



Optimizing Strength in Full-Arch Restorations: Various Height for Cantilevered Zirconia on Titanium Frameworks -An In Vitro Study

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ABSTRACT

Zirconia full-arch fixed complete dentures are increasingly favored for the rehabilitation of edentulous patients due to their mechanical strength and esthetic qualities. Nonetheless, concerns persist regarding the risk of fracture, particularly in cases where restorative space is limited. This in vitro study investigated the compressive fracture resistance of zirconia superstructures with different occlusal-cervical heights (2mm, 4mm, and 6mm) when supported by rigid titanium frameworks with cantilever extensions.

INTRODUCTION

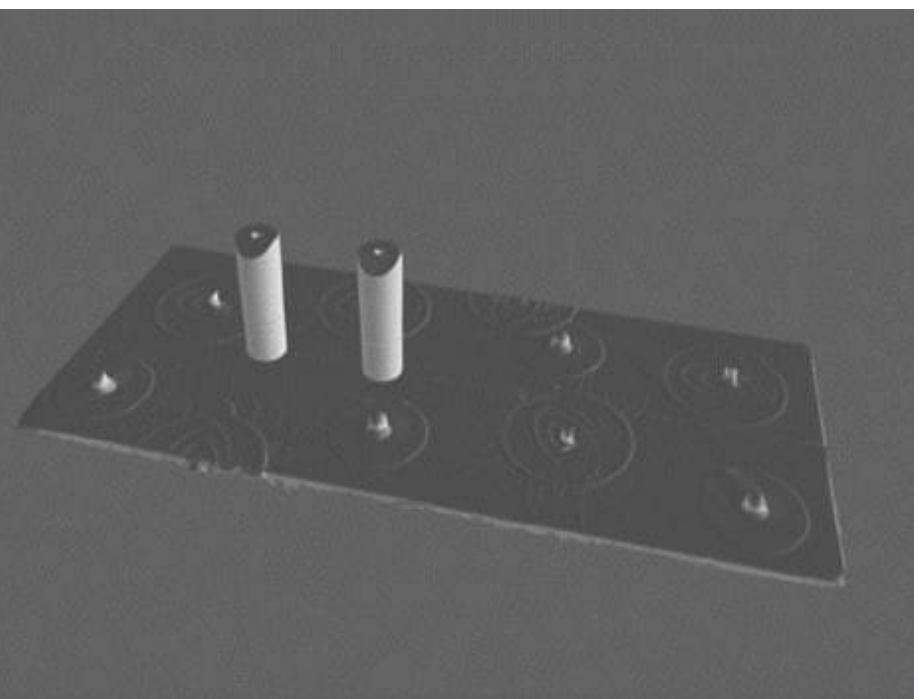
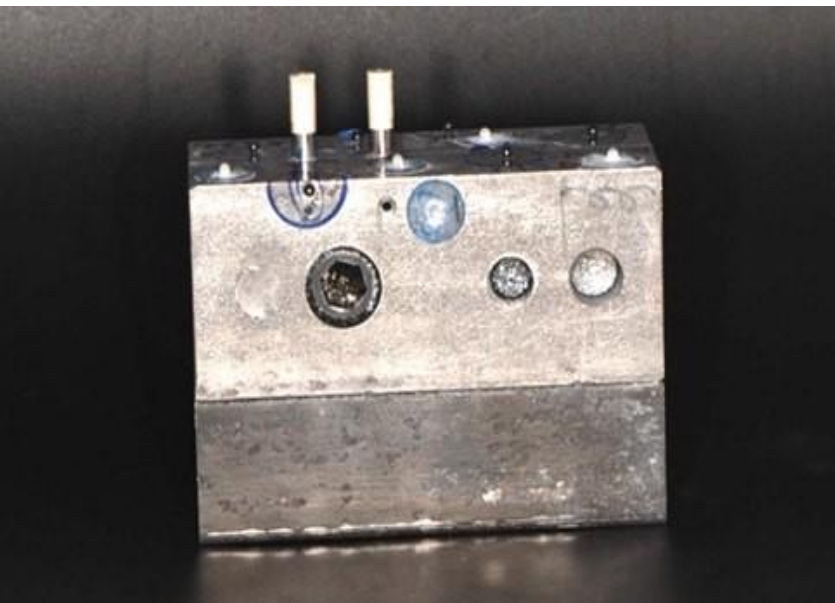
Dental implants have transformed prosthodontics by enabling predictable long-term rehabilitation of edentulous patients. Among available options, full-arch zirconia prostheses supported by titanium frameworks (Ti) are increasingly popular due to their esthetics, strength, and biocompatibility. The bilayer design—zirconia bonded to Ti enhances force distribution and protects against ceramic fracture compared to monolithic zirconia. Titanium provides excellent mechanical support, while zirconia offers durability and low bacterial adhesion. Despite these advantages, zirconia remains vulnerable under tensile and shear stresses, particularly in cantilevered designs. Current in vitro studies often simplify loading and geometry, limiting clinical relevance. While factors such as Ti-base height and cement type have been studied, little is known about how zirconia height influences structural performance. This study evaluates the load-to-fracture behavior of zirconia superstructures of varying occlusal–cervical heights (2 mm, 4 mm, 6 mm) bonded to Ti frameworks with cantilevers, aiming to provide baseline data for future clinically relevant research.

