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Original Article

Evaluation of soft tissue parameters around titanium and zirconia implants in the maxillary anterior region: A retrospective study

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ABSTRACT

Background: Recent advancements in dental implant materials have highlighted zirconia as a promising alternative to traditional titanium implants. The soft tissue response is crucial for the long-term success and esthetics of dental implants. Therefore, this study aims to compare soft tissue thickness, pocket depth, bleeding on probing (BOP), and gingival color around zirconia and titanium implants. **Materials and Methods:** This retrospective cohort study enrolled 60 patients 1 year post-implant placement, conducted at King Abdulaziz University Faculty of Dentistry in Jeddah, Saudi Arabia, from April to October 2024. Soft tissue parameters (thickness, pocket depth, BOP) around zirconia and titanium implants were measured using a UNC-15 periodontal probe. Data were analyzed using IBM Statistical Package for the Social Sciences version 27. **Results:** Significant differences were found between zirconia and titanium implants in terms of soft tissue thickness ($P = 0.031$), color ($P < 0.001$), and BOP ($P = 0.004$). Zirconia implants were associated with thinner soft tissue (53.8%) compared to titanium implants (73.5% thick tissue). All patients with titanium implants experienced color changes, while 82.1% of zirconia patients reported no change. In addition, all titanium implant patients had BOP, whereas none of the zirconia implant patients did. **Conclusion:** Zirconia implants appear to be reliable replacements for situations wherein titanium is not a feasible choice or where esthetics are a priority. Further research is recommended to continue exploring the long-term outcomes and potential advantages of zirconia implants in diverse patient populations.

Keywords: Clinical practice, Follow-up, Peri-implant soft tissue, Titanium implant, Zirconia implant

Introduction

Dental implantology has transformed the domain of restorative dentistry, providing patients with a reliable method for replacing missing teeth and reestablishing oral function and esthetics.[1,2] The enduring success and longevity of dental implants are fundamentally dependent on the complex interaction between implant materials and the surrounding soft tissues.[3,4]

Titanium and titanium alloys are the most widely used materials for dental implants due to their long-term clinical success, excellent biocompatibility, reliable physical and mechanical properties, and versatility for the manufacturing of different designs of implants and components.[5,6] Because of the development of grayish stains on the soft tissues in thin peri-implant mucosal biotypes, in gingival recession scenarios where the implants' necks are visible, and in the anterior areas of individuals who have a high lip line, titanium implants can be unpleasant from an esthetic standpoint.[7] Clinical studies have also discovered that certain people with titanium hypersensitivity may experience immunologic responses.[8,9]

In recent years, zirconia has emerged as an alternative to traditional titanium implants.[10,11] Zirconia implants offer several advantages over titanium implants, the high esthetic potential of zirconia implants is a significant advantage, particularly in the anterior region,

as they closely resemble natural teeth.[10-13] In addition, zirconia implants exhibit low plaque affinity, potentially reducing the risk of peri-implantitis.[5]

Recent advancements in dental implant technology have focused on improving the interaction between implants and surrounding soft tissues.[5] Understanding these interactions is crucial for enhancing the overall success and longevity of dental implants. However, the influence of implant material on soft tissue parameters remains an area of ongoing investigation and debate.[14] The soft tissue interface surrounding dental implants serves as a critical barrier between the oral environment and the underlying bone, contributing significantly to implant stability, peri-implant health, and esthetic outcomes.[15,16] Various soft tissue parameters, including peri-implant mucosal thickness, inflammation, and color stability, are integral components of implant success and patient satisfaction.[17]

Thus, this study aims to compare soft tissue parameters around zirconia and titanium implants, thereby contributing to a more comprehensive understanding of their roles in implant dentistry. The null hypothesis is that there is no difference in soft tissue parameters (including soft tissue thickness, gingival color change, pocket depth, and bleeding on probing [BOP]) around zirconia and titanium implants.

Materials and Methods

Study design and patients

This retrospective cohort study enrolled 60 patients who had dental implants placed for at least 1 year before data collection. The data collection for this research was conducted at the King Abdulaziz University Faculty of Dentistry (KAU) in Jeddah, Saudi Arabia, from April 2024 to October 2024. Ethical approval was granted by the institutional review board at KAU (Approval No. 161-11-23, dated March 27, 2024). All patients explicitly provided written informed consent to participate in the study. The inclusion criteria for patients were: (a) aged 18 years or older; (b) had a single implant restored with final prosthetic crowns in the maxillary anterior region (specifically, central incisor, lateral incisor, canine, or first pre-molar); (c) had at least 2 mm of keratinized tissue width, including the free gingival margin, pocket, and attached gingiva; (d) had sufficient bone quality and quantity for implant placement without the need for bone augmentation; and (e) had natural neighboring teeth. Patients were excluded if they: (a) were smokers; (b) had systemic or localized illnesses that could interfere with implant therapy; (c) exhibited untreated periodontitis or generalized gingivitis; or (d) displayed significant bruxism or clenching behaviors.

