CLINICAL DENTISTRY AND RESEARCH 2020; 44(3): 80-85 Original Research Article

INFLUENCE OF CONNECTOR AREA AND ABUTMENT MATERIAL ON FRACTURE STRENGTH OF IMPLANT-SUPPORTED CANTILEVERED ZIRCONIA FRAMEWORKS

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ABSTRACT

Background and Aim: The purpose of this study was to compare the fracture strength of implant-supported cantilevered zirconia frameworks with different connector areas that were fabricated on zirconia and titanium abutments.

Materials and Methods: A total of 40 cantilevered implant-supported three-unit frameworks with two premolar abutments and one molar pontic, both on a 2 titanium or zirconia abutment, were fabricated and divided into four groups according to connector areas and abutment materials (TZ-9/TZ-15: titanium abutment-zirconia framework, ZZ-9/ZZ-15: zirconia abutment-zirconia framework). All cantilevered frameworks were cemented and loaded in a universal testing machine until the framework fractured or decemented. Two-way ANOVA with post hoc (LSD) testing was used to analyze the fracture force and the relation between the connector dimension and abutment material.

Results: The results of fracture strength tests showed that the mean fracture loads were approximately 188.73, 480.86, 234.41, and 406.03 N for TZ-9, TZ-15, ZZ-9, and ZZ-15, respectively. There was a statistically significant difference in fracture strength between TZ-9 and TZ-15, and between ZZ-9 and ZZ-15 ($p \leq 0.05$).

Conclusions: The increase in the connector cross-sectional area had a positive effect on the fracture strength of the implant-supported cantilevered zirconia frameworks.

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Clin Dent Res 2020; 44(2): 80-85

Keywords: Abutment Material, Cantilever, Connector Area Fracture Strength

Submitted for Publication: 05.04.2020
Accepted for Publication : 11.16.2020

CLINICAL DENTISTRY AND RESEARCH 2020; 44(3): 80-85 Orijinal Araştırma

KONEKTÖR ALANI VE DAYANAK MATERYALİNİN İMPLANT ÜSTÜ KANTİLEVIR UZANTILI ZİRKONYA ALT YAPILARIN KIRILMA DAYANIMINA ETKİSİ

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ÖZ

Amaç: Bu çalışmanın amacı, implant destekli kantilevır uzantılı zirkonya alt yapıların zirkonya ve titanyum dayanaklardaki ve farklı konektör alanlarındaki kırılma dayanımlarının karşılaştırılmasıdır.

Gereç ve Yöntem: 2 adet titanyum veya zirkonya dayanak üzerine iki premolar ve bir molar (kantilever uzantı) içeren konnektör alanı 9 mm^2 veya 15 mm^2 olan toplam 40 adet implant üstü üç ünite zirkonya altyapı üretildi ve herbir grupta 10 örnek olacak şekilde 4 gruba gruba ayrıldı (TZ-9/TZ-15: titanyum dayanak-zirkonya altyapı, ZZ-9/ZZ-15: zirkonya dayanak-zirkonya altyapı). Tüm kantilevır uzantılı zirkonya alt yapılar, kırılma ya da desimantasyon olana kadar, universal bir test cihazında yüklenmiştir. Konektör boyutu ve abutment materyali ile kırılma dayanımı arasındaki ilişkiyi analiz etmek için iki yönlü bir varyans ile birlikte post hoc (LSD) analizi kullanıldı.

Bulgular: Kırılma dayanımı testlerinin sonuçları, ortalama kırılma yüklerinin TZ-9, TZ-15, ZZ-9 ve ZZ-15 için sırasıyla yaklaşık 188.73 N, 480.86 N, 234.42 N ve 406.04 N olarak elde edilmiştir. TZ-9 ile TZ-15 arasında ve ZZ-9 ile ZZ-15 arasında kırılma dayanımında istatistiksel olarak anlamlı bir fark bulunmuştur ($p \leq 0.05$).

Sonuçlar: Konektör kesit alanındaki artış, implant üstü kantilevır uzantılı zirkonya alt yapıların kırılma dayanımını olumlu yönde etkiler.

Clin Dent Res 2020; 44(2): 80-85

Anahtar Kelimeler: Dayanak Materyali, Kantilevır, Konnektör Alanı, Kırılma Dayanımı

Yayın Başvuru Tarihi : 04.05.2020

Yayına Kabul Tarihi :16.11.2020

INTRODUCTION

Implant-supported cantilever fixed dental prostheses (FDP) could allow a simpler rehabilitation procedure compared to various surgical techniques used to reconstruct vertically deficient posterior maxilla and mandibulars for the FDP design.[1] Metal or zirconia may be used as a framework material on implant-supported cantilever FDPs. Zirconia FDPs' durability over time may depend on several factors, such as the veneering material, and the framework's physical properties and design.[2,3] However, a high fracture incidence in the connector areas of all-ceramic FDPs has been demonstrated in finite element analyses[4, 5] and in-vitro studies.[6,7]

Increasing the dimensions of the connector area would have a beneficial effect on a zirconia reconstruction's strength; however, because of the reduced vertical dimension, this is not always possible. In addition to the connector area, the abutment material that supports the restorations may play a significant role in cantilevered restorations' fracture strength.

