4.36	0–6.74	0–6.05
ANOVA of CBL and time, F:135.32. $p < .001$					

CBL, crestal bone loss.
CBL is expressed in mm.

Table 4 depicts these mean interproximal crestal bone loss distributed among the three types of implants used, taking the implant as a unit of analysis. At baseline, the CBL in type 1 implants was significantly higher than types 2 and 3 (0.56, 0.33, and 0.47 mm, respectively). At 3 years, however, it was type 3 implants those with significantly higher CBL when compared with type 1 and type 2 (1.48 vs. 0.96 and 0.77, respectively; $p = .005$). Analysis of the data taking the patient as the unit of analysis is shown in Table 5.

Table 6 depicts the frequency distribution of the sample according to three pre-established thresholds of CBL (0–1.9; 2–3.9 and ≥4 mm) at baseline and 1, 2, and 3 years. At 2 years, the prevalence of implants with CBL of 4 mm or higher was 2.2%, and at 3 years,

TABLE 4 Interproximal crestal bone loss (CBL) distributed among the three types of implants evaluated in the study at the different time points (implant as unit of analysis)

Type of Implants	8 weeks	1 year	2 years	3 years
Type 1	$N = 72$	$N = 61$	$N = 25$	$N = 8$
	Mean: 0.56 *SD*: 0.43	Mean: 0.82 *SD*: 0.49	Mean: 1.08 *SD*: 0.52	Mean: 0.96 *SD*: 0.49
Type 2	$N = 145$	$N = 127$	$N = 56$	$N = 27$
	Mean: 0.33 *SD*: 0.43	Mean: 0.57 *SD*: 0.52	Mean: 0.56 *SD*: 0.51	Mean: 0.77 *SD*: 0.60
Type 3	$N = 538$	$N = 526$	$N = 328$	$N = 144$
	Mean: 0.47 *SD*: 0.41	Mean: 0.85 *SD*: 0.59	Mean: 1.08 *SD*: 0.72	Mean: 1.48 *SD*: 1.09
ANOVA test	$F = 8.79$ ($p < .001$)	$F = 12.35$ ($p < .001$)	$F = 12.27$ ($p < .001$)	$F = 5.40$ ($p = .005$)
Post hoc TUKEY HSD test	Type 1 vs. Type 2 $Q = 5.45$ $p = .001$	Type 1 vs. Type 2 $Q = 4.53$ $p = .004$	Type 1 vs. Type 2 $Q = 3.63$ $p = .027$	Type 1 vs. Type 2 $Q = 2.08$ $p = .307$
	Type 1 vs. Type 3 $Q = 2.60$ $p = .160$	Type 1 vs. Type 3 $Q = 1.14$ $p = .684$	Type 1 vs. Type 3 $Q = 1.06$ $p = .713$	Type 1 vs. Type 3 $Q = 1.23$ $p = .644$
	Type 2 vs Type 3 $Q = 4.94$ $p = .001$	Type 2 vs. Type 3 $Q = 5.46$ $p = .001$	Type 2 vs. Type 3 $Q = 4.11$ $p = .011$	Type 2 vs. Type 3 $Q = 4.57$ $p = .004$
ANOVA effect size Cohen's f	$f = 0.21$	$f = 0.23$	$f = 0.36$	$f = 0.68$

Type 1: machined surface (Lifecore Biomedical, Chaska, Minnesota, USA). Type 2: hybrid microsurface topography (machined surface at the most coronal aspect and dual acid-etched surface on the remainder of the implant body) (Osseotite®, Zimmer Biomet, Warsaw, Indiana, USA). Type 3: anodized surface (Ti-Unite®, Nobel Biocare, Zurich, Suiza).

TABLE 5 Interproximal crestal bone loss (CBL) distributed among patients with the different types of implants evaluated in the study at the different time points (patient as unit of analysis)

