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Crestal bone loss associated with different implant surfaces in the posterior mandible in patients with a history of periodontitis. A retrospective study

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Abstract

Objective: To retrospectively assess the interproximal bone loss (CBL) in external hexagon implants (EHI), with different surface micro-topography, placed in the posterior mandible in patients with a history of periodontitis undergoing supportive periodontal care.

Material and methods: 268 consecutive patients received 755 EHI implants in the mandibular molar region between 2007 and 2015 with the following surface characteristics: 72 turned, 145 hybrids (double acid-etched/turned), and 538 anodized. CBL was yearly evaluated by analysing calibrated digital periapical radiographs, with a follow-up of 1–6 years. Data on implant survival were also calculated.

Results: At 6 years (53 patients), the mean CBL was 1.34/1.42 mm at patient/implant level, respectively (range: 0–5.2 mm). Significantly higher CBL was detected in anodized implants than in turned and hybrid implants (1.92/1.46/1.02 mm) ($p < .01$). The maximum CBL values were found in 2 anodized implants at 4 years (6.3 and 8.1 mm). CBL ≥2 mm was detected in 18% of implants at 3 years and 35% at 6 ($p < 2.2 \times 10^{-16}$), this prevalence being 2.6 times higher in the anodized than in the hybrid and turned group (40%/15.6%, $p < .0094$). At 6 years, 25 anodized implants presented CBL ≥3 mm (18%). 6 anodized implants (5 patients) were removed between 4 and 5 years.

Conclusion: A significant higher CBL was observed in anodized, compared to hybrid and turned implants, when placed in the mandibular molar region of periodontal patients, with a follow-up of 1 to 6 years.

KEYWORDS

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

1 | INTRODUCTION

Peri-implantitis has been recently defined at the World Workshop for the Classification of Periodontal and Peri-implant Diseases, as a plaque-associated pathological condition occurring in tissues around dental implants, characterized by inflammation in the peri-implant mucosa and subsequent progressive loss of supporting bone (Berglundh et al., 2018). Its reported prevalence varies depending on the different case definitions used in the epidemiological studies and may range from 11% to 47% of all patients with implant supported restorations over five years of function (Koldsland et al., 2010). However, recent systematic reviews with meta-analysis have estimated a prevalence of peri-implantitis at patient level of around 20% (Derks & Tomasi, 2015; Rakic et al., 2018), a figure, which will certainly rise due to the expected increase of the time in function of existing implants and the growing number of implants placed per year (Millennium Research Group & I, 2015). This will imply that unless the appropriate preventive and therapeutic measures are implemented, peri-implantitis will not only jeopardize the function of implant supported restorations, but will also cause important public health concerns, due to the chronic diseased status of the oral tissues, the need for further interventions and the discomfort, cost and time affecting a growing patient population (Ferrantino et al., 2019; Simonis et al., 2010).

Although it is well established that the primary aetiological factor of peri-implantitis is the accumulation of dental biofilms on the implant/abutment surface, the aetiological impact of other risk factors, such as the patient's history of periodontitis, smoking and poor plaque control is quite significant (Heitz-Mayfield, 2008). Even if other risk indicators have been studied, as the presence of certain genetic traits, limited amounts of keratinized tissue, inadequate bone availability, and differences in the implant surface micro-topography, their aetiological impact is still matter of controversy, mainly due to the lack of prospective cohort studies (Doornewaard et al., 2017; Klinge et al., 2012, 2015; Mombelli et al., 2012; Renvert & Quirynen, 2015).

One of the risk indicators that may be particularly relevant is the impact of the implant surface micro-topography, since in the last 15–20 years, most of the implants placed worldwide have surfaces with intermediate roughness, due to their improved ability to attain osseointegration after implant placement (Wennerberg & Albrektsson, 2011). However, these surfaces, which are aimed to be in contact with the peri-implant bone through osseointegration, may become exposed if the marginal bone is lost and hence subject to plaque accumulation if the soft tissues are inflamed and, in consequence, lose their tight sealing function. It is, therefore, key in peri-implantitis prevention to maintain crestal bone levels over time and in fact, one of the most frequently used outcome measurements to assess the long-term clinical response of dental implants is the amount of interproximal peri-implant bone loss (CBL) (Albrektsson, Buser, & Sennerby, 2012), which is indirectly estimated by measuring the crestal bone level changes over time (distance between the implant shoulder and the first bone to implant contact) (Doornewaard et al., 2017). Furthermore, with the use of current periapical radiographical techniques, there is an underestimation of bone loss of around 0.6–0.7 mm (Serino et al., 2017).

Long-term studies on the maintenance of crestal bone levels when using dental implants with minimally rough (turned) surfaces (Sa ranging between 0.5 and 1) have shown a CBL of 0.4–1.8 mm during the remodelling phase after implant placement (Doornewaard et al., 2017; Wennerberg & Albrektsson, 2011), followed by a period of stability during the first year in function with subsequent minimal annual remodelling (0.05 to 0.1 mm) (Adell et al., 1981; Attard & Zarb, 2004; Bergenblock et al., 2012; Ferrantino et al., 2019; Friberg et al., 1997; Jemt, 1994; Jemt et al., 2002; Jemt & Johansson, 2006; Lindquist et al., 1996; Ortorp & Jemt, 2012). A recent systematic review and meta-analysis with data from 87 studies with at least 5 years of follow-up have evaluated the CBL of dental implants with different surfaces, reporting significantly higher CBL in implants with moderately rough surfaces (Sa between 1.0 and 1.5) (Doornewaard et al., 2017). These findings are in agreement with other reviews, prospective and retrospective case series (Esposito et al., 2014; Gallego et al., 2018; Mir-Mari et al., 2012; Raes et al., 2018).

