ORIGINAL ARTICLE

The Effect of Implant Abutment Material of Titanium, Zirconia, and Polyether Ether Ketone on Prosthetic Screw Fracture Resistance

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Abstract

Purpose: In this study, the fracture resistance of prosthetic screws was tested using abutments made of titanium, zirconia, and Polyether Ether Ketone (PEEK) on dental implants.

Materials and Methods: From Easy Implant by easy prod, France, dental implants with specified dimensions and prosthetic screws were purchased. Three different materials (Ti, Zr, and PEEK) were used for abutment preparation. The implant-abutment units were subjected to a constant vertical force using a Universal Testing Machine (UTM) until the prosthetic abutment broke. The force that caused fracture was measured, and one-way ANOVA and Tukey's post-hoc tests were used to statistically analyze the data.

Results: For Titanium, Zirconia, and PEEK abutments, the mean fracture resistance (±standard deviation) was 727±31 N, 516±21 N, and 289±23 N, respectively. A substantial difference in fracture resistance was found between the various abutment materials according to the one-way ANOVA ($p<.001$). Zirconia showed much stronger fracture resistance than PEEK ($p <0.05$) and Titanium abutments demonstrated significantly higher resistance than both Zirconia and PEEK ($p <0.01$), according to post-hoc tests.

Conclusion: The type of the material affects the fracture resistance and fracture pattern of the implant abutment. Titanium, Zirconia, and PEEK abutments show different fracture resistance. Titanium requires more force to be fractured while polyether ether ketone shows less required force. This may affect the prosthetic screw fracture and affect the longevity of the implant.

Keywords: Implants; Fracture Resistance; Titanium; Zirconia; Polyether Ether Ketone.

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1. Introduction

The introduction of dental implants has transformed restorative dentistry by providing a reliable and long-lasting remedy for tooth loss. The abutment, which connects the implant and the prosthesis, is one of several components that go into dental implants. The durability of the prosthetic restoration and the implant's success both heavily depend on the abutment material [1]. The fracture of the prosthetic screw, which can result in issues like the prosthesis becoming loose or falling off and necessitating extra surgical procedures, is one of the main difficulties in dental implantology [2].

The material of the implant abutment is one of many variables that affects the fracture resistance of the prosthetic screw [3]. Less focus has been placed on the specific influence of abutment material on prosthetic screw fracture resistance, even though several studies have looked at the biomechanical features of implant abutments and their impact on implant survival rates [4]. By filling in this knowledge gap, this article hopes to benefit dental practitioners and further the continuous drive to enhance patient outcomes in implant dentistry [5]. Understanding this link is essential because it may have an impact on the choice of abutment materials used in clinical settings, thereby enhancing dental implants' durability and elevating patient satisfaction [6].

The fracture resistance of prosthetic screws affects the success of the dental implant treatment so that to get a better outcome of this treatment it is important to put in mind the interaction between the screw fracture resistance and the abutment [7]. The success and general effectiveness of implant-based restorations are significantly impacted by the biomechanics of dental implants, notably the fracture resistance of prosthetic screws. Improved knowledge of implant biomechanics that would enable more precise forecasting of implant success and longevity would result from taking into account the interaction between prosthetic screw fracture resistance and abutment material [8].

By providing a thorough examination of the impact of implant abutment material on prosthetic screw fracture resistance, this paper intends to fill this gap in the literature. By doing this, we hope to help dental professionals by offering insightful information and supporting the ongoing endeavor to enhance patient outcomes in implant dentistry.

2. Materials and Methods

2.1. Study Design

The design of this investigation was an in-vitro experiment. The impact of various implant abutment materials on prosthetic screw fracture resistance was investigated.

2.2. Dental Implants, Abutments, and Screws

From Easy Implant by Easy Pro, France, dental implants with standard specifications (4 mm diameter, 10 mm length) were obtained. The dental implant is made from Titanium alloy in compliance with the current version of standard EN ISO 5832-3, prosthetic accessories, and reusable surgical instruments. Three different materials—Titanium (Ti) (JDM5PRO), Zirconia (Zr) (Zircon zahn), and polyether ether ketone (PEEK) (JUVORA) were used to fabricate the abutment specimens (Figure 1). The specimens were fabricated via CAD CAM; this is done in order to standardize the design of the abutments.

Abutments were prepared with the same size and shape from different materials: Titanium, Zirconia, and polyether ether ketone as shown in Figure 1.

The same manufacturer of the dental implant supplied standardized prosthesis screws that worked with the specified dental implants (Figure 2 and Figure 3).

