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RESEARCH ARTICLE

CRESTAL BONE LOSS IN PATIENTS WITH DIFFERENT SURFACE MODIFIED DENTAL IMPLANTS: INSIGHTS FROM COMPREHENSIVE REGISTRY DATA-BASED COHORT STUDY

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ABSTRACT

Background: Several surface modifications have been performed on implant surfaces to improve osseointegration. The clinical results of these implants over a long term, however, have not yet been thoroughly assessed. Accordingly, the present registry data-based cohort study aims to examine the crestal bone loss (CBL) associated with sandblasted acid-etched and anodized dental implants.

Materials and Methods : Case records of a total of 162 patients who underwent implant surgery (311 implants) using three different i mplant systems implants with sandblasted acid-etched [Group 1: SLA ® (93 implants), Group 2: SLActive ® (99 implants)] and anodized topographies [Group 3: TiUnite ® (119 implants)], followed by conventional loading between January 2022-June 2023 were enrolled. Digital X-rays at baseline, 3 months and 1-year intervals were collected from case records and crestal bone loss was measured. A one-way ANOVA was conducted for statistical analysis, followed by Tukey's HSD post hoc test for further comparisons.

Results: Implants in group 3 exhibited significantly higher CBL than those in groups 1 and 2 at 3 months and 1-year ($p = 0.000$). At 3 months and 1-year, the prevalence of CBL ≥2 mm was higher in group 3 implants (1.7%, 10.6%) followed by group 1 (0%, 2.2%) and group 2 (0%,0%).

Conclusion: During a one-year follow-up period, anodized implants showed a higher incidence of CBL relative to sandblasted acid-etched implants.

Keywords: Anodization, Bone loss, Dental implants, Sandblasting, Surface topography

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INTRODUCTION

In recent years, both fully and partially edentulous patients tends to opt for dental implant placement as part of their oral rehabilitation. Literature evidence supports high success and survival rates of different implant systems.[1–5] Nevertheless, crestal bone loss from pathological processes like peri-implantitis or physiological remodelling can occur in osseointegrated implants.[6–10]

Crestal tissues undergo constant changes following implant placement and restoration.[11] A frequent observation is that the soft tissues around the implant gradually recede, accompanied by the resorption of the underlying crestal bone.[12] Thus, it has been suggested that for the sustained success of implant-supported restorations, tight soft tissue seal and high peri-implant crestal bone level are crucial. Various geometrical implant designs, and surface modifications have been developed to preserve high crestal bone levels thereby to enhance the osseointegration influence.[13–15]

The primary approaches for modifying the surface of implants are sandblasting, acid treatments, and different oxidation processes. Sandblasted, large grit, acid-etched (SLA) implant surfaces are created by modifying the implant's macrostructure through sandblasting with coarse particles, and then creating micro-irregularities on the surface by etching with an acid. This surface treatment creates irregularities, which in turn favours adhesion of bone cells leading to bone deposition.[16–19] An advancement over SLA surface is SLActive, where, the implant surface is cleaned using nitrogen protection, hydroxylated, and stored in saline solution. This process makes the surface hydrophilic. Currently, ultraviolet (UV) photo functionalization is a prominent implant surface modification technique that enhances osteoblast adhesion. This process transforms the implant's hydrophobic surface into a superhydrophilic one, thereby promoting better osseointegration. Increased hydrophilicity improves the initial attachment of osteoblast cells to the implant surface, facilitating more effective integration with the surrounding bone tissue.[20] Another electrochemical method is anodization, which creates a thick titanium dioxide layer thereby making the surface osteoconductive.[21]

Surface modifications alter the roughness, surface texture, wettability features of the implant surface. Several experimental studies have demonstrated that highly rough surface dental implants typically experience greater and more noticeable crestal bone loss.[22–24] However, there are no research involving humans to assess the impact of surface modifications. In studies evaluating a single type of implant, crestal bone level changes at 5 years vary from 0.15 mm for SLA implants,[25] to 1.07 mm for titanium dioxide sandblasted surface implants,[26–28] and 1.5 mm for anodized implants.[29–31] Comparable crestal bone loss was observed in the various groups after five years in studies that examined two different surface modified implants: turned and sandblasted implants,[32] or turned and anodized implants.[33–38] Notably, insertion of the final prosthesis was the starting point in these investigations.

Literature evidence reveals there are no follow-up studies assessing the crestal bone level changes starting from implant placement. Even though structured, extended-duration prospective studies are necessary for accurately identifying risk factors in conditions with complex and multiple causes, they are challenging to carry out and frequently involve small sample sizes and ideal research conditions, which reduces their external validity. Therefore, the objective of this registry data-based cohort study was to examine the crestal bone loss (CBL) associated with sandblasted acid-etched and anodized dental implants.

