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Endurance Limit Comparison of Axial and Oblique Forces of Titanium-Based Implant Supported Lithium Disilicate Monolithic Crowns

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Endurance Limit Comparison of Axial and Oblique Forces of Titanium-Based Implant Supported Lithium Disilicate Monolithic Crowns

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ABSTRACT

Background. The purpose of this research was to compare the endurance limits of axial (0°) and oblique (20°) cyclic loading and survival of e.max lithium disilicate monolithic crowns cemented to TiBase hybrid abutments. Null hypothesis: there is no difference in endurance limits of TiBase implant supported lithium disilicate mesostructured crowns subjected to axial and oblique forces.

Methods. A total of 40 lithium disilicate premolar crowns (IPS e.max CAD Ivoclar Vivadent) cemented on TiBase (NB RS 3.5L, Dentsply-Sirona) abutments were separated into 2 groups. Group 1 consisted of 20 samples and was subjected to axial forces at 0°. Group 2 consisted of 20 samples and was subjected to oblique forces at 20° from the axial orientation. Force was applied to the samples by a universal testing machine (Model 5543, Instron, Canton, MA) using the staircase fatigue technique. The data was collected and analyzed to calculate the endurance limit of axial vs oblique forces. Statistical analysis was performed using t-test with a p-value <0.001 considered significant.

Results. 38 samples were included in the data comparison. Success group showed a mean endurance limit of 721N for 0° and 951N for 20°, P= 0.027. Failure groups showed a mean endurance limit of 635N for 0° and 1014N for 20°, P= <0.001.

Conclusion. The null hypothesis was rejected. TiBase lithium disilicate mesostructures have different endurance limits at 0° vs 20°. The endurance limit of mesostructures subjected to oblique loading at 20° was significantly greater than those subjected to an axial load at 0°.

Practical Implications. Lithium disilicate crowns are one of the most common esthetic final restorations or mesostructures that can be designed and fabricated using CAD/CAM technology. Occlusal forces during masticatory movements vary in direction and it's therefore important to investigate endurance limits to oblique forces on these lithium disilicate monolithic crowns cemented to TiBase hybrid abutments.

Key Words. CAD/CAM, TiBase lithium disilicate, e.max, CEREC, endurance limit, oblique loading

TiBases (Sirona) are implant abutment superstructures that have become convenient for dentists to use due to their simplistic and user-friendly computer aided design and computer aided manufacturing (CAD/ CAM) modality. TiBase kits contain a titanium base, abutment screw and a scan body. This system allows dental providers to restore an implant using CAD/CAM technology with same day delivery of a final implant TiBase-supported lithium disilicate monolithic crown. The TiBase system reduces lab costs and improves time efficiency due to bypassing the need to take traditional impressions for submission to a dental lab.

As the use of the TiBase restoration system increases in popularity, it is crucial to investigate the stresses that the system can withstand to oblique forces, to determine if these restorations can withstand the forces of mastication. Specifically, a key question in need of investigation is whether mesostructures cemented on TiBases can withstand true physiological chewing forces.

In an ideal fixed prosthodontic restoration, non-axial masticatory forces would be reduced or eliminated. This is difficult to achieve as we chew in a modified tear-drop pattern, as described by the masticatory review of Soboļeva et al.[1] Unfortunately, most studies on the compressive strength of dental materials are focused on axial loading only, and do not give the clinician a full understanding of the strength of the restoration as it relates to actual function.

Although it is impossible to determine clinical performance of dental materials from an *in vitro* benchtop study, testing can be completed to provide important values a clinician can use to determine the best material for a given situation. One such property that can be tested in order to provide insight to clinical performance is endurance limit. Endurance limit is defined as "the maximum stress that can be maintained without failure over an infinite number of cycles."[2] Knowing the endurance limit of a restorative material could allow a clinician to have an idea of the longevity of the restoration being placed.

An alternative to TiBase abutment selection would be the use of a zirconia abutment. Zirconia abutments provide a more esthetic outcome when compared to TiBases.[3] To the author's knowledge, there have been no studies testing endurance limits of zirconia versus titanium. However, Cavusogle et al observed a larger microgap and increased microleakage in zirconia abutments when compared to titanium abutments.[4] Therefore, further studies of the functional load capacity of TiBase and Zirconia restorations are important to help clinicians weigh the pros and cons of different materials.

Currently, lithium disilicate and zirconia restorations are still the most common, esthetic restorations designed and fabricated using CAD/CAM technology.[3] Regardless of material selection (zirconia or TiBase), all mesostructured implant restorations are fabricated with a screw channel for access to the fixture for screw retention, which then gets cemented on the base. The screw channel on these mesostructured crowns may significantly weaken the fatigue load of the material, causing clinical failure of the restoration.

