Incidence of Peri-Implantitis and Marginal Bone Loss on Anodized and Sandblasted, Large-grit, Acid-etched Surface Implants: A retrospective analysis

Shunsuke Kamimura, DDS; Joseph Kan, DDS, MS; Charles Goodacre, DDS, MSD; Sasiya Bhumpattarachai, DDS, MSD; Jaime Lozada, DDS

Advanced Dental Education in Implant Dentistry, Loma Linda University School of Dentistry, Loma Linda, California, USA

Introduction

Long-term implant success depends on osseointegration, which is influenced by surface characteristics such as roughness, topography, and wettability[1]. Implant surface modifications have evolved from early machined (turned) surfaces to conventional sandblasted large-grit acid-etched surfaces, followed by chemically modified sandblasted large-grit acid-etched surfaces with enhanced wettability, as well as anodized surfaces, with more recent developments introducing multi-zone anodized surfaces designed to optimize both bone integration apically and peri-implant tissue stability coronally. However, clinical data on these multi-zone anodized surfaces remain limited due to their relatively recent introduction. Currently, these four surface modifications represent the most widely used titanium implant surfaces in clinical practice. While numerous studies have evaluated individual titanium surface modifications[2,3], few have directly compared multiple surface types, limiting clinicians' ability to make evidence-based surface selection decisions.

Purpose

The purpose of this retrospective study was to compare implant survival, marginal bone level changes, and peri-implantitis incidence among four titanium surface modifications: sandblasted large-grit acid-etched, modified sandblasted large-grit acid-etched, anodized, and multi-zone anodized surfaces. Furthermore, the risk factors associated with these clinical parameters were also analyzed.

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Materials and Methods

Study Design

- Retrospective study approved by the IRB of Loma Linda University (IRB #5250131)
- Patient records reviewed from **2008–2025** at the Center for Implant Dentistry

Patient / Implant Selection

Inclusion criteria:

- Implant-supported single crowns or fixed partial prostheses
- One of four implant surfaces:
  - Sandblasted, large-grit, acid-etched
  - Modified sandblasted, large-grit, acid-etched
  - Anodized
  - Multi-zone anodized
- ≥ 1-year follow-up after definitive prosthetic loading
- Availability of periapical radiographs at T0 (implant placement), T1 (prosthesis delivery), and T2 (latest follow-up) (Fig.1)
- Clinical and soft-tissue assessments recorded at T2, including PPD, BOP, mPI (six sites per implant), facial keratinized tissue width (KTW), and mucosal thickness (MT)

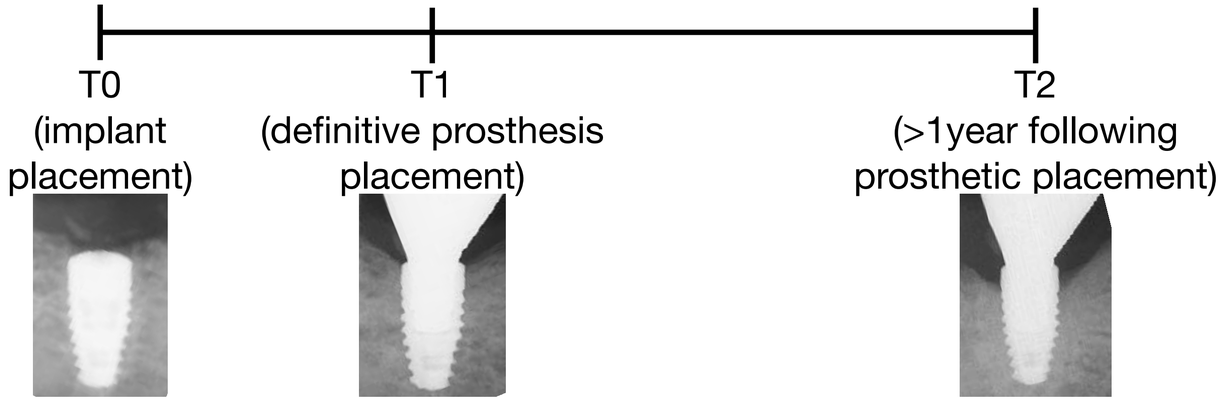


Fig. 1: Timeline of implant placement, prosthetic loading, and follow-up evaluation (T0–T2)

Sample Size:

A power analysis (effect size = 0.45, α = 0.05, power = 0.80) indicated that approximately 79 implants per group were required.