In spite of this evidence, however, there is a lack of rigorous evaluation on whether implants with similar characteristics, albeit with different micro-surface topography, would result in higher crestal bone loss (Doornewaard et al., 2017; Jungner et al., 2014). This is particularly relevant when assessing the performance of dental implants in specific patient risk populations, such as patients with a history of periodontitis (Gallego et al., 2018; Sanz & Chapple, 2012). It was, therefore, the purpose of this clinical study to evaluate the radiographic CBL in a cohort of periodontal patients under supportive periodontal care wearing dental implants in the posterior mandible, with different surface micro-topographies.

2 | METHOD

This retrospective case series consisted of 268 consecutive patients treated in a private clinic specialized in Periodontology (Clínica Sicilia, Oviedo, Spain) and selected according to the following entrance criteria: a) history of periodontitis; b) previous periodontal treatment and currently in periodontal supportive care; c) dental implants placed in the posterior mandible with a follow-up of at least one year in function, and up to 6 years. Patients were excluded if presenting complex or uncontrolled systemic diseases (≥ASA III) or if implants were placed on regenerated bone or with simultaneous bone regeneration or with immediate function. The research protocol was approved by the Research Ethics Committee of the Principality of Asturias (Spain) (Protocol # 174/17) and the results of this investigation have been reported using the STROBE guidelines for observational studies.

In this patient population, 755 dental titanium implants were placed in the posterior mandibular region. These implants had all a similar platform size (4.1 mm) and external connection (external hexagon of 2.9 × 0.7 mm), but they were from three different brands, each with "non-identical" macroscopic design and varying micro-surface topography: turned (Sa between 0.2 and 0.4) (Lifecore Biomedical); hybrid with a turned surface in the most coronal part of the implant and double acid-etched in the rest (Sa between 0.6 and 0.8) (Osseotite®, Zimmer Biomet); and anodized with a moderately rough surface (Sa between 1.1 and 1.3) (Ti-Unite®, Nobel Biocare).

All implants were placed by the same surgeon (AS) aiming for a bone level positioning, with the use of a surgical microscope (MSX2001, Leica Microsystems AG). Healing abutments were simultaneously placed, and the implants were allowed to heal without loading during 8–10 weeks. Patients were then re-evaluated after postoperative healing (baseline visit) and referred to the restorative dentist for fabrication and installation of the definitive implant supported screwed-retained prosthesis. These restorations were all metal–ceramic prosthesis connected directly to the implant, with adequate hygienic emergence profiles. Patients were then asked to continue their supportive periodontal care that included a periodontal examination and annual radiographs of the implant sites. The flow of the study design is depicted in Figure 1.

The primary outcome variable was radiographical interproximal CBL. At baseline and subsequent yearly visits, digital periapical radiographs were taken using a parallel cone technique (Rinn® XCP film holder, Dentsplay). Radiographs were calibrated using as reference the known length of each implant. After this process, an experienced observer (LG) measured the distance between the border of the implant platform and the most identifiable bone to implant contact at crestal level with a specific digital measuring tool (Digora®, Soredex) (Gallego et al., 2018).

As secondary outcomes, we assessed the following variables: baseline patient characteristics, such as age, sex, smoking, systemic status, visible plaque index (O'Leary et al., 1972), gingival bleeding index (Joss et al., 1994), periodontitis severity in the remaining dentition (Armitage, 1999; Lang & Lindhe, 2015), frequency and compliance with the supportive periodontal programme and type of antagonistic dentition.

2.1 | Data analysis

The primary outcome variable was evaluated by one examiner (LG) and calibrated through a series of repeated measurements on randomly selected digital radiographs. After dividing the crestal bone level values in three categories according to a pre-determined threshold: from 0 to 0.25 mm, >0.25 to 0.50 mm, and >0.50 mm,

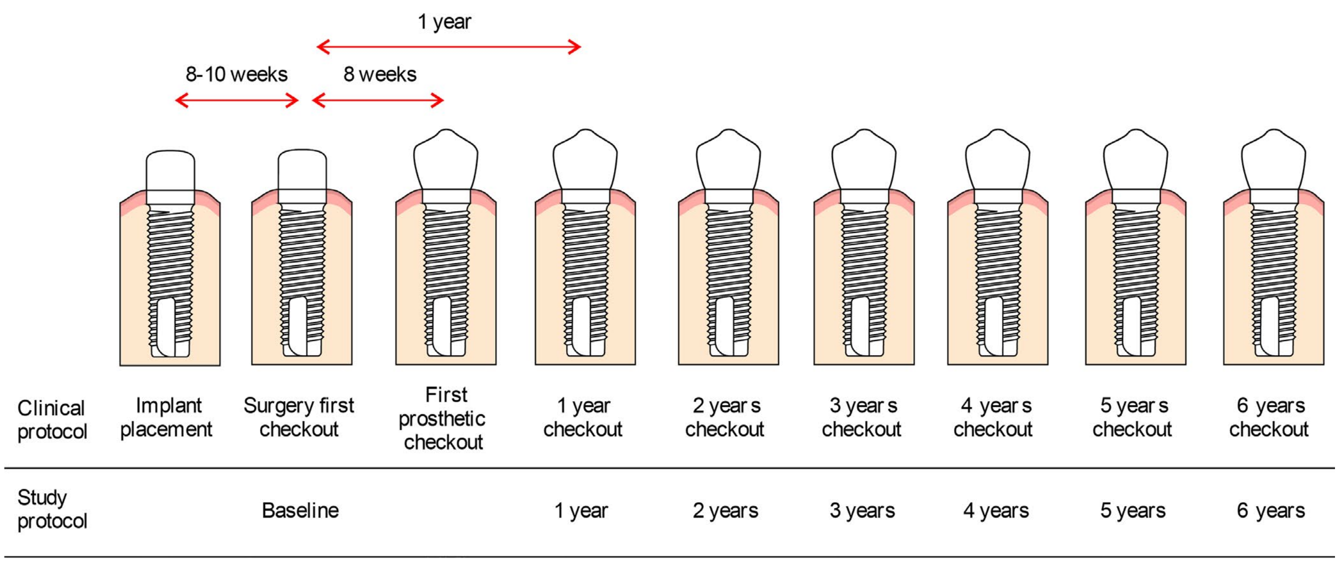

FIGURE 1 Study protocols and clinical follow-up performed during the periodontal maintenance programme [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 1 Interproximal Crestal bone loss (CBL) observed at the different stages