This study will specifically focus on the endurance limits of TiBase implant restorations. The null hypothesis of this study is that there is no difference in endurance limits of TiBase implant supported lithium disilicate mesostructured crowns subjected to axial and oblique forces.

MATERIALS AND METHODS

Fabrication of Resin Jig Housing Implant.

Expired 3.4mm platform Nobel Replace Tapered Groovy implants were embedded in resin cylindrical jigs (EpoxiCure Resin). The length of the implants varied from 8mm to 15mm. The Cylindrical resin jigs (14mm in diameter x 24mm in height) were fabricated to house the implants. Each jig was made with a round anti-rotational depression (4mm in diameter x 2mm in depth) on the side of the resin cylinder. The depression corresponded to the mesial side of the cemented crowns, to maintain consistency of placement and positional stability during the fracture and fatigue tests.

Fabrication of e.max Lithium Disilicate Crowns

The 40 identical premolar mesostructures (IPS e.max CAD Ivoclar Vivadent) were scanned and designed using the CEREC Primescan (Version 5.1, Dentsply-Sirona, York, PA) and ScanBody (NB RS 3.5 L, Dentsply-Sirona, York, PA). The mesostructures were milled (Sirona CEREC MC XL) and crystallized (Programat P310, Ivoclar Vivadent). All crowns had an even thickness of 2.3mm.

Crown Cementation to TiBases

The TiBases were sandblasted with 50-micron aluminum oxide grit and steam-cleaned prior to cementation. The mesostructures were cemented onto the TiBases with resin cement (Multilink Hybrid Abutment, Ivoclar Vivadent) and torqued to 35Ncm onto the resin mounted implants. The screw channel was covered with vinyl polysiloxane (Aquasil, Dentsply-Sirona) and Filtek Supreme Ultra composite resin (3M ESPE) was used to fill in the remaining screw channel and was highly polished.

Endurance Limit

The samples were secured in an Instron testing jig (Figure 1) at their corresponding axial or oblique load position. Axial loading forces were applied to occlusal surfaces of the samples extending along the vertical axis of the implant. Oblique loading forces were applied at a 20° angle to the axial forces. Force was applied to the samples by a universal testing machine (Model 5543, Instron, Canton, MA) using the staircase fatigue technique and results were recorded (Figure 2).

The sinusoidal duration of load cycles was set to 6000 cycles and 2 hertz for each sample. Half of the average load of lithium disilicate, determined from previous, unpublished studies, was used for the initial staircase experiment, 588N. Intervals for each subsequent sample was ±20% of the load. If the sample failed after 6000 cycles, the next sample's load was decreased 20%. If the sample succeeded the next sample's load was increased by 20%. This is similar to what was done by Pollak et al.[5] The following formula was then used to calculate the endurance limit:

$$S'_e = \sigma_0 + d\left(\frac{A_n}{\sum n_i} \pm \frac{1}{2}\right),\ A_n = \sum i n_i$$

where σ_0 represents the lowest load value in the group and n_i represents the number of either failure or successful events. If the sample failed, a negative sign was used in the equation, and a positive one if the sample was successful as described by Schmid et al.[6]

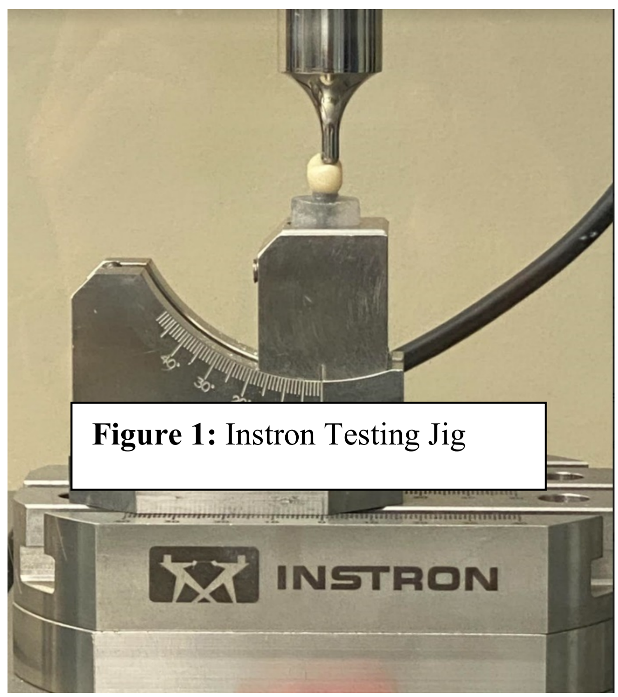

Figure 1: Instron Testing Jig

Statistical Analysis

Figure 2: Instron Universal Testing Machine, Model 5543

Data was analyzed using a t-test with p-value <0.001 being significant.

RESULTS

A total of 38 samples were included in the statistical analysis. Two samples were defective (the resin housing the implant was soft) and were not included in the analysis. The 0° axial group (n=18) had 10 failures and 8 successful TiBase mesostructures. The 20° oblique group (n=20) had 8 failures and 12 successful TiBase mesostructures.