METHODS

Experimental Setup

Universal testing machine (Columbia University, Carleton Lab). Custom low-carbon steel base fabricated to simulate implant fixation.

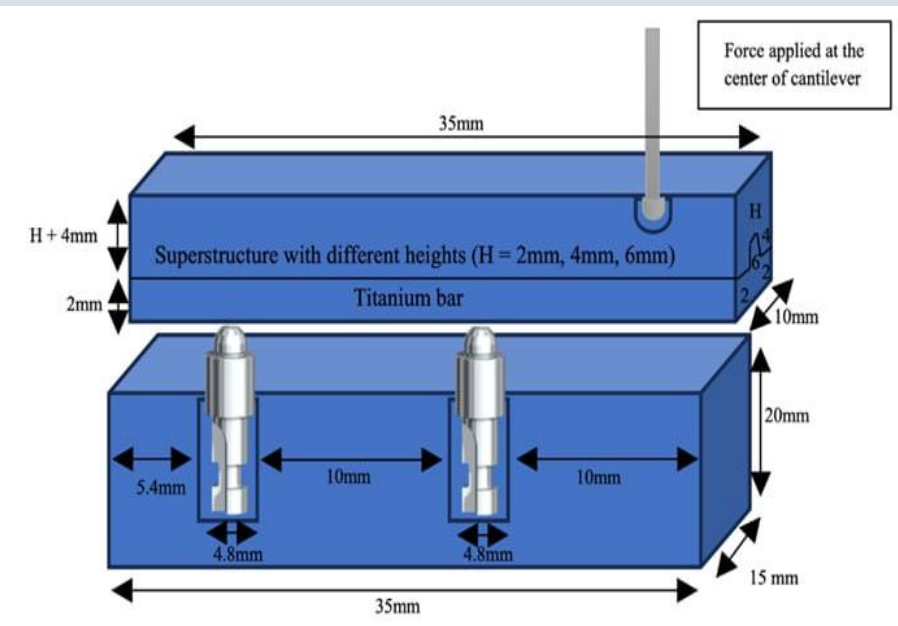
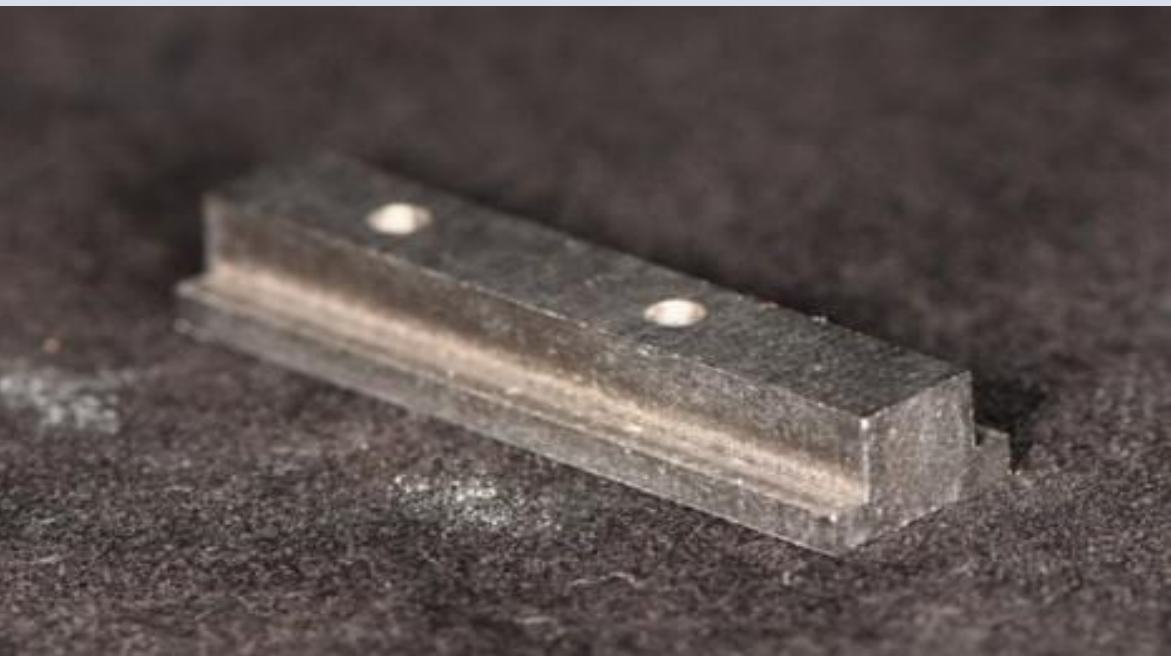
Base scanned with 3Shape E4 Lab Scanner → STL files generated for CAD/CAM design.