	8 weeks	1 year	2 years	3 years	4 years	5 years	6 years	Dif. 8 weeks–6 years
Interproximal Crestal Bone Loss (CBL) (patient as unit of analysis)								
Mean (*SD*)	0.44 (0.34)	0.79 (0.52)	1.03 (0.67)	1.28 (0.90)	1.59 (1.04)	1.72 (1.00)	1.77 (0.89)	1.34 (0.82)
Median	0.42	0.70	0.91	1.10	1.35	1.48	1.62	1.08
Range *n*	0–2.1 268	0–2.72 263	0–3.37 218	0–6.26 170	0–6.42 111	0–4.62 80	0.49–3.94 53	0–3.39
ANOVA of CBL and time, *F*: 73.73 $p < .001$.								
Interproximal Crestal Bone Loss (CBL) (implant as unit of analysis)								
Mean (*SD*)	0.44 (0.42)	0.82 (0.59)	1.07 (0.73)	1.30 (0.99)	1.66 (1.29)	1.71 (1.08)	1.78 (1.00)	1.42 (0.94)
Median	0.39	0.74	0.95	1.09	1.35	1.51	1.60	1.24
Range *n*	0–2.19 755	0–3.64 744	0–4.36 609	0–8.08 479	0–8.07 346	0–5.29 246	0–5.21 172	0–4.46
ANOVA of CBL and time, *F*:167.74 $p < .001$								

Note: CBL is expressed in mm.

TABLE 2 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	4 years	5 years	6 years	8 weeks–6 years
TURN (1)	*N* = 72 Mean: 0.56 *SD*: 0.43	*N* = 71 Mean: 0.91 *SD*: 0.52	*N* = 60 Mean: 1.18 *SD*: 0.54	*N* = 51 Mean: 1.25 *SD*: 0.54	*N* = 28 Mean: 1.36 *SD*: 0.49	*N* = 15 Mean: 1.29 *SD*: 0.44	*N* = 11 Mean: 1.46 *SD*: 0.39	*N* = 11 Mean: 1.12 *SD*: 0.58
HYB (2)	*N* = 145 Mean: 0.33 *SD*: 0.43	*N* = 143 Mean: 0.64 *SD*: 0.58	*N* = 112 Mean: 0.88 *SD*: 0.77	*N* = 83 Mean: 1.00 *SD*: 0.87	*N* = 46 Mean: 1.19 *SD*: 1.68	*N* = 32 Mean: 1.06 *SD*: 0.93	*N* = 21 Mean: 1.02 *SD*: 0.60	*N* = 21 Mean: 0.74 *SD*: 0.44
ANOD (3)	*N* = 538 Mean: 0.47 *SD*: 0.41	*N* = 530 Mean: 0.85 *SD*: 0.59	*N* = 437 Mean: 1.10 *SD*: 0.73	*N* = 345 Mean: 1.38 *SD*: 1.05	*N* = 272 Mean: 1.77 *SD*: 1.26	*N* = 199 Mean: 1.84 *SD*: 1.09	*N* = 140 Mean: 1.92 *SD*: 1.03	*N* = 140 Mean: 1.52 *SD*: 0.95
ANOVA test	$F = 8.79$ ($p < .001$)	$F = 8.51$ ($p < .001$)	$F = 4.92$ ($p = .008$)	$F = 5.28$ ($p = .005$)	$F = 4.97$ ($p = .007$)	$F = 9.09$ ($p < .001$)	$F = 8.81$ ($p < .001$)	$F = 8.34$ ($p < .001$)
ANOVA effect size Cohen's f	$f = 0.21$	$f = 0.21$	$f = 0.21$	$f = 0.68$	$f = 0.35$	$f = 0.48$	$f = 0.57$	$f = 0.57$

Note: TURN: turned surface (Lifecore Biomedical, Chaska, Minnesota, USA). HYB: hybrid micro-surface topography (turned surface at the most coronal aspect and dual acid-etched surface on the remainder of the implant body) (Osseotite®, Zimmer Biomet, Warsaw, Indiana, USA). ANOD: anodized surface (Ti-Unite®, Nobel Biocare, Zurich, Switzerland.

the resulting intra-examiner variability using kappa statistics was k: 0.983, hence demonstrating a high degree of reproducibility.

Data were presented in a descriptive fashion using frequency distributions of the prevalence of the different thresholds of crestal bone level values expressed as percentages, with their corresponding 0.05% confidence intervals, or in accumulated frequency graphs.

A detailed descriptive interpretation of data is provided using a frequency distribution of the different CBL intervals, which have been expressed as percentages and are associated to their corresponding 95% confidence intervals, as well as CBL accumulated frequency graphs at 8 weeks, 3 and 6 years.

The normality of the quantitative variables was assessed using the Kolmogorov–Smirnov test, and assuming a normal distribution, the changes in crestal bone levels were compared with the Analysis of Variance for independent samples, using the Tukey HSD test as post hoc analysis. The comparisons in the qualitative variables were done using the Chi square test. The effect size was calculated using the Cohen's f statistic (Cohen, 1988; Turturean, 2015). The statistical analysis was performed using Stata software (Stata®/IC 13.0 for Windows®).