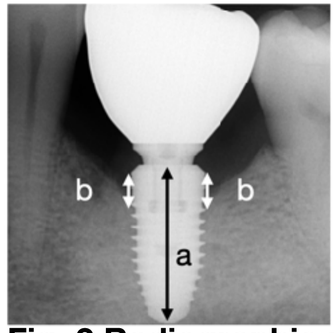
Data Collection

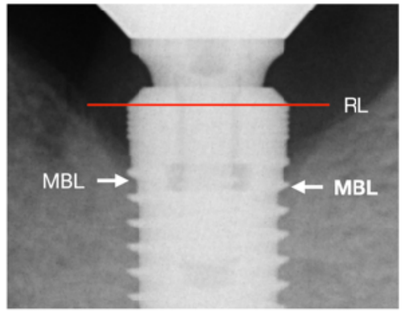
- Patient factors: age, sex, smoking status, diabetes, history of periodontitis
- Implant/prosthetic factors: implant size, location, placement timing, loading timing, prosthesis type
- Operator experience: **>5 vs <5 years**

Outcome Measures

- **Implant survival:** implant present and functional at T2

- **Marginal bone level change (MBLC):**
  - Pre-prosthetic (T0–T1) and overall (T0–T2)
  - Measured on periapical radiographs using ImageJ (Fig.2)
  - Reference: implant platform
  - Intra-examiner reliability: **ICC = 0.982**





$$X = b \times c / a$$

Fig. 2 Radiographic measurement of marginal bone level change (MBLC): a = implant length in radiograph, **b** = distance between the Reference Line (RL) and first bone contact in radiograph (MBL)**, c** = actual implant length**, X** = actual distance from RL to first bone contact

- **Peri-implantitis:**
  - BOP/suppuration
  - PPD ≥ 6 mm
  - Bone loss ≥ 3 mm apical to the implant platform [4]

Statistical Analysis

One-way ANOVA was used to compare MBLC among surface modifications, t-tests to evaluate MBLC by risk factors, and chi-square tests to assess differences in implant survival and peri-implantitis prevalence (α = 0.05).

Result

Study Population

- **266 patients / 800 implants** included
- **Mean age:** 62.2 years (18–86)
- **Mean follow-up:** 61.3 months (12–214); anodized 93.8, multi-zone anodized 20.3, sandblasted large-grit acid-etched 58.2, modified sandblasted large-grit acid-etched 76.7 months

Implant Survival

- Overall survival rate: 92.7% (742/800 implants; mean follow-up: 61.3 months)
- No significant difference among surface modifications (**p = 0.581**) (Fig.3)
- Higher survival associated with: Experienced surgeons (>5 years) (p = 0.038)