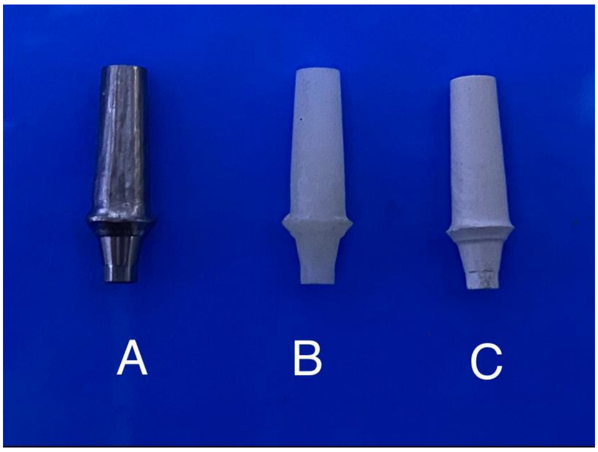

Figure 1. Three different materials— A: Titanium (Ti), B: Zirconia (Zr), and C: polyether ether ketone (PEEK) were used to make the abutments

Figure 2. Dental implant supplied with its screw

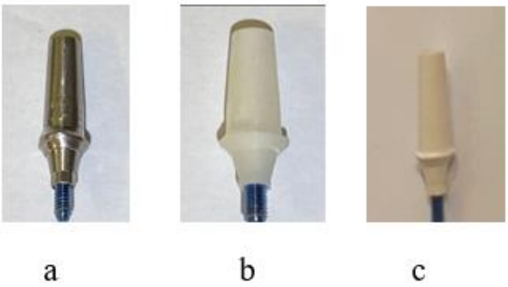

Figure 3. Abutments attached to screws. a: Ti, b: Zr and c: PEEK

- **Sterilization of Dental Implants and Abutments**

The implants and the corresponding screws when supplied by the manufacturer are decontaminated and delivered in a sterile condition. They are sterilized using gamma rays having a dose of between 25 and 40 KGy.

- **Assembly of Implant-Abutment Units**

The implant-abutment units were put together to ensure a perfect fit between the parts with the aid of the specific screws (Figure 4).

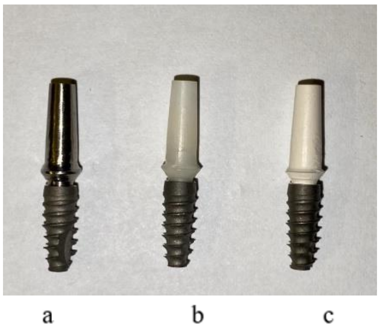

Figure 4. Abutments attached to the implant by the use of the screws. a: Ti abutment attached to the implant, b: Zr abutment attached to the implant, and c: PEEK attached to the implant

2.3. Testing Equipment

Utilizing controlled forces, a Universal Testing Machine (UTM) (Instron, France) was utilized to assess fracture resistance.

2.4. Testing Procedures

- Force Application

By the use of UTM, a vertical force of cross-head speed of 10m/min was applied until the prosthetic abutment broke.

- Measurement of Fracture Resistance

The force that caused the fracture of the prosthetic abutment was recorded by the UTM. The force of fracture was measured in Newton (N).

2.5. Data Collection and Analysis

- Data Collection Method

The data of the forces that cause fracture of the prosthetic abutment, which were recorded by the UTM were gathered for further study.

2.6. 2.6. Error Analysis

Variations in the implant-abutment units' assembly and the UTM's calibration were identified as potential causes of inaccuracy, and they were kept to a minimum. To gauge the accuracy of the data, the standard error of the measurements was also determined.

2.7. 2.7. Experimental Environment

To reduce the impact of outside variables on the materials, the trials were conducted in a temperature-controlled laboratory setting. The laboratory temperature was 30°C while the outside temperature was 22 °C.

2.8. 2.8. Ethical Considerations

Despite the fact that our study did not use human participants, all methods were planned and executed in compliance with the ethical standards for scientific research. To represent a real-world clinical scenario as nearly as possible while eliminating any potential ethical issues, standard-sized dental implants and prosthetic screws were used.

2.9. Replicability

All the tools and procedures used in this study were explained thoroughly in order to be replicated by other researchers.

2.10. Statistical Analysis

The data were plugged into Microsoft Excel. Then the data were analyzed using SPSS-27 (statistical packages for social sciences-version 27). To compare the fracture resistance of the various abutment materials, one-way ANOVA was employed. Tukey's post-hoc test was used to compare each group with the other.

