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Comparison Of Crestal Bone Loss Around Implants With Different Crown Materials

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ABSTRACT

Background: Crestal bone stability is a key indicator of long-term implant success. Different crown materials may influence biomechanical load transfer and thereby affect peri-implant bone remodeling. This study compared crestal bone loss (CBL) around implants restored with porcelain-fused-to-metal (PFM), monolithic zirconia, and resin-modified ceramic crowns.

Materials and Methods: A prospective clinical study was conducted on 60 bone-level implants placed in 54 patients. Following standardized healing and prosthetic protocols, implants were randomly assigned to one of three crown material groups (n = 20 each). Crestal bone levels were measured radiographically at crown placement (baseline), 6 months, and 12 months using a standardized paralleling technique and digital analysis. Clinical parameters, including plaque index, probing depth, and bleeding on probing, were recorded.

Results: All implants survived over the 12-month follow-up. Mean 12-month CBL was 0.68 ± 0.18 mm (PFM), 0.59 ± 0.15 mm (zirconia), and 0.64 ± 0.17 mm (resin-modified ceramic), with no statistically significant differences among groups ($p > 0.05$). Soft-tissue parameters remained stable and comparable across groups.

Conclusion: Within the study limits, crown material did not significantly influence early crestal bone remodeling. All three restorative materials demonstrated minimal and clinically acceptable bone loss after 1 year of loading.

Keywords: *Dental implants; Crestal bone loss; Crown materials; Zirconia; Porcelain-fused-to-metal; Resin-modified ceramics; Marginal bone level; Prosthetic rehabilitation.*

1. INTRODUCTION

Dental implants have become a predictable option for the rehabilitation of partially and completely edentulous patients, with long-term survival rates exceeding 90% in many cohorts [1,2]. Crestal (marginal) bone stability around the implant neck is a key biologic parameter for defining implant success, as originally proposed by Albrektsson et al., who suggested that vertical bone loss should not exceed 1.5 mm during the first year of function and 0.2 mm annually thereafter [1]. Subsequent reviews have reinforced marginal bone loss (MBL) as a critical success criterion in addition to implant immobility, absence of pain, infection, and radiolucency [2].

Despite advances in implant macro-design, surface topography, and surgical protocols, some degree of early crestal bone remodeling is expected after loading [3,4]. This initial remodeling is multifactorial, related to surgical trauma, biologic width establishment, implant–abutment microgap, and biomechanical loading conditions [3]. Clinical studies have reported mean MBL values typically within the "acceptable" threshold defined by classic criteria, but with wide interindividual variation [3,4]. For example, Uppala et al. reported mean crestal bone loss within 1-year limits considered compatible with success, yet highlighted the influence of local grafting conditions on the magnitude of bone changes [3].

The vertical position of the implant shoulder and the configuration of the implant–abutment complex can further modulate the pattern of marginal bone remodeling [4]. A prospective study by Sargolzaie et al. demonstrated comparable MBL around crestal and subcrestal bone-level implants, but emphasized that even small differences in the implant–bone interface may influence peri-implant hard tissue stability [4]. These observations support the concept that peri-implant bone response results from the interplay between surgical, implant-related, prosthetic, and patient-related factors [4].

Among prosthetic variables, restoration type and crown material are increasingly recognized as potential determinants of peri-implant bone behavior [5–8]. Different materials exhibit distinct elastic moduli, fracture resistance, surface roughness, and wear characteristics, which in turn may influence occlusal load distribution to the implant and surrounding bone [5,8,9]. In addition, the choice of material can affect crown contour, emergence profile, and cement space, thereby altering stress concentration at the crestal region and the cleansability of the restoration [8,9]. Recent conceptual reviews have highlighted prosthetic factors such as crown–implant ratio, abutment design, and emergence profile as contributors to MBL, underscoring the need for evidence-based material selection [9,10].

Several clinical studies have specifically evaluated the influence of crown materials on peri-implant bone levels. Shen et al. compared implant-supported metal-ceramic and monolithic zirconia single crowns in the posterior region and found that marginal bone changes over 1–5 years of follow-up were comparable and within clinically acceptable limits [6]. Similarly, Aldebes et al. investigated zirconia implants restored with porcelain-fused-to-metal (PFM) and indirect composite resin crowns and reported no significant difference in marginal bone resorption between materials after 18 months [5]. Agustín-Panadero et al. evaluated metal-ceramic versus resin-modified ceramic crowns over 5 years and observed acceptable peri-implant bone loss in both groups, with differences mainly in mechanical performance rather than bone response [7].

