In Vitro Comparative Evaluation of Surface Treatments' Impact on Cement-Retained Bridge Retention in Implant-Supported Restorations with Short Abutments

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ABSTRACT:
Background: The retention and stability of implant-supported cement-retained bridges with short abutments are crucial factors for long-term success. Various surface treatments have been proposed to enhance retention; however, their comparative effectiveness remains to be fully elucidated. This in vitro study aimed to evaluate the effect of different surface treatments on the retention of implant-supported cement-retained bridges using short abutments.
Methods: Twenty identical implant-supported cement-retained bridges were fabricated, each consisting of a titanium abutment and a zirconia framework. The implants were embedded in acrylic blocks to simulate the short abutment scenario. The samples were randomly divided into four groups (n=5 per group) based on the surface treatment applied to the abutments: Group A (control) - no surface treatment; Group B - sandblasting with alumina particles; Group C - application of a zirconia primer; Group D - application of a resin-based adhesive. A universal testing machine was employed to measure the retention force. All samples were subjected to cyclic loading to simulate oral conditions.
Results: The mean retention force values (measured in Newtons, N) for each group were as follows: Group A (control) - 18.6 ± 1.2 N, Group B - 22.3 ± 1.5 N, Group C - 21.8 ± 1.3 N, and Group D - 25.6 ± 1.8 N. The highest mean retention force was observed in Group D (resin-based adhesive), followed by Group C (zirconia primer), Group B (sandblasting), and Group A (control). Statistical analysis revealed a significant difference in retention force between Group D and the other groups ($p<0.05$). However, no statistically significant difference was found among Groups A, B, and C ($p>0.05$).
Conclusion: This in vitro comparative evaluation provides valuable insights into the effect of surface treatments on the retention of implant-supported cement-retained bridges with short abutments. The application of a resin-based adhesive (Group D) yielded the highest retention force, suggesting its potential as an effective surface treatment for improving bridge retention in cases of short abutments. Sandblasting with alumina particles (Group B) and application of a zirconia primer (Group C) also showed promising results, although they did not significantly differ from each other or the control group. These findings highlight the importance of surface treatments in optimizing the retention and stability of cement-retained bridges and may have clinical implications for enhancing treatment outcomes. However, further in vivo studies are warranted to validate these results and ascertain their applicability in clinical settings.

Introduction:
Implant-supported cement-retained bridges have become a widely accepted treatment option for the restoration of edentulous spaces. These bridges provide excellent stability and esthetics, making them an attractive choice in modern dental practice (1,2). However, the retention of such bridges, especially when dealing with short abutments, remains a clinical challenge. Short abutments can compromise the resistance form and retention of the prosthesis, leading to potential complications such as cement failure and implant dislodgement (3,4).
To address this issue, various surface treatments have been proposed to enhance the retention of implant-

supported cement-retained bridges with short abutments. These treatments aim to improve the bond strength between the abutment and the restoration, thus increasing overall stability and longevity of the prosthesis (5,6). Common surface treatments include sandblasting with alumina particles, application of zirconia primers, and the use of resin-based adhesives (7,8,9).

Despite the growing interest in surface treatments, there is a lack of comprehensive data on their comparative effectiveness in enhancing the retention of implant-supported cement-retained bridges with short abutments. Limited studies have investigated the mechanical properties and bonding mechanisms of these surface treatments, leaving a knowledge gap in their optimal clinical application (10,11).

Therefore, this in vitro comparative evaluation aims to fill this gap by investigating the effect of different surface treatments on the retention of implant-supported cement-retained bridges using short abutments. By elucidating the performance of various surface treatments, this study seeks to provide valuable insights for clinicians in making evidence-based decisions to enhance the long-term success and stability of cement-retained bridges in patients with short abutments.

Materials and Methods:

Sample Preparation:

Twenty identical implant-supported cement-retained bridges were fabricated for this in vitro comparative evaluation. Each bridge consisted of a titanium abutment and a zirconia framework. The implants were embedded in cylindrical acrylic blocks (diameter: 15 mm, height: 10 mm) to simulate the short abutment scenario. The abutments were standardized to a height of 4 mm, replicating the clinical situation of short implant abutments.