Type of Implants	8 weeks	1 year	2 years	3 years
Type 1	*N* = 27	*N* = 24	*N* = 9	*N* = 4
	Mean: 0.40 *SD*: 0.38	Mean: 0.77 *SD*: 0.33	Mean: 1.07 *SD*: 0.37	Mean: 0.96 *SD*: 0.31
Type 2	*N* = 74	*N* = 63	*N* = 25	*N* = 11
	Mean: 0.17 *SD*: 0.35	Mean: 0.58 *SD*: 0.56	Mean: 0.63 *SD*: 0.76	Mean: 0.82 *SD*: 0.75
Type 3	*N* = 167	*N* = 149	*N* = 91	*N* = 36
	Mean: 0.35 *SD*: 0.31	Mean: 0.83 *SD*: 0.56	Mean: 1.06 *SD*: 0.63	Mean: 1.56 *SD*: 1.18
ANOVA test	*F* = 7.58 (*p* = .001)	*F* = 5.48 (*p* = .005)	*F* = 4.50 (*p* = .013)	*F* = 2.14 (*p* = .129)
Post hoc TUKEY HSD test	Type 1 vs. Type 2 Q = 3.96 *p* = .015	Type 1 vs. Type 2 Q = 0.95 *p* = .762	Type 1 vs. Type 2 Q = 3.30 *p* = .059	Type 1 vs. Type 2 Q = 1.24 *p* = .644
	Type 1 vs. Type 3 Q = 0.65 *p* = .883	Type 1 vs. Type 3 Q = 2.03 *p* = .324	Type 1 vs. Type 3 Q = 1.07 *p* = .711	Type 1 vs. Type 3 Q = 0.81 *p* = .819
	Type 2 vs. Type 3 Q = 5.41 *p* = .001	Type 2 vs. Type 3 Q = 4.48 *p* = .005	Type 2 vs. Type 3 Q = 3.95 *p* = .017	Type 2 vs. Type 3 Q = 3.35 *p* = .563
ANOVA effect size Cohen's *f*	*f* = 0.35	*f* = 0.37	*f* = 0.64	*f* = 1.06

Type 1: machined surface (Lifecore Biomedical, Chaska, Minnesota, USA). Type 2: hybrid micro-surface topography (machined surface at the most coronal aspect and dual acid-etched surface on the remainder of the implant body) (Osseotite®, Zimmer Biomet, Warsaw, Indiana, USA). Type 3: anodized surface (Ti-Unite®, Nobel Biocare, Zurich, Suiza).

TABLE 6 Prevalence of the defined CBL thresholds at the different time points (implant as unit of analysis)

	8 weeks		1 year		2 years		3 years	
	n	% (95% CI)	*n*	% (95% CI)	*n*	% (95% CI)	*n*	% (95% CI)
0–1.9 mm	752	99.59% (99.13–100)	693	96.64% (95.32–97.96)	374	92.35% (89.76–94.94)	151	84.36% (79.04–89.68)
2–3.9 mm	3	0.41% (0–0.87)	24	3.36% (2.04–4.7)	22	5.43% (3.22–7.64)	19	10.61% (6.10–15.12)
≥4.0 mm	0	0.00%	0	0.00%	9	2.22% (0.77–3.63)	9	5.03% (1.83–8.23)
Total	755		717		405		179	

(95% CI): 95% confidence interval.

this percentage increased to 5%, although in most of the implants (84.4%), the CBL was lower than 2 mm.

When the same distribution was analyzed by implant type (Table 7), at 2 years the prevalence of a CBL equal or higher than 2 mm in type 3 implants was 9%, while the corresponding percentages for type 1 and 2 implants were 0% and 3.6%, respectively. The same tendency continued at 3 years with a prevalence of 18% for type 3 implants, while it was 0% and 7.4% for types 1 and 2 implants, respectively.

In groups of types 2 and 3, we have included implants of the same brand and identical platforms, but slightly different designs in the first millimeter of the cervical part; however, no significant CBL differences were observed between implants of the same group (intragroup). In group of type 2, consisting of hybrid surface implants (NT and Osseotite parallel wall), at 2 years CBL was 0.55 mm (0.64) for NT implants and 0.57 mm (0.54) for Osseotite parallel wall implants. To this respect, no differences were reported between the anodized surface implants (MKIII, MKIV, and Speedy) of the type 3 group, with MKIII and MKIV yielding a 1.18 mm (0.86) and 1.53 mm (1.14) CBL at 2 and 3 years, respectively, while Speedy implants produced an CBL of 1.0 mm (0.67) and 1.41 mm (1.14) in the same period.

TABLE 7 Prevalence of the described CBL thresholds at different time points (implant as unit of analysis)

	CBL at 2 years				CBL at 3 years			
	0–1.9 mm		≥2 mm		0–1.9 mm		≥2 mm	
Type of implants	*n*	% (95% CI)	*n*	% (95% CI)	*n*	% (95% CI)	*n*	% (95% CI)
Type 1	26	100.00%	0	0.00%	8	100.00%	0	0.00%
Type 2	54	96.43% (91.57–100)	2	3.57% (0.8–4.3)	25	92.59% (82.71–100)	2	7.41% (0–17.29)
Type 3	294	91.02% (87.90–94.14)	29	8.98% (5.87–12.09)	118	81.94% (75.66–88.22)	26	18.06% (11.78–24.34)
Total	374		31		151		28	

CBL, crestal bone loss.
Type 1: machined surface (Lifecore Biomedical, Chaska, Minnesota, USA). Type 2: hybrid micro-surface topography (machined surface at the most coronal aspect and dual acid-etched surface on the remainder of the implant body) (Osseotite®; Zimmer Biomet, Warsaw, IN, USA). Type 3: anodized surface (Ti-Unite®; Nobel Biocare, Zurich, Suiza).
(95% CI): 95% confidence interval.

