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Comparison of Mechanical Properties and Aesthetic Results Titanium Implant, Zirconia Implant and Titanium Implant with Zirconia Abutment: A Systematic Review

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KEYWORDS

Dental Implant, Abutment Implant, Titanium, Zirconia.

ABSTRACT

The research method used is a Systematic Literature Review, which includes analysis of various studies related to mechanical properties and aesthetic result titanium dental implant, zirconia dental implant and titanium dental implant with zirconia abutment. This study aims to evaluate the success of implant-supported dental bridges in patients with total tooth loss and identify factors that influence this success. Complete tooth loss can have a significant impact on the patient's oral function and quality of life, so effective restorative solutions are necessary. Research results show that the success rate of dental implant bridges ranges from 85% to 95%, with factors such as gum health, patient compliance with post-operative care, and dentist experience contributing significantly to the success. Titanium dental implants offers many advantages, some studies show that zirconia implants provide superior cosmetic benefits, especially when the implant is placed in the anterior region. Zirconia is renowned for its color and transparency, which is similar to natural teeth, and can provide superior cosmetic. Titanium implants with zirconia abutments have emerged as an attractive option because they combine the strength of titanium with the aesthetics of zirconia. The conclusions of this study confirm that implant-supported dental bridges are an effective solution for patients with total tooth loss, and attention to factors influencing success can improve long-term outcomes.

1. INTRODUCTION

Losing teeth is a common worry for many people, especially in old age. In an effort to overcome this problem, dental implants have become one of the most successful and widely used options in modern dentistry (Albrektsson et al., 1986). Dental implants can be made from a variety of materials, including titanium and zirconium. Titanium has traditionally been the material of choice for dental implants due to its excellent mechanical qualities and good biocompatibility. According to World Health Organization (WHO) estimates, more than 30% of the world's population experiences major tooth loss, and this percentage increases with age (Chmielewski et al., 2024). Treatment of tooth loss is becoming increasingly important in contemporary dentistry (Davoudi et al, 2023).

Dental implants have emerged as one of the most popular treatment options for correcting complete or partial tooth loss. Dental implants are artificial devices that are placed in the jawbone to replace missing tooth roots (Inriany, 2021). These implants can be made from a number of materials, with titanium and zirconia being the two materials most frequently

compared in studies. Titanium has traditionally been the material of choice for dental implants due to its excellent mechanical qualities, good biocompatibility, and ability to fuse with bone through osseointegration (Roccuzzo et al., 2022). The process of osseointegration is critical to implant success, where the implant interacts with the bone tissue and develops a strong connection, thereby providing the stability necessary to support the dental prosthesis (Ferreiroa et al., 2015).

Although titanium offers many advantages, some studies show that zirconia implants provide superior cosmetic benefits, especially when the implant is placed in the anterior region. Zirconia is renowned for its color and transparency, which is similar to natural teeth, and can provide superior cosmetic effects compared to titanium implants (Lugas et al., 2020). Additionally, zirconia offers superior corrosion resistance and allergic response, making it an attractive option for metal-sensitive individuals. Conversely, titanium implants with zirconia abutments have emerged as an attractive option because they combine the strength of titanium with the aesthetics of zirconia (Puspitasari & Herda,2022).

Figure 1: Evolution in implant dentistry (Titanium implant, Titanium implant with zirconia abutment and Zirconia implant) (Haghighat, 2024) (https://portlandperioimplantcenter.com/zirconia-versus-titanium-dental-implants/)

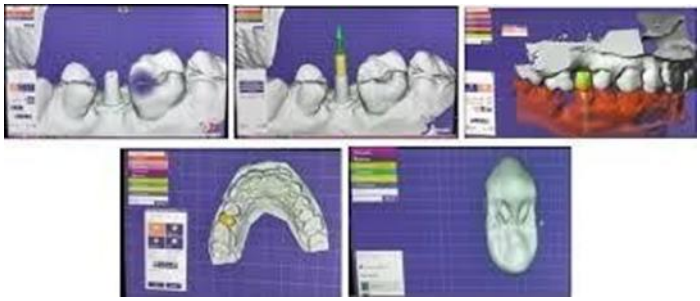

Figure 2: Process CAD/CAM zirconia abutment and restoration crown supported dental implant (Prawesthi & Handayani, 2023)