3 | RESULTS

The selected population consisted of 268 consecutive patients with 755 dental implants placed in the posterior mandible. The following number of patients/implants with different surface micro-topography was evaluated: 27 patients with 72 turned surface implants, 74 patients with 145 hybrid turned-dual acid-etched surface implants, and 167 patients with 538 anodized surface implants. At the 6-year follow-up visit, 53 patients and 172 implants were evaluated.

The follow-up results for this group at first stage (between 8 weeks and 3 years) have been previously published reporting the conditions of the sample population and its homogenous initial situation. No significant variations in subjects receiving the different types of implants were observed at baseline regarding age, sex, smoking, severity of periodontal disease, presence of diabetes, type of antagonistic dentition, and bleeding and plaque index (Gallego et al., 2018).

The mean baseline CBL was 0.44 mm, both at the patient and implant level, increasing significantly over time and reaching a mean value of 1.8 mm at 6 years. The CBL between baseline and 6 years was 1.34 mm at patient level and 1.42 mm at implant level, being the highest crestal bone levels detected 6.4 mm and 8.1 mm, both observed in two subjects with anodized implants at the 4-year evaluation visit (Table 1).

Even though the mean baseline CBL was significantly higher in turned implants when compared with both hybrid and anodized implants (0.56, 0.33 and 0.47 mm, respectively), after six years, CBL was significantly higher (1.92 mm) in anodized implants, compared to turned and hybrid implants (1.46 mm and 1.02 mm, respectively). The CBL observed between 8 weeks and 6 years was also significantly higher in anodized (1.52 mm) implants when compared with turned

TABLE 3 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	4 years	5 year	6 years	8 weeks–6 years
TURN (1)	*N* = 27 Mean: 0.40 *SD*: 0.38	*N* = 27 Mean: 0.85 *SD*: 0.39	*N* = 23 Mean: 1.08 *SD*: 0.42	*N* = 20 Mean: 1.18 *SD*: 0.43	*N* = 8 Mean: 1.30 *SD*: 0.28	*N* = 5 Mean: 1.24 *SD*: 0.27	*N* = 3 Mean: 1.40 *SD*: 0.25	*N* = 3 Mean: 0.67 *SD*: 0.58
HYB (2)	*N* = 74 Mean: 0.17 *SD*: 0.35	*N* = 71 Mean: 0.62 *SD*: 0.57	*N* = 57 Mean: 0.87 *SD*: 0.79	*N* = 43 Mean: 1.06 *SD*: 0.90	*N* = 22 Mean: 1.16 *SD*: 1.05	*N* = 16 Mean: 1.21 *SD*: 1.15	*N* = 9 Mean: 1.04 *SD*: 0.62	*N* = 9 Mean: 0.81 *SD*: 0.47
ANOD (3)	*N* = 167 Mean: 0.35 *SD*: 0.31	*N* = 165 Mean: 0.85 *SD*: 0.50	*N* = 138 Mean: 1.09 *SD*: 0.63	*N* = 107 Mean: 1.39 *SD*: 0.95	*N* = 81 Mean: 1.74 *SD*: 1.05	*N* = 59 Mean: 1.90 *SD*: 0.94	*N* = 41 Mean: 1.96 *SD*: 0.88	*N* = 41 Mean: 1.51 *SD*: 0.80
ANOVA test	$F = 7.58$ ($p = .001$)	$F = 5.18$ ($p = .006$)	$F = 2.39$ ($p = .094$)	$F = 2.25$ ($p = .109$)	$F = 3.13$ ($p = .048$)	$F = 3.87$ ($p = .025$)	$F = 4.88$ ($p = .012$)	$F = 4.56$ ($p = .015$)
ANOVA effect size Cohen's f	$f = 0.35$	$f = 0.35$	$f = 0.38$	$f = 0.41$	$f = 0.68$	$f = 0.91$	$f = 1.36$	$f = 1.36$

Note: TURN: turned surface (Lifecore Biomedical, Chaska, Minnesota, USA.). HYB: hybrid micro-surface topography (turned surface at the most coronal aspect and dual acid-etched surface on the remainder of the implant body) (Osseotite®, Zimmer Biomet, Warsaw, Indiana, USA). ANOD: anodized surface (Ti-Unite®, Nobel Biocare, Zurich, Switzerland).

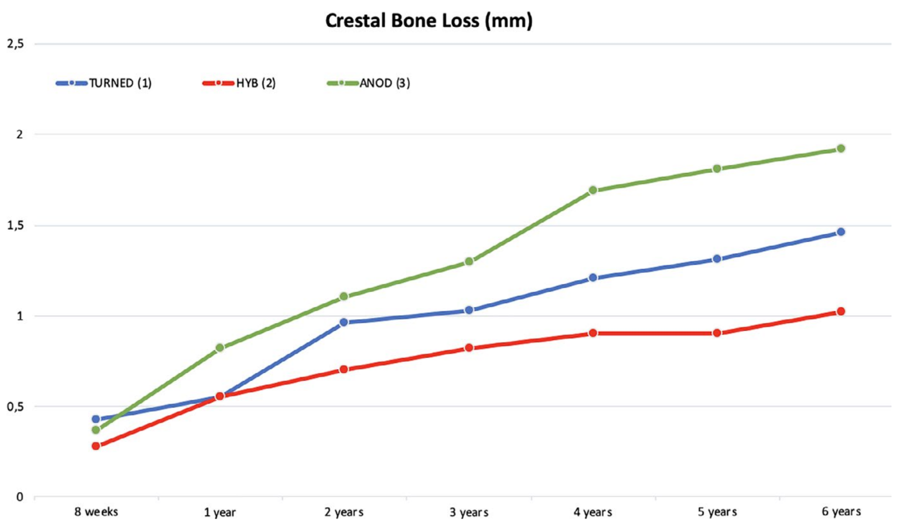

FIGURE 2 Evolution of bone loss according to the type/surface of the implant. Analysis performed only on patients present at all time stages. MACH: Turned surface (Lifecore Biomedical, Chaska, Minnesota, USA.). HYB: Hybrid micro-surface topography (turned surface at the most coronal aspect and dual acid-etched surface on the remainder of the implant body) (Osseotite®, Zimmer Biomet, Warsaw, Indiana, USA). ANOD: Anodized surface (Ti-Unite®, Nobel Biocare, Zurich, Switzerland) [Colour figure can be viewed at wileyonlinelibrary.com]

