

FRACTURE STRENGTH OF CAD/ CAM FABRICATED ZIRCONIUM-OXIDE COPINGS IN THE MOLAR AREA

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ABSTRACT

Background and Aim: High strength ceramics fabricated with CAD/ CAM technology have widely extended the applications of all ceramic restorations from inlay, onlay and single crowns to multi-unit bridges, showing more favorable mechanical characteristics compared to the conventional metal ceramic materials. The aim of this in-vitro study was to investigate the fracture strengths of high strength CAD/ CAM fabricated zirconium oxide copings with two different core structure materials in the molar area.

Materials and Methods: Ten metal and twenty DC-Tell dies produced by the means of Lava® procedure for the mandibular I. molar were manufactured. Partially stabilized zirconia blanks (DC-Zircon) have been used to prepare the ceramic copings. Thermo-cycling was done to ten metal and ten DC-Tell die specimens. All the samples were then tested for their fracture characteristics with a universal testing machine (Zwick-Q10, Ulm, Germany).

Results: The fracture strength results of the DC-Tell samples with thermo-cycling showed the lowest values (753,60 N) and the metal samples showed the highest values (2282,20 N). ($p = 0.001$)

Conclusion: While constructing cores under crowns with CAD/ CAM fabricated zirconium-oxide copings, good mechanical properties and clinical successes can be achieved with metallic materials.

Key words: Biomechanics, CAD/ CAM, Fracture Strength, Zirconium-Oxide.

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MOLAR BÖLGEDE CAD/ CAM İLE ÜRETİLEN ZİRKONYUM-OKSİT KOPİNGLERİN KIRILMA DAYANIKLILIĞI

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ÖZET

Amaç: CAD/CAM teknolojisi ile üretilen yüksek dayanıklılığa sahip seramikler, geleneksel metal-seramik materyallere göre daha olumlu mekanik özellik sergilediklerinden, tam seramiklerin uygulama alanları, inley, onley ve tek kronlardan, çoklu-üyelı köprülere genişlemiştir. Bu in-vitro çalışmanın amacı, molar bölgede, iki farklı kor materyali için hazırlanan, CAD/CAM ile üretilen yüksek dayanıklılığa sahip zirkonyum-oksit kopinglerin kırılma dayanıklılıklarının araştırılmasıdır.

Gereç ve Yöntem: Lava® yöntemi ile alt 1. azı diş için 10 adet metal ve 20 adet DC-Tell day üretildi. Seramik kopinglerin hazırlanması için kısmi-stabilize zirkonyum bloklar (DC-Zircon) kullanıldı. On metal ve on DC-Tell daya termal siklus uygulandı. Daha sonra tüm örnekler, kırılma karakteristiklerin tespiti için evrensel test cihazında (Zwick-010, Ulm, Almanya) test edildi.

Bulgular: Termal-siklus uygulanmış DC-Tell örneklerin kırılma dayanıklılık değerleri en düşük bulunurken (753,60 N), en yüksek değeri metal örnek grubu gösterdi (2282,20 N). (p = 0.001)

Sonuçlar: CAD/ CAM ile üretilen zirkonyum oksit alt yapılı kronlara kor hazırlanırken, metalik materyaller ile daha iyi mekanik özellik ve klinik başarı elde edilebilir.

Anahtar Kelimeler: Biyomekanik, CAD/CAM, Kırılma Dayanıklılığı, Zirkonyum Oksit

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INTRODUCTION

All-ceramic crown and bridge systems are becoming to be very popular because of their good aesthetics, excellent biocompatibility and enhanced mechanical properties when compared to the conventional metal-ceramic technology.^{1,2} However, their inadequate mechanical long term properties limit their application mainly in the anterior regions.³ In order to extend the application of all-ceramic systems in the stress bearing posterior areas, high strength ceramic materials on the base of aluminum oxide [Al₂O₃], zirconium-oxide [ZrO₂], silicon carbide [SiC] and silicon nitride [Si₃N₄] have been developed.⁴⁻⁹ In dentistry, the most common are aluminum and zirconium oxide which have passed for many years of clinical experience in hip replacement.^{10,11} Because studies have shown that the aluminum oxide does not have sufficient mechanical properties to make larger bridges, especially zirconium oxide ceramics represent an important