Puspitasari & Herda (2022) found the fact that this combination can provide good results both mechanically and aesthetically. Zirconia abutments, which connect the implant to the dental prosthesis, can improve the cosmetic appearance, especially in patients who desire a more natural appearance (Puspitasari & Herda, 2022). However, comparing these three types of implants—titanium implants, zirconia implants, and titanium implants with zirconia abutments (figure 1) requires systematic evaluation to thoroughly analyze the mechanical quality and cosmetic results (Fabbri et al., 2021). The mechanical qualities of dental implants, such as tensile strength, compressive strength, and fatigue resistance, are critical to their long-term effectiveness. Some studies show that titanium implants have better mechanical resistance than zirconia implants, while zirconia implants are more resistant to cosmetic damage (Halim & Poedjiastoeti, 2024). Therefore, it is important to analyze how these mechanical qualities influence therapeutic success and patient satisfaction (Morinaga et al., 2024 ; Haghighat, 2024).

In addition to mechanical features, aesthetic results are also an important consideration when selecting implants. Dental aesthetics includes not only the color and shape of the teeth, but also their interaction with the surrounding soft tissues, such as the gums (Roccuzzo et al., 2022).

According to research, zirconia implants can provide better cosmetic results, especially in terms of soft tissue integration, thereby improving the overall appearance of the patient's smile. However, there is concern that zirconia implants are likely to fail in certain situations, for example in individuals with a history of periodontal disease. Based on the background of this problem, researchers will conduct systematic review journal research which aims to discuss the comparison of Titanium Implants, Zirconia Implants, and Titanium Implants with Zirconia Abutments (figure 1 and table 1) (Chmielewski et al., 2024 ; Davoudi et al., 2023 ; Prawesthi & Handayani, 2023 ; Schimmel et al., 2019).

2. METHOD

This study used a systematic literature review (SLR) design to evaluate the mechanical properties and aesthetic results of titanium implants, zirconia implants, and titanium implants with zirconia abutments. With research questions, what are the mechanical properties of the three types of implants?, and what are the aesthetic results of the three types of implants in dental rehabilitation? Then the inclusion criteria used were studies published in English or Indonesian. then Studies involving titanium implants, zirconia implants, or titanium implants with zirconia abutments, and Studies reporting mechanical properties and/or aesthetic results. Meanwhile, the exclusion criteria are studies that do not involve dental implants. The study only involved patients with partial tooth loss. And articles that are not peer-reviewed.

A literature search was conducted through databases such as PubMed, Scopus, and Google Scholar, using keywords such as "dental implants", "titanium implants", "zirconia implants", and "mechanical properties". Boolean operators will be used to expand or narrow the search. Then, study selection was carried out in two stages: initial screening based on the title and abstract, followed by a full review to ensure compliance with the inclusion criteria. This process was carried out by two independent researchers. And the data collected includes basic study information, population characteristics, Intervention details, and outcomes reported. Data is recorded in a table for further analysis. Data analysis was performed descriptively, with the possibility of meta-analysis to calculate combined estimates of mechanical properties and aesthetic results. Heterogeneity between studies was evaluated using statistics. And the last thing to do is describe the results of the review prepared in accordance with PRISMA guidelines, including a flow diagram for study selection, a summary of study characteristics, and analysis results.

3. RESULT AND DISCUSSION

First Research

The research entitled “All-on-4 implant treatment: difficulties and general methods” was conducted by Nur Inriany and Eri Hendra Jubhari, published in December 2021. This study focuses on the concept of All-on-1 dental implants, using qualitative research methods, analyzing experiences and results from more than 500 arches treated with the All-on-4 technique. This approach allows a comprehensive understanding of common difficulties encountered during the care process. With research results the All-on-4 Technique has demonstrated high success rates in both short-term and long-term studies, with reported success rates exceeding 98% in various literature, then Research identifies common problems that arise before, during, and after All-on-4 treatment -on-4, emphasizes the

importance of proper planning and knowledge to minimize potential complications (Inriany, 2021).