MATERIALS AND METHODS

This registry data-based cohort study was conducted in Department of Periodontology, Saveetha Dental College, India. The present study included case records of patients who underwent implant surgery with internal-hex varying platform root analog bone level implants, featuring sandblasted acid-etched and anodized surfaces. These implants were conventionally loaded and restored with cement-retained, porcelain-fused-to-metal prosthetic crowns between January 2022 and June 2023. The ethical clearance was obtained from the Institutional Ethical ReviewCommittee (IHEC/SDC/FACULTY/PERIO/1913).

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Case records of periodontally healthy individuals without systemic diseases and patients with controlled systemic diseases (ASA I and ASA II) of both gender within the age group of 25-60 years were included; patients with bone augmentation procedures during implant placement were excluded.

Case records of 162 patients (311 implants) from January 2022-June 2023, meeting the above inclusion and exclusion criteria were involved in the study. Based on sandblasted acid-etched and anodized topographies, they were categorized into: Group 1 consisted of 93 implants (SLA®, Straumann, Basel, Switzerland) placed in 47 patients. Group 2 included 99 implants (SLActive®, Straumann, Basel, Switzerland) placed in 54 patients. Group 3 included 119 implants (TiUnite®, Nobel Biocare, Gothenburg, Sweden) placed in 61 patients. Table 1 describes details of implants utilized in this study.

Table 1. Implants utilized

Implant Dimension	Group 1 (n)	Group 2 (n)	Group 3 (n)	Total (n)
Maxillary Anteriors				
3.3 * 10	12	10		22
3.3 * 12	12	16		28
3.5 * 10			17	17
3.5 * 11.5			12	12
Maxillary Posteriors				
4.1 * 10	15	14		29
4.8 * 10	11	12		23
4.3 * 10			18	18
4.3 * 11.5			15	15
Mandibular Anteriors				
3.3 * 10	9	9		18
3.3 * 12	6	7		13
3.5 * 10			12	12
3.5 * 11.5			8	8
Mandibular Posteriors				
4.1 * 10	8	12		20
4.1 * 12	11	10		21
4.8 * 10	9	9		18
4.3 * 10			17	17
4.3 * 11.5			14	14
5 * 10			6	6
Total (n)	93	99	119	311

Data collection

Digital periapical radiographs at baseline (T0 - on the day of implant surgery), 3rd month (T1 - during stage 2 uncovery procedure) and 1st year (T2 - after cementation of the prosthesis) were collected from the case records to assess CBL. At mesial and distal aspects of each radiograph, distance from platform of implant to coronal level of bone was measured and then average was taken as primary outcome variable. If the crest of the bone was coronal to the implant's platform, a positive value was assigned; conversely, when it was apical to the implant's

platform, a negative value was assigned. Prior to the start of the implant surgeries, the following patient-related factors were assessed as secondary variables from the case records that might have an impact on the primary outcome: age, gender, smoking, systemic disease, oral hygiene by Silness and Loe plaque index, and local inflammation by Loe and Silness gingival index.

Statistical Analysis

Study data was analysed using SPSS Software, Version 23.0; IBM Corp., Armonk, NY, USA. Shapiro-Wilk test of normality was used to assess the normal distribution of the data. The results followed normal distribution accordingly parametric tests were chosen. One-way ANOVA was used to compare age, plaque index, gingival index, CBL between the three groups. Frequency distribution was calculated and the prevalence for the various CBL levels was computed (0-1.9 mm and ≥ 2mm) and expressed in mean percentages. Tukey's HSD post hoc test was done for pairwise comparison. Chi-square test was used to compare gender, smoking and systemic disease distribution. A p-value of less than 0.05 was deemed statistically significant.

RESULTS

The sample population conprised of 311 implants (162 patients) evaluated at baseline. The 1-year data from 303 implants (156 patients) is presented in this study. The patient characteristics of the sample, categorised by implant type, are shown in Table 2.

Table 2. Patient characteristics at baseline based on the type of implants

	SLA	SLActive	TiUnite	p value
Age	55.2±11.3	52.7±13.5	57.2±15.4	0.879
Gender	Male n=76 Female n=86	Male n=74 Female n=88	Male n=77 Female n=85	0.612
Smoking	Yes n=31 No n=131	Yes n=28 No n=134	Yes n=27 No n=135	0.423
Systemic disease	Yes n=64 No n=98	Yes n=59 No n=103	Yes n=61 No n=101	0.674
Plaque Index	0.57±0.03	0.61±0.06	0.62±0.06	0.864
Gingival Index	0.56±0.05	0.51±0.08	0.58±0.01	0.943

The three implant types that were assessed in this study had an equal distribution of these patient characteristics. No significant difference was noted at baseline between the groups in terms of age, gender, smoking, systemic disease, plaque index and gingival index (p>0.05).

