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RESEARCH AND EDUCATION

Comparison of the effects of cement removal from zirconia and titanium abutments: An in vitro study

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ABSTRACT

Statement of problem. Excess cement around dental implants is a significant cause of peri-implant inflammation. Research has focused on approaches to cement removal, the type of cement used, and the different instruments used for cement removal with titanium abutments. However, data comparing zirconia with titanium abutments are lacking.

Purpose. The purpose of this in vitro study was to compare the effectiveness of excess cement removal from zirconia and titanium custom abutments using an explorer and to compare the effects of cement removal on the abutment surfaces.

Material and methods. Implant analogs were placed in a cast in the position of the 2 maxillary central incisors. After creating similar emergence profiles for both the implant abutments, 18 zirconia and titanium custom abutments were fabricated with 1-mm subgingival finish lines on the facial and interproximal areas and an equigingival finish line on the palatal side. The crowns were cemented with zinc oxide-eugenol cement, and a steel explorer was used to remove the excess cement. All abutments were analyzed under a scanning electron microscope for cement remnants and scratches.

Results. The mean surface area of cement remnants on the zirconia abutments was 778 ±113 μm^2, and for titanium abutments, it was 1123 ±252 μm^2, which in terms of the mean percentage area was 3.27% of the total surface area of zirconia and 4.71% of titanium abutments. Only a few abutments from each group showed scratches, and no deep scratches or gouges were observed.

Conclusions. Zirconia and titanium abutments had statistically similar cement remnants. Scratches were observed on only a few specimens. (J Prosthet Dent 2019;121:504-9)

With the growing emphasis on esthetics and advances in dental technology, zirconia has been widely adopted as an esthetic alternative to other dental materials. Its use improves esthetics in the anterior maxilla, especially when a patient has a thin gingival biotype. Unlike titanium, zirconia does not give a dark or grayish hue to the marginal gingiva and harbors less plaque, resulting in better gingival esthetics.[1-6] Histologically, fewer leukocytes have been observed in the barrier epithelium at zirconia abutments than in titanium and cast-to gold abutments. This observation indicates that zirconia provides appropriate conditions for epithelial attachment to establish a proper mucosal seal and may lead to faster healing of peri-implant soft tissues.[3,5] The popularity of zirconia abutments has increased with increased material strength and the development of titanium inserts to address the concern of fracture associated with zirconia abutments.[7-11] A 4-year retrospective clinical study of 54 zirconia abutments for single crowns in the anterior region showed no structural failure and good peri-implant tissue health.[8,9] Similar survival rates have been found for zirconia and titanium abutments in posterior regions and after 5 years in function.[10,11] The angulation of bone in the anterior maxilla restricts implant placement with ideal

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Clinical Implications

The interproximal areas may have more cement remnants than the facial or lingual areas, and with careful instrumentation, surface scratches can be minimized.

angulation for screw-retained crowns. In such circumstances, a cement-retained crown is required. Considering that the surface hardness of zirconia (1681 Hv)[12] is 5 times greater than that of Type V titanium alloy (maximum approximately 340 Hv)[13] and cement adhesion is less than that of titanium, it may be the material of choice for cement-retained implant-supported crowns.[14,15]

Various techniques for cementing implant crowns have been studied, with the focus directed toward the amount of excess cement expressed into the gingival sulcus around an implant abutment.[16] Remnants of dental cement can lead to peri-implantitis[17]; thus, excess cement must be removed. Linkevicius et al[18] reported that the greatest amount of undetected cement was found when the margins were more than 2 mm subgingival and least when supragingival. Hence, the margins on abutments should be supragingival or equigingival whenever possible to aid cement removal, and an instrument must be used to remove excess cement.[17] Various instruments have been studied for their efficiency in cement removal and their effect on the surface of titanium abutments.[19-22]

With advances in dental materials, the use of zirconia abutments has increased. A recent survey of prosthodontists of the American College of Prosthodontists and the American Academy of Maxillofacial Prosthodontists revealed that custom-milled ceramic abutments were preferred by 53% of prosthodontists for highly esthetic areas.[23] However, studies on the ability to clean dental cement from the surface of zirconia abutments and the effect of different instruments on the surface characteristics of zirconia are lacking. Therefore, the null hypothesis of this in vitro study was that no difference would be found between the zirconia and titanium abutments after cement removal.