More recently, Sabău et al. performed a retrospective analysis of implant-supported fixed prostheses and showed that although overall MBL remained limited, prosthetic material and restoration type (single crowns versus partial fixed dental prostheses) had a measurable impact on the amount of bone resorption [8]. In a complementary line of evidence, Abdul Rahim et al. demonstrated that unfavorable crown-implant ratios and increased implant inclination were associated with greater marginal bone loss around posterior single crowns [9]. A comprehensive 2025 review by Chu highlighted prosthetic determinants—including material properties, occlusal scheme, and restoration design—as modifiable risk factors that may help clinicians optimize peri-implant bone stability [10].

Although these studies suggest that different crown materials (PFM, monolithic zirconia, and resin-based ceramics) can achieve acceptable marginal bone outcomes, the available data are heterogeneous with respect to implant systems, loading protocols, follow-up duration, and radiographic assessment methods [5–8]. Furthermore, there is limited prospective evidence directly comparing crestal bone loss around implants restored with different crown materials under standardized surgical and prosthetic conditions.

Therefore, the present clinical study aims to compare crestal bone loss around bone-level implants restored with three different crown materials—porcelain-fused-to-metal, monolithic zirconia, and resin-modified ceramic—over a 12-month post-loading period using standardized periapical radiographs. The null hypothesis is that there is no difference in peri-implant crestal bone loss among the three crown material groups.

2. MATERIALS AND METHODS

This was designed as a **prospective, randomized, parallel-group clinical study** among 60 subjects comparing peri-implant crestal bone loss around implants restored with three different crown materials:

Group I: Porcelain-fused-to-metal (PFM) crowns

Group II: Monolithic zirconia crowns

Group III: Resin-modified ceramic crowns

The study was conducted in the Department of Prosthodontics and Implant Dentistry of a tertiary care dental teaching institution. The protocol was approved by the Institutional Ethics Committee and the study followed the principles of the Declaration of Helsinki. All participants received verbal and written information, and written informed consent was obtained prior to enrollment.

Sixty eligible participants were adults aged 20–65 years requiring single posterior implant-supported crowns, with healed ridges and adequate bone volume. Exclusion criteria included uncontrolled systemic disease, antiresorptive therapy, heavy smoking, pregnancy, parafunctional habits, and sites needing major grafting. All implants were bone-level, internal-connection titanium implants placed under local anesthesia using standardized surgical protocols. Healing periods ranged from 8–12 weeks in the mandible and 12–16 weeks in the maxilla.

After confirming osseointegration, implants were randomly allocated to crown material groups using computer-generated sequences with concealed envelopes. Prosthetic procedures included standardized impressions, prefabricated titanium abutments, and crown fabrication via CAD/CAM or conventional layering depending on material. Cementation was performed with controlled occlusion and meticulous cement removal.

Crestal bone levels were assessed radiographically at baseline, 6 months, and 12 months using a standardized long-cone paralleling technique and calibrated digital measurements. Two blinded examiners performed assessments with reliability testing. Clinical parameters—plaque index, bleeding on probing, probing depth, and signs of peri-implant disease—were recorded at each visit. The primary outcome was mean 12-month bone loss, with secondary comparisons across time points and influencing covariates. Data analysis employed ANOVA, Kruskal–Wallis, repeated-measures tests, and chi-square where appropriate, with significance set at $p < 0.05$.

3. RESULTS

A total of **60 implants** in **54 patients** were evaluated. All implants survived during the 12-month follow-up, yielding a **100% survival rate**. No peri-implantitis was detected; minor mucositis was noted in 3 cases and resolved after oral hygiene reinforcement.

Baseline demographic and implant-related characteristics were comparable across all three groups (**p > 0.05** for all variables). Mean age ranged from **44.6 to 46.1 years**, and the distribution of implant sites and jaw location showed no significant differences between groups. Implant dimensions were also similar, indicating that all groups were well matched at baseline and suitable for comparative analysis (Table 1).

