AMERICAN COLLEGE OF PROSTHODONTISTS

Evaluation of Load at Fracture of Procera AllCeram Copings Using Different Luting Cements

Bandar M. A. AL-Makramani, BDS, HDD, MDSc,[1] A. A. A. Razak, BDS, MSc, PhD,[2] & M. I. Abu-Hassan, BDS, MDSc, PhD[3]

[1]Postgraduate Student, Department of Conservative Dentistry, Faculty of Dentistry, University of Malaya, Kuala Lumpur, Malaysia
[2]Head, Department of Conservative Dentistry, Faculty of Dentistry, University of Malaya, Kuala Lumpur, Malaysia
[3]Dean, Department of Restorative Dentistry, Faculty of Dentistry, Universiti Teknologi MARA, Shah Alam, Malaysia

Keywords
Procera AllCeram; luting cements; load at fracture; modes of fracture.

Correspondence
Bandar M. A. Al-Makramani, Department of Conservative Dentistry, Faculty of Dentistry, University of Malaya, 50603 Kuala Lumpur, Malaysia. E-mail: makramani@yahoo.com

Accepted October 3, 2006.

doi: 10.1111/j.1532-849X.2007.00270.x

Abstract

Purpose: The current study investigated the effect of different luting agents on the fracture resistance of Procera AllCeram copings.
Methods: Six master dies were duplicated from the prepared maxillary first premolar tooth using nonprecious metal alloy (Wiron 99). Thirty copings (Procera AllCeram) of 0.6-mm thickness were manufactured. Three types of luting media were used: zinc phosphate cement (Elite), glass ionomer cement (Fuji I), and dual-cured composite resin cement (Panavia F). Ten copings were cemented with each type. Two master dies were used for each group, and each of them was used to lute five copings. All groups were cemented 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: ANOVA revealed significant differences in the load at fracture among the three groups ($p < 0.001$). The fracture strength results showed that the mean fracture strength of zinc phosphate cement (Elite), glass ionomer cement (Fuji I), and resin luting cement (Panavia F) were 1091.9 N, 784.8 N, and 1953.5 N, respectively.
Conclusion: Different luting agents have an influence on the fracture resistance of Procera AllCeram copings.

Due to an increasing interest in esthetics and concerns about toxic and allergic reactions to dental alloys, patients and dentists have been looking for metal-free tooth-colored restorations. All-ceramic materials were developed in response to an increasing demand for biocompatible and esthetically pleasing restorations. Ceramics are routinely used for dental restorations. Despite the high fracture resistance of traditional metal ceramic crowns, limitations are imposed on the systems by esthetic concerns.[1,2]

Ceramics are brittle and have low tensile strength and fracture toughness because of the presence of inherent flaws within the material. Numerous techniques have been developed in an attempt to overcome this problem and allow the use of all-ceramic restorations on posterior teeth. One such development is the use of high-alumina cores such as the Procera AllCeram core, which contains a densely sintered alumina core.[2,3]

The past 10 years have seen significant changes, and it is likely that the next decade will continue to herald both innovations and fine-tuning of existing techniques. Many changes in the field of dental ceramics technology within the last few years have seen evolutions of existing techniques. There have also been completely new innovations, such as the use of electronic data transmission to enable remote fabrication at a central facility.[4] The Procera AllCeram crown was developed by Andersson and Oden. The system uses computer-aided design/computer-aided manufacturing (CAD/CAM) technology to produce an all-ceramic restoration with many improved physical properties over existing all-ceramic systems.[5–8]

The role of cement in fixed prosthodontics is to preserve the integrity and health of the prepared tooth structure, providing a seal against microleakage at tooth–crown interface. Laboratory studies are useful tools to identify preferred cementation methods and bonding materials before their clinical use. The number of laboratory studies on resin bonded to densely sintered alumina is small, and there is no long-term data available on resin bonded to the Procera AllCeram intaglio surface.[9,10]

Adhesive composite resin luting systems are now recommended for cementation of many all-ceramic systems; however, because of multistep clinical luting procedures, the tooth-restoration adhesion actually achieved might be strongly affected by the individual clinical situation, especially in the posterior region. Therefore, cements with less complicated clinical