MATERIAL AND METHODS

A dentate maxillary cast was used to simulate implant placement in the area of the maxillary central incisor. The maxillary central incisors were trimmed to the cervical margin, ending in an ovate recess approximately 3 mm apical to the cementoenamel junction (CEJ) of the adjacent teeth. A hand-milling unit (AF30; Nouvag AG) was then used to place the implant analogs precisely in the site of the 2 central incisors. The gingival profile for the abutments was fabricated in wax, and a silicone device

Figure 1. Definitive cast.

was fabricated for the emergence profile of the right maxillary central incisor. This device was then used to make a similar emergence profile for the left maxillary central incisor implant abutment. This ensured that both abutments had similar emergence profiles.

An open tray polyvinyl siloxane (PVS) impression (Aquasil Ultra; Dentsply Sirona) was made of the implants, and a silicone gingival replication material (GI-Mask; Coltène) was placed around the impression copings before pouring the impression in Type III dental stone (Microstone; Whip Mix Corp). The silicone material replicated the gingival profile and acted as a substitute for gingiva on the cast (Fig. 1).

The cast was then scanned, and custom abutments were designed with computer-aided design (CAD) and fabricated in titanium and zirconia for each implant such that the finish line was 1 mm subgingival on the facial and interproximal aspects and gradually transitioned to equigingival on the palatal aspect (Figs. 2 and 3). During the CAD process of the custom abutment, a space of 200 μm was incorporated between the silicone gingival replication material and the abutment. This space permitted a limited flow of excess cement around the abutments for this study. Computer-aided design and computer-aided manufacture (CAD-CAM) acrylic resin (Telio CAD; Ivoclar Vivadent AG) crowns were fabricated to a standardized cement thickness. Because the study's focus was on removing excess cement from the abutment surface, the crown material was not considered relevant. The crowns were cemented on the titanium and zirconia abutments with interim zinc oxide-eugenol cement (Temp-Bond; Kerr Corp).[24] An equal amount of cement was mixed, and crowns were half filled with cement to ensure excess. Each crown was individually seated with firm finger pressure. One crown was seated at a time while the other crown was in place. The cement was allowed to set for 4 minutes, following the manufacturer instructions (Fig. 4).

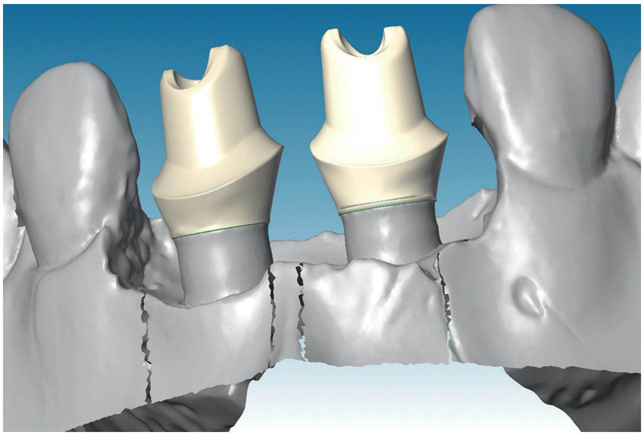


Figure 2. Computer-aided design of custom abutments.

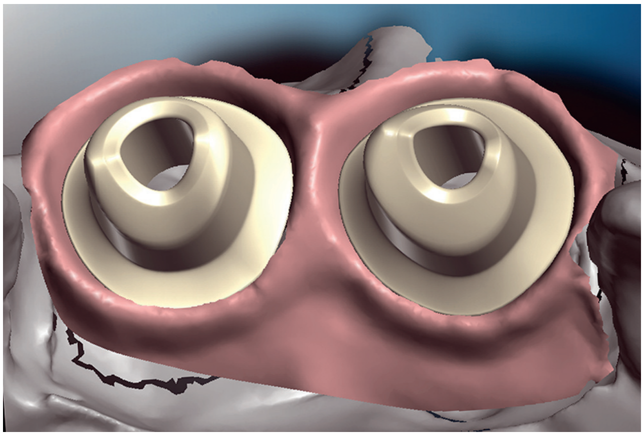


Figure 3. Finish line placement.