indication extension of all-ceramic restorations for crowns and multi-unit bridges.^{12,13} Various studies suggest that the mechanical properties of zirconium oxide are sufficient for crowns and bridges (Table 1).¹⁴⁻¹⁶ Zirconium oxide has a white color, which provides a good base to achieve high-quality aesthetic results. Despite dense sintering characteristic of high-strength ceramics, the zirconium oxide frameworks exhibit high translucency to allow a harmonious transition for reconstructing the lost tooth structure.¹⁷⁻¹⁹

MATERIALS AND METHODS

In this investigation, ten metal and twenty DC-Tell dies produced by the means of Lava® (3M, ESPE, Seefeld, Germany) procedure for the mandibular I. molar with a chamfer preparation design were manufactured. The physical properties of DC-Tell are shown in Table 2. To achieve the equal distribution of stresses in the apical area, the root cross section was designed (Figures 1 and 2). The

Table 1. Material properties of DC-Zirkon.

Properties DC-Zirkon	Value
ZrO ₂ /Y ₂ O ₃	95/5 %
Purity (Zr/Hf/Y)	99.9 %
Flexural Strength	1200 MPa
Hardness, Vickers	1200s HV
Compression resistance	2000 MPa
Wear (ring on disc)	<0.002 mm ³ /h
Coefficient of thermal expansion t 25-500°C	10×10 ⁻⁶ /K
Elasticity Modulus	210 GPa
Colour	White

Table 2. Material Properties of DC-Tell.

Properties DC-Tell	Value
Density	1.69 g/cm ³
Elastic Modulus	22000 Mpa
Flexural Strength	380 MPa
Solubility	<1 mg/mm ³
Melting Point	260°C
Water Absorbtion	30.2 mg/mm ³
Max. Working Temperature (continuous)	100-120°C
Max. Working Temperature (short term)	180°C



Figure 1. Metal die sample with cross section root design.



Figure 2. DC Tell sample.

three-dimensional data was set after full optical digitizing of the die surface. (Figure 3) DCS system® (DCS dental AG, Switzerland) based on the optical digitizing was used for the preparation of the frameworks. (Figure 4) This system allows fabrication of crown and bridge substructures made of titanium, aluminum-oxide and zirconium-oxide. The blanks of partially stabilized zirconium dioxide ceramic (DC-Zircon, DCS Dental AG, Switzerland) have been used to prepare the ceramic copings for to test their strengths of fracture in this study. The thickness of the Precident DCS copings were 0.6 mm for all samples. The frameworks were checked for their fit to the corresponding dies and cemented with fast-

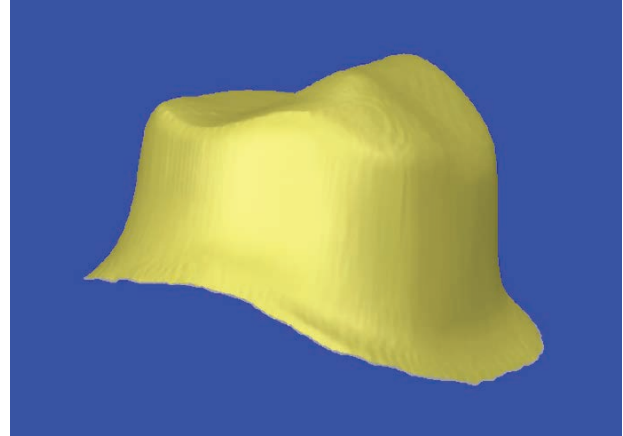


Figure 3. Three-dimensional optical digitizing of the die surface.