and hybrid implants (1.12 mm and 0.74 mm, respectively) (Table 2). Finally, when comparing the evolution of patients assessed at 1 and 6 years, a higher significant CBL ($F = 8.57$; $p = .001$) of 1.07 mm was registered for anodized implants, while for turned and hybrid surfaces, the values obtained were 0.55 and 0.38 mm, respectively. Similar results in the comparisons of mean CBL were observed at the patient level analysis, especially after the fourth-year evaluation (Table 3).

Figure 2 graphically depicts the evolution of CBL, stratified by implant groups, including only the patients who were present in all phases of the study. It is notable how these mean values diverge significantly, mainly when comparing hybrid and anodized implants at all time points.

When analysing the frequency distribution at the different CBL levels at implant level, the percentage of implants with advanced CBL exhibits a significant increased overtime, from 0.4% of implants with CBL ≥2 mm at 8 weeks to 18% and 35% at 3 and 6 years, respectively ($p < 2.2 \times 10^{-16}$) (Table 4). On the other hand, in the assessment of CBL according to surface type, the percentage of CBL ≥2 mm is significantly higher in anodized implants than in minimally rough-surfaced, hybrid and turned implants. This is observed at 3 years and, more markedly, at 6 years, with anodized implants presenting a 1.7 times higher percentage (20.1% versus 11.8%) of CBL ≥ 2 mm at 3 years, and 2.6 times higher at 6 years (40% versus 15.6%), as illustrated in Table 5.

Figures 3-5 depict the cumulative percentage of implants as a function of increased CBL, with hybrid and turned implants (Minimally Rough - MR) pulled together and compared with anodized. It is noticeable in the graphic how the bone loss curve separates and diverges markedly over time, with the maximum divergence at 6 years. In the MR implant group, only 5 implants exceeded the 2 mm threshold in CBL, while in the anodized implant group, 56 implants exceeded this threshold, with CBL reaching 5 mm. At 6 years, 25 anodized implants (18%) (CI: 11.9–25.2) had a CBL of 3 mm or greater. There were no minimally rough implants in this category.

TABLE 4 Prevalence of the defined CBL thresholds at the different time points (implant as unit of analysis)

	8 weeks		1 year		2 years		3 years		4 years		5 years		6 years	
	n	% (95% CI)	*n*	% (95% CI)	*n*	% (95% CI)	*n*	% (95% CI)	*n*	% (95% CI)	*n*	% (95% CI)	*n*	% (95% CI)
0–1.9 mm	752	99.59% (99.13–100)	711	95.56% (94.08–97.04)	545	89.49% (87.05–91.93)	394	82.25% (78.83–85.67)	251	72.54% (67.84–77.24)	167	67.88% (62.05–73.71)	111	64.53% (57.38–71.68)
2–3.9 mm	3	0.41% (0–0.87)	33	4.44% (2.96–5.92)	60	9.85% (7.48–12.22)	71	14.82% (11.64–18.00)	76	21.97% (17.61–26.33)	66	26.83% (21.29–32.37)	54	31.39% (24.45–38.33)
≥4.0 mm	0	0.00%	0	0.00%	4	0.66% (0.02–1.30)	14	2.93% (1.42–4.44)	19	5.49% (3.09–7–89)	13	5.29% (2.49–8.09)	7	4.08% (1.12–7.04)
Total	755		744		609		479		346		246		172	

Note: Fisher test (8 weeks–3 years–6 years) $p < 2.2 \times 10^{-16}$.

Abbreviation: (95% CI), 95% confidence interval.

Six implants were explanted in 5 patients (Figure 5), 3 at 4 years and 3 at 5 years, due to advanced bone loss (between 40% and 95% of the length of the implant), presence of uncontrollable inflammation, suppuration or mobility. These 5 patients were female, and all implants were of anodized surface. Four were heavy smokers (>20 cigarettes per day), poor adherents to the periodontal supportive care and with poor plaque control (4 out of 5). In 3 patients, peri-implantitis surgery had been previously performed (3 out of 5). The five patients, after implant explantation, abandoned the periodontal maintenance treatment (Table 6). The loss of minimally rough-surfaced implants was not registered in this study.

4 | DISCUSSION

The purpose of this retrospective study was to report long-term crestal bone level changes of three implant systems with similar macro-design, but different micro-surface topography in a homogeneous patient population (patients with a history of periodontal disease), in the same intraoral location, by the same implant surgeon, and following the same periodontal support care programme. Fifty-three patients (172 implants) were examined in the 6-year evaluation visit, demonstrating a significant increase in the crestal bone level loss (CBL) compared to the baseline visit of 1.34 and 1.42 mm at patient and implant level. This mean CBL was significantly higher in the anodized implant group when compared to the hybrid implant group (1.52 versus. 0.74 mm) or to the turned implant group (1.52 versus. 1.12 mm). These data confirm and enlarge the tendency described in the previous publication of this retrospective study reporting the short-term (8 weeks-3 years) data (Gallego et al., 2018), as well as in other long-term (5–17 year) retrospective case series recently published (Ferrantino et al., 2019). A similar tendency of higher CBL in moderately rough surface implants has also been observed in recent meta-analyses (Doornewaard et al., 2017), reviews (Esposito et al., 2014), randomized studies (Donati et al., 2018; Raes et al., 2018), and in several prospective and retrospective studies (Jungner et al., 2014; Mir-Mari et al., 2012; Sayardoust et al., 2013; Vandeweghe et al., 2016).