Table 1. Baseline Characteristics of Study Participants and Implant Sites

Variable	PFM (n = 20)	Monolithic Zirconia (n = 20)	Resin-Modified Ceramic (n = 20)	p-value
Age (years), mean ± SD	44.6 ± 8.1	46.1 ± 7.5	45.8 ± 9.2	0.88
Sex (M/F)	11/9	10/10	12/8	0.83
Jaw location (Maxilla/Mandible)	9/11	10/10	8/12	0.76
Implant site (Premolar/Molar)	7/13	6/14	8/12	0.79
Implant diameter (mm), mean ± SD	4.1 ± 0.2	4.0 ± 0.3	4.1 ± 0.3	0.62
Implant length (mm), mean ± SD	10.3 ± 0.5	10.1 ± 0.6	10.2 ± 0.6	0.57

Crestal bone loss increased gradually from 6 to 12 months in all groups. At 12 months, the **PFM group showed the highest mean bone loss (0.68 ± 0.18 mm)**, followed by the **resin-modified ceramic group (0.64 ± 0.17 mm)** and **monolithic zirconia group (0.59 ± 0.15 mm)**.

Although the zirconia crowns demonstrated slightly lower bone loss numerically, the differences among groups were **not statistically significant** at either 6 or 12 months (**p > 0.05**, Table 2).

Table 2. Mean Crestal Bone Loss (mm) at Different Time Points

Time Point	PFM (n = 20) Mean ± SD	Monolithic Zirconia (n = 20) Mean ± SD	Resin-Modified Ceramic (n = 20) Mean ± SD	p-value (ANOVA)
T1: 6 months	0.41 ± 0.12	0.36 ± 0.10	0.39 ± 0.11	0.27
T2: 12 months	0.68 ± 0.18	0.59 ± 0.15	0.64 ± 0.17	0.23

Post-hoc pairwise analysis (Tukey HSD) showed **no significant differences** between any pair of crown material groups at the 12-month evaluation. The largest difference observed was between **PFM and zirconia crowns (mean diff: 0.09 mm)**, but this did not reach statistical significance (**p = 0.19**). All confidence intervals crossed zero, indicating an absence of clinically meaningful differences in crestal bone levels attributable to crown material type (Table 3).

Table 3. Intergroup Comparison of 12-Month Crestal Bone Loss (Post-Hoc Test)

Comparison	Mean Difference (mm)	95% CI	p-value (Tukey)
PFM vs. Zirconia	0.09	−0.03 to 0.22	0.19
PFM vs. Resin-Modified Ceramic	0.04	−0.08 to 0.17	0.71
Zirconia vs. Resin-Modified Ceramic	−0.05	−0.17 to 0.07	0.55

Clinical peri-implant soft-tissue parameters showed no significant group differences at the 12-month follow-up. Mean probing depths remained within the physiologic range (**2.7–2.8 mm**), and bleeding on probing was minimal (**4–7%** across groups). Only two implants exhibited minor buccal soft-tissue recession. These findings indicate overall excellent soft-tissue health and rule out inflammation as a confounding variable affecting crestal bone levels (Table 4).

Table 4. Clinical Parameters at 12 Months

Parameter	PFM (n = 20)	Monolithic Zirconia (n = 20)	Resin-Modified Ceramic (n = 20)	p-value
Plaque Index (0–3) Mean ± SD	0.72 ± 0.30	0.69 ± 0.28	0.74 ± 0.32	0.88
Bleeding on Probing (%)	6%	4%	7%	0.79
Probing Depth (mm) Mean ± SD	2.8 ± 0.4	2.7 ± 0.3	2.8 ± 0.3	0.63
Sites with recession	1/20	0/20	1/20	0.62

4. DISCUSSION

The present study evaluated crestal bone loss (CBL) around implants restored with three commonly used crown materials—porcelain-fused-to-metal (PFM), monolithic zirconia, and resin-modified ceramic—and found **no statistically significant differences** among the groups at either 6 or 12 months. Although zirconia crowns exhibited numerically lower CBL than PFM and resin-modified ceramics, these variations did not reach significance. Overall, the results indicated that **crown material did not meaningfully influence early peri-implant crestal bone changes**, which is consistent with previous clinical observations.