Evaluation of soft tissue parameters surrounding the implant

Soft tissue parameters around zirconia and titanium implants, including soft tissue thickness, pocket depth, and BOP, were measured by two board-certified periodontists using a UNC-15 periodontal probe. The transparency of the probe through the gingival margin was used to determine the gingival biotype (thick or thin). Patients were then categorized into two groups based on gingival biotype (thin or thick) regardless of whether they received a titanium or zirconia dental implant. The collected data were analyzed to compare the soft tissue responses between zirconia and titanium implants, with a focus on identifying any significant differences in the soft tissue parameters measured.

Statistical analysis

This study was analyzed and visualized using IBM Statistical Package for the Social Sciences version 27 (IBM Corp., Armonk, N.Y., USA). Simple descriptive statistics were used to define the characteristics of the study variables through a form of counts and percentages for the categorical and nominal variables while continuous variables were presented by mean and standard deviations. The Chi-square test was applied to determine the relationship between categorical variables, assuming a normal distribution. Finally, a $P < 0.05$ was used as the threshold to reject the null hypothesis.

Results

Socio-demographic characteristics of the studied patients

Sixty patients agreed to participate in this study. The majority of the patients were female (60%). 51.7% of patients were between 40 and 59 years old. In terms of the patients' implants, 61.7% were titanium, and 38.3% were zirconia, with 76.7% being 4.1 mm in size. The most prevalent method of restoration used was screw-retained (83.3%) [Table 1].

Table 1: Socio-demographic characteristics of the studied patients (n=60)

Demographics	Count	%
Gender		
Male	24	40.0
Female	36	60.0
Age		
Young adults 18–39	29	48.3
Middle-aged 40–59	31	51.7
Implant type		
Zirconia	23	38.3
Titanium	37	61.7
Implant size		
3.3 mm	14	23.3
4.1 mm	46	76.7
Implant location		
Upper left	17	28.3
Upper right	43	71.7
Type of restoration		
Cement retained	10	16.7
Screw retained	50	83.3
Titanium type		
Tissue level	24	40.0
Bone level	36	60.0
Total	60	100.0

Patients' soft tissue parameters

The study indicated significant differences between the zirconia and titanium groups in terms of thickness ($P = 0.031$), color ($P < 0.001$), and BOP ($P = 0.004$). In the zirconia group, 53.8% had thin soft tissue implants, while 73.5% of the titanium group had thick soft tissue implants. Another notable distinction between the two groups was the color of the implant over time. All patients with titanium implants noticed a change in color, but 82.1% of zirconia patients reported no change. Furthermore, the findings showed that 18.34% of implants had BOP, all of which were on titanium implants; none of the patients with zirconia implants did [Table 2].

Discussion

This study compared the soft tissue parameters of patients with zirconia and titanium implants, revealing significant differences in terms of thickness, color, and BOP. The majority of the patients in this study had titanium implants, which is expected given their widespread use due to their good biological compatibility, ensuring few negative impacts on the human body.[18] Furthermore, titanium implants are corrosion-resistant and have high mechanical properties such as hardness, tensile strength, yield strength, and fatigue strength.[19] Zirconia implants were found in 38.3% of the participants in the present study. Zirconia implants were developed to overcome some of the drawbacks of titanium implants. Several investigations demonstrated that zirconia exceeded titanium in mechanical characteristics and biocompatibility.[20,21]

This study included comparative evaluations of the zirconia and titanium implants. Significant variations were discovered in terms of implant size, implant location, restoration method, and implant type. The findings demonstrated that the majority of patients with zirconia implants had a narrow implant size (3.1 mm), upper right implant location, had cement restoration, and tissue-level implant. Whereas, patients with titanium implants had a standard implant diameter (4.1 mm), an upper left implant site, screw-type restoration, and a bone level implant.

Some patients preferred zirconia implants over titanium due to their cosmetic advantages. Zirconia implants offer a tooth-like appearance, making them especially preferable in the maxillary anterior area. According to de Moura Costa *et al*., zirconia and titanium show color disparities when compared to natural teeth, with zirconia having an improved chromatic match.[22] Previous studies reported that zirconia is a preferable choice for the anterior region in individuals with gingival thickness of <2 mm.[17,23]

The present study revealed significant differences between zirconia and titanium implants in terms of thickness, color, and BOP. Notably, all patients with titanium implants reported bleeding, whereas no bleeding was observed in the zirconia group. This finding aligns with Bienz *et al*., who reported lower plaque and bleeding scores for zirconia implants under experimental mucositis conditions.[24] Similarly, de Beus *et al*. found significant differences in bleeding scores ($P = 0.013$) and probing depths ($P = 0.025$) between the two materials.[25] Ferrantino *et al*.'s randomized controlled trial yielded comparable results, showing no significant changes in bone levels but worsening plaque index, BOP, and probing depths in both groups.[26] In contrast, Koller *et al*.'s randomized pilot trial found no significant differences in BOP, plaque index, pink esthetic score, or marginal bone loss between two-piece zirconia and titanium implants.[6]

Pocket depth was another soft tissue parameter considered in this study. In the present study, all patients had a pocket depth of 3 mm or less. However, no significant difference was found between zirconia and titanium implants. The prospective study by Lorenz