Second Research

The second research was conducted (Chmielewski et al., 2024) with the title The Fracture Resistance Comparison between Titanium and Zirconia Implant Abutments with and without Aging: Systematic Review and Meta-Analysis in 2024. This study used a systematic review and meta-analysis research methods, which is a comprehensive approach to synthesize existing studies on the fracture resistance of dental implant abutments made of titanium and zirconia.

The participants in this study were not individual subjects but rather studies included in a systematic review. A total of 17 relevant articles were selected after an initial search that yielded 4031 results. These articles were selected based on specific inclusion criteria, with a focus on in vitro load testing of dental implant abutments, including one-piece and two-piece zirconia abutments for comparison with titanium abutments (Chmielewski et al., 2024).

This research was conducted through electronic searches of databases such as MEDLINE (PubMed) and Scopus (Embase), which included studies published from January 1, 2007, to January 29, 2023. This time period allowed the researchers to collect a variety of data on the performance of different support materials in various conditions. The results showed that titanium remained the strongest material for abutments, followed by two-piece zirconia, while one-piece zirconia abutments showed the weakest performance. This study found that cyclic loading above 1,000,000 cycles significantly decreased the fracture resistance of the abutments. Additionally, the primary failure mode for titanium abutments was identified as screw bending or fracture, while one-piece zirconia often resulted in catastrophic failure (Koutouzis & Ali, 2021). Findings suggest that two-piece zirconia abutments may be suitable for the posterior region due to their comparable fracture resistance to titanium abutments, although one-piece zirconia is recommended primarily for anterior applications due to its failure characteristics.

Third Research

The study entitled “Relationship of CAD/CAM zirconia dental implant abutments with periodontal health and final aesthetic aspects; A systematic review” was conducted to evaluate the impact of CAD/CAM zirconia (Zr) implant abutments on peri-implant health and aesthetics compared to other types of abutments (figure 2) (Davoudi et al., 2023), This study used a systematic review methodology, involving a comprehensive search of five Electronic databases: PubMed, Web of Science, Scopus, ProQuest, and Embase, as of September 2020.

The search strategy used a Boolean approach to identify relevant studies based on the PICO framework, with a focus on dental implants (population The systematic review included a total of six studies, consisting of three prospective cohort studies and three randomized clinical trials. The total sample size across these studies was 304 implants, primarily placed in the anterior maxilla, with some also in the mandible. Then the results and findings show that although there is no significant difference in papilla filling, white esthetic score (WES), pink esthetic score (PES), and distance from bone crest to contact point between Zr CAD/CAM (figure 2) and Zr stock abutments, Zr CAD/CAM showed better results in terms of soft tissue stability and papilla recession index (Davoudi et al., 2023).

Fourth research

The fourth research entitled Differences in Titanium, Titanium-Zirconium, Zirconia Implants Treatment Outcomes: a Systematic Literature Review and Meta-Analysis" written by Haimov et al., was published 2023 in Journal of Oral & Maxillofacial Research. This research is a systematic review and meta-analysis that follows PRISMA guidelines. The total participants in this study were 301 patients who underwent oral rehabilitation with titanium, titanium-zirconium, and zirconia implants. Of these, 92 male patients and 69 female patients were reported, while some studies did not include gender data. Results: Across the 10 studies included in this review, a total of 637 implants were used, consisting of 304 titanium implants, 134 titanium-zirconium implants, and 199 zirconia implants. The results showed that titanium-zirconium implants had a lower failure rate compared with zirconia implants. The study also noted that all studies showed a risk of bias, but some studies did not show significant bias. The final results showed differences in success rates and clinical outcomes between different types of implants (Haimov et al., 2023).

Fifth Research

The research entitled "Relevant Aspects of Titanium and Zirconia Dental Implants for Their Fatigue and Osseointegration Behavior" was conducted by the author Aragoneses et al, was published 2022 in Journal Materials (MDPI). This study aims to explore the osseointegration capabilities and mechanical behavior of dental implants made of commercially pure titanium and zirconia, focusing on the influence of material properties and surface roughness on these factors.