Crestal bone remodeling is a multifactorial biological process influenced by surgical trauma, implant design, microgap positioning, biologic width re-establishment, and mechanical loading [1,2]. Albrektsson et al. originally proposed that early bone loss of up to 1.5 mm in the first year is considered acceptable for a successful implant [1]. Subsequent studies have consistently reported marginal bone loss values within or below this threshold, with modern implant surfaces often showing even more favorable outcomes [3,4]. In the present study, mean 12-month CBL across all groups ranged between **0.59 mm and 0.68 mm**, aligning well with these contemporary findings.

A key focus of this investigation was the effect of **restorative crown material** on crestal bone stability. Several authors have proposed that materials with differing mechanical properties—such as elastic modulus, fracture resistance, and damping capacity—may influence biomechanical stress transmitted to the peri-implant bone [5,6]. Monolithic zirconia, having a higher modulus of elasticity compared to PFM or hybrid ceramics, theoretically transfers greater loads to the abutment–implant complex, potentially increasing crestal stress concentrations. However, this theoretical risk has not been consistently demonstrated clinically.

The results of the present study corroborate previous clinical observations. Shen et al. found no significant difference in CBL between implants restored with metal-ceramic and monolithic zirconia crowns over a 1–5-year follow-up period [7]. Similarly, Aldebes et al. reported that marginal bone resorption around zirconia implants restored with PFM versus indirect composite resin crowns did not differ significantly after 18 months [5]. Agustín-Panadero and colleagues also showed that both metal-ceramic and resin-modified ceramic crowns produced acceptable and statistically comparable CBL values over a 5-year period [7]. Consistent with these studies, the current findings suggest that **prosthetic material alone is unlikely to be a primary determinant of marginal bone remodeling** in the early loading period.

It is important to interpret these findings within the broader context of peri-implant biomechanics. Stress distribution around the implant depends largely on occlusion, crown design, crown-implant ratio, implant inclination, and abutment geometry rather than crown material alone [6,10]. Abdul Rahim et al. demonstrated that unfavorable crown-implant ratios and steep implant angulation significantly increased marginal bone loss, regardless of the restorative material used [9]. In the present study, all crowns were standardized in occlusal morphology, cementation protocol, and abutment selection, minimizing potential biomechanical confounders. This methodological uniformity likely explains the absence of significant intergroup variation.

Soft-tissue health parameters were favorable across all groups, with minimal bleeding on probing, shallow probing depths, and absence of suppuration. Inflammatory soft-tissue conditions are known risk factors for progressive bone loss [11]. Their absence supports the conclusion that the observed bone changes represent normal biologic remodeling rather than inflammatory bone loss. Furthermore, controlled oral hygiene and maintenance visits likely contributed to the stable peri-implant tissues observed.

One notable finding was the numerical trend of lower CBL in the zirconia group. Although not statistically significant, similar trends have been observed elsewhere. Zirconia crowns may present favorable occlusal stability due to improved wear resistance and minimal chipping potential, which may help maintain consistent occlusal contacts over time [12-15]. However, the lack of clinical significance in the present study suggests that longer-term outcomes or larger sample sizes might be required to determine whether this trend holds meaningful implications.

Strengths and Limitations

A major strength of this study was the **prospective design**, **strict standardization of surgical and prosthetic protocols**, and the use of radiographic reproducibility techniques, which enhanced measurement accuracy. Random allocation of implants to crown material groups minimized selection bias.

However, several limitations must be acknowledged:

Short follow-up period (12 months): While early bone remodeling is most significant in the first year, longer-term follow-up is necessary to determine whether crown materials influence mid- or long-term bone levels.

Single implant system: Findings may not be generalizable to all implant designs or connections.

Sample size limitations: Although powered for detecting moderate differences, smaller subtle differences may require larger cohorts [14-16].

Future research should include **longitudinal follow-up beyond five years**, evaluation of **different implant–abutment interfaces**, and consideration of **occlusal loading patterns** using digital force-mapping technologies.

5. CONCLUSION

This study demonstrates that crestal bone levels around implants remain stable during the first year of loading, regardless of whether the restorations are porcelain-fused-to-metal, monolithic zirconia, or resin-modified ceramic. Although slight numerical differences were noted, none were statistically significant, indicating that crown material alone does not meaningfully influence early peri-implant bone remodeling when surgical and prosthetic protocols are standardized. Soft-tissue parameters also remained healthy across all groups, supporting the overall biological stability of the implants. Within the study's limitations, all three restorative materials provided comparable outcomes. Longer-term research is recommended to confirm these results over extended follow-up periods.

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