EFFECT OF PROSTHETIC-ABUTMENT CONNECTION TYPE ON FRACTURE STRENGTH OF CANTILEVER MONOLITHIC ZIRCONIA IMPLANT-SUPPORTED PROSTHESES

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Introduction

Implant supported fixed complete dentures (ISFCDs) serve as a solution for patients with edentulism or failing dentition desiring better retention and support than removable options. Monolithic zirconia (MZ) has emerged as a newer material option for ISFCDs that take advantage of zirconia's esthetics and strength while allowing for efficient fabrication through a CAD-CAM workflow[1].

The MZ prosthesis can interface with the multi-unit abutments (MUA) with several different prosthetic-abutment connections (PACs), including cementation on a bar substructure or with titanium bases (ti-bases). Technical complications have been described clinically with MZ ISFCDs, including fracture and ti-base debonding[2]. Newer technology, such as prosthetic screws that allow direct connection to the MUA, eliminate the need for ti-bases. Removing this metal interface eliminates the potential for debonding and can also increase the material thickness near this interface. However, no studies exist documenting their performance and potential complications.

Research Aims

The purpose of this *in-vitro* study was to investigate the maximum load-to-failure and observed failure modes of cantilever-zirconia frameworks retained with ti-bases or direct-to-multiunit screws (DTMS).

The null hypothesis was that there would be no difference in maximum load-to-failure or failure mode of cantilever-zirconia frameworks with ti-bases or DTMS.

Materials/Methods

The experimental design is depicted in Figure 1. Two MUA analogs (Analog for Screw-Retained Abutment, Straumann, REF 025.0050) were fixed in a parallel orientation with 15mm between the center of the analogs, then embedded into an acrylic resin block suitable for a universal testing machine (Biocryl ICE, Great Lakes Dental Technologies, Tonawanda, NY). This master model was then duplicated with splinted open tray impression copings (Impression coping for screw-retained abutment, Straumann, REF 022.0012) using Pattern Resin (GC America) to create a total of three testing models, one for each experimental group. The master model was digitized with the appropriate scanbody for each PAC using a lab scanner (Ceramill MAP600+, Amann Girrbach, Germany).

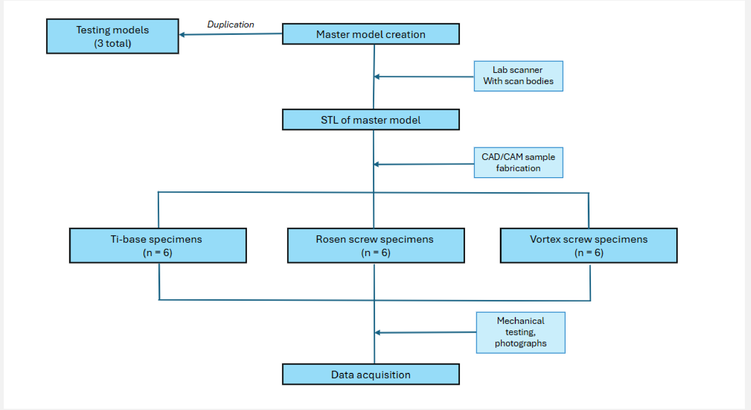

Figure 1: Experimental Design

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Materials/Methods

18 cantilever bar specimens were designed in a CAD/CAM software to model the distal portion of a ISFCD. Six specimens were designed with a ti-base as the PAC to serve as the control and the remaining two groups of six were designed with two types of direct-to-multiunit screws (Table 1). Specimens were designed according to previous cantilever zirconia studies[3]: 30 mm x 7 mm x 8 mm with a 10 mm cantilever to represent the span of one molar (Figure 2).

Table 1: Tested Prosthetic-abutment connections (PACs)

Experimental Group	PAC Specifications	Recommended torque
Group T: Titanium-base	Variobase for Bar/Bridge Straumann, REF 023.0028	15 Ncm
Group R: Direct-to-MUA screw	Rosen screw, 1.4 mm Rosen Implant Solutions, RSC14	<20 Ncm
Group V: Direct-to-MUA screw	Vortex screw, 1.4 mm Louisiana Dental Implant Laboratory	15 Ncm

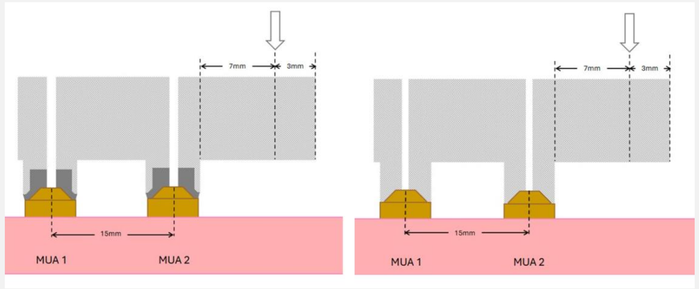

Figure 2: Testing setup for specimens with a ti-base (A) or DTMS (B) as the PAC.

