Soft tissue esthetics is one of the ongoing challenges in implant dentistry. Zirconia dental implant abutments improve the gingival discoloration that occurs when titanium abutments are used for patients with thin soft tissue.\(^1\)\(^-\)\(^3\) However, some clinical concerns are associated with the use of zirconia implant abutments. These include zirconia fracture and wear of the titanium implant body at the zirconia interface.\(^4\)\(^-\)\(^10\)

Wear of the implant body at the abutment interface has been compared for titanium and zirconia 1-piece abutments after various intervals of cyclic loading in vitro\(^4\) and quantified with scanning electron microscopy and image analysis software. Implants paired with zirconia abutments experienced a greater initial rate of wear and more overall wear than implants with titanium abutments.\(^4\) The findings of this pilot study were corroborated by a recent in vitro study comparing the maximum interface of implants connected to titanium and zirconium abutments.\(^11\) After cyclic loading, SEM images of implant interface areas were made and analyzed with inspection software. The maximum wear for implants coupled with zirconia was 10.2 \(\mu m\) and 0.7 \(\mu m\) for those coupled with titanium abutments. This difference was statistically significant.\(^11\)

Zirconia abutments are now designed with titanium cores or inserts to achieve a titanium to titanium interface.
Clinical Implications

The results of this study suggest that using zirconia abutments with titanium elements may be preferable to using 1-piece zirconia abutments for the tested internal hexagon tapered implant.

interface. Implant interface wear has not been compared for zirconia 1-piece abutments and zirconia abutments with titanium inserts. However, in vitro fatigue testing showed that zirconia implant abutments attached to a titanium core had greater fracture strength than 1-piece zirconia abutments for at least 1 implant system.5

In addition, mean fracture strengths were measured and compared for 3 abutment types: conventional titanium, ceramic alumina, and zirconia sintered onto a titanium insert for an external hexagon Osseotite implant (Biomet 3i).12 Among these 3 abutments, fracture strength was highest for the titanium abutment. However, the fracture strength of the zirconia abutment with the titanium insert was not statistically different from that of the titanium abutment. The ceramic alumina abutment had significantly lower fracture resistance than either of the other 2 abutments.12 The authors recommended using the zirconia abutment with a titanium insert as an aesthetic alternative for anterior single implants.

The abutment connection also influences the fracture resistance of zirconia abutments.2 A comparison of zirconia abutments for internal and external connections, with and without metal inserts, revealed better strength for internal connections with a secondary metallic component. Internally connected 1-piece zirconia abutments were the weakest in this in vitro study.2

Diameter has also been shown to play a role in the survival of zirconia abutments.13 Rotational fatigue testing of ceramic abutments for 4 implant systems revealed no statistically significant difference among implant systems. However, statistically significant differences were found for implant diameter. It was concluded that narrow and regular diameter systems posed a greater risk of fatigue failure than wide diameter systems.13

Recent evidence has shown that the fit accuracy of zirconium abutments is related to fracture resistance.14 Decreasing the microgap size at the implant to abutment interface improved the fracture resistance of zirconia abutments in vitro, which may have been due to a subsequent reduction in micromotion.14

Implant angulation is another factor that has affected the fracture resistance of zirconia in vitro.15 For this study, abutments were custom milled from monolithic zirconia to restore implants placed at different apical positions or angles to the direction of occlusal force.

Tilting the implant apex 20 degrees in the lingual direction significantly decreased the fracture resistance of zirconia abutments customized to correct the angulation compared with non-angled zirconia abutments placed on ideally placed implants.15

The fracture resistance of zirconia is influenced by many factors. Abutment selection is 1 of the controllable factors. With several abutment options available to restore any 1 implant system, knowing whether they all perform equally with regard to fracture resistance would be helpful. This study aimed to compare the fracture resistance of 5 zirconia abutments for the tapered screw-vent implant (Zimmer Dental) featuring an internal hexagon implant. The null hypothesis was that no difference in load to fracture would be found for the 5 abutments tested.

MATERIAL AND METHODS

Five different zirconia abutments (n=3 per group) were selected for load to fracture tests. Of the 5 implant abutments, 3 were anatomic-contour zirconia: Atlantis (ATL) (Dentsply Implants), Inclusive (INC) (Glidewell Laboratories), and Astra Tech ZirDesign (ATZD) (Dentsply Implants). Two of the abutments were zirconia with titanium elements: the Legacy Straight Contoured abutment (LSC) (Implant Direct) features a titanium hexagon and core luted to the zirconia superstructure, and the Zimmer Zirconia Contour (ZC) (Zimmer Dental) has a titanium ring that is press-fit onto the zirconia abutment (Table 1). An abutment design was completed, and all custom abutments were milled in this design by the same computer-aided manufacturing (CAM) machine. Five implants (1 implant per abutment group) 4.1 mm in diameter and 11.5 mm in length (Ti-6Al-4V alloy, Zimmer TSV; Zimmer Dental) were attached to a metal fixture mount at a 30-degree angle. All abutments were tightened onto their respective implants to 30 Ncm with a torque driver (Zimmer Dental) and loaded until the screw or the abutment fractured. A universal testing machine was used to apply the load (Instron 132; Instron Corp) with a ±2 N load measurement resolution. Acrylic resin copings were prepared for the abutments to evenly distribute the load on the coronal portion of the abutments. Testing was repeated 3 times for each abutment type. The mode of failure was also documented photographically (EOS Rebel T3; Canon Inc).