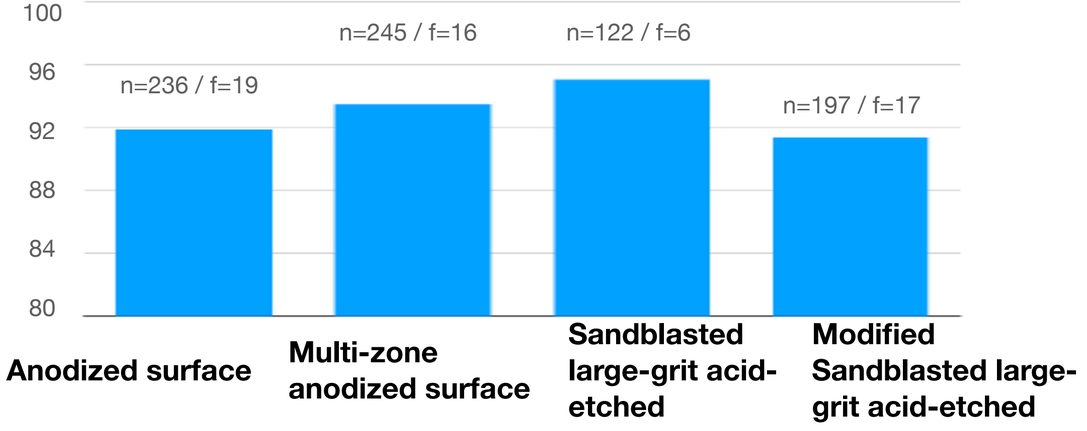


Fig.3 Implant survival rate (%) by surface modification

Marginal Bone Level Change (MBLC)

- Overall MBLC (T0–T2)**: –0.97 ± 1.00 mm**
  (n = 742; mean follow-up: 61.3 months)
- Pre-prosthetic MBLC (T0–T1): **–0.73 ± 0.82 mm**
  (n = 742; mean follow-up: 11.9 months)
- No significant difference among the four surface modifications
  (Overall MBLC: **p = 0.069**; Pre-prosthetic MBLC: **p = 0.101**) (Fig.4, Fig.5)

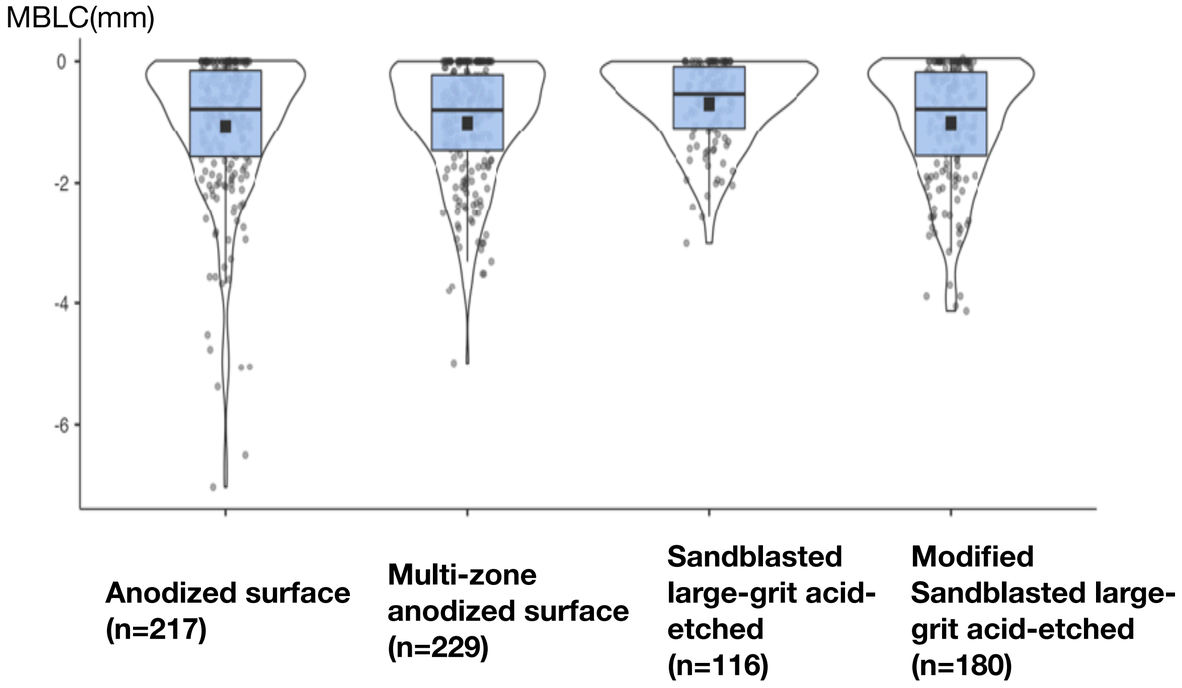


Fig. 4 Violin-box plot of overall marginal bone level change (MBLC, T0–T2) by surface modification. Boxes represent interquartile ranges with medians; squares indicate means; dots represent individual implants.