The specimens were milled in 3 mol% yttria MZ (Haus HT + Zirconia, Haus Milling, Dallas, TX) with a 5-axis milling machine. No finishing or glazing was completed after final sintering.

For Group T, ti-bases were cemented to the zirconia specimens using a self-curing luting composite (Multilink Hybrid Abutment cement, Ivoclar Vivadent) per the manufacturer's instructions by the same operator.

Once assembled, each specimen was seated on the respective testing. The prosthetic screws for each respective PAC were torqued to 15 Ncm. Specimens underwent static load-to-failure testing in an Instron 5567A with crosshead speed of 1mm/min. Maximum load-to-failure values (N) were recorded for each specimen and photographs were collected of each sample for qualitative analysis of failure mode.

An *a priori* power analysis was completed based on a similar previous study[3] using power of 0.95 and $\alpha = 0.05$. Statistical analysis was completed in SPSS. Shapiro-Wilk test was used to assess for normality followed by Kruskal-Wallis and Mann-Whitney U tests with alpha corrections.

Figure 3: Assembled specimens. *Right to left:* Group T, Group R, Group V.

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Results

Maximum load-to-failure for each group is shown in Figure 4. There was a significant interaction between PAC and maximum load-to-failure (p=0.011, test statistic 9.039).

Failure modes are shown in Figure 5. After load testing, the screws of three of the six samples in Group R were unable to be retrieved with the driver and the zirconia specimens were sectioned to analyze the failure mode.

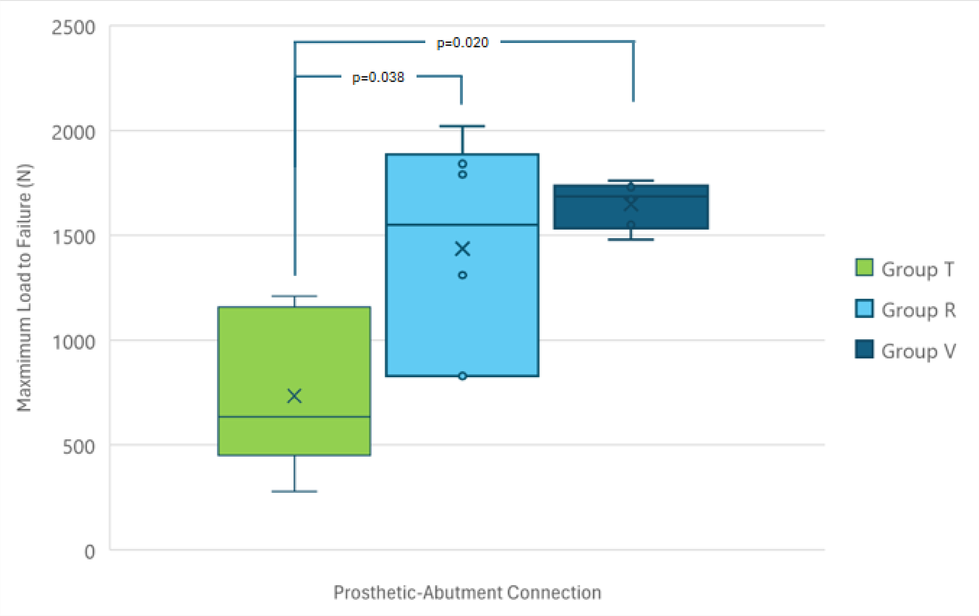

Figure 4: Load-to-failure testing for each experimental group. α=0.05.

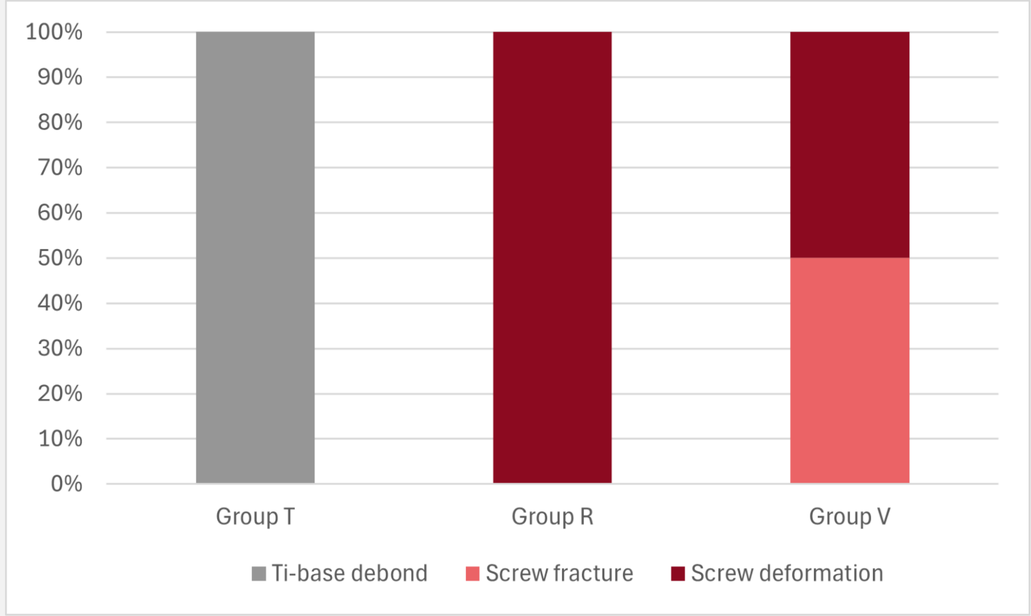

Figure 5: Mode of failure for each experimental group.

