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Comparison of the Load at Fracture of Turkom-Cera to Procera AllCeram and In-Ceram All-Ceramic Restorations

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Abstract

Purpose: This study investigated the occlusal fracture resistance of Turkom-Cera-fused alumina compared to Procera AllCeram and In-Ceram all-ceramic restorations.
Materials and Methods: Six master dies were duplicated from the prepared maxillary first premolar tooth using nonprecious metal alloy (Wiron 99). Ten copings of 0.6 mm thickness were fabricated from each type of ceramic, for a total of thirty copings. Two master dies were used for each group, and each of them was used to lute five copings. All groups were cemented with resin luting cement Panavia F according to manufacturer's instructions and received a static load of 5 kg during cementation. After 24 hours of distilled water storage at 37°C, the copings were vertically compressed using a universal testing machine at a crosshead speed of 1 mm/min.
Results: The results of the present study showed the following mean loads at fracture: Turkom-Cera (2184 ± 164 N), In-Ceram (2042 ± 200 N), and Procera AllCeram (1954 ± 211 N). ANOVA and Scheffe's post hoc test showed that the mean load at fracture of Turkom-Cera was significantly different from Procera AllCeram ($p < 0.05$). Scheffe's post hoc test showed no significant difference between the mean load at fracture of Turkom-Cera and In-Ceram or between the mean load at fracture of In-Ceram and Procera AllCeram.
Conclusion: Because Turkom-Cera demonstrated equal to or higher loads at fracture than currently accepted all-ceramic materials, it would seem to be acceptable for fabrication of anterior and posterior ceramic crowns.

With an increased demand for esthetics and concerns about toxic and allergic reactions to dental alloys, full coverage all-ceramic crowns have become very popular with both patients and clinicians because of their highly esthetic results and biocompatibility.[1] Furthermore, metal-based crowns have other disadvantages, such as galvanic reaction, and the metal underlying the veneer's porcelain can show through as a dark line.[2,3]

As the demand for more natural-looking crowns has increased, dentists and porcelain manufacturers have investigated methods to help reinforce ceramics with the goal of fabricating an all-ceramic restoration that delivers excellent esthetics and good biocompatibility. Silica-based ceramics such as feldspathic porcelain and glass ceramic are frequently used to veneer metal frameworks or high-strength ceramic copings for all-ceramic restorations.[4] Their excellent esthetic properties make them the material of choice for ceramic laminate veneers and inlays/onlays.[5,6] Despite the inherent brittleness and limited flexural strength of silica-based ceramics, final adhesive cementation with composite increases the fracture resistance of the ceramic restoration.[7]

Leucite-reinforced feldspathic porcelain (i.e., IPS Empress, Ivoclar-Vivadent, Schaan, Liechtenstein) achieves significantly higher fracture strength and provides the restorative team with the ability to fabricate full-coverage all-ceramic restorations for both anterior and posterior teeth if resin bonding techniques are properly applied.[6]

Several new all-ceramic systems, which offer comparable stability to porcelain-fused-to-metal (PFM) restorations, good esthetics, and simplified fabrication procedures, have been introduced. Recently, new dental materials and techniques have been introduced to fabricate esthetic ceramic restorations with improved strength and marginal adaptation. This becomes more important for posterior areas, where forces are much higher than for the anterior region and can reach 522 N in the average person.[8,9]

In order to provide satisfactory posterior all-ceramic restorations, strong alumina cores have been produced. Turkom-Cera all-ceramic material (Turkom-Ceramic (M), Kuala Lumpur, Malaysia), Procera AllCeram (Nobel Biocare, Goteborg, Sweden), and In-Ceram (Vita Zahnfabrik, Bad Sackingen, Germany) are three ceramic systems that incorporate a high alumina core. These cores differ in their manufacturing process and are also intrinsically different in that the Procera AllCeram core contains a densely sintered alumina core, whereas Turkom-Cera and In-Ceram are made of a high alumina core, which is subsequently crystal hardened or glass infiltrated. However, alumina cores tend to be opaque and require the use of veneer porcelain to mask the core and provide the desired contours.[4,10]

Many factors, such as microstructure of the ceramic material, preparation design, crown thickness, direction and location of the applied load, luting methods, and storage conditions before loading to fracture, influence the results of the fracture load of all-ceramic crowns.[11-16] A new all-ceramic alumina core material, Turkom-Cera, is being introduced in an attempt to provide a high-quality, high-strength, cost-effective coping that will result in improved clinical success. Independent studies of basic comparative data are necessary to characterize this new material in relation to mechanical properties. The present study attempted to isolate the ceramic material as the only variable. Attempts were made to standardize the other variables that may have an effect on the results of the fracture load. The objectives of this study were to study the occlusal fracture resistance of Turkom-Cera copings compared to In-Ceram and Procera AllCeram copings, and to investigate the mode of fracture of the copings.