The axial group had an endurance limit of 635N ± 99.2N for the failure groups and 721N ± 146N for the success groups (Figure 3). The oblique group had an endurance limit of 1014N ± 74N for the failure groups and 951N ± 243N for the success groups (Figure 4). The t-tests for 0° axial and 20° oblique failure groups showed the results to be statistically significant (p<0.001). Likewise, differences between the 0° axial and 20° oblique success groups were also found to be statistically significant.

The types of failures were further categorized into catastrophic, internal crack (non-visible), and external crack (visible). The 0° axial group had eight catastrophic failures and two internal crack failures. The 20° oblique group had seven catastrophic failures and one external crack failure.

DISCUSSION

The null hypothesis was rejected due to statistically significant differences in endurance limits between the 0° and 20° groups. The oblique (20°) group had a significantly higher endurance limit than the axial (0°) group. Roberts et al demonstrated that lithium disilicate screwmentable mesostructures on TiBases subjected to axial forces, had a fracture resistance similar to what was found in this study.[7] However, it is important to note that in their experiment, the samples underwent 100,000 cycles of cyclic fatigue. Due to time limitations, the samples in this study only underwent a 6000-

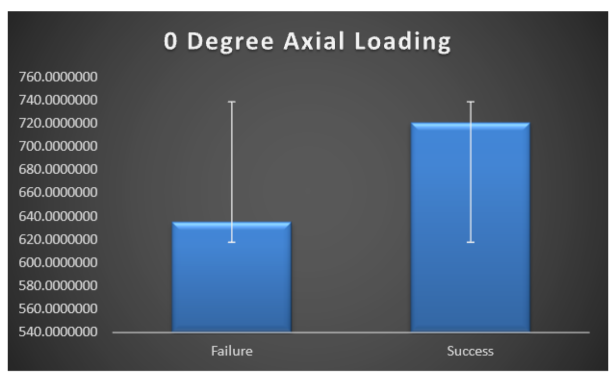

Figure 3: 0° axial loading endurance limits of e.max lithium disilicate monolithic crowns cemented to TiBase hybrid abutments.

cycle loading, and had constant pressure applied without the piston lifting off the restoration, as was done in the Roberts et al study. Thus, it is important to note that this type of sinusoidal loading does not fully replicate oral forces. Future studies with longer sinusoidal cycle loading would be beneficial to the clinical relevance of the results of this study.

The oblique load force was applied to this study because occlusal forces during masticatory movements vary in direction. However, it was difficult to evaluate oblique loading with the type of piston used, as it would often slip off the mesostructures. To prevent slippage, a piece of parafilm was placed between the piston and the crowns similar to the technique used by Gerogianni et al. [8] In future studies it may be beneficial to use a different type of piston to prevent slippage when testing oblique loads.

Tortopidis et al measured the maximum bite force between second premolar and the first molar and found a mean force of 580N.[9] The findings in this study show both failure groups (0° and 20° loading) to have a higher endurance limit than 580N. It can be concluded that the type of restoration tested in this study will withstand the occlusal loading stated by Tortopidis et al.

Another important limitation to this study to consider is the small number of samples in each group. A small sample size may undermine the validity of any study and can make it difficult to see a difference of mean endurance limits between the groups.

Also, samples were not exposed to a wet environment which would have better simulated intraoral conditions and affected cement properties. It would be advantageous in further studies to expose samples to a wet environment before cycle fatigue, increase the number of samples, and increase the number of cycles samples were loaded. Lastly, implant length consistency may be considered in future studies as it could have an impact on implant prostheses failure.

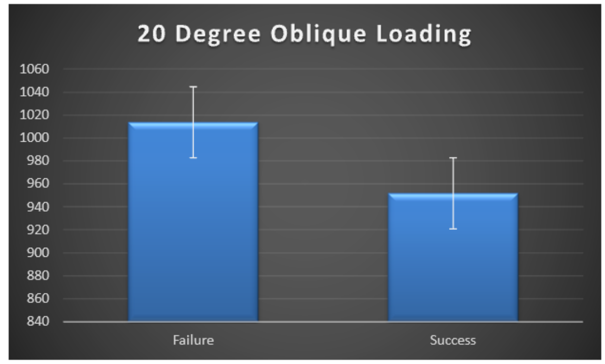

Figure 4: 20° oblique loading endurance limits of e. max lithium disilicate monolithic crowns cemented to TiBase hybrid abutments.

CONCLUSION

This research project compared the endurance limits of 0° axial vs 20° oblique cyclic loading and survival of e.max lithium disilicate monolithic crowns cemented to TiBase hybrid abutments. The null hypothesis was rejected but due to limitations of this in vitro study further investigation is needed to understand the effects of oblique loads on these mesostructures.

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