Effect of Die Materials on the Fracture Resistance of CAD/CAM Monolithic Crown Restorations

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Abstract

The effect of the die materials on the fracture strength of CAD/CAM monolithic ceramic crowns was studied in this research. Three different types of die materials (dentin, Ni-Cr alloy, epoxy resin) were prepared. The monolithic crowns were fabricated using a CAD/CAM System; CEREC 4. The CAD/CAM crowns were cemented to dies using a resin cement. The specimens were tested under compressive load at a crosshead speed of 1 mm/min using a universal testing machine until fracture occurred. Recorded data were statistically analyzed using one-way analysis of variance and LSD Post hoc tests (p=0.05). While CAD/CAM crowns on Ni-Cr alloy dies showed the highest fracture resistance values, CAD/CAM crowns on dentin dies showed the lowest fracture resistance values. There is no significant difference between groups statistically. Ni-Cr alloy and epoxy resin dies could be used alternatively instead of teeth for in vitro studies.

Key Words: Die materials, Fracture resistance, CAD/CAM, Monolithic crown

Introduction

The fracture resistance of all-ceramic and glass ceramic materials is of major worry in the clinical use of these materials [1]. Fracture resistance connected the elastic modulus of the die materials, the fabrication technique, preparation design, properties of the luting cement, method of luting, surface roughness, residual stress, microstructure of ceramic material, crown thickness, the surface finish of the restorations, cyclic preload and thermal cycling [1-10].

Using natural teeth can cause difficulties in standardization because natural teeth show a large variation depending on anatomy, patient age and storage time after extraction [11]. Therefore many studies using metal [12-15], brass [16,17], epoxy resin [18,19], and acrylic resin [20] as supporting die materials for evaluating fracture resistance of all-ceramic crowns [20-23]. In this way, preparation of tooth is standardized and the same physical properties of materials are used [11]. But elastic modulus of die materials is dissimilar. The fracture resistance of CAD/CAM ceramic crowns is increased as a result of raise in elastic modulus of the supporting die [1].

Fracture test of ceramic specimens produced in the form of anatomic configuration of teeth can be a beneficial tool for determination their behavior [24]. The in vitro test contains loading the anatomic specimens (bridges, crowns, inlays) until the result of failure. Mechanical properties of a new restorative material can be determined upon by comparing the results achieved from these in vitro studies with the results of well described and accepted materials in the same trial [25-27].

The purpose of this study was to evaluate and compare the effect of die materials on the fracture resistance of CAD/CAM monolithic crown restorations. The hypothesis was CAD/CAM crowns on Ni-Cr dies would show the highest fracture resistance values and CAD/CAM crowns on epoxy resin and dentin dies would show the similar fracture resistance.

Materials and Methods

Ethical approvial (no:17/2013) was obtained from the Ataturk University Faculty of Dentistry Ethical Committee for the study. Non-carious and non-cracked human premolars were selected for this study. Calculus deposits and soft tissues were removed and teeth were stored in % 0.1 thymol solution. These teeth were prepared for CEREC restorations according to manufacturer's recommendations.

There are various finish lines, described by researchers [10, 28], could be used for all-ceramic crown preparations; such as 0.9 or 1.2 mm chamfer, 1 or 1.2 or 1.5 mm shoulder finish line. In this in vitro study, a circumferential shoulder finish line of 1 mm was used.

The teeth were prepared with a 12 degree angle cervico-occlusally, and a 1 mm wide shoulder finish line. This master core was duplicated with metal (Ni-Cr alloy) and epoxy resin (Epoxy-Die, Ivoclar AG). Tooth immobility has been shown to play an important role when evaluating fracture strength [29, 30]. They were fixed in the center of specimen holders with a chemically polymerizing resin (Paladur, Kulzer, Wehrheim, Germany). Feldspatic ceramic crowns were milled using a CEREC 4 (Sirona Dental Systems.GmbH, Bensheim, Germany) machine. A spray (CEREC Optispray) consists of fluorinated hydrocarbon including pigment was used to reflect the light of the intraoral camera of the CEREC 4 and a digital impression was taken. CEREC 4 software (Version, 4.2.0.57192) was used for designing and milling the crowns. The spacer was set at 80 μm. Following milling, the restorations were examined for defects or cracks and their fit was assessed on the tooth using a 2.5x magnification. Five crowns were seated on each die materials using adhesive technique (n=5).

The CAD/CAM crowns were fabricated according to the manufacturer's instructions to produce optimum sequels. All monolithic crowns were manufactured to the same shape and size to ensure standardization and polished with porcelain polisher (KENDA AG, Vaduz, Liechtenstein) after fabrication. No failure was determined to happen between the cement and crown material.

