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Evaluation of Removal Force of Abutments in Frictional Dental Implants- In Vitro Study

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ABSTRACT

Background: Frictional dental implants rely on precise fit and surface contact between the abutment and implant for stability and retention. The removal force required to detach the abutment is a critical parameter influencing implant longevity, prosthetic stability, and ease of retrieval. This in vitro study aims to evaluate and compare the removal force of different abutment designs in frictional dental implants.

Materials and Methods: A total of 30 frictional dental implants were divided into three groups (n=10) based on abutment design: Group A (tapered abutments), Group B (parallel-walled abutments), and Group C (hybrid abutments). Each abutment was inserted with a standardized force and subjected to cyclic loading for 500,000 cycles to simulate masticatory forces. A universal testing machine was used to measure the force required to remove each abutment. Data were analyzed using one-way ANOVA and Tukey's post-hoc test with a significance level of $p<0.05$.

Results: The mean removal force (N) for Group A was 125.4 ± 5.6, Group B was 98.7 ± 4.3, and Group C was 110.2 ± 4.9. Statistical analysis revealed a significant difference among the groups ($p<0.05$), with Group A showing the highest removal force, followed by Group C and Group B. The results suggest that abutment design significantly affects the retention of frictional dental implants.

Conclusion: Tapered abutments exhibited the highest removal force, indicating superior retention in frictional dental implants. Parallel-walled abutments demonstrated the lowest retention, which may facilitate easier retrieval but could compromise long-term stability. Hybrid abutments provided a balance between retention and retrievability. Further studies are recommended to assess clinical implications and long-term performance.

Keywords: *Frictional dental implants, abutment removal force, implant retention, tapered abutment, in vitro study.*

1. INTRODUCTION

Dental implants have become a widely accepted solution for replacing missing teeth, providing both functional and aesthetic benefits (1). Among various implant-abutment connections, frictional implants rely on a precision fit between the abutment and implant to achieve stability and retention without the need for screw fixation or cementation (2). The force required to remove the abutment plays a crucial role in determining the effectiveness of these implants, as it directly influences their long-term clinical success and retrievability (3).

The stability of frictional abutments is influenced by several factors, including surface characteristics, material composition and insertion force (4). Tapered abutments are designed to maximize contact and frictional retention, whereas parallel-walled abutments offer ease of retrievability but may compromise stability (5). Hybrid designs attempt to balance these properties by incorporating features of both configurations (6).

Previous studies have demonstrated that frictional implant systems exhibit high mechanical stability, but variations in abutment design can significantly affect retention forces (7). Understanding these forces is essential for optimizing implant selection based on clinical needs, whether prioritizing retention or retrievability (8). This in vitro study aims to evaluate and compare the removal force of different abutment designs in frictional dental implants. The findings may contribute to improving prosthetic outcomes and guiding clinicians in selecting the most appropriate abutment type for different clinical scenarios.

2. MATERIALS AND METHODS

Study Design

This in vitro study was conducted to evaluate the removal force of different abutment designs in frictional dental implants. A total of 30 implant-abutment assemblies were tested, categorized into three groups based on abutment design.

Sample Selection and Grouping

Thirty frictional dental implants with identical dimensions (4.0 mm diameter, 10 mm length) were used. The implants were divided into three groups (n=10) based on the type of abutment:

- Group A: Tapered abutments
- Group B: Parallel-walled abutments
- Group C: Hybrid abutments

All implants and abutments were obtained from the same manufacturer to ensure standardization.

Abutment Placement and Load Simulation

Each abutment was inserted into its respective implant using a standardized force of 100 N to ensure uniform seating. The assemblies were mounted in acrylic resin blocks to simulate bone support. A cyclic loading protocol was applied using a mechanical loading device, subjecting each sample to 500,000 cycles at a frequency of 1 Hz to replicate masticatory forces over an extended period.

Measurement of Removal Force

After cyclic loading, the removal force required to detach the abutment was measured using a universal testing machine. The abutment was subjected to a vertical pull-out force at a crosshead speed of 1 mm/min until complete separation occurred. The peak force recorded at the moment of abutment removal was noted in Newtons (N).

Statistical Analysis

The data were analyzed using one-way ANOVA to compare the removal forces among the three groups. Tukey's post-hoc test was performed to identify significant differences between individual groups. A p-value of <0.05 was considered statistically significant. All statistical analyses were conducted using SPSS software version 25.0.

3. RESULTS

The removal force of abutments varied significantly across the three groups. The mean removal force for Group A (Tapered Abutments) was 125.4 ± 5.6 N, which was the highest among all groups. Group B (Parallel-Walled Abutments) exhibited the lowest mean removal force of 98.7 ± 4.3 N, whereas Group C (Hybrid Abutments) had an intermediate value of 110.2 ± 4.9 N (Table 1).