Figure 4. Computer-aided designing of the zirconia core.

curing Zinc-oxid-phosphate cement (Harvard Dental, Berlin, Germany). All samples were stored in distilled water for 24 hours before testing.

Ten metal and ten DC-Tell samples were exposed to a thermocycling of 20.000 cycles before fracture tests. The remaining ten DC-Tell die specimens without thermocycling served as the control group. Using a 3 mm diameter ceramic antagonist ball with a traverse speed of 1 mm/min, and a loss of force by 30%, all the samples were tested for their fracture resistances with a universal testing machine (Zwick-010, Ulm, Germany) until the fracture occurred. (Figure 5) The strength of the fracture has been defined by the occurrence of the first crack.

The statistical analyses were carried out by using Statistical Product and Service Solutions (SPSS) version 11.5. The means and standard deviations for each group



Figure 5. Static fracture strength testing of zirconia core with a universal testing machine.

were calculated. The fracture values (MPa) of each group were first compared by Kruskal Wallis test. When statistical significance was found among the groups with Kruskal Wallis, Bonferroni corrected Mann-Whitney U test was done for the pairwise comparisons.

RESULTS

All 20 specimens survived the thermocycling of 20000 cycles and no fracture occurred. The results of the subsequent static fracture tests were seen in Table 3 and Figure 6.

With Kruskal Wallis test for the independent samples were determined the differences of strength differences among the group. The fracture strengths of DC-Tell samples with thermocycling showed the lowest (753,60 MPa) while the metal samples with thermocycling showed the highest values (2282,20 MPa). In addition, DC-Tell dies had significantly lower resistance capacity after thermocycling compared to the DC-Tell specimens without thermocycling.

Significant difference was found in (MPa) values among three groups ($p=0.001$). According to the pairwise comparisons, all the three groups were statistically different from each other ($p<0.05$). The results of significances are shown in Table 3.

DISCUSSION

This in-vitro study took place under laboratory conditions. Therefore, the clinical situation is not precisely simulated where as additional dynamic occlusal stresses within the material occur in clinical conditions. However, in order to simulate the natural conditions as closely as possible, all the samples of this study were produced with same dimensions and in the same material quality. In both groups, the cores were accomplished as if they were intended for clinical use. The CAD/CAM copings were performed according to the manufacturer's instructions, with appropriate dimensions and identical for all groups. Cementations were made according to the manufacturer's recommendations, with fast-curing Zincoxid-phosphate cement on metallic and DC-Tell die cores. In addition, DC-Tell was used to simulate the dentine. The elastic modulus of DC-Tell is 22 Gpa similar to that of dentin which is 18-20 Gpa.²⁰⁻²⁴ DC-Tell also has thermal expansion and water absorption capacity similar to the dentin. Hence, the fracture lines of all models were equal by standardized ratios (Figure 7).^{25,26} Depending on the less variances within the models, more accurate analyzes on the fracture strength could be achieved.

According to Scherrer²⁰, increasing elastic modulus of the supporting material results in increased fracture strength. In this study, zirconia copings supported with the metallic core samples showed higher fracture strength values than the DC-Tell cores which is also in accordance with the literature.^{21,22}

From the static fatigue, it is generally assumed that there is a chemical reaction between water vapor and surface defects within the ceramic restoration. Ceramic structures tend to fail

Table 3. Results of the statistical analysis [MPa].