Materials and methods

This study evaluated the difference in fracture strength of Turkom-Cera, Procera AllCeram, and In-Ceram all-ceramic systems, when luted with resin cement Panavia F (Kuraray Medical Inc., Okayama, Japan).

The methods used in this study were similar to previous studies.[10,16-18] The metal dies designed and used in this study, although not replicating the elastic modulus of teeth, were homogenous in composition and provided a standard size and shape for the ceramic coping support. Cobalt–chromium alloy was used because of its markedly superior physical properties to porcelain, to ensure that the die would not break or get damaged.[19] Furthermore, natural teeth show a large variation depending on their age, individual structure, and storage time after extraction, thus causing difficulties in achieving standard support.[20,21]

To avoid the influences of preparation design, loading direction, and loading stylus radius, an identical abutment analog and loading apparatus were used for all test specimens. In addition to that, the load was directed vertically in the center of the occlusal surface down the long axis of each cemented coping.[11-13,15]

In this study, six master dies were duplicated from the prepared maxillary first premolar tooth using a nonprecious metal alloy (Wiron 99, BEGO, Bremen, Germany). The six master

Figure 1 Turkom-Cera-fused alumina kit.

dies were divided into three groups according to the type of all-ceramic materials used. Ten all-ceramic copings of 0.6 mm thickness were fabricated from each type of ceramic. Two master dies were used for each group, and each of them was used to lute five copings.

For the Turkom-Cera group, five impressions were made for each of the two master dies (total of ten impressions) and poured in die stone (Densite, Shofu Inc., Kyoto, Japan). The preparation of Turkom-Cera all-ceramic copings in the dental laboratory does not require more than a standard laboratory furnace, propane gas flame, standard laboratory micromotor, and Turkom-Cera all-ceramic kit (Fig 1). Using the Turkom-Cera technique, the stone die was covered by red plastic foil of 0.1 mm thickness and dipped in the Turkom-Cera Alumina Gel (Batch no. 610). After drying of the alumina gel, the coping with the red plastic foil was removed from the stone die and fired in the furnace (Programat p300, Ivoclar-Vivadent) for 5 minutes at 1150°C. The sintered coping was hardened using Turkom-Cera Crystal Powder (Batch no. 110). The Turkom-Cera crystal powder was mixed with water, applied on the sintered Turkom-Cera coping, and fired in the same furnace for 30 minutes at 1150°C. The excess crystals were removed using a laboratory micromotor (NSK Ultimate 500, NSK Nakanishi Inc., Kanuma, Japan) with a coarse laboratory diamond bur at slow speed. Ten copings with a thickness of 0.6 mm were fabricated.

For the In-Ceram group, five impressions were made for each of the two master dies (total of ten impressions) using an addition polymerization silicone material (Dent Silicone Plus, Shofu Inc., Kyoto, Japan) with a plastic ring. These impressions were poured with In-Ceram special plaster to make refractory models. The In-Ceram alumina slip was prepared by mixing In-Ceram alumina powder (Batch no. 26270) with In-Ceram mixing fluid and additive supplied by the manufacturer and applied to the models. After applying a stabilizer, the coping was fired on the plaster dies in the furnace (Inceramat, Vita) for 6 hours at 120°C and 4 hours at 1120°C. The In-Ceram Glass Powder (Batch no. 6134K) was mixed with water, and the sintered In-Ceram copings were then glass infiltrated in a second firing process in the same furnace for 30 minutes at 200°C and 4 hours at 1100°C. The excess glass was removed using a laboratory micromotor (NSK Ultimate 500) with a coarse laboratory diamond bur at slow speed. Ten copings were fabricated with a thickness of 0.6 mm.

For the Procera AllCeram group, one impression was made for each of the two master dies (total of ten impressions) and poured in die stone (Densite). Each stone die was mounted in a Procera scanning machine (Nobel Biocare) linked to a computer and modem. The die was scanned, and the data were then forwarded to Nobel Biocare in Sweden, where five Procera copings were manufactured with a thickness of 0.6 mm for each master die (total of ten copings made, batch no. 3128 2720).

The Turkom-Cera copings were prepared by one technician, who has attended many training courses arranged by the Turkom-Cera Company. In-Ceram and Procera copings were prepared by a different technician. The two technicians were supervised and instructed to keep the coping thickness standard (0.6 mm). After finishing, all copings were visually inspected under 2.5 × magnification, measured for thickness on the center of the buccal, occlusal, and lingual surfaces, and then matched to their specific die.