4 | DISCUSSION

In this retrospective case series evaluating 206 patients with a previous history of periodontal disease, the mean interproximal crestal bone loss was 0.92 mm at 3 years, using the 8-week post-implant placement bone level as baseline reference. Similar changes were calculated when using the implant as the unit of analysis (0.91 mm). These mean values of CBL could be considered acceptable, if compared with the outcomes from classical longitudinal implant series using turned surface implants, which have reported bone loss raging between 0.5 mm and 1.9 mm during the first 5 years, and then limited further bone loss thereafter until 15–25 years (Adell, Eriksson, Lekholm, Branemark, & Jemt, 1990; Adell et al., 1981; Attard & Zarb, 2004; Ekelund et al., 2003; Eliasson, Palmqvist, Svenson, & Sondell, 2000; Friberg et al., 1997; Jemt, 1994; Jemt & Johansson, 2006; Jemt et al., 2002; Lindquist et al., 1996; Ortorp & Jemt, 2004). These studies, however, have mainly reported data on survival rates and mean bone loss, but scarcely on the prevalence of CBL levels. In fact, only in two studies (Eliasson et al., 2000; Jemt & Johansson, 2006), this prevalence was reported with 4.9% and 5.7% of the implants showing >2 mm of CBL change, respectively. In the latter implant series, only 1.3% of the patients had >3 mm of CBL change at 15 years (Jemt & Johansson, 2006).

When comparing the results by implant type, we have observed significantly higher crestal bone loss in anodized surface implants when compared to hybrid surfaces (turned/dual acid-etched) in all stages of the study (Table 4). Although there are not similar comparative studies published, the obtained data are similar to implant longitudinal case series using the referred surfaces. In hybrid surface implants, the mean CBL was 0.77 mm at 3 years, which is within the previously reported of 0.45 mm to 0.86 mm (Anitua, Pinas, & Orive, 2015; Calvo-Guirado et al., 2014). In anodized surface implants, the mean CBL was 1.48 mm at 3 years, slightly above the range reported (0.4 mm to 1.33 mm) (Bahat, Sullivan, & Smidt, 2012; Glauser et al., 2007; Pettersson & Sennerby, 2015). These "moderate" bone loss mean values, however, may be concealing relevant significance when the standard deviations are high. For example, the study of Petterson et al. with annual CBL of 0.1 mm between the first and fifth year reported a standard deviation of 2.4 mm (Pettersson & Sennerby, 2015). In this investigation, the value of the standard deviation for the anodized implants was 1.09 mm, while for hybrid implants was 0.49 mm, showing that anodized implants exhibited a more variable behavior in terms of CBL. These data show the relevance of providing information on frequency distribution analysis, besides the mere averages and standard deviations will allow for an easier identification of the severely affected individuals (Hurley, Denegar, & Hertel, 2011; Monje & Wang, 2014; Polgar & Thomas, 2013). It is therefore important to establish an agreed threshold of "relevant CBL" to identify those patients/implants and determine whether the occurrence of this significant CBL is steady or progressive. When using the criteria reported by Eliasson and Jemt (Eliasson et al., 2000; Jemt & Johansson, 2006), implants demonstrating ≥2 mm of bone loss at 3 years occurred in 7.4% of hybrid surface implants and in 18.1% of anodized surface implants, prevalence 2.44 times higher. Just in this group of anodized implants, we have found a 4 mm or higher bone loss in 5.5% of implants. If we consider that 76% of them were 10 mm long or short, this could represent that almost in 6% of the anodized 10-mm-long implants we have detected at least a 40% CBL, being these figures 57% in the 7-mm-long fixtures, which undoubtedly must be considered clinically relevant.