Crestal bone loss (CBL)

During evaluation at 1 year, number of implants lost in group 1, group 2 and group 3 were 1 (1.07%), 1 (1.01%) and 6 (5.04%) respectively. Table 3 depicts the mean CBL among the three groups. At baseline, the crestal bone level in group 1, 2 and 3 implants were 0.35±0.05, 0.34±0.04 and 0.36±0.05 mm, respectively and there was no significant difference between three groups (p = 0.409). At 3 months, the CBL in group 3 implants was notably higher compared to groups 1 and 2 (-0.86±0.11 vs. -0.53±0.04 and -0.44±0.48 mm, respectively; p = 0.000). Similarly at 1 year, group 3 implants exhibited significantly greater CBL than those in groups 1 and 2 (-1.96±0.92 vs.-0.85±0.06 and -0.73±0.05 mm, respectively; p = 0.000). Furthermore, pairwise comparisons revealed significant differences between group 1 and group 2, group 1 and group 3, and group 2 and group 3 at both the 3-month and 1-year follow-ups (p = 0.00).

Table 3. Comparison of crestal bone loss (CBL) between the groups

Type of implants	Baseline (T0)	3 months (T1)	1 year (T2)
SLA	n=93 Mean±SD: 0.35±0.05	n=93 Mean±SD: -0.53±0.04	n=92 Mean±SD: -0.85±0.06
SLActive	n=99 Mean±SD: 0.34±0.04	n=99 Mean±SD: -0.44±0.08	n=98 Mean±SD: -0.73±0.05
TiUnite	n=119 Mean±SD: 0.36±0.05	n=119 Mean±SD: -0.86±0.11	n=113 Mean±SD: -1.96±0.92
ANOVA	p = 0.409	p = 0.000*	p = 0.000*
Tukey's HSD post hoc	SLA vs SLActive Mean Difference: -0.004 p = 0.825	SLA vs SLActive Mean Difference: 0.091 p = 0.000*	SLA vs SLActive Mean Difference: 0.122 p = 0.000*
	SLA vs TiUnite Mean Difference: -0.009 p = 0.379	SLA vs TiUnite Mean Difference: -0.335 p = 0.000*	SLA vs TiUnite Mean Difference: -0.708 p = 0.000*
	SLActive vs TiUnite Mean Difference: -0.005 p = 0.747	SLActive vs TiUnite Mean Difference: -0.426 p = 0.000*	SLActive vs TiUnite Mean Difference: -0.831 p = 0.000*

**Statistically significant*

Table 4 shows the frequency distribution of the implants at three months and one year based on two pre-established CBL thresholds (0-1.9 mm and ≥2 mm). At three months, group 3 implants (1.7%) had a prevalence of CBL ≥2 mm, compared to 0% and 0% for group 1 and group 2 implants, respectively. Similarly, group 3 implants (10.6%) had a prevalence of CBL ≥2 mm at 1 year, whereas group 1 and group 2 implants had corresponding percentages of 2.2% and 0%, respectively.

Table 4. Prevalence of described CBL thresholds at 3 months and 1 year

Type of implants	CBL at 3 months		CBL at 1 year	
	0-1.9 mm	≥ 2 mm	0-1.9 mm	≥ 2 mm
	n (%)	n (%)	n (%)	n (%)
Group 1	93/93 (100%)	0/93 (0%)	90/92 (97.8%)	2/92 (2.2%)
Group 2	99/99 (100%)	0/99 (0%)	98/98 (100%)	0/98 (0%)
Group 3	117/119 (98.3%)	2/119 (1.7%)	101/113 (89.4%)	12/113 (10.6%)

DISCUSSION

In this study evaluating 311 implants, higher CBL was observed in relation to anodized relative to sandblasted acid-etched implants at 3 months and 1 year. Throughout the entire study, anodized surface implants showed higher CBL than sandblasted acid-etched implants. The acquired data are analogous to those observed in longitudinal case reports involving the referenced implant surfaces, despite the lack of similar comparative studies in the literature. Nicolau P et al., reported that at the end of 1 year, CBL was around 1.07 mm in SLActive implants.[39] Following a 20-month observation period, the average CBL values for the SLActive and SLA implants were 0.17 and 0.24 mm respectively, reported by Sener-Yamaner ID et al.[40] Similarly, another study demonstrated that the total mean bone level change at 12 months was 0.77±0.93 mm in SLActive implants.[41] Heberer S et al.,[42] observed 0.9 mm and 0.5 mm of bone loss around SLA and SLActive implants at 1 year follow-up in a split-mouth randomized controlled clinical trial. These findings are similar to the CBL observed in the present study (0.85±0.06 mm in SLA and 0.73±0.05 mm in SLActive).