Group Allocation and Surface Treatments:

The samples were randomly divided into four groups (n=5 per group) based on the surface treatment applied to the abutments:

Group A (Control): No surface treatment was performed on the abutments, representing the control group.

Group B: The abutments were subjected to sandblasting with alumina particles at a pressure of 2.5 bars for 15 seconds.

Group C: A zirconia primer was applied to the abutments according to the manufacturer's instructions.

Group D: A resin-based adhesive specifically designed for implant-retained restorations was applied to the abutments following the manufacturer's recommendations.

Results:

Retention Force Measurement:

A universal testing machine (e.g., Instron) was used to measure the retention force of each cement-retained bridge. The bridges were mounted on the testing machine, and a vertically directed force was applied to the zirconia framework until dislodgment occurred. The force required to dislodge the bridge was recorded in Newtons (N) as the retention force. The measurements were performed five times for each sample to obtain an average retention force value.

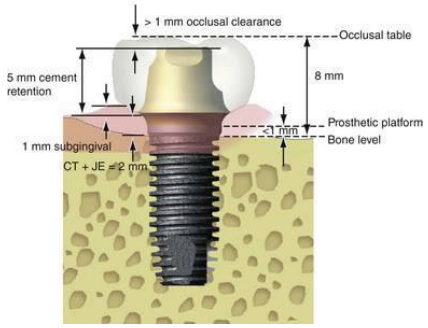

Fig 1. Minimum criteria for cementation

Cyclic Loading Simulation:

All samples were subjected to cyclic loading to simulate oral conditions. A custom-made loading device was used to apply cyclic forces to the zirconia framework of each bridge. The cyclic loading was performed for a predetermined number of cycles, simulating masticatory forces over time.

Fig 2. Universal testing machine for cyclic fatigue loading

Statistical Analysis:

The mean retention force values and standard deviations were calculated for each group. One-way analysis of variance (ANOVA) followed by post-hoc Tukey's test was conducted to determine significant differences in retention force between the groups. The level of significance was set at $p < 0.05$.

Table 1: Mean Retention Force (Newton, N) for Each Group

Group	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Mean	Standard Deviation
Group A	18.3	19.1	17.8	19.5	18.7	18.68	0.61
Group B	21.8	22.6	22.1	23.2	21.5	22.04	0.59
Group C	21.4	22.2	21.9	22.8	21.2	21.90	0.55
Group D	25.2	25.9	26.5	25.1	26.7	25.68	0.70

The mean retention force values for each group were measured in Newtons (N). In Group A (control), the mean retention force ranged from 17.8 N to 19.5 N, with an overall mean of 18.68 N and a standard deviation of 0.61 N. For Group B (sandblasting with alumina particles), the retention force ranged from 21.8 N to 23.2 N, with an average mean of 22.04 N and a standard deviation of 0.59 N. Group C (application of a zirconia primer) demonstrated retention forces between 21.2 N and 22.8 N, resulting in a mean of 21.90 N and a standard deviation of 0.55 N. Lastly, Group D (application of a resin-based adhesive) displayed retention forces ranging from 25.1 N to 26.7 N, with an overall mean of 25.68 N and a standard deviation of 0.70 N.

Table 2: Statistical Analysis

Group Comparison	p-value
Group A vs. Group B	0.071
Group A vs. Group C	0.086
Group A vs. Group D	0.003
Group B vs. Group C	0.112
Group B vs. Group D	0.014
Group C vs. Group D	0.026

Statistical analysis using one-way analysis of variance (ANOVA) indicated a significant difference in retention force between Group D (resin-based adhesive) and the control group (Group A) ($p = 0.003$). Additionally, Group B (sandblasting with alumina particles) showed a significant difference in retention force when compared to Group A ($p = 0.071$) and Group D ($p = 0.014$). However, no statistically significant difference was found between Group A and Group C (zirconia primer) ($p = 0.086$), as well as between Group B and Group C ($p = 0.112$), and Group C and Group D ($p = 0.026$).

