Effect of Different Surface Treatments Applied to Short Zirconia and Titanium Abutments

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**Purpose:** The aim of this study was to compare the effect of different surface treatments applied to short titanium and zirconia abutments on the bond strength of single-unit zirconia crowns. **Materials and Methods:** Sixty titanium abutments were shortened to 3 mm in length, fixed to analogs, and embedded in acrylic blocks. Three-dimensional views of abutments were obtained by scanning; then, zirconia abutments and copings were produced. The samples, which included titanium (n = 60) and zirconia (n = 60) abutments, were divided into five different groups (n = 12), and surface treatments were carried out; 1.5-W and 3-W Er,Cr:YSGG laser treatment, Al2O3 sandblasting, and tribochemical silica coating were applied to the groups, and the control group had no surface treatment. Copings were cemented to the samples with self-adhesive resin cement. The samples were then subjected to the pull-out test, and the results were processed via statistical analysis. **Results:** There was a significant difference between the titanium and zirconia groups (P < .001). The mean bond strength values of the titanium samples were higher than those of the zirconia samples. The tribochemical silica coating gave a higher bond strength than the other treatments when applied to titanium abutments. For the zirconia abutments, the 1.5-W laser treatment, 3-W laser treatment, tribochemical silica coating, and Al2O3 sandblasting groups differed significantly from the control group; however, they were not significantly different from each other. **Conclusion:** The bond strength of zirconia crowns to short titanium and zirconia abutments increases with surface treatments. Furthermore, the surface treatments were more effective in increasing the bond strength for the titanium abutments than for the zirconia abutments. Int J Oral Maxillofac Implants 2020;35:948–954. doi: 10.11607/jomi.8224

**Keywords:** dental, implant, retention, short abutment, titanium, zirconia

Dental implants are nowadays included in routine treatment options in dentistry. In particular, in the case of single tooth loss, implant treatments have replaced traditional fixed partial dentures. Implant-supported crowns can be applied in the form of either screw-retained or cement-retained types. However, because of esthetic concerns, it may be necessary to use the cement-retained type instead of the screw-retained type in anterior region implant treatments with short abutments. Cement-retained abutments provide more flexibility in the positions and angles of the implants, while zirconia abutments provide better esthetic treatment results. Screw-retained restorations offer more mechanical complications, and they cannot be applied for each case.1 However, single-unit cement-retained restorations exhibit more frequent de-cementation problems, especially in the case of short crown length.

Researchers have studied various techniques to reduce the de-cementation of single-unit restorations. Nejatidanaesh et al2 applied several surface treatments inside the copings. Safari et al3 and Özarslan et al4 evaluated the bond strength of a single restoration by using different sizes of abutments and luting agents. Similarly, several researchers have studied the effects of abutment surface topography and abutment height on bonding strength.5,6 Several studies have investigated the effect of abutment surface treatments on bonding strength and have shown promising results. These treatments include Al2O3 sandblasting, tribochemical silica coating, and various laser applications.7–9 However, the bond strength values of zirconia and titanium abutments following surface roughening procedures have not previously been comparatively researched. Concerning esthetic purposes, zirconia abutments stand out as an alternative to titanium abutments. In this context, it is important to investigate how the length and diameter of the abutment, as well as the cement material, relate to crown retention, especially in single-unit restorations. The aim of the present study was to compare the effect of various surface treatments, applied to short
titanium and zirconia abutments, on bond strength of single-unit zirconia copings.

MATERIALS AND METHODS

In the present study, a total of 120 zirconia copings were prepared over 60 titanium and 60 zirconia abutments. Power analysis was performed to determine the sample size. The power analysis with 85% power, alpha of .05, and a 0.40 effect size resulted in a minimum sample size of 9. However, 12 samples for each group were prepared considering the potential for specimen loss and failure during the experiment.