Consequently, it starts to become evident that moderately rough implants can induce a significant increase in CBL; however, as per most of the articles, clinical effect does not seem to be relevant (Doornewaard et al., 2017). This may be due to the fact that bone loss is multifactorial, to the heterogeneity of the studies in the inclusion of patients at risk, or to the poor presentation of the information (Doornewaard et al., 2017). In this last sense, it should be emphasized that the analysis of the CBL should not remain a mere comparison of mean values, which masks the extent of the problem and does not allow easy identification of severely affected individuals (Hurley et al., 2011; Monje & Wang, 2014; Polgar & Thomas, 2013), but an analysis of the frequency distribution is recommended (Ferrantino et al., 2019; Gotfredsen & Karlsson, 2001; Jemt & Johansson, 2006). However, this is not a criterion usually followed in the reviewed bibliography (Donati et al., 2018; Doornewaard et al., 2017; Esposito et al., 2014; Ferrantino et al., 2019; Jungner et al., 2014; Mir-Mari

TABLE 5 Prevalence of the described CBL thresholds at different time points (implant as unit of analysis)

	CBL at 3 years				CBL at 6 years			
	n	0–1.9 mm % (95% CI)	*n*	≥2 mm % (95% CI)	*n*	0–1.9 mm % (95% CI)	*n*	≥2 mm % (95% CI)
Turned + hybrid	120	88.2% (81.6–93.1%)	16	11.8% (6.9–11.8%)	27	84.4% (67–95%)	5	15.6% (5.3–32.8)
Anodized	274	79.9% (75.2–84.0)	69	20.1% (16.0–24.8%)	84	60% (51.4–68.2%)	56	40% (31.8–48.6%)
Total	394		85		111		61	
	$\chi^2 = 4.654$ $p = .030981$				$\chi^2 = 6.7615$ $p = .009315$			

Note: Turned: turned surface (Lifecore Biomedical, Chaska, Minnesota, USA.). Hybrid: hybrid micro-surface topography (turned surface at the most coronal aspect and dual acid-etched surface on the remainder of the implant body) (Osseotite®, Zimmer Biomet, Warsaw, Indiana, USA). ANODIZED: anodized surface (Ti-Unite®, Nobel Biocare, Zurich, Suiza). (95% CI): 95% confidence interval.

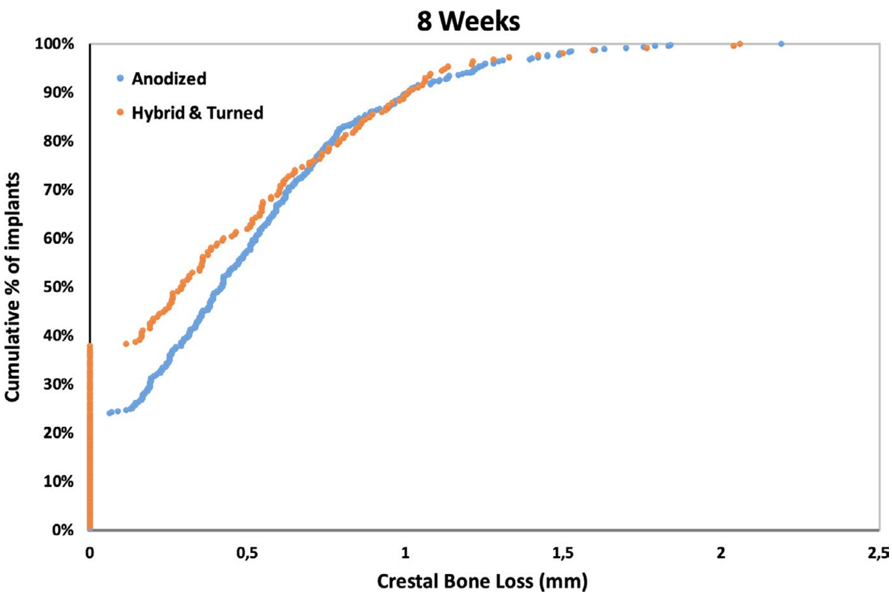

FIGURE 3 Accumulated percentage of implants based on the CBL observed at 8 weeks, 3 and 6 years. The 6 implants that have been removed (all anodized) are shown in blue boxes on the right [Colour figure can be viewed at wileyonlinelibrary.com]

et al., 2012; Raes et al., 2018; Sayardoust et al., 2013; Vandeweghe et al., 2016). Bearing this in mind, we can critically analyse the meaning of the data in the present study. Here, the comparison of the mean crestal bone level changes of minimally rough implants (0.87 mm) versus anodized implants (1.52 mm) between baseline and 6 years may seem clinically irrelevant. However, when evaluating these data by frequency distributions, the prevalence of implants with bone loss over 2 mm is almost three times higher in the anodized implants when compared to MR ones (40% versus. 15.6%). Similarly, the prevalence of CBL between 2.9 and 5 mm was 18% in the anodized, compared to none in the MR implants. In addition, since this study only evaluated implants in the posterior mandible, which usually oscillate between 7 and 10 mm in length, the resulting CBL at 6 years in the anodized surface implants represented between 30% and 71% of the implant length, which is undoubtedly clinically relevant (Gallego et al., 2018). These results are very similar to the results of the study by (Ferrantino et al., 2019) reporting the outcome of 223 anodized implants with a retrospective follow-up of 5 to 17 years. Even though the mean difference of crestal bone level changes between 1 year and the end-of-study analysis (5 to 17 years) was 0.9 mm, 42.6% of implants had CBL ≥ 2 mm, 18% ≥3 mm, 49% of the patients were diagnosed of peri-implantitis and 5% suffered from late implant failures due to peri-implantitis, which also boils down to a serious clinical problem poorly evidenced by the mean CBL of 0.9 mm.