Table 2: Association between zirconia and titanium implants in terms of demographics and soft tissue parameters (*n*=60)

Variables	Total	Implant type		*P*-value
		Zirconia (%)	Titanium (%)	
Total	60	23 (38.3)	37 (61.7)	-
Demographics				
Gender				
Male	24	6 (25.0)	18 (75.0)	0.083
Female	36	17 (47.2)	19 (52.8)	
Age				
Young adults 18–39	29	12 (41.4)	17 (58.6)	0.639
Middle-aged 40–59	31	11 (35.5)	20 (64.5)	
Implant size				
3.3 mm	14	9 (64.3)	5 (35.7)	0.023a
4.1 mm	46	14 (30.4)	32 (69.6)	
Implant location				
Upper left	17	3 (17.6)	14 (82.4)	0.038[a]
Upper right	43	20 (46.5)	23 (53.5)	
Type of restoration				
Cement retained	10	9 (90.0)	1 (10.0)	<0.001[a]
Screw retained	50	14 (28.0)	36 (72.0)	
Implant level				
Tissue level	24	23 (95.8)	1 (4.2	<0.001[a]
Bone level	36	0 (0.0)	36 (100.0)	
Soft tissue parameter				
Thickness				
Thin	26	14 (53.8)	12 (46.2)	0.031[a]
Thick	34	9 (26.5)	25 (73.5)	
Color				
No color change	28	23 (82.1)	5 (17.9)	<0.001[a]
Color change (shadow show off)	32	0 (0.0)	32 (100.0)	
Pocket depth				
3 mm or less	60	23 (38.3)	37 (61.7)	-
Bleeding on probing				
Yes	11	0 (0.0)	11 (100.0)	0.004[a]
No	49	23 (46.9)	26 (53.1)	

[a]significant using the Chi-square test at <0.05 level

et al. demonstrated no difference in bleeding index, attachment level, or bacterial colonization between the control group (natural teeth) and the implants. However, zirconia implants showed greater pocket depths compared to the control group.[27] Duncan *et al*. found that the pocket depths of titanium and zirconia implants were both 2.2 mm, but the pocket depth of zinc implants decreased significantly after 8 years (1.9 mm).[28]

Limitations and directions for future studies

While our study endeavors to shed light on the soft tissue parameters surrounding titanium and zirconia dental implants, several limitations should be acknowledged to contextualize the findings. The relatively small sample size of our study may limit the generalizability of our results. A larger cohort would enhance the statistical power and strengthen the validity of our conclusions.

In addition, the duration of our study might be relatively short. A longer-term investigation would provide a more comprehensive understanding of the evolution of soft tissue parameters around dental implants over time. Such extended study duration would enable us to observe any potential variations between titanium and zirconia implants in terms of their long-term effects on soft tissue health.

Future studies should include baseline measurements of gingival thickness before implant placement and compare them with follow-up measurements to better isolate the effects of the implant materials. This approach would provide a more accurate assessment of how different materials influence gingival phenotype over time.

This study may not have accounted for all potential confounding variables that could influence soft tissue parameters. Factors, such as variations in oral hygiene practices among participants, differences in prosthetic design, or variations in the skill level of the operators placing the implants could have impacted our results. Future research should focus on addressing

these variables to provide a more comprehensive understanding of the factors impacting soft tissue health around dental implants.

Future studies should explore the use of digital imaging techniques, such as 3D intraoral scans and high-definition photography, for non-invasive assessment of gingival biotype. In addition, incorporating ultrasound imaging to evaluate soft tissue characteristics is recommended. This approach allows for real-time assessment of gingival thickness and morphology, providing valuable insights while ensuring patient comfort. By adopting such methods, future researchers can enhance our understanding of soft tissue parameters in relation to dental implants while prioritizing patient comfort and safety.

Conclusion

The findings of this study held significant implications for the enhancement of patient outcomes. By elucidating the soft tissue response to titanium and zirconia implants, clinicians were better equipped to tailor treatment strategies to the specific needs of individual patients, thereby improving clinical outcomes and patient satisfaction.

Although this study did not introduce novel innovations, it served to reinforce and validate existing knowledge within the field. By comparing the performance of titanium and zirconia implants, the study provided valuable insights that could inform future advancements in implant design and material science. These insights contributed to incremental improvements, leading to the development of more biocompatible, esthetically pleasing, and functionally reliable implant solutions. Ultimately, these advancements elevated the standard of care in implant dentistry.

Authors Contributions

Conceptualization, A.M., D.B., and R.I.; methodology, A.M., D.B., R.I., and H.A.; validation, A.M., D.B., R.I., F.B., and R.S.; formal analysis, D.B., R.I., F.B., H.A. and R.S.; investigation, D.B., R.I. ; resources, A.M.; data curation, F.B., H.A., and R.S.; writing—original draft preparation, A.M., D.B., R.I., and R.S.; writing—review and editing, F.B. and H.A.; supervision, A.M.; All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

The data presented in this study are available on request from the corresponding author.

Conflicts of Interest

The authors declare no conflict of interest

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