Preparation of Titanium Abutments

Flat abutments of 1-mm gingival height, which are used for 4.2-mm diameters of implants (NucleOSS T4 Implants, Şanlılar), were used as implant abutments. Abutments were fixed to appropriate analogs to carry out laboratory processes and torqued at 20-Ncm strength. The height of each titanium abutment was reduced to 3 mm with a carbon steel disk. A guide ring (Wiron 99, BEGO) made from chrome-nickel alloy was used for the procedure. After the preparation of abutments was completed, including the occlusal surface, the abutments were thoroughly examined with a dental loupe at 2.5× zoom (SuperVu Galilean system, XL Advantage, Keeler). Abutments were carefully controlled in terms of straight edges and corners. Where irregularities were observed, corrections were applied to the sections using a carbon steel disk and silicone rubber polishing burs. The screw access channels of the titanium abutments were filled with gutta-percha (Fig 1).

Preparation of Zirconia Abutments

Y-TZP was used for the production of copings. Zirconia copings were produced using a CAD/CAM system in accordance with the titanium and zirconia abutments that were fixed to analogs. The sidewall thicknesses of the copings were prepared at 0.8 mm. In the CAD process, the amount of material allowed by the zirconia block was left in the occlusal part of the coping (5.5 mm) such that steel wire could be passed to connect the coping to the upper part of the tester (Fig 2). Following the design of the 3D models, the zirconia blocks were subjected to the CAM procedure. All the abutments were drilled with a 1.5-mm-diameter drill hole for the connection of a universal pull-test device (Fig 1). The samples were sintered in a sintering furnace at 1,500°C for 8 hours according to the manufacturer’s recommendations. The inner surface of the crowns was then air-dried.

Surface Treatment Process

All abutments were embedded in acrylic pulp (Paladent, Heraeus Kulzer) that was filled into cylindrical PVC rings with the long axis perpendicular to the horizontal plane. The PVC rings were removed from the samples after the hardening process. The zirconia and titanium abutments were divided into 5 groups containing 12 samples each according to the surface treatment to be applied:

- Control groups: No surface procedures were carried out.
- 1.5-W laser treatment groups: Er,Cr:YSGG laser was applied at a distance of 1 mm with a frequency
of 1.5 W at 20-Hz frequency and 80% air and 25% water for 30 seconds.

- 3-W laser-treatment groups: Er,Cr: YSGG laser was applied for 30 seconds at a distance of 1 mm with a frequency of 3 W at 20-Hz frequency and 80% air and 25% water.

- Al₂O₃ sandblasting groups: The bonding surfaces of the abutments were blasted with Al₂O₃ particles for 10 seconds at a distance of 10 mm (Ney, Blastmate II). Next, the samples were washed and air-dried.

- Tribochemical silica coating groups: The tribochemical silica coating device (CoJet Silicate Ceramic Surface Treatment System, 3M ESPE) was filled with 30 μm SiOₓ sand (CoJet Sand, 3M ESPE) and sandblasted to abutments at 2.5 bar pressure for 10 seconds at a distance of 10 mm. Then, the residues were removed by air spray.

Before cementation, all samples and copings were cleaned in a bath containing 96% isopropyl alcohol for 5 minutes and dried with oil-free air.

Cementation Process

The entire cementation procedure was performed by only one operator (N.T.). Abutments and zirconia copings of all the samples were again dried via air for 15 seconds before each coping cementation. A dual-cure self-adhesive resin cement (RelyX U200, 3M ESPE) was used to cement the copings. Cement was placed in the copings and dispersed using a probe tip around the inner walls except in the occlusal part of the copings. After the copings were placed on the abutments, finger pressure was applied for 2 minutes. After cementation, the excess cement was removed with a probe tip. Then, if there was any residue, it was examined by using a dental loop, and the remaining residue was removed. Samples were kept for 24 hours before the bond strength test.

Measuring Bond Strength

For bond strength, each sample was compressed from the acrylic portions into the lower part of the tester. To connect the zirconia copings to the tester, a 0.9-mm-diameter steel orthodontic full round wire (Leowire Fiorentina) was used. The pull-out force was applied to samples at 0.5 mm/min crosshead speed in the test device (Model AG-50 kN, Shimadzu) until separation occurred between the zirconia copings and the abutments (Fig 3). The maximum force values that separated the zirconia copings from the abutments were recorded in Newton (N) units. After testing, the surfaces of the abutments were examined under a stereomicroscope (SZH10, Olympus), and failure types were recorded. Failure type detection was performed according to the following criteria:

1. Adhesive failure was determined if less than 25% of the cement material was on the abutment surface.
2. Cohesive failure was determined if more than 75% of the cement material was on the abutment surface.
3. It was accepted as a mixed (adhesive/cohesive) failure if less cement material remained on the abutment surface than in cohesive failure but more than in adhesive failure.¹⁰

Statistical Analysis

Statistical analysis was performed using the SAS 9.4 v3 (SAS Institute). The data were analyzed using two-way analysis of variance (ANOVA) with Duncan’s multiple comparison test. First, the Levene test was used to assess the homogeneity of variances, which is a precondition for parametric tests, and the Shapiro-Wilk test was used to verify normality. A P value < .05 was considered to be statistically significant.
RESULTS

When the results of the variance analysis were examined, the main effects of titanium and zirconia groups ($P < .0001$), surface treatment types ($P < .0001$), and the interaction term of titanium, zirconia, and surface treatment types ($P = .0343$) were found to be statistically significant. Table 1 shows the mean values and SDs. Regardless of surface treatments, a significant difference was noted between the titanium and zirconia groups ($P < .001$). The mean bond strength values of the titanium samples were higher than those of the zirconia samples. The tribochemical silica coating group displayed a higher mean bond strength than the others on titanium abutments. However, no significant difference was observed among the titanium abutment groups that received tribochemical silica coating, $\text{Al}_2\text{O}_3$ sandblasting, or 1.5-W laser treatment. The bond strengths of the titanium groups that received tribochemical silica coating, $\text{Al}_2\text{O}_3$ sandblasting, or 1.5-W laser treatment were significantly different from the bond strengths of the titanium control group and 3-W laser treatment group. For the zirconia samples, all four treatment groups significantly differed from the control group, but the treatment groups were not statistically different from each other (Table 1).

![Fig 4](failure_mode_distribution.png) Failure mode distribution of titanium and zirconium groups.

![Fig 5](failure_types.png) Failure types of titanium (a to c) and zirconia (d to f) samples.

Table 1  Mean ± SD Values of Bond Strength (in N)

<table>
<thead>
<tr>
<th>Surface treatment</th>
<th>Abutment material</th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Titanium</td>
<td>Zirconia</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>114.34 ± 24.29c</td>
<td>110.90 ± 14.81b</td>
<td></td>
</tr>
<tr>
<td>1.5 W laser</td>
<td>189.3 ± 37.51d/a</td>
<td>156.52 ± 26.15a</td>
<td></td>
</tr>
<tr>
<td>3 W laser</td>
<td>171.62 ± 40.22b</td>
<td>162.50 ± 43.63a</td>
<td></td>
</tr>
<tr>
<td>$\text{Al}_2\text{O}_3$ sandblasting</td>
<td>205.72 ± 61.19b/a</td>
<td>137.48 ± 30.82b/a</td>
<td></td>
</tr>
<tr>
<td>Tribochemical silica coating</td>
<td>236.49 ± 98.64a</td>
<td>155.82 ± 75.79a</td>
<td></td>
</tr>
</tbody>
</table>

- **Significance AM**: abutment material effect; **ST**: surface treatment effect; **AMxST**: abutment material and surface treatment interaction effect.
- For each column, values with the same lowercase letters indicate no statistically significant differences ($P > .05$).
- *Significant at $P < .001$ and **Significant at $P < .05$, respectively.
Failure mode distribution is shown in Fig 4. The most common type of failure was a mixed-type failure in both abutment types. Moreover, cohesive-type failure was more common in titanium abutments than in zirconia abutments (Fig 5).

DISCUSSION

The dental literature has proved widely that dental implant rehabilitations have a high success rate.\textsuperscript{11–13} One potential problem is the lack of interarch distance for prosthetic rehabilitation in the area where the implant treatment is planned. While the use of short abutments can solve the difficulty, this choice may lead to retention problems. For short abutments, a screw-retained superstructure is among the preferred choices. However, it is not possible to apply this option in cases where appearance is important; a screw access channel can cause esthetic problems. In such cases where the use of cement-retained short abutment restorations is mandatory, methods should be applied to strengthen the connection between the abutment and the coping.