This study used a comparative experimental method, using specific dental implant models to ensure consistency across studies. The results showed that the roughness of titanium implants significantly improved their osseointegration compared with smooth variants. After 4 weeks, the bone contact index (BIC) values were approximately 25% for titanium, 32% for zirconia, and 45% for rough titanium implants. After 12 weeks, these values increased to 42% for titanium, 43% for zirconia, and 76% for rough titanium implants. This suggests that surface roughness is a key factor in enhancing osseointegration (Aragoneses et al, 2022) .

Discussion

The Success of the All-on-4 Technique

The high success rate of the All-on-4 technique suggests that this method can be an effective option for dental rehabilitation. However, it is important to pay attention to proper planning and execution to avoid complications. This is in line with other findings showing that good planning can improve clinical outcomes (Inriany, 2021).

Fracture Resistance and Material Selection

Findings regarding fracture resistance indicate that titanium remains the preferred choice for implant abutment. However, two-piece zirconia shows good potential for certain applications, especially in the posterior region. This indicates that the choice of material must be adapted to the patient's location and condition (Chmielewski et al., 2024 ; Haimov et al., 2023).

Aesthetics and Soft Tissue Health

CAD/CAM zirconia abutments show better results in terms of soft tissue stability, which is important for long-term aesthetics (figure 2). This shows that aesthetics depends not only on color and shape, but also on interaction with the surrounding soft tissue (Prawesthi & Handayani, 2023 ; Davoudi et al., 2023).

Combination of Ingredients for Better Results

Results from studies showing that titanium-zirconia implants have lower failure rates suggest that the combination of materials may provide benefits in dental rehabilitation (Chmielewski et al., 2024 ; Haimov et al., 2023 ; Fabbri et al., 2021).

Effect of Surface Roughness on Osseointegration

Research on osseointegration shows that the roughness of the implant surface can influence implant success. This suggests that implant design must consider physical factors to improve osseointegration and, ultimately, the long-term success of the implant (Aragoneses et al., 2022).

Table 1: Comparison between Titanium Implants, Zirconia Implants, and Titanium Implants with Zirconia Abutments.

Criteria	Titanium Implants	Titanium Implant with Zirconia Abutment	Implant zirconia
Mechanical strength	High tensile and compressive strength. Then it has better fracture resistance than zirconia	Combines the strength of titanium with the aesthetics of zirconia. And has good mechanical strength, but depends on the abutment design.	Lower mechanical strength than titanium. Then more susceptible to fracture under certain conditions
Aesthetics	Less than optimal in the anterior. area. and Metal color can be seen.	Improves cosmetic appearance, especially in the anterior area. Zirconia abutments provide better aesthetic results	Very good, similar to real teeth. more natural transparency and color.
Biocompatibility	Very good, does not cause allergic reactions	Excellent, safe combination of materials	Very good, does not cause allergic reactions
Osseointegrase	Good, especially with rough surfaces. The osseointegration process is fast and effective.	Fine, but depends on the abutment design.	Fine, but osseointegration may be slower than titanium
Risk of failure	Low, but there is a risk in patients with a periodontal history	Low, depending on patient condition and post-operative care	Higher in certain situations, especially in patients with a history of periodontal disease
Usage	Commonly used in various cases, especially in the posterior	Used to improve aesthetics in the anterior.	Used primarily in the anterior area for cosmetic results.
Soft Tissue Health	Good, but may cause irritation in some patients	Good soft tissue stability, improving aesthetics	Excellent soft tissue stability, reducing gum recession

4. CONCLUSION

This systematic review shows that both titanium and zirconia implants have their own advantages and disadvantages. Titanium implants are superior in terms of mechanical properties, while zirconia implants offer better aesthetic results. Further research is needed to explore combinations of implants and abutments that can provide optimal results in various clinical situations (Chmielewski et al., 2024 ; Haimov et al., 2023 ; Davoudi et al., 2023). Suggestions for future research include long-term studies to evaluate implant performance in different clinical conditions and cost-effectiveness analyzes of different types of implants. By better understanding the characteristics of each type of implant, practitioners can make more informed decisions to meet their patients needs.

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