Group	Mean	Std. Deviation	Median	Min.	Max.
Metal with Thermocycling	1700,38	266,76	1627,65	1425,70	2282,20
DC-Tell with Thermocycling	916,22	115,99	888,45	753,60	1120,80
DC-Tell without Thermocycling	1192,87	86,95	1219,10	1027,30	1320,10

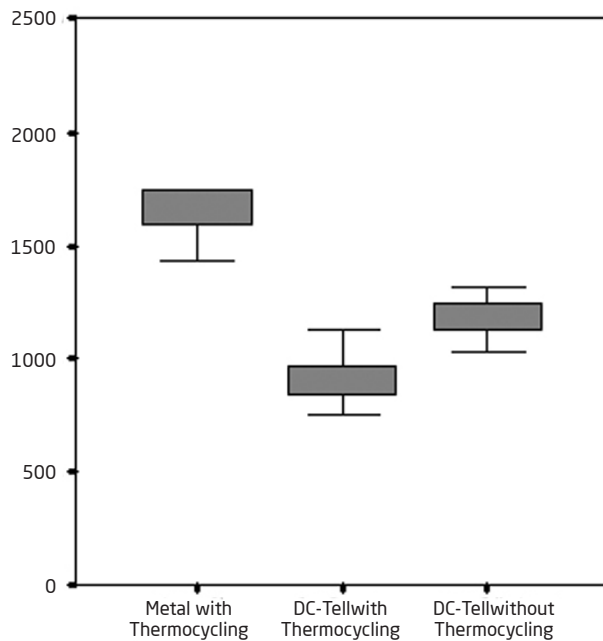


Figure 6. Box- plot of load at fracture values [MPa].

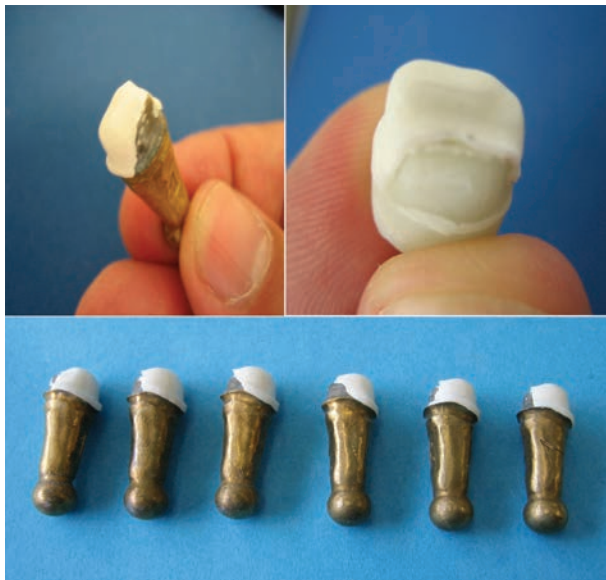


Figure 7. Illustrates the fracture of zirconia copings where the fracture surface is clearly visible for both metal and DC Tell samples.

because of surface tension, here cracks and flaws propagate by slow crack growth leading to the catastrophic failure. In all-ceramic systems, the flaw population (size, number and distribution) can be related to the material, or be affected by

the fabrication process. An outgoing crack defect growth can reach to a critical size so as a consequence it comes to spontaneous breakage of the ceramic.^{27,28} For this reason, ceramic crowns, which are long in the mouth, can break at comparatively with low occlusive forces.

This study showed that DC-Tell dies had a lower resistance capacity after thermocycling compared to the DC-Tell specimens without thermocycling. This was to be expected, because the inner corrosion stress forces cracking with thermocycling.²⁸⁻²⁹ As a result of the hydrolytic processes, the increase of fracture toughness during water storage (thermocycling) could be observed.

According to the findings of this study, the abutment material, as mentioned above, has a significant influence and affected the fracture load of CAD/CAM fabricated zirconia copings for the mandibular first molar. The question that arises is whether the results of the present study can be transferred to the clinical situation and in what extent the fracture strength affects the lifespan of zirconia for different types of cores. CAD/CAM manufacturers have to provide the prerequisites before this technique can be widely advocated for immediate implementation in the market.³⁰ Further studies are needed to validate the results of this investigation.

CONCLUSION

Good mechanical properties and clinical successes can be achieved with metallic materials while constructing cores under crowns with CAD/CAM fabricated zirconium-oxide copings. Further clinical trials are needed to validate the results of this in-vitro study.

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