Multiple studies have reported the clinical advantages of using moderately rough surface implants (Albrektsson & Wennerberg, 2004; Friberg & Jemt, 2008; Le Guehennec et al., 2007; Pinholt, 2003; Rocci et al., 2003), describing higher survival and success rates (Albrektsson, Buser, & Sennerby, 2012), mainly in comparison with turned surface implants, more prone to early failure (Gotfredsen & Karlsson, 2001; Polizzi et al., 2013; Raes et al., 2018; Sayardoust et al., 2013). However, the results of the present clinical study suggest that late failures are probably higher in moderately rough surface implants, as also clearly reported by Ferrantino et al., showing a failure rate of 8.1% in anodized surface implants (Ferrantino et al., 2019). In this paper, early failures have not been observed in any of the groups, but, on the contrary, 6 late failures have occurred between year 4 and 5 of follow-up, all in the anodized implant group.

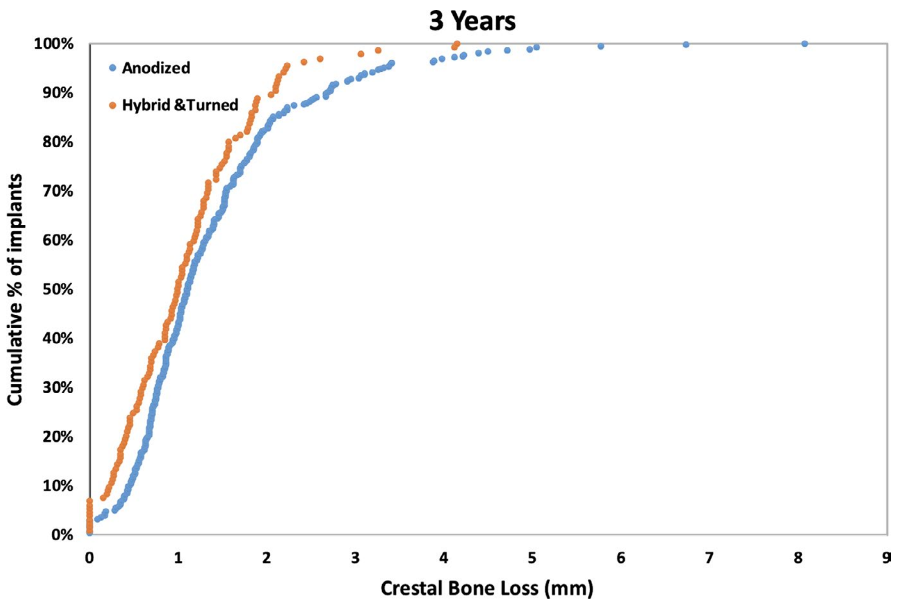

FIGURE 4 Accumulated percentage of implants based on the CBL observed at 8 weeks, 3 and 6 years. The 6 implants that have been removed (all anodized) are shown in blue boxes on the right [Colour figure can be viewed at wileyonlinelibrary.com]

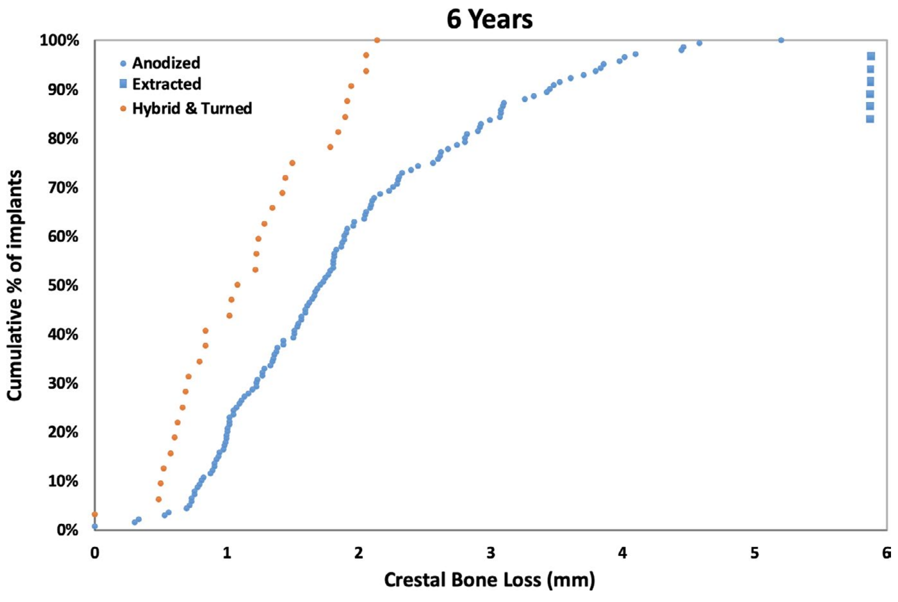

FIGURE 5 Accumulated percentage of implants based on the CBL observed at 8 weeks, 3 and 6 years. The 6 implants that have been removed (all anodized) are shown in blue boxes on the right [Colour figure can be viewed at wileyonlinelibrary.com]

This study presents several limitations, including: a) its observational nature, which prevents from establishing cause–effect relationships (Hurley et al., 2011), and b) its small sample size at some stages (4–6 years), which only allows to qualify as significant variable relationships with a big effect size (Cohen, 1988; Donati et al., 2018; Turturean, 2015).