Titanium and zirconia have been used successfully as abutment material in the anterior and posterior regions up to the premolar area of both jaws.[8] Titanium abutments have been selected traditionally because of their mechanical properties. However, they have a metallic blue-grey color on thin gingival biotypes. In contrast, ceramic abutments can provide more esthetic appearances through the gingiva.[9,10]

This study focused on the framework connector areas and abutment materials. Therefore, the study's aim was to test the null hypotheses that the connector area and abutment material, respectively, would not affect the implant-supported cantilevered zirconia frameworks' fracture strength.

MATERIALS AND METHODS

A master model (3×5×4 cm) was produced from polymethylmethacrylate and two holes were drilled for the implants. The distance between the implants' center points was set at 7 mm. The implants (Strauman AG, Basel, Switzerland) were positioned parallel to each other using a parallelometer and placed into the drilling holes with acrylic resin (Palavit® G, Heraeus Kulzer, Hanau, Germany).

A total of 40 working models was manufactured from a master model using conventional impression and divided into four groups (n=10) according to the fabrication of the framework design and abutment material (TZ-9/TZ-15: titanium abutment-zirconia framework and ZZ-9/ZZ-15: zirconia abutment-zirconia framework). Zirconia (Strauman RC Anatomic IPS e.max abutment-ZrO_2) and titanium (Strauman RC Anatomic abutment-Ti) abutments were connected to the models and tightened to 35 N·cm with a force-control device.

Fabrication of frameworks

After the abutment screw access holes were closed with modeling wax, the implant-abutment complex on the working model was spray-coated with a thin layer of optical reflective medium (Vivadent; Vita Powder Scan Spray, Bad Sackingen, Germany) and digitized using a laser scanner (Dental Wings Inc., Montreal, Canada). The frameworks were designed as three-unit cantilevered FPDs frameworks to replace two premolars and one molar with a reduced span length of 7 mm and a connector area of 9 or 15 mm^2 for each group. A total of 40 frameworks was milled from zirconium oxide blocks (Alliance, Noritake, Nagoya, Aichi Prefecture, Japan) (Figure 1). Following the manufacturer's recommended conditions, they were sintered in a sintering oven for 10 hours until the temperature increased to 1375^{0}C.

The frameworks were cemented on the abutments with zinc-phosphate cement (Adhesor, Spofa Dental, Praque, Czech Republic) according to the manufacturer's



Figure 1. Cantilevered zirconia frameworks

instructions. A load of 5 N was applied until the dental cement set to control cement thickness.

Mechanical Testing

All specimens were tested mechanically until failure occurred. For all specimens, the force was applied at the distal aspect of the pontic. Failure to fracture strength Was assessed using a universal testing machine (Lloyd Testing Machine, Lloyd Instruments LR30 K, Segensworth West, Fareham, UK) at a cross-speed of 0.5 mm/sec.

Statistical analysis was performed using SPSS v. 21.0 (IBM Corp., Armonk, NY, USA). The differences between the study groups were analyzed with a two-way ANOVA, with the level of significance set at .05. When the interaction term was found to be significant, post hoc comparisons were performed with the LSD multiple comparison test.

RESULTS

The results are presented in Tables 1 and 2. When considering the change in the connector's cross-sectional area, the differences in fracture strength between TZ-9 and TZ-15, and between ZZ-9 and ZZ-15 were statistically significant ($p \leq 0.05$). In addition, the interaction between the abutment material and connector area was significant ($p=0.001$).

With respect to the abutment materials, although there was no statistically significant difference between TZ-9 and ZZ-9, the difference between TZ-15 and ZZ-15 was statistically significant ($p \leq 0.05$). In the TZ-9 and ZZ-9 groups, fractures occurred in the connector area of the bridge (Figure 2).

While some of the samples in the TZ-15 and ZZ-15 groups were fractured on the distal wall of the bridge adjacent to the cantilever, other fractures occurred on the mesial wall of the abutment adjacent to the cantilever (Table3).

DISCUSSION

This study tested the fracture strength under static load of two implant-supported cantilevered zirconia frameworks either on a zirconia or metal abutment. The null hypotheses were rejected in part, as significant differences were found in the connector area but not in abutment materials. The force required to fracture cantilevered zirconia frameworks obtained in this study was similar to that in other studies in the literature.[11,12]

There is debate over the clinical description of fixed prostheses with cantilever failure. In all-ceramic restorations, clinical failures have been reported to occur as a result of the connector design.[6,7,13,14] The connectors' dimensions have a significant effect on framework strength and stability. This is because this region is thinner than that in restorations of the pontic and abutment. A potential solution for this would be to increase the connector's surface area. The minimum size of the connector

Table 1. Descriptive statistics of fracture loads (Newton) for all groups TZ: titanium abutment-zirconia framework, ZZ: zirconia abutment-zirconia framework, 9 or 15 represents connector size area.