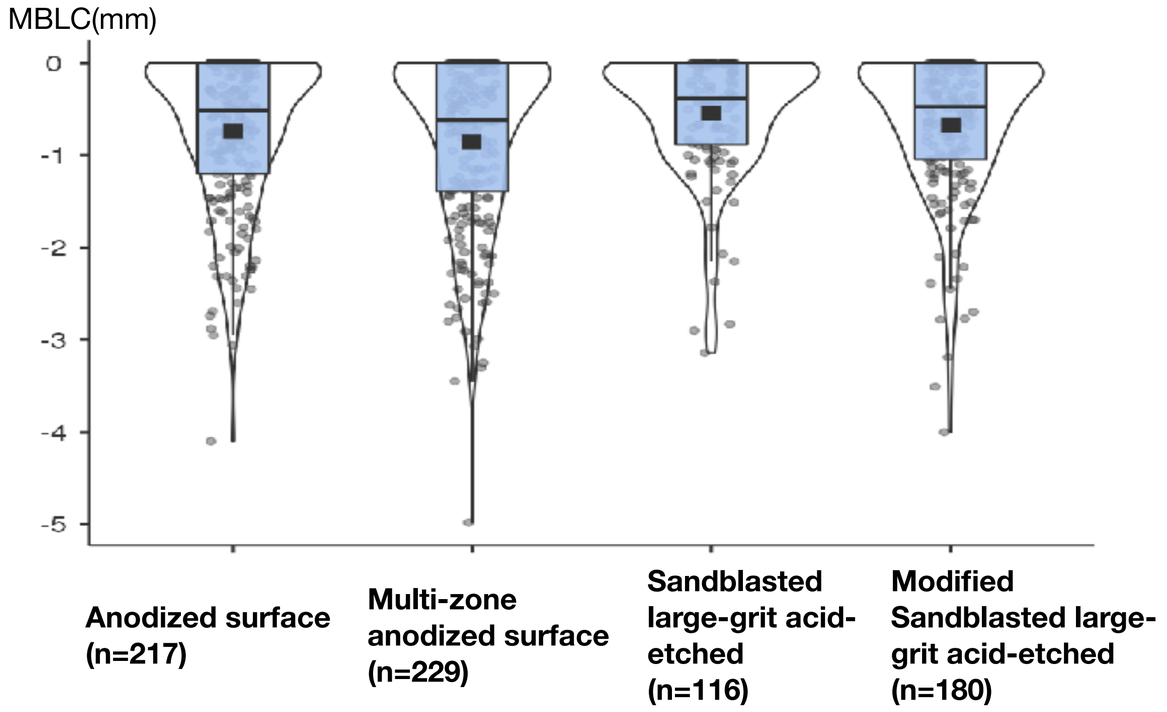


Fig. 5 Violin-box plot of pre-prosthetic marginal bone level change (MBLC, T0–T1) by surface modification.

Factors Associated with Greater Bone Loss (*all* $p < 0.05$):

- Thin soft tissue phenotype
- Keratinized tissue width < 2 mm
- Posterior implant location
- History of periodontitis
- Smoker

Peri-implantitis

- Overall peri-implantitis prevalence: **5.5%** (41/742 implants; mean follow-up: 61.3 months)
- No significant difference among the four surface modifications (**p = 0.089**) (Fig. 6)