Once the cement had set, excess cement on each abutment was removed by one of the investigators (A.D.) using an explorer (3CH Cowhorn; Hu-Friedy). A maximum time of 4 minutes was allowed to remove cement from each abutment. Once the operator had finished removing the excess cement, a hole corresponding to the position of screw access was drilled on the palatal surface of each crown to retrieve the abutment.

After cement removal, the abutments were evaluated with a scanning electron microscope (SEM) (EVO 18; Zeiss). SEM analysis of the abutments before cementation was also performed to act as a control for comparison with the SEM results after cement removal. The image analysis software Image J (National Institutes of Health) was used to record the number and area of cement remnants. The image analysis was performed by another investigator outside the field of dentistry and unaware of the study design to prevent any bias. The software was used to measure the area of each abutment surface and the total area covered by cement remnants.

After SEM analysis, 3 profilometer (Surftest SV-2100; Mitutoyo) readings were made on each surface (buccal, mesial, palatal, and distal), which gave a total of 216 measurements. These were used to calculate the mean surface roughness of both abutments and were expressed as Ra values. The Kolmogorov-Smirnov and Shapiro-Wilk tests were carried out for statistical analysis (α=.05).

RESULTS

SEM images of the abutments before cementation showed a smooth surface for both zirconia and titanium abutments. The SEM images after cement removal showed varying amounts of cement remnants on both zirconia and titanium abutments (Fig. 5). The mean surface area ±standard deviation covered by cement remnants was 778 ±113 μm^2 for zirconia abutments and 1123 ±252 μm^2 for titanium abutments (Fig. 6). The mean percentage area covered by cement remnants was 3.27% for zirconia abutments and 4.71% for titanium abutments. The results from profilometer testing showed that zirconia abutments had an overall rougher surface than titanium with a mean Ra value of 0.20 µm for zirconia and 0.11 µm for titanium.

Figure 4. Excess cement after cementation of interim crowns.

Most of the cement remnants were located in the interproximal areas for both abutment types. Scratches were noticed on only a few abutments. When present, the scratches were shallow, and no deep scratches or gouges were observed on any of the abutments. Unlike cement remnants, the scratches were observed more on the facial and palatal surfaces.

The Kolmogorov-Smirnov and Shapiro-Wilk tests were carried out to test the normality assumption. Data from both the groups failed to have normal distribution. The boxplots depicted in Figure 6 do not show obvious deviation in dispersion between the 2 groups. Therefore, the Mann-Whitney U test was used to compare the surface area between zirconia and titanium abutments.

