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Research Article

Evaluation of Marginal Bone Loss and Peri-Implant Tissue Conditions in Relation to Dental Implant Surface Design: A 12-Month Retrospective Study

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Abstract

Aim: This retrospective study aims to evaluate marginal bone loss and peri-implant tissue conditions in relation to implant surface design.
Material and Method: In our study, data from 50 dental implants placed in patients who underwent routine treatment at the Harran University Faculty of Dentistry Application and Research Center were evaluated. Data obtained for bone loss, gingival and plaque indices were evaluated. Two types of implants were compared based on these data. Type 1 implants feature an HSA (Hybrid Sand Blast and Acid Etched) surface designed to promote osseointegration, whereas Type 2 implants are composed of high-quality titanium alloy and incorporate AB/AE (Acid Etch with Aluminum Oxide Blasting) surface modifications to support osseointegration. The normality of data distribution was evaluated using the Shapiro-Wilk test. Comparisons between groups were made using the Mann-Whitney U test, as it is appropriate for data that does not show normal distribution.
Results: Type 2 implants showed significantly higher gingival index values ($p<0.05$), while no significant differences were observed in plaque index or bone loss between groups.
Conclusion: Implant neck and surface design may influence soft tissue response, particularly gingival inflammation, highlighting the importance of implant morphology in peri-implant tissue health and long-term outcomes.

Keywords: Dental implant, bone loss, gingival index, plaque index

INTRODUCTION

Dental implants are widely used to replace missing teeth. Since their introduction in 1981, there has been a significant increase in the use of titanium implants (1,2). Tooth loss occurs in individuals for different reasons. Among the various causes of tooth loss, periodontal disease is the most prevalent. This is followed by trauma and developmental defects. The success rate of modern titanium implants used today has improved considerably and also complication and failure rate are quite low (1).

Implants are primarily made of commercially pure titanium (cpTi), a material that is in direct contact with the bone. Titanium is preferred due to its favorable mechanical properties, low failure rates, and good biocompatibility (3). Titanium grades range from 1 to 4, categorized based on purity and oxygen content. Grade 4 titanium, commonly used in dentistry, contains 0.4% oxygen, which provides optimal mechanical strength (4,5). The success of implant treatment depends on proper surgical and prosthetic protocols. However, peri-implantitis, a pathological condition affecting the tissues around implants, has become increasingly prevalent in recent years (6).

It has also been reported that individuals with periodontitis history are at a increased risk of occuring periimplantitis than those whitouth periodontal disease history (7,8). Peri-implant diseases are classified as peri-implant mucositis and peri-implantitis. Although both conditions involve inflammation, peri-implantitis is distinguished by the presence of bone loss (9). Several treatment approaches are available for peri-implantitis, including non-surgical and surgical methods. However, once the disease develops, the

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healing process is long and the possibility of recurrence remains even after successful treatment (10).

It has been said that the risk of peri-implantitis can be reduced with regular care and proper oral hygiene following implant placement (11). Although it is problematic for patients to comply with postoperative follow-up appointments, early detection of peri-implant diseases is very important to prevent the progression of the disease and manage it at the peri-implant mucositis stage (12). It has been reported that typical symptoms of peri-implant diseases include bleeding gums and implant mobility (13).

Current implant systems have different surfaces, most of which have shown high success in long-term clinical studies. However, these surfaces have generally been developed based on nonstandard in vivo and in vitro tests, and the role of surface chemistry and structure in the early stages of osseointegration is not fully understood. In the future, it has been said that the development of implant surface designs with controlled and standard studies, and approaches such as drug delivery that support osseointegration, can increase early loading and long-term success (14).

This study aims to evaluate post-treatment bone loss and peri-implant tissue conditions by comparing two implant types with different surface and neck characteristics. By assessing plaque and gingival indices along with bone loss, it seeks to determine the impact of implant design on tissue health and the importance of early intervention for long-term success.

MATERIAL AND METHOD

This retrospective study was conducted using routine clinical data collected from patients treated at the Harran University Oral and Dental Health Application and Research Center. Ethical approval was obtained from the Harran University Clinical Research Ethics Committee, and permission was granted by this committee (Reference: HRÜ/24.08.25, Date: 10.06.2024). The study included 50 dental implants that were evaluated periodontally and radiographically to assess post-treatment bone loss and peri-implant tissue conditions. All implant surgeries were performed by a single experienced clinician under local anesthesia. The procedures were carried out following the manufacturer's protocol and surgical recommendations for each implant system. Standard surgical techniques were applied, including sequential drilling according to the specified implant diameter and length. Post-operative care instructions were standardized for all patients to minimize variability in healing outcomes. Two different implant types were analyzed, categorized as Type 1 and Type 2, based on their surface treatment and material composition. Type 1 implants feature HSA (Hybrid Sand Blast & Acid Etched) surface treatment, designed to enhance osseointegration by creating a roughened surface that promotes better bone-implant contact. Type 2 implants are manufactured from high-quality titanium alloy and utilize AB/AE (Acid Etch + Aluminum Oxide Blasting) surface roughening techniques, which facilitate bone condensation and osseointegration through controlled surface modifications.The implants were evaluated after a 12-month follow-up period using computerized patient records, and all data were systematically documented.