Maintaining the retention and integrity of the restoration is vital for the success of implant treatments. In restorations of the anterior region, esthetics and retention are primary concerns. Dental implants and abutments are usually made of titanium because of its proven biocompatibility and mechanical properties. However, although many modifications have been made in the production and design of metal abutments, one disadvantage is the appearance of metallic components. For example, the opaque grayish background can cause an unnatural bluish appearance of the soft tissue.\textsuperscript{14} Consequently, ceramic abutments have been developed to achieve optimal mucogingival esthetics. Zirconia-based abutments, which are increasingly used among ceramic abutments, are preferred because of their tendency toward less plaque deposition and successful soft tissue compatibility. The use of computer-aided procedures, especially during the construction phase, not only facilitates the reduction of laboratory-related errors but also allows for the creation of prostheses that are highly compatible with peri-implant hard and soft tissues.\textsuperscript{15,16} Nowadays, zirconia abutments and restorations are in common use.\textsuperscript{17,18} However, the retention of zirconia to resin cement and different surfaces remains an issue of significance.

Many factors, such as abutment height and preparation geometry, surface area and surface roughness, abutment material, and cementing agent, affect the retention of prosthetic restorations.\textsuperscript{5,19,20} However, the effect of different surface treatments on the bond strength of physical abutments manufactured by a company has not been investigated sufficiently, and titanium and zirconia abutments have not been compared in terms of bond strength. Realistic results can be obtained from in vitro studies to the extent that they mimic the clinical setting. Many studies that have evaluated the effects of surface treatments on retention have used disk or prism samples rather than implant or titanium abutments, which have clinical geometry.\textsuperscript{21–23} In this respect, the present study, which investigates the bond strength of zirconia copings on titanium and zirconia abutments, is unique.

In previous studies, the insertion force applied during the cementation process varied from 750 g to 10 kg.\textsuperscript{7,24–27} Abbo et al\textsuperscript{28} conducted cementation under finger pressure. In clinical use, especially within the incisors, restorations are cemented under finger pressure. Thus, finger pressure was preferred in the present study for one-to-one imitation of a clinical setting.

A standard test method for determining the retention resistance of crowns to abutments has not yet been established.\textsuperscript{29} In practical terms, functional teeth are subjected to vertical and lateral forces. The tensile force generated during the consumption of especially sticky foods is an important factor in the de-cementation of crowns. In the literature, the vertical pull-out test is commonly used to evaluate retention in single crowns cemented to implants.\textsuperscript{2,30,31} In the present study, to provide a comparison with previous studies, the vertical pull-out test was used to evaluate retention.

It has been reported that surface roughening applied to abutments is important for stronger retention.\textsuperscript{32} Accordingly, the tribochemical silica coating system is a practical method that dentists can use to increase retention.\textsuperscript{33} Kappel et al\textsuperscript{34} reported that the treatment of abutments with 50 μm Al₂O₃ increases the retention of copings. Various studies have also shown that laser applications on the abutment surface increase restoration retention.\textsuperscript{9,31} The results obtained in the present study support previous studies in that surface treatments increased the bond strength of zirconia copings to titanium and zirconia abutments.

In the present study, higher bond strength values were observed in titanium abutments. This may be because the hardness values of the zirconia material are higher than that of the titanium material, and therefore, surface treatments have less effect on the zirconia surface. Titanium abutment preference promises to be more advantageous in terms of retention when the distance between the arcs is low and a short abutment is required. In such cases in the anterior region, the superior esthetics of a zirconia abutment versus the retention advantage provided by a titanium abutment should be thoroughly evaluated. While zirconia abutments are preferred in individuals with high smile lines, titanium abutments may be preferred by compromising gingival esthetics in individuals with low smile lines.
interarch distance, the use of tribochemical silica coating to titanium abutments. In the presence of a diminished effect treatment prognosis. The authors reported no conflicts of interest related to this study.

CONCLUSIONS

Within the limits of this study, the following may be concluded. The bond strength between zirconia copings and titanium and zirconia abutments using resin cement increases with surface treatment. All of the investigated surface treatment methods positively affected the bond strength for both the titanium and zirconia abutments. The surface treatments applied in this study are more effective on titanium abutments than on zirconia abutments.

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REFERENCES


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