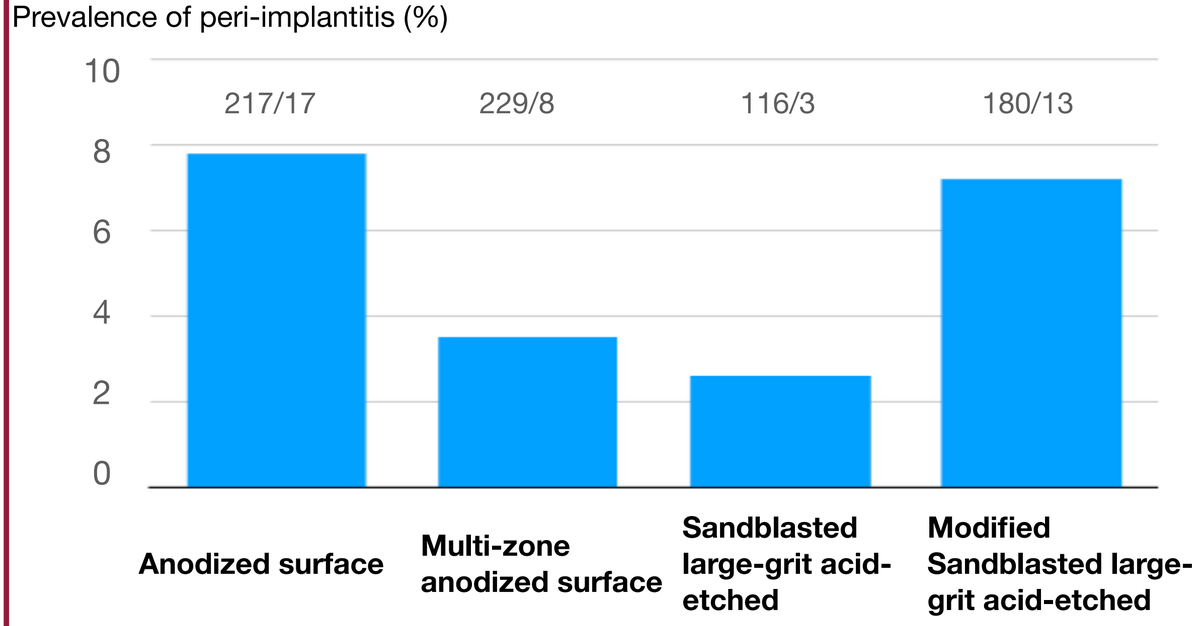


Fig.6 Prevalence of peri-implantitis (%) by surface modification

Factors Associated with Higher Peri-implantitis Prevalence (all p < 0.05)

- Thin soft tissue phenotype
- Keratinized tissue width < 2 mm
- Posterior implant location
- Implant-supported fixed dental prosthesis

Discussion

In this retrospective study with a mean follow-up of 61.3 months, implant survival, marginal bone level change (MBLC), and peri-implantitis prevalence were comparable among four commonly used titanium surface modifications.

No statistically significant differences were observed among surface types; however, the multi-zone anodized surface represents a more recently introduced implant design. Therefore, longer-term follow-up studies are needed to further clarify its long-term clinical performance.

MBLC and peri-implantitis prevalence were significantly associated with smoking, soft tissue conditions, implant location, and prosthetic factors, consistent with previous reports [5-8].

In the present study, most marginal bone level change occurred before final prosthesis delivery. (Fig.7) Previous studies have shown that early bone remodeling primarily takes place shortly after abutment connection and stabilizes within approximately 8 weeks, regardless of loading protocol[9,10]. Our findings are consistent with this pattern, with minimal bone level changes observed after prosthesis delivery.

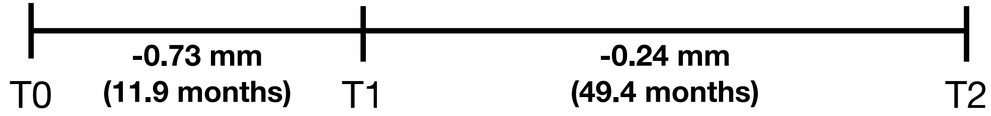


Fig. 7. Temporal pattern of marginal bone level change, showing predominant bone loss before prosthesis delivery (T0–T1; mean 11.9 months) and minimal change thereafter (T1–T2; mean 49.4 month).

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