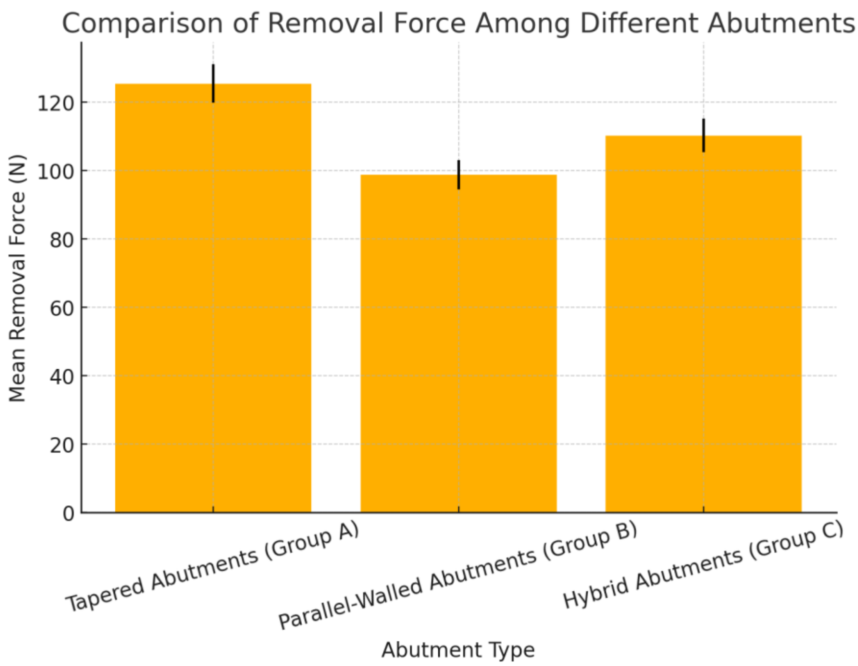
Statistical analysis using one-way ANOVA revealed a significant difference among the groups ($p < 0.05$). Tukey's post-hoc test further confirmed that the removal force in Group A was significantly higher than in Groups B and C, while Group B had the lowest values among all groups.

The graphical representation of the removal force distribution (Figure 1) clearly illustrates the variations between the three abutment designs. Tapered abutments demonstrated superior retention strength, while parallel-walled abutments exhibited easier retrievability due to lower removal forces. Hybrid abutments balanced both aspects, showing moderate removal force values.

Table 1: Removal Force of Different Abutments

Group	Mean Removal Force (N)	Standard Deviation (N)
Tapered Abutments (Group A)	125.4	5.6
Parallel-Walled Abutments (Group B)	98.7	4.3
Hybrid Abutments (Group C)	110.2	4.9

Figure 1: Comparison of Removal Force Among Different Abutments



4. DISCUSSION

The stability and retention of implant-supported prostheses are crucial for their long-term success. In this study, we evaluated the removal force of different abutment designs in frictional dental implants, demonstrating that tapered abutments exhibited the highest retention, followed by hybrid abutments, while parallel-walled abutments had the lowest removal force. These findings align with previous research highlighting the significance of abutment geometry in influencing implant stability (1,2).

Tapered abutments achieve higher retention due to increased frictional contact between the implant and abutment interface. This design enhances mechanical interlocking, reducing micromovement and improving the overall stability of the prosthetic restoration (3,4). Previous studies have shown that tapered connections provide better resistance to rotational and lateral forces, making them ideal for high-load-bearing regions (5,6). However, their increased retention may pose challenges during retrieval, requiring specialized tools for removal in case of abutment loosening or prosthetic adjustments (7).

Parallel-walled abutments, on the other hand, exhibited the lowest removal force, making them easier to retrieve when required. This property is advantageous in cases where frequent adjustments or maintenance procedures are necessary (8,9). However, lower retention could lead to increased micromovement at the implant-abutment interface, which may contribute to mechanical complications such as screw loosening, microgaps, and bacterial colonization (10,11). Studies have reported that excessive micromovement can negatively impact peri-implant bone health, leading to marginal bone loss and implant failure over time (12).

Hybrid abutments, which combine features of both tapered and parallel-walled designs, demonstrated a moderate removal force. This suggests that they may offer a balance between retention and retrievability, making them suitable for clinical situations requiring both stability and ease of prosthetic adjustments (13,14). Clinicians should consider patient-specific factors such as occlusal loading, retrievability needs, and bone quality when selecting an appropriate abutment type (15).

5. CONCLUSION

The findings of this study emphasize the need for careful selection of abutment designs based on clinical requirements.

Further research, particularly long-term clinical trials, is recommended to evaluate the biological and mechanical implications of different abutment geometries in real-world patient settings.

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