3. Results

The study carefully assessed the ability of prosthetic screw, a vital part of dental implants, to resist fracture when used with abutments made of three different materials: Titanium (Ti), Zirconia (Zr), and polyether ether ketone (PEEK). A Universal Testing Machine (UTM) was used to apply a constant vertical force until the fracture point in the abutment was reached. This technique made it possible to quantify the force needed to cause a fracture precisely, giving a clear indication of how resistant each type of material is to fracture. Regarding their resistance to fracture, each of the three abutment materials displayed particular characteristics. The data recorded by the machine were collected and statistically analyzed. One-way ANOVA test revealed that the type of the abutment material had a significant effect on the fracture resistance of the implant abutment (Figure 5). The Titanium material showed the highest fracture resistance of 727N with a standard deviation of 31.82. Zirconia abutment material showed fracture resistance of 516N with a standard deviation of 21.62. PEEK material showed fracture resistance of 289N with a standard deviation of 23.02 (Table 1).

The study also revealed the pattern of the abutment fracture before the complete fracture. Titanium material showed deformity of the upper part of the abutment before a complete fracture of the prosthetic screw, zirconia showed vertical or oblique line of fracture before complete fracture while PEEK material showed sudden complete fracture to fragments.

The goal of this investigation was to identify any appreciable variations in fracture resistance among the Titanium, Zirconia, and PEEK abutments. These results can help clinicians to choose dental implant abutments material which provide extended life and effectiveness of dental implant.

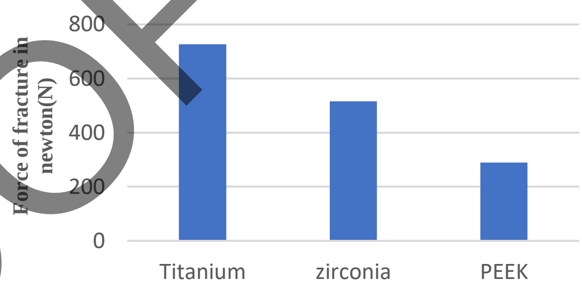

Figure 5. The force required for the fracture of the three abutment materials

Table 1. The mean fracture resistance and standard deviation for each abutment material

Type of the Abutment Material	Mean of Fracture Force(N)	SD	SE	P value
Ti	727	31.8276	14.2337	<0.001
Zr	516			<0.001
PEEK	289			<0.001

Post hoc tests reveal that there is a significant difference between each group with the other one. Titanium and Zirconia are harder materials than PEEK material and require more force to be fractured and Titanium is the strongest material.

3.1. Fracture Resistance of Prosthetic Screws

When prosthetic screws were attached to various abutment materials, there was a noticeable difference in the fracture resistance of the screws. Each of the three types of abutments—Titanium (Ti), Zirconia (Zr), and Polyether Ether Ketone (PEEK)—required a different amount of force to cause the screws to fracture. Titanium was shown to have the highest average force at the screw fracture point, followed by Zirconia and PEEK.

To learn more about these variations after the ANOVA, post-hoc Tukey's tests were used. As compared to Zirconia and PEEK, Titanium abutments greatly increased the prosthetic screws' fracture resistance, according to the data. Additionally, Zirconia abutments provided significantly greater fracture resistance as compared to PEEK.

These results demonstrate the effect of abutment material on prosthetic screw fracture resistance and show that titanium abutments perform best in this area, followed by zirconia and PEEK. By using these findings to inform material selection during dental implant procedures, the longevity and effectiveness of these interventions can be maximized.

3.2. Interpretation of Results

The findings of this study demonstrate a strong relationship between the kind of abutment material and the fracture resistance of prosthetic screws in dental implants. The best fracture resistance was seen in titanium abutments, followed by Zirconia and PEEK. The fracture resistance of dental implants' prosthetic screws composed of various abutment materials has been significantly clarified by our research. Our findings show that the choice of abutment material significantly affects the durability and efficacy of dental implant treatments. As a result, the findings of this study may enable dentists to choose abutment materials with greater knowledge.

4. Discussion

Our investigation made the supposition that every time the abutment and implant fit perfectly. There might be small differences and micro-gaps in actual therapeutic settings. Another drawback was that because the study was conducted in vitro, the outcomes might not accurately reflect the in vivo setting where biological factors are at play.