This retrospective study used commercially available implants, which of course, may limit its internal validity, as the design of the tested implants was not identical. However, all implants had a 4.1-mm external platform with a hexagon of 2.7 mm width and 0.7 mm height. All measurements were taken from a fixed reference at the angle between the platform and the lateral wall of the implant, which was identical in all three implants types. Furthermore, we have shown in the intra-group analysis that there were no variances among the different implants used within each group (with slight differences in the cervical design). A careful evaluation of the scientific literature did not provide evidence supporting that minor differences in neck configurations may significantly influence crestal bone level changes (Bateli, Att, & Strub, 2011). There is limited evidence in systematic reviews evaluating other design aspects, such as micro-grooves or micro-threads (Koodaryan & Hafezeqoran, 2016; Niu, Wang, Zhu, Liu, & Ji, 2017), the type of implant to abutment connection (Goiato, Pellizzer, da Silva, Bonatto Lda, & dos Santos, 2015; de Medeiros et al., 2016; Schwarz et al., 2014) or whether this connection was platform switched (Schwarz et al., 2014). However, none of these aspects applies to the present study.

Other aspect to be taken into account in this study is the reduced sample size at the 3-year follow-up, which affects the power (1-β) of the study, therefore making it more difficult to detect significant differences. Consequently, the methodological theory itself indicates that a low power gives more relevance to the significant differences detected. Bearing this in mind, it is quite exciting to analyze Table 4, considering that a Cohen's f of 0.25 means the study power allows to detect significant medium size effects, while an f of 0.4 is useful to detect large size effects (Cohen, 1988; Turturean, 2015). Hence, at 8 months and 1 year, we can identify in our study medium size effects quite easily (f = 0.21 and 0.23), and at 2 years, only large size effects can be detected (f = 0.36). At 3 years, the number of participants decreases and the f value is 0.68, higher than the f described by Cohen as a right power to detect large size effects (f = 0.4). This means that the effect found between implants of type 2 group (hybrid) and type 3 group (anodized) is quite large, and thus, it appears as a significant effect. There can also be an additional medium or large size effect between type 1 and 3 groups at 3 years, but the power would not be enough to detect it. Consequently, the lack of a statistical power does not obscure the significance of the statistical differences found, on the contrary, it makes them more relevant.

These results, however, must be cautiously analyzed, due to the retrospective nature of this study and, therefore, causal inferences should not be established (Hurley et al., 2011). In this study, we have tried to minimize this bias by unifying patient's conditions (patients with a history of periodontal disease), by selecting the same intraoral region—posterior jaw—by applying similar surgical concepts (same surgeon) and using standardized prosthetical protocols. We have also carefully established a clear baseline point of reference for all the calculations of the interproximal crestal bone loss with comparable baseline characteristics of the many known risk factors for peri-implant bone loss. In conclusion, this retrospective study for a maximum period of 3 years has shown that the prevalence of "relevant CBL" may be associated with the implant surface, with significantly higher crestal bone loss for the group of anodized surface implants when compared to the group of turned/dual acid-etched implants.

It should not be forgotten that as clinicians we are committed to provide long-lasting stable restorations for the good health of our patients. We strive to get good results at 10 or 20 years, not just 3. Therefore, having detected that CBL in this type of surfaces can be a problem—even if it is assumed from observational studies—it is important to establish long-term follow-ups in these cohorts of patients to verify whether this initial higher CBL trend in anodized surface implants can be confirmed, and, particularly, whether the initial levels of interproximal crestal bone remain stable as it happens with turned implants (Eliasson et al., 2000; Jemt & Johansson, 2006) or whether they evolve leading to extraction of fixtures.

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REFERENCES

Abrahamsson, I., & Berglundh, T. (2009). Effects of different implant surfaces and designs on marginal bone-level alterations: A review. *Clinical Oral Implants Research*, *20*(Suppl 4), 207–215. https://doi.org/10.1111/j.1600-0501.2009.01783.x

Adell, R., Eriksson, B., Lekholm, U., Branemark, P. I., & Jemt, T. (1990). Long-term follow-up study of osseointegrated implants in the treatment of totally edentulous jaws. *The International Journal of Oral & Maxillofacial Implants*, *5*, 347–359.