Table 1 Materials used

Material	Manufacturer	Type	Batch number
Elite cement	GC Corporation, Tokyo, Japan	Zinc phosphate cement	Liquid: 0302271 Powder: 0304281
Fuji I cement	GC Corporation, Tokyo, Japan	Glass ionomer cement	Liquid: 0308071 Powder: 0308191
Panavia F cement	Kuraray Medical, Inc., Okayama, Japan	Resin luting cement	A paste: 00240 A B paste: 00133 C
Clearfil Silane Kit	Kuraray Medical, Inc., Okayama, Japan	Silane coupling agent	SE bond primer: 00455 A Porcelain bond activator: 00155 A

luting procedures might minimize the influence of oral conditions and be of benefit in obtaining a sufficient tooth-restoration adhesion.[11–13]

It is obvious from the different studies in relation to the fracture strength of all-ceramic systems that the values reported are highly variable. This is because the testing of the compressive strength of crowns is not a standard procedure like a bending test for a geometrically well-defined bar. Many factors influence the results: preparation design, crown thickness, direction and location of the applied load, and radius of the loading stylus.[1,14–19]

The present study attempted to isolate the cement layer as the only variable. The objectives of this study were to study the fracture strength of the Procera AllCeram copings, to determine in vitro whether Procera AllCeram copings cemented with zinc phosphate or glass ionomer cements to a metal die provide as good fracture resistance as Procera AllCeram bonded to a similar metal die using resin luting cement, and to investigate the mode of fracture of Procera AllCeram copings with the three luting agents used in this study.

Materials and methods

Materials

Three types of luting media—zinc-phosphate cement, glass ionomer cement, and dual-cured composite resin cement with its silane coupling agent—were used in this study (Table 1).

Preparing the specimens

For this study, six master dies were duplicated from the prepared maxillary first premolar tooth using nonprecious metal alloy (Wiron 99, BEGO, Bremen, Germany). The composition of Ni–Cr alloy (Wiron 99) in % by weight is as follows: Ni (65), Cr (22.5), Mo (9.5), Nb (1), Si (1), Fe (0.5), Ce (0.5), and C ($\leq$ 0.02). An impression was made for each master die and poured in die stone (Densite, Shofu, Inc., Kyoto, Japan).

Each stone die was mounted in a Procera scanning machine (Nobel Biocare, Göteborg, Sweden) linked to a computer and modem (Fig 1). The die was scanned, and the data then forwarded to Nobel Biocare in Sweden, where five densely sintered aluminum oxide copings were manufactured with the same dimensions and a thickness of 0.6 mm for each master die (total of 30 copings made).

The specimens were divided into three groups according to the luting cements used. Ten copings were cemented with each type of the above-mentioned luting agents. Two master dies were used for each group, and each of them was used to lute five copings. All copings were cemented onto their corresponding dies according to the manufacturer's instructions.

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. All copings and metal dies were steam cleaned and air dried.

With Elite (zinc phosphate luting cement) a full spoon of powder to three drops of liquid were mixed slowly at room

Figure 1 Procera AllCeram scanner with the die stone secured and ready for scanning.

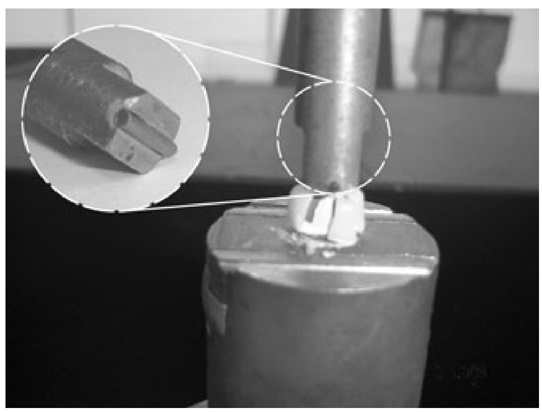

Figure 2 Fractured coping after loading with a 1.6-mm stainless steel bar.

Table 2 Modes of fracture

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

temperature (24°C) to a constant creamy consistency on a cooled, dry, and thick mixing glass slab over a wide area for 60 seconds. For Fuji I (glass ionomer luting cement), a full spoon of powder to two drops of liquid were dispensed onto the mixing pad and mixed rapidly at room temperature (24°C) for 20 seconds. Then a coating of cement was applied to the internal surface of each coping.

With Panavia F (dual-cured composite resin cement), the ED primer was applied to the entire surface of the metal die and allowed to set for 60 seconds before air-drying with gentle airflow. The fit surfaces of all copings were silanated with a mixture of Clearfil Porcelain Bond Activator and Clearfil SE Bond Primer. The mixture was applied to the internal surface of the coping and left for 5 seconds before air-drying with gentle air flow. A sufficient amount of the Panavia F (one complete turn from each cartridge A&B) was dispensed, mixed for 20 seconds, and applied to the internal surface of each coping.