Ten copings from each of the three above-mentioned ceramics were cemented using Panavia F (dual-cured composite resin cement) onto their corresponding dies. Two master dies were used for each group, and each of them was used to lute five copings. To simulate a portion of the bonding steps, ED primer was applied to the entire surface of the metal die and allowed to set for 60 seconds before air drying with gentle air flow. The fit surfaces of all copings were silanated with a mixture of Clearfil Porcelain Bond Activator (Batch no. 00184A) and Clearfil SE Bond Primer (Batch no. 00589A) (Kuraray Medical Inc.). The mixture was applied to the internal surface of the coping and left for 5 seconds before air drying with gentle air flow. One complete turn from each cartridge of Panavia F (Batch no. for paste A: 00245D; paste B: 00140B) was dispensed, mixed for 20 seconds, and applied to the internal surface of each coping.

Before cementation, all copings were internally sandblasted with 50 μm aluminum oxide (Al_2O_3) particles at an air pressure of 2.5 bars for 13 seconds from a distance of 10 mm. After the impressions were completed, the dies were first cleaned with acetone, steam cleaned, and air dried before cementation of the first ceramic coping. After cementation and testing of the first coping, any cement remnants on the die were removed ultrasonically. Then the dies were steam cleaned and air dried before cementation of the following coping. Five copings for each master die were cemented and tested in this manner.

Manual finger pressure was used to initially seat each crown on its die, and any excess paste remaining at the margins was removed with a disposable brush, and a layer of Oxyguard II (Kuraray Medical Inc.) was applied for 3 minutes around the margins of each specimen. The specimens were then placed in a custom-made vertical loading apparatus (Makramani Load) for 10 minutes under a 5 kg load. Following cementation, all specimens were placed in a sealed container of distilled water and left in an incubator at a constant temperature of 37°C for 24 hours.

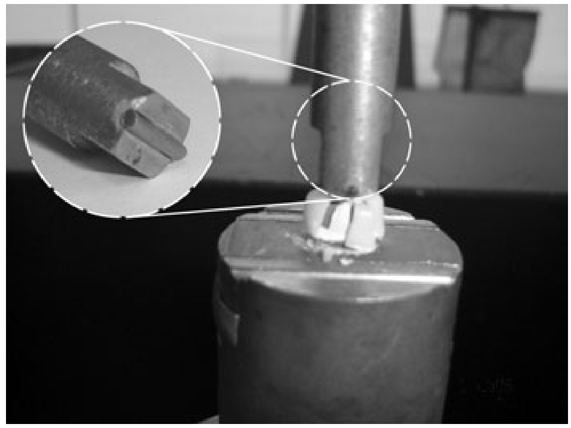

Figure 2 Example of fractured coping after loading with a 1.6 mm stainless steel bar.

The master die with cemented coping was removed from the storage container, dried, left for 15 minutes to attain room temperature before mounting in a specially designed jig, and subjected to testing on the Instron Testing Machine. All tests were performed at room temperature.

A 1.6 mm stainless steel bar mounted on the crosshead of the Instron Testing Machine applied an axial load at the center of the occlusal surface, along the long axis of the cemented copings, at a crosshead speed of 1 mm/min until fracture (Fig 2). The maximum force to produce fracture was recorded in newtons. The fractured crowns were removed, and the master die was ultrasonically cleaned before a new coping was cemented. The force at failure was noted, and the failed coping examined to determine the mode of fracture. The mode of fracture was classified using categories described by Burke (Table 1).[22]

The results of the study were statistically tested by one-way ANOVA and Scheffe's post hoc test to determine if significant differences between test groups were related to the ceramic material used for each group. The nonparametric Kruskal-Wallis test was used to test the association between mode of fracture and fracture strength. The chi-square test was used to test the association between treatment group and mode of fracture.

Results

The mean and median load at fracture, the standard deviation, and the 95% confidence interval (CI) for each experimental

Table 1 Modes of fracture for ceramic copings

Mode of fracture	Description
I	Minimal fracture or crack in coping
II	Less than half of coping lost
III	Coping fracture through midline (half of coping displaced or lost)
IV	More than half of coping lost
V	Severe fracture of coping and/or die

Table 2 Mechanical properties at fracture for ceramic copings

Treatment group	n	Mean, (SD)	95% Confidence interval Lower bound	Upper bound	Median
Turkom-Cera	10	2184 N (164)[a]	2066	2301	2186
In-Ceram	10	2042 N (200)[a,b]	1898	2185	1991
Procera AllCeram	10	1954 N (211)[b]	1803	2104	2025

Means indicated by different superscript letters are significantly different at $p < 0.05$.

group are recorded in Table 2. One-way ANOVA demonstrated that at least one pair of mean values differed significantly ($p < 0.05$). Scheffe's post hoc test gives Scheffe's CI value of 223.3. According to Scheffe's CI value, if the mean difference between two groups is more than this value (223.3), the two groups are statistically different from each other. The mean load at fracture of Turkom-Cera (2184 N) was significantly different from Procera AllCeram (1954 N), as the mean difference between them is more than the Scheffe's CI value (223.3). There was no significant difference between the mean load at fracture of Turkom-Cera and In-Ceram or between the mean load at fracture of In-Ceram and Procera AllCeram, as the mean difference between them is less than the Scheffe's CI value (223.3).