Group	N	Mean	SD	Minimum	Maximum
TZ-9	10	188.73	54.74	144.45	323.3
TZ-15	10	480.86*	64.36	410.57	594.43
ZZ-9	10	234.42	38.26	188.7	289.83
ZZ-15	10	406.04#	60.59	331.53	482.74

* Significant difference between TZ-9 and TZ-15
\# Significant difference between ZZ-9 and ZZ-15

Table 2. Two-way analysis of variance

Source of variation	df	Sum of Squares	Mean Squares	F	P
Connector area	1	537674.069	537674.069	175.200	.001*
Abutment material	1	2123.432	2123.432	.692	.411
Connector area * Abutment material	1	36309.060	36309.060	11.831	.001*

Table 3. Distribution of the failure type of the frameworks according to connector area

	Failure type		
	Fracture from the connector area	Fracture from the connector area with distal wall of second abutment	Fracture from the mesial wall of the second abutment
9mm²	20	-	-
15mm²	-	15	5

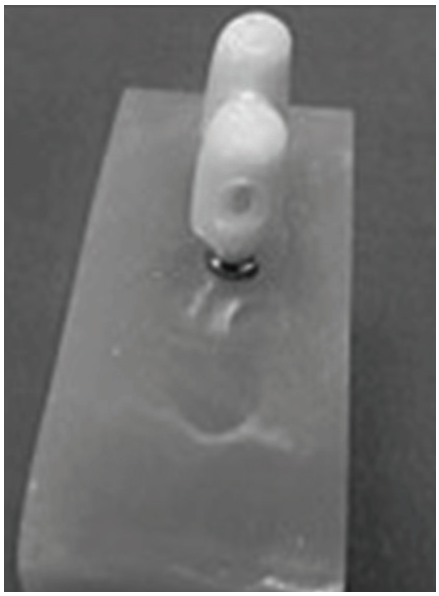


Figure 2. Fractured framework from the connector area

varies according to the type of core material used.[15] The selected materials' properties, anatomical limitations, hygienic reasons, and esthetic expectations are important factors that should be considered in the connector area's design.[16] Several investigators have reported that spaces for the connector-sectional area of the zirconia substructure ranged from 9 mm² to 16 mm².[17-19] The design and dimension of the connectors of the implant supports on zirconia restorations may be the key factors that cause fractures, particularly in patients with limited inter-arch spaces and higher occlusal loads. Fracture failures can be prevented by fabricating connectors with sufficient areas to reduce the stress concentration.[20,21] An increase in the fracture surface area was observed to cause an increase in resistance. These results are consistent with the findings from previous in vitro studies that evaluated the connector surface area.[11] Ohlmann et al.[7] stated that fractures occurred primarily on the distal wall of the terminal abutment adjacent to the pontic. In this study, fractures of the superstructure with a 9 mm² surface area also occurred on the distal wall of abutments adjacent to the cantilever. It should be emphasized that the weakest point in a zirconia superstructure is also the distal wall adjacent to the cantilever. This is because of the fixed partial restoration's torque vector.[22] In addition, it may be because of the compressive stress on the upper part and tensile stress on the lower part of the distal wall when force is applied from the extension of the cantilever.[7] Most of the samples in the 15 mm² cross-sectional area group showed a fracture in the connector area and the distal wall of the second abutment implant, while only 5 showed a fracture in the mesial wall. Similar to these findings, some previous studies have revealed that the stress concentrations were high on the terminal abutment's mesial wall.[23]

Both zirconia and titanium abutments can be used in a zirconia framework. In a systematic review, Sailer et al.[24] stated that there are no differences in the clinical performance of ceramic and metal abutments with different moduli of elasticity. In this study, both zirconia and titanium abutments were used under the zirconia superstructure. It was demonstrated that a zirconia superstructure with a 15-mm² connector surface area fabricated on titanium abutments had greater fracture resistance than a superstructure fabricated on zirconia abutments. However, a zirconia superstructure with a 9-mm² connector surface area did not demonstrate a statistically different fracture resistance with titanium or zirconia abutments. This could be because the thin connector area's fracture resistance was lower than the force affected by stress, causing an increase in the structure's elastic modulus. The limitations of this study include the use of a vertical load and an inability to mimic the natural oral environment.

CONCLUSIONS

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

- Increasing the connector surface area (from 9mm² to 15mm²) enhanced the zirconia superstructure's fracture strength.

- The use of a titanium abutment did not affect the fracture strength of implant-supported cantilevered zirconia frameworks with a 9 mm^2 connector surface area, while it increased the fracture strength of frameworks with a 15 mm^2 connector surface area.

This study was supported by the Scientific Research Unit of

ACKNOWLEDGEMENT

This studu was supported by the Scientific Research Unit of Hacettepe University and numbered as 012 D06 201 004 (6002).

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