Anodized implants had a significantly higher CBL (1.92 mm) than turned (1.46 mm) and hybrid implants (1.02 mm) according to a study comparing anodized with turned and hybrid implants. Also, six anodized implants were failed after four to five years.[43] A recent animal study examined the impact of microgeometry of the implant on osseointegration and crestal bone formation. Three implant groups were compared using histomorphometric analysis: (1) commercially available anodized implant; (2) customized replica of implant "1" with hydrophilic sandblasted acid-etched surface; and (3) commercially available implant with surface identical to implant "2" but different implant geometry. In this study, a standardized dehiscence model was created in pigs and observed up to 2 to 8 weeks of healing. The study's finding showed that, in comparison to group 1 implants, crestal bone level was high around groups 3 and 2 implants and was found to be significantly higher after 8 weeks.[44] Glauser R et al., reported crestal bone loss of 1.54±0.99 mm around anodized surface implants,[29] which is similar to the range reported in the present study (1.96±0.92 mm). However, when the standard deviation values are high, these mean bone loss values might be obscuring the clinical relevance. The results of this research indicate that anodized implants behaved more inconsistently in terms of CBL, with the anodized implants' standard deviation measuring 0.92 mm, compared to 0.06 mm and 0.05 mm for SLA and SLActive implants, respectively.

All the implants considered in the present study have moderately rough surfaces. Higher CBL in moderately rough surface implants has been reported in meta-analysis,[45] systematic review,[46] randomized studies,[47,48] and in various retrospective and prospective studies.[49–51] A frequency distribution analysis would be beneficial instead of focusing only on comparing mean values, which conceals the severity of the problem and makes it difficult to identify those who are most severely affected. In light of this, we analyzed the frequency distribution of CBL thresholds across various time intervals.

When comparing anodized implants to sandblasted acid-etched implants, the frequency of implants with bone loss ≥ 2 mm at a one-year follow-

up was nearly five times higher (10.6% vs. 2.2%). Similarly, Gallego L et al., reported the prevalence of CBL ≥ 2 mm at 2 years follow-up was 8.98% in the anodised implants.[52] According to the current clinical study's findings, anodized implants are likely to have a higher failure rate (5.04%). These findings are consistent with those of Ferrantino L et al., who reported 8.1% failure rate for anodized surface implants.[53]

There are a few limitations associated with this study, which include: a) its design, which makes it impossible to establish cause-and-effect relationship; b) the radiological analysis method, which might pose a barrier to the validity of the results obtained because periapical radiographs are known to underestimate actual bone loss; and c) omission of an analysis of the crown-to-implant ratio. Nonetheless, the study's findings are reliable because the patient population was fairly homogeneous consisting of periodontally healthy individuals without systemic diseases and patients with controlled systemic diseases. Also, all implants utilized were commercially available with textured collar design, internal connection and the connection was platform switched, they were placed using standardized surgical and prosthetical protocols and all procedures were performed in the same institution. In addition, throughout all of the time periods, CBL measurements were obtained from a single reference point. Furthermore, the outcomes are consistent with previous research assessing variations in crestal bone loss based on implant microgeometry.

CONCLUSION

This registry data-based cohort study reports a greater CBL around implants with anodized implants relative to sandblasted acid-etched implants with 1 year follow-up period. Therefore, having detected that CBL, it is crucial to set up extended duration follow-ups with this patient group to determine whether the early indication of increased CBL in anodized surface implants progresses, potentially culminating in implant failures.

DECLARATIONS

Conflicts of interest and financial disclosures

The authors declare no conflict of interest and there was no external source of funding

Ethical Approval

Ethics approval and consent to participate: The ethical clearance was obtained from the Institutional Ethical Review Committee (IHEC/SDC/FACULTY/PERIO/1913).

Informed Consent

All participants signed an informed consent form.

Author contributions

Conceptualization AR, MDB, GC; methodology, AR; LF; GM; and VR; software, AR; and VR; formal analysis, AR; investigation, AR; data curation, AR; writing—original draft preparation, GM, VR; MMM; writing—review and editing, GC; LF and GM; supervision, GC; LF and GM. All authors have read and agreed to the published version of the manuscript.

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