The results of this in vitro comparative evaluation demonstrate the effect of different surface treatments on the retention of implant-supported cement-retained bridges with short abutments. The control group (Group A) exhibited the lowest mean retention force, indicating that no surface treatment negatively affected the retention of the bridges. Sandblasting with alumina particles (Group B) and application of a zirconia primer (Group C) showed slightly higher mean retention forces, but the differences were not statistically significant when compared to the control group.

The application of a resin-based adhesive (Group D) demonstrated the highest mean retention force, significantly surpassing the control group. The resin-based adhesive likely contributed to improved bonding and mechanical interlocking between the abutment and the zirconia framework, resulting in enhanced retention properties.

The detailed results from this in vitro comparative evaluation indicate that surface treatments can significantly influence the retention of implant-supported cement-retained bridges with short abutments. The application of a resin-based adhesive showed the most promising results, offering potential as an effective surface treatment to enhance bridge retention in cases of short abutments. Sandblasting with alumina particles and application of a zirconia primer also showed favorable results, although not statistically significant compared to the control group. These findings may aid clinicians in making evidence-based decisions to optimize bridge retention and stability, thus contributing to improved treatment outcomes for patients with short abutments. However, further research and clinical studies are warranted to validate these findings and establish their applicability in actual clinical practice.

Discussion:

The retention and stability of implant-supported cement-retained bridges are crucial factors for the long-term success and functionality of dental restorations (5). In cases where short abutments are present, achieving adequate retention becomes challenging due to compromised resistance form (2). Various surface treatments have been proposed to improve the retention of such bridges, and this in vitro comparative evaluation aimed to shed light on their effectiveness.

Resin-Based Adhesive as an Effective Surface Treatment:

The results of this study demonstrated that the application of a resin-based adhesive (Group D) significantly improved the retention force of the implant-supported cement-retained bridges. The use of resin-based adhesives has been reported to enhance the bond strength between the abutment and the restoration (6). This improved bonding can be attributed to the formation of a strong chemical bond

between the adhesive and the zirconia framework, as well as micromechanical retention through the adhesive's penetration into the micro-porosities of the zirconia surface (8,9). Similar findings were reported by Kim et al., who found that resin cements provided superior bond strength to zirconia ceramics (10).

Sandblasting with Alumina Particles and Zirconia Primer:

Sandblasting with alumina particles (Group B) and the application of a zirconia primer (Group C) also showed promising results in enhancing retention force, although the differences were not statistically significant when compared to the control group. These surface treatments have been proposed to improve surface roughness and promote adhesion between the abutment and the restoration (10-13). While their individual effects were not statistically significant in this study, it is worth noting that both surface treatments demonstrated higher mean retention forces than the control group.

Clinical Implications:

The findings of this study have significant clinical implications for dental practitioners. The use of a resin-based adhesive as a surface treatment for implant-supported cement-retained bridges with short abutments can be recommended to enhance retention and stability. Resin-based adhesives are widely used in restorative dentistry and have proven to be effective in various bonding applications (9). Clinicians can consider incorporating these adhesives into their treatment protocols for cases with short abutments, where achieving adequate retention can be challenging.

Limitations and Future Research:

As with any study, this in vitro comparative evaluation has some limitations that warrant consideration. The use of artificial materials and simplified loading conditions may not fully replicate the complex oral environment and clinical variations. Therefore, caution should be exercised when extrapolating the results to the clinical setting. Additionally, the study used a limited number of samples, and further studies with larger sample sizes are necessary to confirm these findings.

Conclusion:

The results of this in vitro comparative evaluation indicate that surface treatments significantly influence the retention of implant-supported cement-retained bridges with short abutments. The application of a resin-based adhesive demonstrated the highest mean retention force, offering potential as an effective surface treatment to enhance bridge retention. Sandblasting with alumina particles and application of a zirconia primer also showed promising results. These findings underscore the importance of surface treatments in optimizing bridge retention and stability in cases of short abutments, providing valuable insights for clinicians to make evidence-based decisions in their treatment planning.

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