Clinical Measurements

Bone loss and peri-implant tissue conditions were assessed using probing. Measurements were taken from four regions of each implant: buccal, lingual, mesial, distal. The values were recorded, and comparisons were made between the two implant types. In addition, plaque index and gingival index values were recorded to evaluate soft tissue health around the implants.

Plaque Index Assessment

The plaque index was recorded to assess the presence and extent of plaque accumulation on the implant surfaces. The following scale was used:

- 0 = No plaque present; the probe remains completely clean.
- 1 = No visible plaque, but a thin film of plaque becomes apparent after probing.
- 2 = Visible plaque accumulation on the implant surface or detectable plaque mass using a probe.
- 3 = Heavy plaque or calculus deposits that are clearly visible on the implant surface.

Gingival Index Assessment

The gingival index was evaluated to determine the degree of inflammation in the peri-implant tissues. The classification was as follows:

- 0 = Normal gingiva with no signs of inflammation.
- 1 = Mild inflammation, slight discoloration, and minor edema, with no bleeding after probing.
- 2 = Moderate inflammation with redness, edema, and bleeding upon probing.
- 3 = Severe inflammation characterized by significant redness, edema, ulceration, and spontaneous bleeding (15,16).

Statistical Analysis

The normality of the data distribution was evaluated using the Shapiro-Wilk test. The results indicated that none of the three variables satisfied the assumptions of normality ($p<0.05$). Consequently, non-parametric methods were employed for further analyses. Comparisons between groups were conducted using the Mann-Whitney U test, as it is appropriate for non-normally distributed data. Statistical significance was set at $p<0.05$. Descriptive statistics, including the mean±standard deviation, were calculated and recorded for all variables. All statistical analyses were performed using IBM SPSS Statistics version 20. This approach ensured a robust and reliable evaluation of the dataset while adhering to rigorous statistical standards.

RESULTS

In this study, Type 1 and Type 2 dental implants were evaluated in terms of plaque index, gingival index, and bone loss to compare their effects on peri-implant tissue health.

The plaque index was measured as 0.43±0.05 for Type 1 implants and 0.55±0.07 for Type 2 implants. While the mean value for Type 2 implants was slightly higher, the difference was not statistically significant. This suggests that both implant types exhibit comparable peri-implant conditions within the study period.

The gingival index was recorded as 0.26±0.03 for Type 1 implants and 0.50±0.06 for Type 2 implants. The difference between the two groups was statistically significant ($p<0.005$), indicating that peri-implant soft tissues around Type 2 implants exhibited a higher degree of inflammation compared to Type 1 implants.

For bone loss, the mean values were 1.23±0.04 mm for Type 1 implants and 1.43±0.09 mm for Type 2 implants. Although Type 2 implants showed slightly greater bone resorption, the difference was not statistically significant, indicating that both implant types provided similar levels of bone stability over the 12-month follow-up period (Table 1).

Table 1. Statistical analysis of the study

	Group 1 (mean±std.dev)	Group 2 (mean±std.dev)	P value
Plaque index	.43±.05	.55±.07	.291*
Gingival index	.26±.03	.50±.06	**.008***
Probing depth	1.23±.04	1.43±.09	.113*

*Mann-Whitney U test

DISCUSSION

Dental implants have been widely recognized in the scientific community since their introduction at the Toronto Conference in 1982, where early studies reported implant stability rates of 81% in the maxilla and 91% in the mandible (15). Over time, research has established key criteria for implant success, including the absence of radiolucency, implant mobility, pain, and infection. Long-term clinical studies have further explored factors affecting implant survival, particularly the impact of marginal bone loss on implant longevity.

A retrospective study conducted by Chrcanovic et al. in Sweden analyzed implant outcomes over a 20-year follow-up period. The findings revealed a significant correlation between marginal bone loss and implant failure, with the majority of failures (62%) occurring within the first three years of placement. Additionally, implants exhibiting bone loss greater than 3 mm had a survival rate of 87.8%, indicating that excessive bone loss may compromise implant stability. These findings emphasize the importance of early detection and intervention to minimize marginal bone loss, particularly in the critical early years post-placement. Furthermore, the study highlighted that short-term failure rates were more prominent, reinforcing the need for long-term observational studies to better understand the progression of bone loss and its implications for implant success (16).

Fransson et al. emphasized that the primary objective of implant therapy is to maintain tissue integrity, which is closely linked to the preservation of adequate bone support. Their findings highlight marginal bone loss as a key determinant of implant success, underscoring its clinical significance in long-term stability (17).