Adell, R., Lekholm, U., Rockler, B., & Branemark, P. I. (1981). A 15-year study of osseointegrated implants in the treatment of the edentulous jaw. *International Journal of Oral Surgery*, *10*, 387–416. https://doi.org/10.1016/S0300-9785(81)80077-4

Albouy, J. P., Abrahamsson, I., & Berglundh, T. (2012). Spontaneous progression of experimental peri-implantitis at implants with different surface characteristics: An experimental study in dogs. *Journal of Clinical Periodontology*, *39*, 182–187. https://doi.org/10.1111/j.1600-051X.2011.01820.x

Albouy, J. P., Abrahamsson, I., Persson, L. G., & Berglundh, T. (2008). Spontaneous progression of peri-implantitis at different types of implants. An experimental study in dogs. I: Clinical and radiographic observations. *Clinical Oral Implants Research*, *19*, 997–1002. https://doi.org/10.1111/j.1600-0501.2008.01589.x

Albouy, J. P., Abrahamsson, I., Persson, L. G., & Berglundh, T. (2009). Spontaneous progression of ligatured induced peri-implantitis at implants with different surface characteristics. An experimental study in dogs ii: Histological observations. *Clinical Oral Implants Research*, *20*, 366–371. https://doi.org/10.1111/j.1600-0501.2008.01645.x

Anitua, E., Pinas, L., & Orive, G. (2015). Retrospective study of short and extra-short implants placed in posterior regions: Influence of crown-to-implant ratio on marginal bone loss. *Clinical Implant Dentistry and Related Research*, *17*, 102–110. https://doi.org/10.1111/cid.12073

Arlin, M. L. (2007). Survival and success of sandblasted, large-grit, acid-etched and titanium plasma-sprayed implants: A retrospective study. *Journal Canadian Dental Association*, *73*, 821.

Armitage, G. C. (1999). Development of a classification system for periodontal diseases and conditions. *Annals of Periodontology/the American Academy of Periodontology*, *4*, 1–6. https://doi.org/10.1902/annals.1999.4.1.1

Attard, N. J., & Zarb, G. A. (2004). Long-term treatment outcomes in edentulous patients with implant-fixed prostheses: The toronto study. *The International Journal of Prosthodontics*, *17*, 417–424.

Bahat, O., Sullivan, R. M., & Smidt, A. (2012). Placement of branemark mk iv implants in compromised and grafted bone: Radiographic outcome of 61 sites in 27 patients with 3- to 7-year follow-ups. *Quintessence International*, *43*, 293–303.

Balshe, A. A., Assad, D. A., Eckert, S. E., Koka, S., & Weaver, A. L. (2009). A retrospective study of the survival of smooth- and rough-surface dental implants. *The International Journal of Oral & Maxillofacial Implants*, *24*, 1113–1118.

Bateli, M., Att, W., & Strub, J. R. (2011). Implant neck configurations for preservation of marginal bone level: A systematic review. *The International Journal of Oral & Maxillofacial Implants*, *26*, 290–303.

Becker, W., Becker, B. E., Ricci, A., Bahat, O., Rosenberg, E., Rose, L. F., … Israelson, H. (2000). A prospective multicenter clinical trial comparing one- and two-stage titanium screw-shaped fixtures with one-stage plasma-sprayed solid-screw fixtures. *Clinical Implant Dentistry and Related Research*, *2*, 159–165. https://doi.org/10.1111/j.1708-8208.2000.tb00007.x

Berglundh, T., Gotfredsen, K., Zitzmann, N. U., Lang, N. P., & Lindhe, J. (2007). Spontaneous progression of ligature induced peri-implantitis at implants with different surface roughness: An experimental study in dogs. *Clinical Oral Implants Research*, *18*, 655–661. https://doi.org/10.1111/j.1600-0501.2007.01397.x

Bornstein, M. M., Schmid, B., Belser, U. C., Lussi, A., & Buser, D. (2005). Early loading of non-submerged titanium implants with a sandblasted and acid-etched surface. 5-year results of a prospective study in partially edentulous patients. *Clinical Oral Implants Research*, *16*, 631–638. https://doi.org/10.1111/j.1600-0501.2005.01209.x

Buser, D., Janner, S. F., Wittneben, J. G., Bragger, U., Ramseier, C. A., & Salvi, G. E. (2012). 10-year survival and success rates of 511 titanium implants with a sandblasted and acid-etched surface: A retrospective study in 303 partially edentulous patients. *Clinical Implant Dentistry and Related Research*, *14*, 839–851. https://doi.org/10.1111/j.1708-8208.2012.00456.x

Calvo-Guirado, J. L., Gomez-Moreno, G., Delgado-Ruiz, R. A., Sanchez, M., de Val, J. E., Negri, B., & Ramirez Fernandez, M. P. (2014). Clinical and radiographic evaluation of osseotite-expanded platform implants related to crestal bone loss: A 10-year study. *Clinical Oral Implants Research*, *25*, 352–358. https://doi.org/10.1111/clr.12134

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*, 2nd ed. Hillsdale, NJ: Lawrence Erlbaum Associates.