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Before cementation, the internal surface of all crowns were etched for 60 s using 4.9 % hydrofluoric acid (Ceramics Etch, Vita) and thoroughly rinsed and dried. Then a resin cement (RelyXTM U200; St.Paul, MN 55144-1000, USA) was used to cement the crowns to the prepared samples. Adequate amount of adhesive resin cement was mixed and applied to the milled surface of each crown. While cementation, the crowns were held in position for 3 minutes with finger pressure. Excess cement was removed from the margins were finished and polished with flexible disks. (Sof-lex) A 22 N static load was applied for 5 minutes with a loading apparatus. One hour after cementation, the specimens were immersed in water bath at 37°C for 1 week before testing.

A stainless steel bar with a 3.5 mm diameter ball mounted on the crosshead of the universal testing machine (Instron) was used to apply compressive loads along the long axis of restored teeth at a crosshead speed of 1 mm/min until fracture [31]. The compressive load was centered on the central groove of each crown, so that the load was applied to the triangular ridges of both fasial and palatal cusps. The compressive load (N) required for causing fracture was recorded for each specimen.

Fracture strength data were statistically analyzed with one-way analysis of variance and LSD Post hoc tests (α=0.05).

Results

The mean fracture resistance for CAD/CAM monolithic crowns on the epoxy resin, dentin, and Ni-Cr dies were 595 N, 578N, and 606 N respectively. CAD/CAM monolithic crowns on Ni-Cr dies showed the highest fracture resistance among groups (Table 1) (Figure 1). No significant differences were found in the fracture resistance between groups (p>0.05).

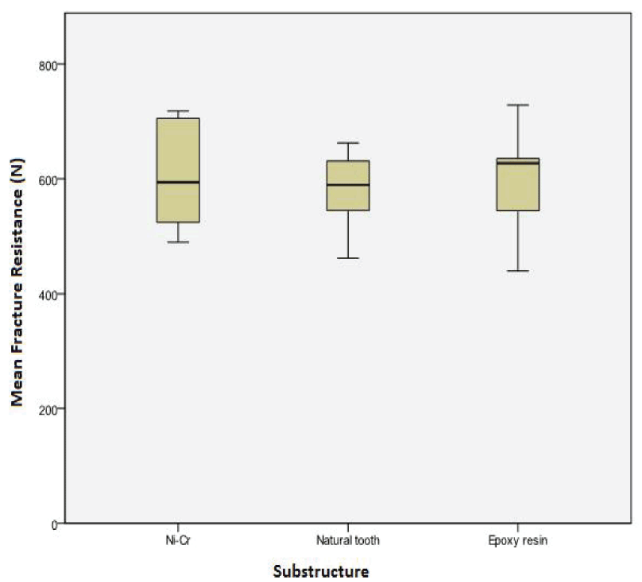

Figure 1: *Boxplot of the fracture resistance of CAD/CAM monolithic crown. The box represents the spreading of the data between the first and third quartile. The whiskers extend to the minimum and maximum value measured.*

Discussion

The outcomes of this study suggest that the elastic modulus of the die material has not an important effect on the fracture resistance of CAD/CAM monolithic crowns. In the present study, CAD/CAM monolithic crowns on dentin and epoxy resin dies showed lower fracture resistance values than Ni-Cr dies. Metal dies are very rigid and have a higher elastic modulus than dentin and epoxy resin so that these dies deform less, resulting in a lower shear stress at the inner crown surface [32]. Scherer and Rijk **1** studied the effect of three different die materials (acrylic resin that was polymerized with heat: Paragon, and two kinds of composite resin that were polymerized with visible light: Herculite XR, Kerr, Romulus, MI and Dr J.M. Antonucci, NIST, Gaithersburg, MD) on the fracture resistance; reported that the mean fracture load value of feldspathic porcelain crowns were 960 N, on acrylic resin dies; and 1600 N and 2800 N, on composite resin dies that was polymerized with visible light.

Table 1. Mean and standard deviation values of the fracture resistance of CAD/CAM monolithic crowns that cemented to different die materials.

Die Materials	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Ni-Cr	5	606,29	1,03,369	46,228	477,94	734,64	490	718
Natural tooth	5	578,00	78,679	35,186	480,31	675,69	462	663
Epoxy resin	5	594,98	1,08,712	48,617	459,99	729,96	439	729
Total	15	593,09	91,340	23,584	542,51	643,67	439	729

They concluded that die material had an effect on the fracture resistance. They found that the fracture loads of all-ceramic crowns increased with the elastic modulus of the supporting structure. In the present study, results are in agreement with this finding.