The Kruskal-Wallis test showed no evidence of association between mode of fracture and fracture strength ($p > 0.05$). The chi-square test showed no significant association between treatment group and mode of fracture ($p > 0.05$). The descriptive summary for modes of fracture and mean load at which the various fracture modes occurred was recorded for each type of ceramic materials (Table 3).

Discussion

This study evaluated the load at fracture of Turkom-Cera-fused alumina compared to In-Ceram and Procera all-ceramic systems using metal supporting structure. In the present study, none of the six metal dies used were found to be broken or damaged. Some investigators have used resin dies instead of metal dies as a supporting structure. Chai et al compared the probability of fracture of four systems of all-ceramic crowns using composite resin master dies. From the results of fracture mode of the tested crowns, it was clear that up to 50% of the tested specimens from each group suffered from fracture of the supporting die.[23] Therefore, metal supporting dies were used in this study to ensure that the supporting die would not break before the coping.

Table 3 Descriptive summary for modes of fracture and mean load at fracture of ceramic materials

Mode of fracture	Frequency of fracture mode, n (%)	Mean load at fracture (SD) (in N)	Fracture frequency per group (Turkom-Cera)	(Procera)	(In-Ceram)
I	22 (73)	2033 (213)	8	8	6
II	4 (13)	2058 (183)	0	1	3
III	0	–	0	0	0
IV	1 (3)	2068 (0)	1	0	0
V	3 (10)	2254 (210)	1	1	1

Figure 3 Most common mode of fracture for ceramic copings (minimal fracture).

The results of the present study indicated that Turkom-Cera copings (2184 N) luted with the resin luting cement (Panavia F) provided resistance to fracture higher than that obtained by Procera AllCeram (1954 N) and In-Ceram (2042 N) copings luted with the same cement. Statistical analysis using Scheffe's post hoc test showed a significant difference between the mean load at fracture of Turkom-Cera and Procera AllCeram. The same test showed no significant difference between the mean load at fracture of Turkom-Cera and In-Ceram or between the mean load at fracture of In-Ceram and Procera AllCeram.

Burke found that biting forces of up to 800 N have been measured clinically in natural teeth and that experimental forces of this value may be considered to be of clinical relevance.[24] The results of this study cannot be directly compared with either mean chewing forces or maximal biting forces, because the copings were cemented to metal dies. Scherrer and de Rijk found that a die with a high modulus of elasticity can result in increased fracture loads of ceramic.[25]

This study was in agreement with the findings of previous studies,[10,17,26] which found no difference in compressive strength between resin-cemented Procera and In-Ceram crowns. This may be attributed to resin cementation of die and ceramic, which act as a bonded system with load transfer through each interface.

Examination of the mode of fracture of specimens revealed that the majority of Turkom-Cera (80%) and Procera AllCeram (80%) copings exhibited minimal fracture (Fig 3), whereas only 60% of In-Ceram copings exhibited minimal fracture. However, data analysis revealed no significant association between mode of fracture and treatment group or between mode of fracture and fracture strength.

This study evaluated the load at fracture of all-ceramic materials supported to metal dies. The advantages of using such abutments are maintaining the possibility of standardized preparation, ensuring that the die will not break or be damaged during testing, and maintaining the identical physical quality of materials; however, abutments made of metal do not reproduce the actual force distribution that may occur on crowns cemented to natural teeth. Chemo-mechanical interaction between the dentine and the luting agent also cannot be tested with this type of simulation.[10,18,27] Therefore, further studies are ongoing to evaluate the load at fracture of Turkom-Cera copings supported to tooth structure using conventional and finite element analysis (FEA) methods.

Fatigue in ceramics refers to the subcritical growth of cracks aided by the combined influence of water and stress.[28] Despite the high strength reported with high alumina-based ceramics, they are susceptible to fatigue failure that can considerably reduce their strength over time. Fatigue failure due to cyclic or thermal loading is now recognized as a potentially significant contributor to the eventual failure of dental restorations.[29-31] Therefore, further study is highly recommended to evaluate the fracture analysis and fatigue behavior of Turkom-Cera core material under wet cyclic loading.

Conclusion

Within the limitations of this study, Turkom-Cera can be used for fabrication of all-ceramic crowns both anteriorly and posteriorly.

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