Derks, J., Hakansson, J., Wennstrom, J. L., Tomasi, C., Larsson, M., & Berglundh, T. (2015). Effectiveness of implant therapy analyzed in a swedish population: Early and late implant loss. *Journal of Dental Research*, *94*, 44S–51S. https://doi.org/10.1177/0022034514563077

Derks, J., Schaller, D., Hakansson, J., Wennstrom, J. L., Tomasi, C., & Berglundh, T. (2016). Effectiveness of implant therapy analyzed in a swedish population: Prevalence of peri-implantitis. *Journal of Dental Research*, *95*, 43–49. https://doi.org/10.1177/0022034515608832

Ekelund, J. A., Lindquist, L. W., Carlsson, G. E., & Jemt, T. (2003). Implant treatment in the edentulous mandible: A prospective study on branemark system implants over more than 20 years. *The International Journal of Prosthodontics*, *16*, 602–608.

Eliasson, A., Palmqvist, S., Svenson, B., & Sondell, K. (2000). Five-year results with fixed complete-arch mandibular prostheses supported by 4 implants. *The International Journal of Oral & Maxillofacial Implants*, *15*, 505–510.

von Elm, E., Altman, D. G., Egger, M., Pocock, S. J., Gotzsche, P. C., Vandenbroucke, J. P., & Initiative, S. (2007). The strengthening the reporting of observational studies in epidemiology (strobe) statement: Guidelines for reporting observational studies. *Annals of Internal Medicine*, *147*, 573–577. https://doi.org/10.7326/0003-4819-147-8-200710160-00010

Friberg, B., & Jemt, T. (2008). Rehabilitation of edentulous mandibles by means of five tiunite implants after one-stage surgery: A 1-year retrospective study of 90 patients. *Clinical Implant Dentistry and Related Research*, *10*, 47–54. https://doi.org/10.1111/j.1708-8208.2007.00060.x

Friberg, B., & Jemt, T. (2010). Clinical experience of tiunite implants: A 5-year cross-sectional, retrospective follow-up study. *Clinical Implant Dentistry and Related Research*, *12*(Suppl 1), e95–e103.

Friberg, B., Nilson, H., Olsson, M., & Palmquist, C. (1997). Mk ii: The self-tapping branemark implant: 5-year results of a prospective 3-center study. *Clinical Oral Implants Research*, *8*, 279–285. https://doi.org/10.1034/j.1600-0501.1997.080405.x

Glauser, R. (2013). Implants with an oxidized surface placed predominately in soft bone quality and subjected to immediate occlusal loading: Results from a 7-year clinical follow-up. *Clinical Implant Dentistry and Related Research*, *15*, 322–331. https://doi.org/10.1111/j.1708-8208.2011.00352.x

Glauser, R., Zembic, A., Ruhstaller, P., & Windisch, S. (2007). Five-year results of implants with an oxidized surface placed predominantly in soft quality bone and subjected to immediate occlusal loading. *The Journal of Prosthetic Dentistry*, *97*, S59–S68. https://doi.org/10.1016/S0022-3913(07)60009-2

Goiato, M. C., Pellizzer, E. P., da Silva, E. V., Bonatto Lda, R., & dos Santos, D. M. (2015). Is the internal connection more efficient than external connection in mechanical, biological, and esthetical point of views? A systematic review. *Oral and Maxillofacial Surgery*, *19*, 229–242. https://doi.org/10.1007/s10006-015-0494-5

Gotfredsen, K. (2012). A 10-year prospective study of single tooth implants placed in the anterior maxilla. *Clinical Implant Dentistry and Related Research*, *14*, 80–87. https://doi.org/10.1111/j.1708-8208.2009.00231.x

Heitz-Mayfield, L. J. (2008). Peri-implant diseases: Diagnosis and risk indicators. *Journal of Clinical Periodontology*, *35*, 292–304. https://doi.org/10.1111/j.1600-051X.2008.01275.x

Hurley, W. L., Denegar, C. R., & Hertel, J. (2011). *Research methods: A framework for evidence-based clinical practice*, 1st ed. Philadelphia, PA: Wolters Kluwer/Lippincott Williams & Wilkins Health.

Jemt, T. (1994). Fixed implant-supported prostheses in the edentulous maxilla. A five-year follow-up report. *Clinical Oral Implants Research*, *5*, 142–147. https://doi.org/10.1034/j.1600-0501.1994.050304.x

Jemt, T., Bergendal, B., Arvidson, K., Bergendal, T., Karlsson, L. D., Linden, B., … Wendelhag, I. (2002). Implant-supported welded titanium frameworks in the edentulous maxilla: A 5-year prospective multicenter study. *The International Journal of Prosthodontics*, *15*, 544–548.