For fracture testing, an epoxy resin die might be used rather than a metal die to achieve realistic fracture resistance values [32]. In this study the master die was prepared according to the CEREC 4 recommendation to receive an all ceramic restoration. 90-degree shoulder line angle is recommended for all ceramic restorations in vivo [33]. In the present study 1 mm 90-degree shoulder line angle and 12 degree taper was prepared. This preparation was duplicated using epoxy resin and Ni-Cr casting. Epoxy resin, a material which has a elasticity similar to that of dentin (12.9 GPa). In addition, epoxy resin responds to 34% phosphoric acid etching by forming micro-roughness for bonding [34]. Zahran et al [19] concluded that the epoxy resin dies are able to be etched with phosphoric acid and bonded well to resin cements. Therefore, the risk of debonding between epoxy resin dies and adhesive resin cement is reduced. This investigation aimed to compare natural teeth (dentin die) with artificial materials (Ni-Cr and epoxy die). The dimensions of the natural tooth were chosen close to each other.

In humans, the mean masticatory forces during mastication and swallowing to be almost 40 N. But, the mean maximum posterior masticatory forces may change from 150 N to 665 N. 2, [34, 35]. In this in-vitro study, the mean fracture load of the monolithic crowns were higher than the mean masticatory forces. Consequently, it may be supposed that monolithic CAD/CAM crowns made from Cerec Blocs machinable ceramics withstand the maximum intraoral masticatory forces [36].

Kelly [37] stated that testing the material by preparing in the form that it will be used in the mouth, will lead to more realistic results. In this study, some of the experimental samples that were prepared in the form of the natural teeth were used. Conducting the study by using the natural teeth is advised because of the better comparison in terms of clinical features; strength character, thermal conductivity, bonding characteristic, and elasticity modulus [25]. Rosentritt et al. [38] researched the marginal adaptation and fracture resistance of ceramic crowns. They used natural teeth and supported teeth that were made of liquid crystal, and examined the differences between the two. They stated that when natural teeth were used, it was observed that marginal adaptation and fracture resistance decreased, so the use of natural teeth would lead to more realistic results.

Hui et al. [39] examined the effect of different preparations on the endurance of porcelain laminates; they used acrylic replicas that were obtained from natural and plastic teeth. As a result, they reported higher fracture resistance in laminates that were applied on natural teeth. In the present study, natural tooth, epoxy resin, and Ni-Cr dies were compared; the natural teeth were served as control group. It was found that crowns that were tested on Ni-Cr dies had higher fracture resistance.

Beschnidt and Strub [40] used extracted human central incisor teeth; and stated that they could not reach a total standardization of the samples because these teeth showed a variety in terms of their age, size, anatomy, storage conditions after extraction, and storage time. As a result, many researchers [10,19,20,41,42] used metal or resin die while assessing the fracture resistance. However, samples obtained from metal or resin dies cannot completely reflect the natural condition of the tooth.

Skoguchi et al [42] examined two different composite resin crowns fracture as a result of cyclic loading test by using epoxy resin, metal and composite as die materials; and they concluded that crowns that were cemented over resin dies showed more fracture resistance than those that were cemented over metal dies regardless of crown material.

Bindl et al. [20] reported that elasticity modulus affected the fracture sensitivity of cemented ceramic crowns, so they used hybrid resin composite as die material because its elasticity modulus was close to the elasticity modulus of the tooth. (Hybrid resin composite: 11.5 GPa and the tooth: 5.2-19.3 GPa)

Kwon et al. [43] preferred Ni-Cr alloy as die material while comparing the fracture resistances of two different zirconium restorations prepared using a CAD/CAM device. They reported that elasticity modulus of Ni-Cr (218 GPa) was different from the elasticity of the tooth (12 GPa). They also stated the reasons why they had preferred this metal alloy: It was not possible to reach a standardization of the size of the natural teeth, mineralization, internal fissure, pulpal size, and mechanical features; and it was possible for the natural teeth to fracture during the testing process.

Conclusion

Using three different materials for the supporting dies under either a complete CAD/CAM monolithic crown design, it can be concluded that, the fracture resistance of Feld spathic all-ceramic crowns is not dependent on the die materials.

While CAD/CAM crowns on Ni-Cr alloy dies showed the highest fracture resistance values, CAD/CAM crowns on dentin dies showed the lowest fracture resistance values

CAD/CAM crowns on epoxy resin dies showed similar fracture resistance values with CAD/CAM crowns on dentin dies.

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