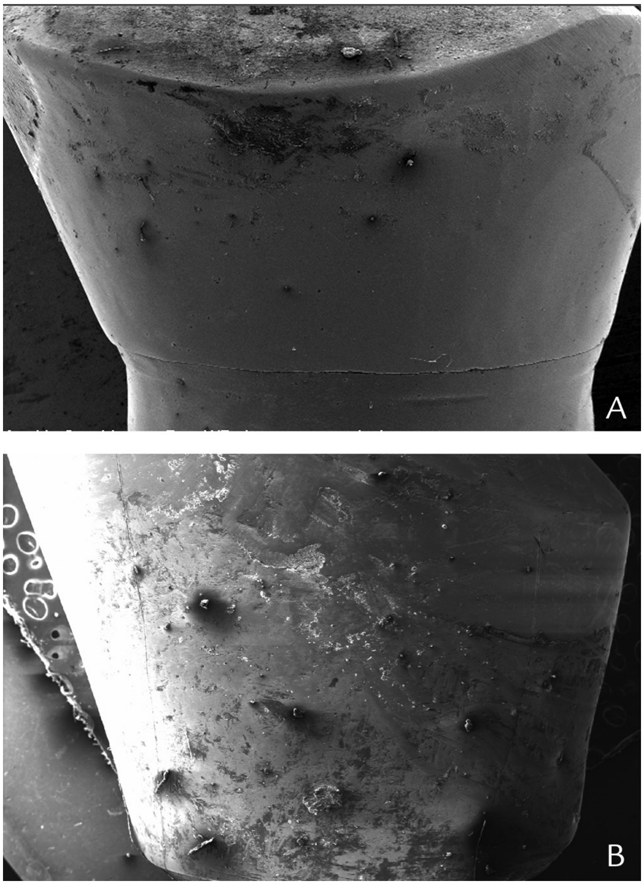


Figure 5. Scanning electron microscope images after removal of excess cement at original magnification of ×25. A, Zirconia abutment. B. Titanium abutment.

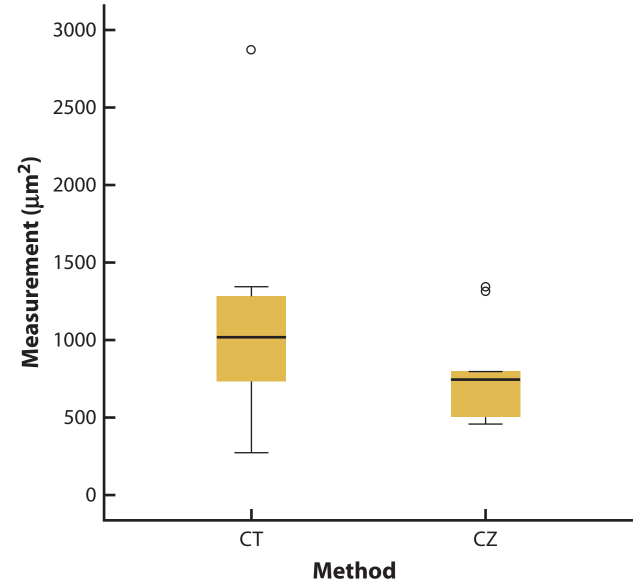
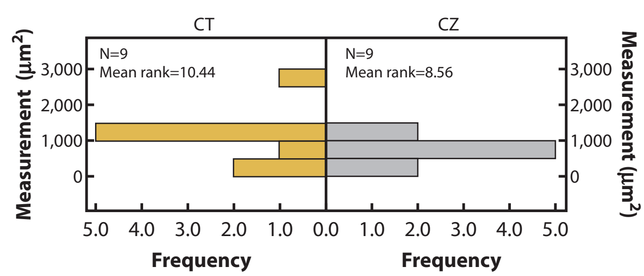


Figure 6. Cement remnants (μm²) on zirconia (CZ) and titanium (CT) abutments.



Total N	18
Mann-Whitney U	32.000
Wilcoxon W	77.000
Test statistic	32.000
Standard error	11.325
Standardized test statistic	–.751
Asymptotic Sig. (2-sided test)	.453
Exact Sig. (2-sided test)	.489

Figure 7. Mann-Whitney *U* test. CT, titanium; CZ, zirconia.

The *P* value of .45 for the Mann-Whitney U test indicated that the differences between zirconia and titanium abutments in terms of cement remnants were not statistically significant (Fig. 7). Power analysis was conducted to estimate the sample size needed to achieve significance. We assumed that the surface area covered by cement remnants follows exponential distribution. Based on the observed medians, the scale parameter of exponential distribution was estimated to be 1443 and 1082 for zirconia and titanium abutments, respectively. The 2-sided Mann-Whitney U test was used to compare values between the 2 groups. At the 5% significance level, the size of 255 per group would have provided a power of 80% for detecting a significant shift in location for the cement surface area between zirconia and titanium abutments.