METHODS

Sample Preparation

Multi-unit implant replicas mounted on steel base.
Zirconia superstructures (2, 4, 6 mm heights) + titanium frameworks milled via CAD/CAM. All zirconia: 35 mm L × 10 mm W, Ti base: 35 × 10 mm with 6 × 4 mm vertical strut.
10 mm distal cantilever included to mimic clinical scenario.10 specimens per group (power analysis $\alpha = 0.05$, power = 80%)



Bonding Protocol

Fit checked; surfaces abraded with 50 μ m alumina, ultrasonically cleaned.
Clearfil Ceramic Primer + Panavia V5 resin cement used.
Superstructures screw-retained (15 Ncm torque).

Testing Protocol

Vertical monotonic loading (1 mm/min) at cantilever midpoint (5 mm from distal end).
Load-to-fracture defined when force dropped to 50% of peak.
Limitations: no lateral/cyclic loading, simplified geometry.

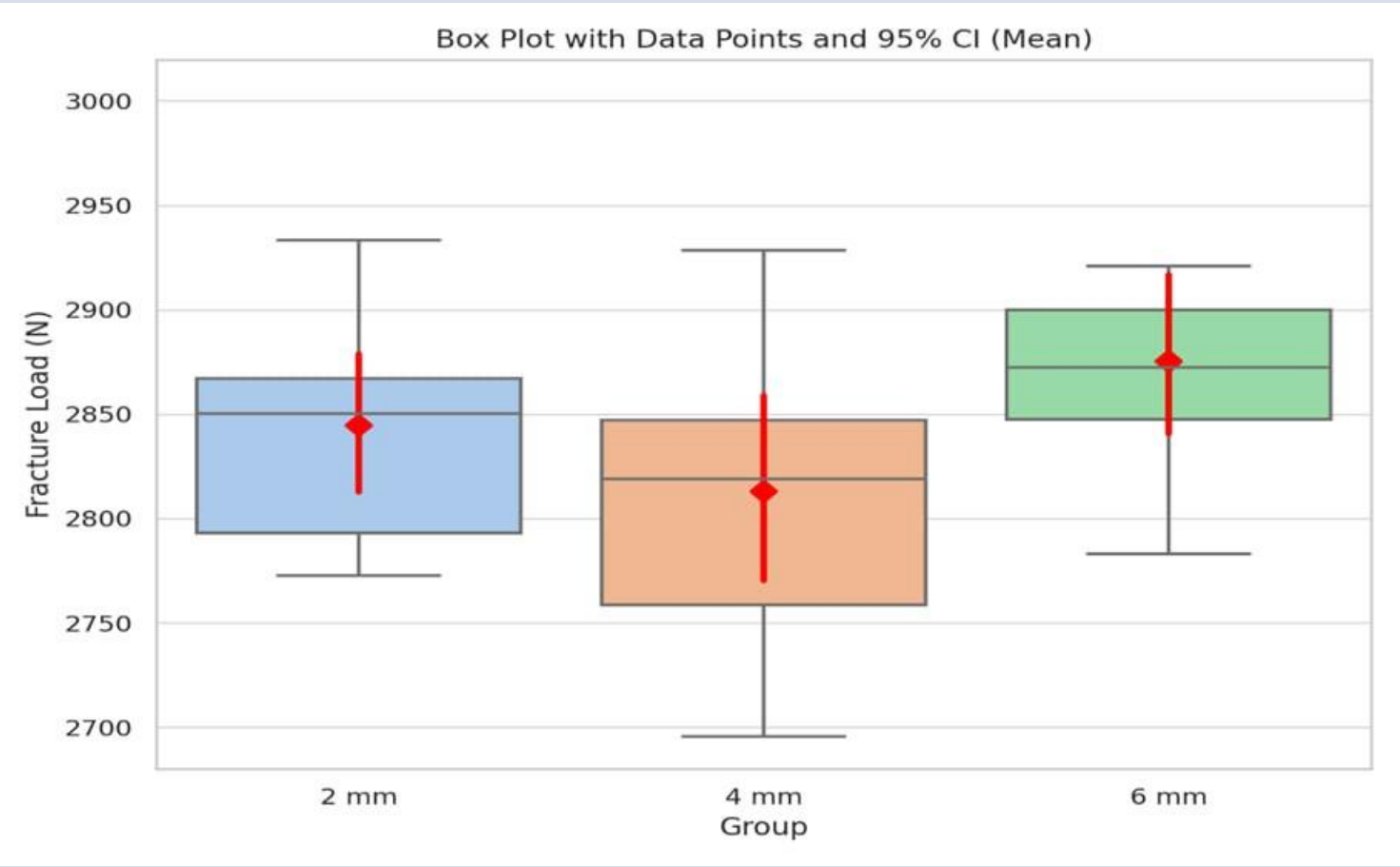
Statistical Analysis

One-way ANOVA (SAS 9.4).
Post-fracture: Keyence VHX-5000 microscope (50 $\times$) for failure documentation.

RESULTS

Table 1. Fracture strength results (Newtons, N)			
Group	N	Mean Load Sustained (SD)	95% Confidence Interval
2 mm	10	2809.45 $\pm$ 78.43	2757 – 2862
4 mm	10	2895.60 $\pm$ 104.49	2821 – 2970
6 mm	10	2892.30 $\pm$ 76.54	2830 – 2898

The same capital letters in the confidence interval column represent no statistically significant differences among groups.



30 samples tested, 29 showed no visible cracks in zirconia. Failures mainly at prosthetic screw fracture/loosening at distal abutment when the loading is more than 2750 N. The result suggests stress absorbed at screw–abutment interface, not zirconia or Ti framework. Zirconia superstructures with reduced height (2 mm) showed comparable compressive strength to thicker designs when supported by rigid titanium frameworks. These findings suggest that an implant-fixed prosthesis with minimal zirconia thickness and a cantilever design may be feasible in restorative spaces limited to less than 10 mm when supported by a rigid titanium framework.

REFERENCES

Simon H, Yanase RT. Terminology of implant prostheses. Int J Oral Maxillofac Implants **2003**; 18:539–543. Bornstein MM, Halbritter S, Harnisch H, Weber H-P, Buser D. A retrospective analysis of patients referred for implant placement to a specialty clinic: Indications, surgical procedures, and early failures. Int J Oral Maxillofac Implants **2008**;23: 1109–1116.