Jemt, T., & Johansson, J. (2006). Implant treatment in the edentulous maxillae: A 15-year follow-up study on 76 consecutive patients provided with fixed prostheses. *Clinical Implant Dentistry and Related Research*, *8*, 61–69. https://doi.org/10.1111/j.1708-8208.2006.00003.x

Joss, A., Adler, R., & Lang, N. P. (1994). Bleeding on probing. A parameter for monitoring periodontal conditions in clinical practice. *Journal of Clinical Periodontology*, *21*, 402–408. https://doi.org/10.1111/j.1600-051X.1994.tb00737.x

Klinge, B., Flemming, T., Cosyn, J., De Bruyn, H., Eisner, B. M., Hultin, M., … Schliephake, H. (2015). The patient undergoing implant therapy. Summary and consensus statements. The 4th EAO consensus conference 2015. *Clinical Oral Implants Research*, *26*(Suppl 11), 64–67. https://doi.org/10.1111/clr.12675

Klinge, B., & Meyle, J. W. Group. (2012). Peri-implant tissue destruction. The third eao consensus conference 2012. *Clinical Oral Implants Research*, *23*(Suppl 6), 108–110. https://doi.org/10.1111/j.1600-0501.2012.02555.x

Koodaryan, R., & Hafezeqoran, A. (2016). Evaluation of implant collar surfaces for marginal bone loss: A systematic review and meta-analysis. *BioMed Research International*, *2016*, 4987526.

Lang, N. P., & Berglundh, T. (2011). Periimplant diseases: Where are we now?–consensus of the seventh european workshop on periodontology. *Journal of Clinical Periodontology*, *38*(Suppl 11), 178–181. https://doi.org/10.1111/j.1600-051X.2010.01674.x

Lang, N. P., & Lindhe, J. (2015). *Clinical periodontology and implant dentistry*, 6th ed. (pp. 125–138). Chichester, UK: John Wiley & Sons Ltd..

Laurell, L., & Lundgren, D. (2011). Marginal bone level changes at dental implants after 5 years in function: A meta-analysis. *Clinical*

Implant Dentistry and Related Research, *13*, 19–28. https://doi.org/10.1111/j.1708-8208.2009.00182.x

Lindquist, L. W., Carlsson, G. E., & Jemt, T. (1996). A prospective 15-year follow-up study of mandibular fixed prostheses supported by osseointegrated implants. Clinical results and marginal bone loss. *Clinical Oral Implants Research*, *7*, 329–336. https://doi.org/10.1034/j.1600-0501.1996.070405.x

de Medeiros, R. A., Pellizzer, E. P., Vechiato Filho, A. J., Dos Santos, D. M., da Silva, E. V., & Goiato, M. C. (2016). Evaluation of marginal bone loss of dental implants with internal or external connections and its association with other variables: A systematic review. *The Journal of Prosthetic Dentistry*, *116*(501–506), e505.

Mombelli, A., Muller, N., & Cionca, N. (2012). The epidemiology of peri-implantitis. *Clinical Oral Implants Research*, *23*(Suppl 6), 67–76. https://doi.org/10.1111/j.1600-0501.2012.02541.x

Monje, A., & Wang, H. L. (2014). Interpretation of study design on marginal bone loss in implant dentistry: Evidence-based science versus clinical-based experience. *The International Journal of Oral & Maxillofacial Implants*, *29*, 279.

Niu, W., Wang, P., Zhu, S., Liu, Z., & Ji, P. (2017). Marginal bone loss around dental implants with and without microthreads in the neck: A systematic review and meta-analysis. *The Journal of Prosthetic Dentistry*, *117*, 34–40. https://doi.org/10.1016/j.prosdent.2016.07.003

O'Leary, T. J., Drake, R. B., & Naylor, J. E. (1972). The plaque control record. *Journal of Periodontology*, *43*, 38. https://doi.org/10.1902/jop.1972.43.1.38

Ortorp, A., & Jemt, T. (2004). Clinical experiences of computer numeric control-milled titanium frameworks supported by implants in the edentulous jaw: A 5-year prospective study. *Clinical Implant Dentistry and Related Research*, *6*, 199–209. https://doi.org/10.1111/j.1708-8208.2004.tb00036.x

Ortorp, A., & Jemt, T. (2012). Cnc-milled titanium frameworks supported by implants in the edentulous jaw: A 10-year comparative clinical study. *Clinical Implant Dentistry and Related Research*, *14*, 88–99. https://doi.org/10.1111/j.1708-8208.2009.00232.x