Similarly, a study conducted by Schou et al. assessed patients over a 5 to 10-year follow-up period, categorizing them based on their history of periodontitis. The results indicated that while bone loss was more pronounced in patients with both prostheses and implants, the observed difference, although statistically significant, was only 0.5 mm. Notably, this minor variation was deemed clinically insignificant for individuals with a prior history of periodontitis, suggesting that while periodontitis may influence bone remodeling, it does not necessarily translate into a clinically meaningful impact on implant outcomes (18).

Marginal bone loss around both natural teeth and dental implants is influenced by multiple factors, including biological aging, mechanical stress, and systemic conditions. Similar to natural teeth, implants also experience progressive bone remodeling over time, which is often considered a physiological process associated with aging. However, in edentulous areas, bone resorption may occur at a different rate, particularly around implants, due to altered biomechanical loading and changes in bone metabolism. A study by Bryant et al. evaluated patients with long-term edentulism as well as those who received implants shortly after tooth extraction. Their findings indicated that bone loss progressed more rapidly in patients who underwent implant placement following short-term tooth loss, suggesting that the absence of a natural dentition for an extended period may allow for a more gradual adaptation of bone to mechanical forces. Additionally, implants placed in the basal bone demonstrated a lower rate of bone resorption compared to those placed in the alveolar bone, emphasizing the role of implant location in long-term bone stability (19-22).

Our findings are in partial agreement with recent systematic reviews and meta-analyses evaluating the impact of implant surface characteristics on peri-implant tissue health. For instance, Hussein A. et al. (23) reported that machined surface implants showed a trend toward reduced marginal bone loss and significantly lower probing pocket depths, although no significant differences were observed in implant failure rates compared to rough surfaces. Similarly, in our study, the implants with a more aggressive neck design and rougher surface (Type 2) demonstrated significantly higher gingival index values, suggesting an increased inflammatory response. However, no significant differences were found in terms of marginal bone loss or plaque index. These results collectively underscore that while rough surfaces may support osseointegration, their influence on soft tissue health—especially gingival inflammation—should not be underestimated.

Two types of implants were evaluated in our study. As stated in previous studies, neck resorption in implants is a physiological event. Many factors affect the survival life of the implant. Therefore, the specific difference of the implants we used is that their neck structures are different. Implants with an aggressive neck part irritate the tissues surrounding the implant more after resorption and cause more inflammation. In addition, more resorption was observed in aggressive implants, although it was not statistically significant. We think that this is due to the thinner thickness in the neck region. We think that bone nutrition is weakened in aggressive implants.

Today, implant systems have different surface designs and the effect of these surfaces on the osseointegration process is still being investigated. Although long-term clinical studies have shown that different surface modifications provide successful results, the development of these surfaces is usually based on various in vivo and in vitro tests. However, most of these tests are non-standard experiments and include differences in the cell populations and animal models used. This makes it difficult to fully understand the biological interaction of implant surface properties with bone (14). The surface roughening techniques of the implant types compared in our study are different; Type 1 implants have HSA (Hybrid Sandblasting and Acid Etching) surface treatment, while Type 2 implants were processed with AB/AE (Acid Etching + Aluminum Oxide Sandblasting) method. It has been reported in the literature that hydrophilic micro-rough surfaces accelerate osseointegration, and further clinical studies are needed to better understand the effect of implant surface design on early bone attachment and long-term stability. In the future, standardized research to better understand tissue and cell interactions with implant surfaces may contribute significantly to early loading protocols and long-term implant success.

While this study provides valuable insights into the effects of implant design on peri-implant tissue health, several limitations also need to be recognized. Firstly, the sample size was relatively small (n=50 implants), which may limit the generalizability of the findings. A larger cohort with a more diverse patient population could provide a more comprehensive understanding of the long-term effects of implant morphology. Secondly, bone loss was evaluated clinically by probing and no radiographic imaging was used, which may limit the precision in detecting subtle crestal bone changes. Third, the study only included implants that were entirely surrounded by native bone without any grafting procedures, and all participants were systemically healthy individuals. While this homogeneity reduces confounding factors, it may also limit the generalizability of the findings to broader clinical populations. Additionally, demographic data such as patient age, gender, implant placement site, and whether the implants were single or part of a splinted unit were not recorded or analyzed, and thus could not be included in subgroup comparisons. These omissions should be considered in the interpretation of our findings and addressed in future studies.

CONCLUSION

In this study, peri-implant bone loss and soft tissue conditions were evaluated in two different implant designs during a 12-month follow-up period. While no significant difference was found between implant types in terms of bone loss, gingival index was observed to be significantly higher in Type 2 implants, which may be related to increased inflammatory response due to implant neck design. This finding emphasizes the role of implant morphology on peri-implant tissue health and long-term stability. The importance of periodontal care increases especially in implants with more aggressive neck structures. Future studies should evaluate the effects of additional variables such as occlusal forces, bacterial biofilm formation and systemic factors on peri-implant tissue dynamics and implant longevity more comprehensively.

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