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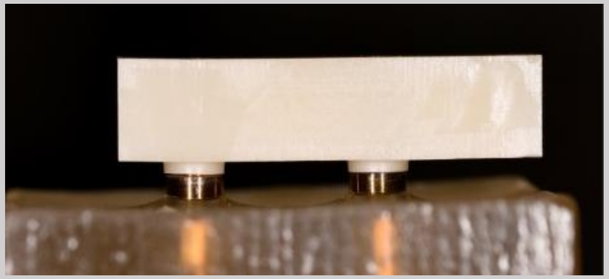
Results

All specimens, regardless of the PAC, experienced failure in the prosthetic components and not the zirconia. All noted failure occurred at the MUA furthest from the cantilever (MUA 1).

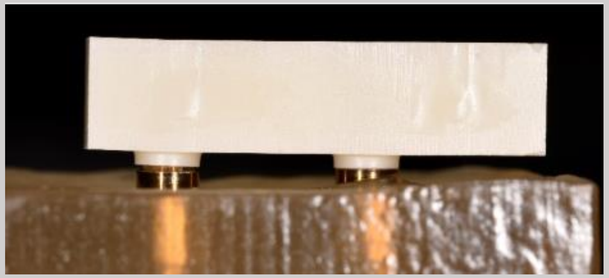
For Group T, all specimens exhibited adhesive failure between the cement and zirconia, causing the ti-base to debond. No damage to other prosthetic components was noted.
In Group R, all Rosen screws at MUA 1 showed signs of deformation, concentrated at the apical portion. Damage to the internal threading of MUA 1 was observed.
In Group V, 50% of the Vortex screws of MUA 1 were deformed at the apical portion, and the remaining screws fractured completely through the screw body. All screws demonstrated loss of clamping force upon failure resulting in easy retrievability of the specimens from the testing models with the prosthetic driver.

Group T

Group R



Group V



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Discussion

The null hypotheses were rejected. The maximum load-to-failure was statistically significantly higher for specimens with DTMS as compared to ti-bases. The failure modes were also different, as the ti-base group exhibited ti-base debonding and the DTMS groups exhibited failure of the prosthetic screw and/or metal interface.

The failure loads for the DTMS groups were well above the maximum bite force range of 245-1245N as described in the literature[4]. Group T was within this range, suggesting ti-base debonding could occur before reaching maximum bite force. However, clinical data shows incidence of ti-base debonding as a rather small proportion of complications[5], and caution should be utilized in translating this finding to a clinical scenario.

The “tapered cone” concept of most prosthetic screws takes advantage of mechanical friction fit to reduce micromovements in the threads with the goal of limiting screw loosening[6]. When comparing the two DTMS in this study, Rosen screws have a longer taper of the screw head, theoretically transferring force more effectively away from the screw threads than Vortex screws. This may explain why screw fracture was seen in Group V but not Group R.

Qualitatively, the zirconia specimens were easily retrievable in Group T and Group V. Sectioning of the zirconia was required in some of Group R due to a wedging effect of the screw. If this were to occur clinically, this finding could have implications for chair time and success of screw retrieval.

When globally comparing failure modes, only the DTMS groups exhibited catastrophic failure of the prosthetic components. The failure mode of Group T was seen within the cement layer and can be considered a “repairable” failure in clinical practice, as the ti-base could be recemented.

Limitations of this *in-vitro* study include lack of artificial aging or cyclic loading of the specimens, difficulty in assessment of precise mode of failure, and small sample sizes. Future studies could involve adding more MUAs to better resemble a full-arch ISFCD, utilizing an anatomically-shaped framework, or utilizing more advanced imaging techniques such as scanning electron microscope for investigation of component damage.

Conclusions

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

1. The prosthetic-abutment connection significantly affected maximum load-to-failure values of MUA-level cantilever zirconia prostheses. Specimens with ti-bases failed at lower load values than those with direct-to-MUA screws ($p<0.05$).
2. The mode of failure under static loading was restricted to the prosthetic components instead of the zirconia in all groups. Specimens with ti-bases exhibited adhesive failure at the cement with no other damage noted, while specimens with direct-to-MUA screws exhibited catastrophic failure of the prosthetic screw.
3. Screw designs may affect retrievability and repairability of the prosthesis, which can help guide clinical decision-making when restoring MUA-level cantilever zirconia prostheses.

References & Acknowledgements

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