Effect of Fatigue Loading on Fracture Strength of Screw-retained Zirconia Crowns on Zirconia and Titanium Implant Systems

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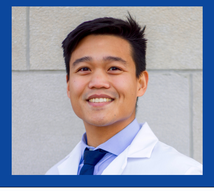

Objective

The objective of this study was to compare the fracture strength of screw-retained zirconia crown fabricated on zirconia and titanium implants.

Introduction

Titanium (Ti) implants have been embraced as the material of choice with decades of research and time-tested durability and stability. However, the demand for Ti substitutes has grown as a result of Ti related allergy, aesthetic concerns and biocompatibility considerations. Zirconia (Zr) implants have emerged as a promising alternative. However, restorations fabricated on Zr implants may not have the fracture strength to withstand the average occlusal forces of a healthy human (ranging between 98 to 1031N) due to the mechanical properties of Zr implants. The goal of this study is to compare the fracture strength of screw-retained zirconia assembled on Zr and Ti implants.

Materials and Methods

Forty-eight screw-retained Zr crowns (IPS e.max® ZirCAD Prime, Shade A2; Ivoclar Vivadent) were designed and manufactured on two Ti and two Zr implant systems, each 12. Screw-retained zirconia crowns were adhesively cemented to the associated abutment using a resin adhesive cement (Multilink Hybrid Abutment; Ivoclar Vivadent) and they were torqued to their assigned implant following the manufacturers' instructions.

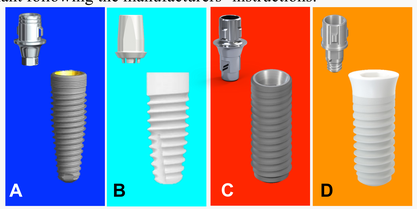

Fig. 1: A) NobelReplace Conical Connection PMC (Nobel Biocare) (ZrCCTi); B) NobelPearl (Nobel Biocare) (ZrNPZr); C) Roxolid SLActive (Straumann AG) (ZrBLTi); D) Pure Ceramic (Straumann AG) (ZrPZr)

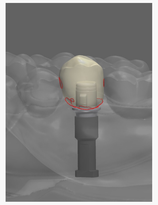

Fig. 2: Crowns designed following a diagnostic wax-up

Specimens were subjected to dynamic loading (Chewing Simulator CS-4; SD-Mechatronik) for 1,200,000 loading cycles at a loading force of 70 N with 1mm horizontal slide. Then, all specimens were subjected to loading using a universal testing machine (MTS 858 Mini Bionix. II) at an angle of 30° at a cross-head speed of 2 mm/min until failure (N). Specimens were evaluated under a microscope at 50x (DinoXLite; Dunwell Tech, Inc) to assess the failure mode following criteria defined in Table 1.

One-way ANOVA followed by Tukey post hoc test were used to assess the impact of implant system on the the fracture strength of screw-retained Zr Crown (α=0.05).

Results

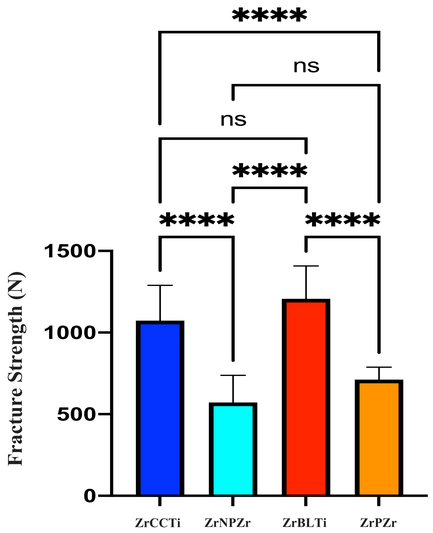

Fig. 3. Fracture Strength of Screw-Retained Zirconia Crowns on Various Implant Systems.

The fracture strength of screw-retained Zr crowns fabricated on Ti implants were significantly higher ($p<0.05$) than the fracture strength of screw-retained Zr crowns fabricated on Zr implants regardless of the manufacturing system. There were no significant differences ($p>0.05$) between the fracture strength of screw-retained Zr crowns fabricated on either of the Zr implants. In addition, there were no significant differences ($p>0.05$) between the fracture strength of screw-retained Zr crowns fabricated on either of the Ti implants.

The majority of Zr crowns assembled on Ti implants fractured (75%-83.3%) and their abutment went through plastic deformation (ZrBLTi=2.24° and ZrCCTi=4.64°). However, all of the implants fractured (100%) when Zr implants were used. Crown and abutment fracture accounted for 16.7% and 8.3% of ZrPZr and ZrNPZr group, respectively.

Fracture Mode	Description	ZrCCTi	ZrNPZr	ZrBLTi	ZrPZr
Type 1	Fracture occurs on the crown without abutment deformation/fracture or implant fracture	2	0	2	0
Type 2	The implant connection segment of the abutment deforms/fractures with or without any destruction of the crown.	8	0	8	0
Type 3	Crown is de-bonded from the abutment with or without abutment deformation/fractures	2	0	2	0
Type 4	Fracture occurs on the implant with or without fracture of crown, abutment or screw	0	12	0	12

Table 1. Fracture Mode and Distribution (N) of Fracture Mode in Each Group

Zi Implant

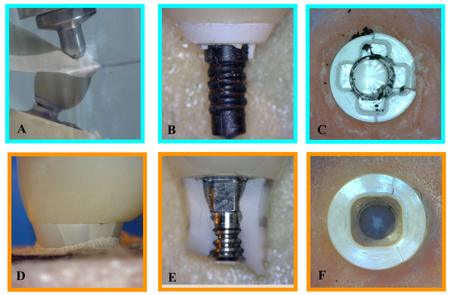

Fig. 4. Examples of Failure Mode for Zirconia Implant Groups- ZrNPZr Group (A, B, C) and ZrPZr Group (D, E, F)

Ti Implant

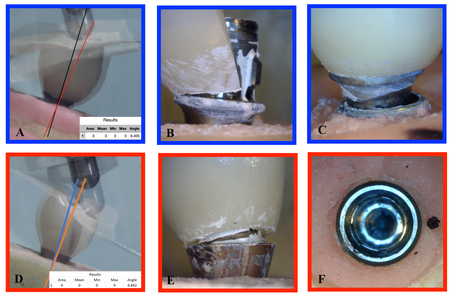

Fig 5. Examples of Failure Mode for Titanium Implant Groups- ZrCCTi Group (A, B, C) and ZrBLTi Group (D, E, F)

Conclusions

Within the limitations of this study:

1. Screw-retained Zr crowns fabricated on Zr implants had significantly lower ($p<0.05$) fracture strength than the ones fabricated on Ti implant.
2. The failure mode in Zr implant groups were type 4 fractures, where fracture occurred at the implant level.
3. There were no significant differences ($p>0.05$) in the fracture strength between the two Zr implant groups and between the two Ti implant groups.

References

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Thanks to Ivoclar Vivadent for partial in-kind support of the study