Another possible barrier in the validity of the obtained results could be the method used in the radiological analysis (Donati et al., 2018; Gallego et al., 2018), since there is a well-established underestimation in the periapical radiographs when compared with the actual bone loss (Serino et al., 2017). However, the longitudinal monitoring of CBL by repeated interproximal periapical x-rays is a well-accepted method (Albrektsson, Buser, Chen, et al., 2012), mainly when evaluated by a single examiner with a high degree of reproducibility. Another factor that may have influenced the outcome is the usual "abandonment bias" occurring in periodontal maintenance programmes, which may tend to underestimate the actual bone loss, since patients who leave the preventive programmes are regularly those with lesser health conscience. The results from this study, although they are only observational, have a high external validity, since the patient population was very homogeneous (history of periodontitis), all implants were commercially available implants, they have been placed in the same location (posterior mandible), and by the same implant surgeon, all treatments have been carried out in a private clinic (Sanz & Chapple, 2012), and in periodontal patients following a regular supportive care programme (Becker et al., 2016; Dalago et al., 2016; Daubert et al., 2015; Donati et al., 2018; Doornewaard et al., 2016; Marrone et al., 2013; Maximo et al., 2008; Renvert et al., 2012, 2014; Roos-Jansaker et al., 2006; Simonis et al., 2010). Moreover, the results obtained are coincident

TABLE 6 Patients that needed extraction of any of the implants. Clinical characteristics

			CBL (mm)						
	Patient/implant	Tooth #	8 weeks	1 year	2 years	3 years	4 years	5 years	Comments
1	NS 4 × 10	36	0	0.8	1.2	4.3	IMPL-EXT (5.8)		Female/69 years. Implant #36. Occasional smoker. Good complier PM. Previous regenerative peri-implantitis surgery, bad complier PM afterwards, BI&PLI > 40%. Disappointed. Quit PM.
2	MK3 4 × 7	36	1.8	3.2	4.1	4.7	5.4	IMPL-EXT (6.1)	Female/66 years. Implants #35, 36, & 37.^Smoker (>20 cd). Previous access peri-implantitis surgery. Erbium-Yag Laser disinfection. Bad complier PM, BI: 10%, PLI: 50%. #35 maintained. Disappointed. Quit PM.
	4 × 7	37	1.1	2.3	3.7	4.6	5.0	IMPL-EXT (6.7)	
3	NS 4 × 10	37	0.8	1.1	1.1	2.0	IMPL-EXT (4.2)		Female/59 years. Implants #36 & 37. Smoker (>20 cd). OB (7 years). Non-restored absence of #45, 46 & 47. Bad complier PM, BI&PLI > 60%. #36 maintained. Disappointed. Quit PM.
4	NS 4 × 10	45	0.4	1.1	1.3	1.4	IMPL-EXT (4.3) (mobility/sup.)		Female/56 years. Implants #45, 46 & 47. Smoker (>40 cd), ex-drug addict (Coccaine). Bad complier PM. Previous access peri-implantitis surgery. BI&PLI > 70%. #46 & 47 maintained. Disappointed. Quit PM.
5	NS 4 × 8.5	47	0	0.2	0.3	1.4	3.8	IMPL-EXT (6.1)	Female/56 years. Implants #45, 46 & 47. Smoker (>20 cd). Good complier PM, BI: 20%, PLI: 15%. Bad complier PM after depression. #45 & 46 maintained. Disappointed. Quit PM.

Abbreviations: BI & PLI, Bleeding and Plaque Index; CBL, Crestal Bone Loss; IMPL-EXT (5.8), Implant extraction (bone loss in mm); NS & MKIII, anodized implants Nobel Speedy and MKIII; PM, Periodontal maintenance.

with other studies evaluating differences in crestal bone loss depending on the implant micro-surface topography (Doornewaard et al., 2017).

The use of commercial non-identical implants in the present study could have an influence, at least in theory, in the CBL causing a bias. However, it should be remarked that the macrostructure of all implant types tested here were very similar at the coronal aspect, featuring the same platform (4.1 mm) with a 2.7 mm x 0.7 mm external hexagon; and that CBL measures were taken from a fixed reference point—the angle formed by the implant's lateral side and the platform, which is identical in all implants. Additionally, there is no evidence in the reviewed literature indicating that small morphological differences in the implant's neck would have any effect in interproximal bone loss (Bateli et al., 2011). Nowadays, it has been accepted that some variations on the neck design, such as microgrooves or microthreads, the type of implant-abutment connection or the use of the "reduced-platform" concept may have a limited effect on the initiation of CBL (Goiato et al., 2015; Koodaryan & Hafezeqoran, 2016; de Medeiros et al., 2016; Niu et al., 2017; Schwarz et al., 2014). However, none of these design alternatives is applicable to this study. Finally, a randomized clinical study comparing implants with identical macrostructure but different surface (Raes et al., 2018) shows at 5 years differences in CBL for turned and anodized implants equivalent to those found in this study.

5 | CONCLUSION

In conclusion, this retrospective study, with a follow-up period of 1 to 6 years, confirms the findings of the previous report at three years, in which a prevalence of "relevant crestal bone loss" was associated with the dental implant placed, demonstrating higher bone loss in implants with anodized micro-surface topography when compared to turned or hybrid dental implants.

AUTHOR CONTRIBUTION

Alberto Sicilia: Conceptualization (lead); Methodology (equal); Supervision (equal); Writing-original draft (equal); Writing-review & editing (lead). **Luis Gallego:** Conceptualization (equal); Formal analysis (equal); Investigation (equal); Writing-original draft. **Pelayo Sicilia:** Investigation (equal). **Carmen Mallo:** Investigation (equal); Writing-original draft (equal). **Susana Cuesta:** Investigation (equal); Writing-original draft (equal). **Mariano Sanz:** Methodology (equal); Writing-original draft (equal).

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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