DISCUSSION

No statistical difference was found between cement remnants on zirconia and titanium abutments, and so the null hypothesis was accepted. A study by Agar et al[22] compared the surfaces of titanium abutments after removal of excess cement using different instruments. Multiple scratches and deep notches were produced on the titanium surface, and cement remnants were left behind.[22] Cement remnants adversely affect the periodontium and lead to unesthetic inflamed gingival tissues.[6,22] In this study, excess cement was also left behind on abutments in varying amounts. Most cements have poor bond strength to zirconia unless certain surface modifications are completed, and methods to improve cement bond strength to zirconia have been published.[14,15] Thus, in the event of no surface modification to zirconia abutments, it was presumed that it would be easier to remove excess cement from the zirconia surface. Indeed, the zirconia abutments in this study showed fewer cement remnants than the titanium abutments, which can be attributed to zirconia's surface free energy that is less than titanium (18.50 erg/cm^2 versus 26.62 erg/cm^2).[25] For all abutments, excess cement was removed to the investigator's satisfaction, but the presence of excess cement on the abutments was surprising. Similar findings were reported by Agar et al,[22] where investigators thought they had removed all excess cement but were surprised to find how much cement was left behind on the abutments. Thus, cement that is radiopaque should be used, even in thin films.

Zinc-containing cements are radiopaque, making it easier to identify excess cement on an intraoral radiograph.[24] However, only interproximal cement can be identified on a radiograph, which is where most of the excess cement was found in this study. Any excess cement on the facial or palatal/lingual surface can be a challenge to identify and successfully remove. The zinc oxide-eugenol cement used in this study was interim cement with high solubility in oral fluids, and any excess cement might be expected to dissolve over time.[26] However, how much time the process would take is unclear. Many interim resin cements have been reported to be either nonradiopaque or visible in radiographic imaging in a thickness of at least 2 mm, and thus they were not selected for this study.[24]

The biologic and mechanical properties of titanium, in addition to its long and well-documented history of clinical use, have encouraged clinicians to use it when fabricating an implant abutment for a cement-retained crown. Recently, the growing esthetic demands for restoring anterior implants have increased the use of zirconia abutments. Titanium can lead to an unesthetic grayish appearance of the gingival margin when the gingival thickness is 2 mm or less.[1] Conversely, zirconia does not cause any significant color change and thus provides better esthetic results.[2]

The effect of different scalers on the surface finish of titanium and zirconia abutments has been evaluated.[19,20] The use of titanium or stainless-steel curettes on titanium produced surface roughness, and cuts or gouges may also adversely affect the adhesion of fibroblasts because of surface contamination. The same study also reported that titanium curettes caused more surface roughness than steel or plastic curettes, and so titanium curettes were not used in this study.[19,20] Another study comparing the effects of different instruments on zirconia surfaces reported that a stainless-steel scaler caused the least alteration on the zirconia surface.[21] Considering that a stainless-steel explorer would be readily available in every dental practice, a decision was made to use this instrument in the study. However, while removing the excess cement, care was taken to use the side of the instrument with minimal use of its tip. The effect of this technique was seen in the results; scratches were found on only a few abutments, and no deep scratches or gouges were found on any abutment. Hence, it was decided to use a profilometer to study the surface roughness of abutments.

Though the mean surface roughness of zirconia was at the threshold level of 0.20 μm, few zirconia abutments had a surface roughness well above 0.20 μm. The higher roughness of zirconia was found to be related to the presence of grooves from milling. Machined surfaces exhibit extensive microcracking as well as some grain refinement within machined grooves.[27] A recent study reported both direct and indirect evidence of residual subsurface cracks related to machining.[28] Grinding zirconia with fine diamond rotary instruments and fine polishing the zirconia to a mirror finish successfully eliminates the thin layer of the monoclinic phase and compressive stresses and, given the grain pullout and formation of microcraters, may not fully remove deep defects. This in turn can make the zirconia more sensitive to low-temperature degradation.[27] Other recommendations include refiring the zirconia after grinding to reverse the phase transformation.[27] However, research is necessary to find the long-term effects on zirconia abutment strength and performance after these interventions.

Limitations of the study include a small sample size and few tested variables, and the model may not accurately represent the clinical situation. The zirconia abutments had less remnant cement than the titanium abutments, but a small sample size meant low power. Thus, future studies with a higher sample size need to be carried out to identify any significant differences.

CONCLUSIONS

Within the limitations of this in vitro study, the following conclusions were drawn:

1. Zirconia and titanium abutments had statistically similar cement remnants.
2. Zirconia could be a scratch-resistant abutment option for cement-retained crowns.

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