The analysis of the effects of various implant abutment materials on prosthetic screw fracture resistance revealed that the prosthetic screw's overall performance and durability are greatly impacted by the material choice. This confirms the results of earlier studies, which found that material parameters were crucial in determining the mechanical properties of dental implants [9]. To put it more precisely, the results show that Titanium abutments performed better than PEEK and Zirconia abutments in terms of the mean of the maximum load before failure. This is in agreement with the findings of Pisulkar and Godbole who find that Titanium the best to be used as abutment material because of its intrinsic mechanical strength and durability [10]. The good results of Titanium in our study may be attributed to its durability and biocompatibility. On the other hand, PEEK and Zirconia abutments demonstrated reduced fracture resistance. In spite of the cosmetic benefit and superior biocompatibility of the PEEK and zirconia, their mechanical qualities in relation to dental implants are more debatable [11]. This study proves that these materials might not be adequate in all loading situation because of their mechanical performance particularly to heavy masticatory forces. It's interesting to note that the data also showed differences in the pattern of the abutment fracture between the various abutment materials. This is due to the rigidity, porosity, and compressive properties of the abutment material. The survival rates of dental implants are significantly influenced by preload, torque, cantilever design, and implant abutment design, among other variables [12]. In order to maximize fracture resistance, the findings of this study highlight the significance of careful material selection in dental implant abutment design. This underlines the necessity of ongoing research into the creation of materials that combine aesthetics, biocompatibility, and mechanical durability for longer-lasting implants. The findings of our study also shed light on the interactions between many elements that can affect the general effectiveness of dental implant abutments. The surface morphology of the abutment materials is one such element that has been demonstrated to have an impact on the stability and integration of dental implants [13]. For instance, titanium abutments' microstructure can improve the biological response of the tissues around them, encouraging greater osseointegration and long-term stability [14]. The dynamic oral environment is another crucial factor to take into account since it subjects dental implant abutments to a variety of stresses, including masticatory loads and changes in temperature and pH [15]. This highlights the requirement for materials that can endure these circumstances without losing their structural integrity. The potential impact of abutment material choice on the general success of patient treatment must also be taken into account. For instance, the choice of abutment material may impact patient comfort and satisfaction as well as the predictability of implant-supported restorations [16]. Therefore, for the best patient care and treatment planning, it is essential to understand the relative benefits and limits of different abutment materials. The field of dental implant abutments may undergo a revolution as a result of the development of novel materials and manufacturing methods. Titanium has mechanical characteristics, which include a high strength-to-weight ratio and great fatigue and corrosion resistance [17]. On the other hand, PEEK and Zirconia abutments have been discovered to offer substantial advantages in terms of aesthetics and biocompatibility, respectively, despite their considerably lower fatigue resistance [4]. PEEK is a desirable option for anterior restorations, where aesthetics are of utmost importance, due to its tooth-like hue. Zirconia, on the other hand, has a stellar reputation for great biocompatibility and soft tissue response, which might be helpful in situations where there are thin biotypes or high aesthetic expectations [14]. Notably, the three abutment materials had different maximum loads before failure, with titanium abutments being able to bear larger loads before failure [12]. This emphasizes how crucial it is to take the patient's occlusion and functional load into account when choosing the material for the abutment, as patients with significant occlusion or parafunctional habits may benefit more from stronger materials like titanium. The effectiveness and longevity of dental implant abutments can also be impacted by patient-related factors, such as age, general health, and oral hygiene [18]. Therefore, for optimum dental implant results, individualized treatment planning that considers both patient-specific and material-specific aspects is essential. Future studies may concentrate on creating novel techniques to improve the mechanical qualities of PEEK and Zirconia abutments or looking into new materials that can balance the demands of strength, fatigue resistance, biocompatibility, and aesthetics in dental implantology [4,15].

5. Conclusion

The findings of our study show that the type of abutment material chosen has a considerable effect on the fracture resistance of prosthetic screws, with Titanium offering the strongest resistance, followed by Zirconia and then PEEK. The difference in the amount of the force needed to fracture the abutment and as a result, the screw is due to the chemical composition and mechanical properties of each material. These results may help the dentist choose the best abutment materials, thereby extending the longevity and effectiveness of dental implants. It is important to note, however, that while this study offers a strong foundation, additional research, especially in vivo investigations, is required to properly comprehend the clinical significance of these findings.

This study has identified a number of areas that demand more research. First, additional research could expand on these conclusions by taking into account other abutment materials and prosthetic screws. Secondly, to further explore how biological elements like saliva and temperature, as well as patient-specific elements like age and bone quality, affect the efficacy of dental implants, in vivo research could be conducted to supplement our in vitro experiment. Last but not least, our work has made clear how crucial repeatability is to scientific research. To maintain the validity and reproducibility of findings, we advise future research in this field to continue prioritizing exacting testing processes and open reporting of findings.

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The authors agreed to submit the work to the current journal, gave final approval of the version to be published, and agreed to be responsible for all aspects of the work.

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