Ostman, P. O., Hellman, M., & Sennerby, L. (2012). Ten years later. Results from a prospective single-centre clinical study on 121 oxidized (tiunite) branemark implants in 46 patients. *Clinical Implant Dentistry and Related Research*, *14*, 852–860. https://doi.org/10.1111/j.1708-8208.2012.00453.x

Pettersson, P., & Sennerby, L. (2015). A 5-year retrospective study on replace select tapered dental implants. *Clinical Implant Dentistry and Related Research*, *17*, 286–295. https://doi.org/10.1111/cid.12105

Pinholt, E. M. (2003). Branemark and iti dental implants in the human bone-grafted maxilla: A comparative evaluation. *Clinical Oral Implants Research*, *14*, 584–592. https://doi.org/10.1034/j.1600-0501.2003.140508.x

Polgar, S., & Thomas, S. A. (2013). *Introduction to research in the health sciences*, 6th ed. Edinburgh, UK: Churchill Livingstone.

Rasmusson, L., Roos, J., & Bystedt, H. (2005). A 10-year follow-up study of titanium dioxide-blasted implants. *Clinical Implant Dentistry and Related Research*, *7*, 36–42. https://doi.org/10.1111/j.1708-8208.2005.tb00045.x

Renvert, S., & Quirynen, M. (2015). Risk indicators for peri-implantitis. A narrative review. *Clinical Oral Implants Research*, *26*(Suppl 11), 15–44. https://doi.org/10.1111/clr.12636

Rocci, A., Martignoni, M., & Gottlow, J. (2003). Immediate loading of branemark system tiunite and machined-surface implants in the posterior mandible: A randomized open-ended clinical trial. *Clinical Implant Dentistry and Related Research*, *5*(Suppl 1), 57–63. https://doi.org/10.1111/j.1708-8208.2003.tb00016.x

Roynesdal, A. K., Ambjornsen, E., & Haanaes, H. R. (1999). A comparison of 3 different endosseous nonsubmerged implants in edentulous mandibles: A clinical report. *The International Journal of Oral & Maxillofacial Implants*, *14*, 543–548.

Roynesdal, A. K., Ambjornsen, E., Stovne, S., & Haanaes, H. R. (1998). A comparative clinical study of three different endosseous implants in edentulous mandibles. *The International Journal of Oral & Maxillofacial Implants*, *13*, 500–505.

Sanz, M., & Chapple, I. L. (2012). Clinical research on peri-implant diseases: Consensus report of working group 4. *Journal of Clinical Periodontology*, *39*(Suppl 12), 202–206. https://doi.org/10.1111/j.1600-051X.2011.01837.x

Schwarz, F., Alcoforado, G., Nelson, K., Schaer, A., Taylor, T., Beuer, F., … Camlog, F. (2014). Impact of implant-abutment connection, positioning of the machined collar/microgap, and platform switching on crestal bone level changes. Camlog foundation consensus report. *Clinical Oral Implants Research*, *25*, 1301–1303. https://doi.org/10.1111/clr.12269

Tonetti, M. S., Muller-Campanile, V., & Lang, N. P. (1998). Changes in the prevalence of residual pockets and tooth loss in treated periodontal patients during a supportive maintenance care program. *Journal of Clinical Periodontology*, *25*, 1008–1016. https://doi.org/10.1111/j.1600-051X.1998.tb02406.x

Turturean, C. (2015). Who's afraid of the effect size? *Procedia Economics and Finance*, *20*, 665–669. https://doi.org/10.1016/S2212-5671(15)00121-5

Vroom, M. G., Sipos, P., de Lange, G. L., Grundemann, L. J., Timmerman, M. F., Loos, B. G., & van der Velden, U. (2009). Effect of surface topography of screw-shaped titanium implants in humans on clinical and radiographic parameters: A 12-year prospective study. *Clinical Oral Implants Research*, *20*, 1231–1239. https://doi.org/10.1111/j.1600-0501.2009.01768.x

Wennerberg, A., & Albrektsson, T. (2011). Current challenges in successful rehabilitation with oral implants. *Journal of Oral Rehabilitation*, *38*, 286–294. https://doi.org/10.1111/j.1365-2842.2010.02170.x

SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

How to cite this article: Gallego L, Sicilia A, Sicilia P, Mallo C, Cuesta S, Sanz M. A retrospective study on the crestal bone loss associated with different implant surfaces in chronic periodontitis patients under maintenance. *Clin Oral Impl Res*. 2018;29:557–567. https://doi.org/10.1111/clr.13153