The term “failure” referred to either the fracture of the coronal portion, the apical portion, or the connection of these 2 different portions and/or retentive screws. The load to failure of any these parts was recorded using software (Statistical Analysis System; SAS Institute Inc). Data were compared by using ANOVA with a Tukey-Kramer post hoc test (α=.05).16
RESULTS

The analysis of variance of the force to failure data demonstrated a significant variance (F ratio=284.7, degrees of freedom [numerator/denominator]=4/10, and \( P < .001 \)) among the means of the load to failure of the 5 abutments, and every pairwise difference was statistically significant (\( P = .024 \)). Zirconia abutments with titanium elements demonstrated a greater fracture resistance than the 1-piece zirconia abutments. This difference was statistically significant (\( P < .05 \)) (Fig. 1). Two zirconia abutments, the LSC abutment and the ZC, required significantly more load to fracture than the ATZD or the INC custom zirconia abutment. The average load to fracture for the 3 anatomic-contour zirconia abutments was 275 N. The 2 zirconia abutments with titanium components had a combined average load to fracture of 842 N. The load to fracture of zirconia abutments with titanium components was found to be significantly higher than that of anatomic-contour zirconia abutments (\( P < .05 \)). The anatomic-contour and zirconia abutment (ATZD, INC, ATL) with a press-fit titanium ring (ZC) had fracture of the zirconia hexagon or coronal abutment. Two stock abutments (ATZD, and ZC) and 1 custom abutment (ATL) had fractures of the zirconia hexagon, and a custom anatomic-contour zirconia abutment (INC) had a fracture of its coronal portion. The zirconia abutment with titanium core-hexagon (LSC) had no zirconia or titanium core fractures, but only screw fracture (Table 2, Figs. 1, 2).

DISCUSSION

The null hypothesis that all abutments would have similar load to fracture values was rejected with multiple abutments varying significantly from each other (\( P < .05 \)). The current findings agree with previous studies comparing 1-piece zirconia abutments with zirconia abutments with titanium inserts.\(^5\) Stimmelmayr et al\(^5\) found an average fracture resistance of 526 N for 1-piece zirconia abutments fabricated with computer-aided design/computer-aided manufacturing (CAD/CAM), specifically for the 3.75-mm diameter implants tested. This same group reported an average fracture resistance of 1241 N for zirconia abutments made with CAD/CAM and then attached to titanium cores.\(^5\) Statistically significant differences in fracture strength for full zirconia and zirconia with a titanium core abutments were found for a 3.75-mm diameter and a 5.5-mm diameter implant.\(^5\) For the present study, 1 of the 3 anatomic-contour zirconia abutments was fabricated with CAD/CAM (ATL) and had an average fracture resistance of 465 N. The zirconia abutment with the titanium core (LSC) in the current study had an average force to fracture of 1016 N and resisted fracture more than any of the 1-piece zirconia abutments. The current results correlate highly with the findings of Stimmelmayr et al.\(^5\)

Sailer et al\(^2\) also reported higher fracture loads for zirconia abutments with metallic inserts than for anatomic-contour zirconia abutments. This study attributed differences at least partially to the higher bending moments measured for the zirconia abutments with metal inserts. These abutments experienced plastic deformation of the metallic inserts, abutment screw, and/or implant shoulder. Failure of the abutments with inserts included fracture of the ceramic abutment, deformation of the metal parts, and retention loss.\(^7\)

In contrast, abutment fracture is reported to be the main reason for failure of 1-piece zirconia abutments.\(^9\) For the present study, abutment coronal portion
A fracture was seen only in INC abutments. Two anatomic-contour (ATZD, ATL) and zirconia abutments with titanium ring (ZC) demonstrated hexagon fractures. Similar to the findings of Sailer et al,2 the abutments with a titanium core (LSC) had only abutment screw fracture.

The average loads to fracture for the abutments in the current study were 275 N for the three 1-piece zirconia abutments and 842 N for the 2 abutments with titanium elements. Both of these averages are higher than the reported maximal occlusal force of 233 N for a single anterior tooth or average mean occlusal force of 146 N for a man.17,18 However, average loads to fracture values for 2 of the 1-piece zirconia abutments were 123 N and 236 N. These results indicate that caution should be exercised when using anatomic-contour zirconia abutments, especially for posterior restorations where average occlusal forces may be as high 720 N.19

This in vitro study was limited in its ability to replicate dynamic occlusion, bone structure, and clinical osseointegration. Future work should simulate all of these factors and include thermocycling, to most accurately represent the intraoral condition. The results provided give only a relative comparison, which may or may not be clinically accurate. In addition, the stock and custom abutments tested in this study were different in contour and/or morphology. Accordingly, some abutments were thicker than others, possibly explaining fracture resistance differences among abutments. The size of the abutments may have contributed to the results obtained in this study, because the bulkiest tested abutment had non-abutment fractures and the highest load to fracture values. One implant per abutment group was used during the tests. Having an implant securely fixed with a clamp forming a 1-piece solid foundation for the zirconia abutments to be tested allows the implant to be eliminated as a variable. Implants were inspected for their integrity after each test.

Overall, this study found that the zirconia abutments with metal cores or rings had significantly higher loads to fracture compared with the anatomic-contour zirconia abutments by other manufacturers made for use with the tapered screw-vent implant (Zimmer Dental). Clinical studies are needed to corroborate the findings from this study.

**CONCLUSIONS**

Within the limitations of this study, the following conclusions can be drawn:

1. A stock zirconia abutment with a titanium core-hexagon showed significantly greater resistance to fracture than the other 4 abutments tested.
2. The average load to fracture values for both zirconia abutments with titanium components were significantly higher than for anatomic-contour zirconia abutments made for use with the tapered screw-vent implant by other manufacturers.

**REFERENCES**


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