Finger pressure was used to initially seat each crown on its die, and for the zinc phosphate and glass ionomer cements, each crown was held in place while any excess cement was removed before the luting agent set completely. With resin luting cement (Panavia F), any excess paste remaining at the margins was removed with a disposable brush, and a layer of Oxyguard II (Kuraray) 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), specially designed for this study, 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.

Testing the Fracture Strength

The master die with cemented coping was removed from the storage container and mounted in a specially designed jig and subjected to testing on the Instron Testing Machine. A 1.6-mm stainless steel bar mounted on the crosshead of the Instron Testing Machine was used; the Instron applied a compressive 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 was observed (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. Five Procera AllCeram copings for each master die were tested in this manner. The force at failure was noted, and the failed coping was examined to determine the mode of fracture. The mode of fracture was determined using categories as described by Burke (Table 2).[20] The fractured specimens and fragments were collected, and one specimen from each group was selected for scanning electron microscopic (SEM) examination.

Statistics

The results of the study were statistically tested by one-way analysis of variance (ANOVA) and Duncan's multiple range test to determine if significant differences between test groups were related to the luting 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 for each experimental group are recorded in Table 3. The results were analyzed with one-way ANOVA and demonstrated that at least one pair of mean values differ significantly ($p < 0.001$). Duncan's multiple range test was also applied and indicated that all three group means differ from each other significantly. Procera AllCeram copings cemented with resin luting cement Panavia F (1953.50 N ± 210.682) were significantly stronger than Procera AllCeram copings cemented with either zinc phosphate Elite (1091.92 N ± 194.645) or glass ionomer Fuji I (784.79 N ± 136.612) cements.

Nonparametric Kruskal–Wallis test was used to test if there was any association between mode of fracture and fracture strength. There was no evidence of association between mode of fracture and fracture strength ($p > 0.05$).

Chi-square test was used to test if there was any association between treatment group and mode of fracture. There was no

Table 3 Mean and median load at fracture, standard deviation, and 95% confidence interval for each experimental group (measurements in N)

			95% Confidence interval		
Treatment group	n	Mean (SD)	Lower bound	Upper bound	Median
Group 1 (Elite)	10	1091.9 (194.64)*	952.68	1231.16	1070.5
Group II (Fuji I)	10	784.8 (136.61)†	687.06	882.52	789.3
Group III (Panavia F)	10	1953.5 (210.68) ‡	1802.79	2104.21	2024.5

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

Table 4 Frequency, mean load at fracture (SD), and fracture frequency per luting media for each mode of fracture

Mode of fracture	Frequency of fracture mode (%)	Mean load at fracture, N (SD)	Fracture frequency per group		
			Elite	Fuji I	Panavia F
Minimal fracture (I)	14 (46.7)	1458.0 (571.09)	3	3	8
Less than half of coping lost (II)	1 (3.3)	1060.0 (0.00)	1	0	0
Coping fracture through midline (III)	3 (10.0)	755.0 (106.72)	0	3	0
More than half of coping lost (IV)	2 (6.7)	1657.0 (581.24)	1	0	1
Severe fracture of die and/or coping (V)	10 (33.3)	1125.1 (448.06)	5	4	1

Difference is significant at $p < 0.05$.

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 specimen (Table 4).

SEM images of the fractured surface of Procera AllCeram copings (Figs 3–5) demonstrated that only Procera AllCeram copings cemented with the resin cement showed the line distinguishing between the coping and the cement, which means that there was some sort of bonding between Procera AllCeram copings and resin luting cement (Fig 5).

Discussion

This study was conducted to compare the fracture strength of Procera AllCeram copings using different luting agents. For this reason, metal dies were designed to represent a tooth prepared for a full-ceramic crown, thereby ensuring a standard size and shape for construction. Crown-shaped restorations were used, because it has been reported that these may allow the restorations to behave in a manner that potentially represents the clinical situation more closely than ceramic discs.[21]

The results of the present study indicated that the Procera AllCeram copings luted with the resin luting cement (Panavia F) provided resistance to fracture that was significantly superior to that obtained when conventional luting agents were used, as an important statistical difference was identified. The glass ionomer cement (Fuji I) group gave the lowest fracture resistance of the three examined groups.

Many studies have shown a strong enhancement of the fracture strength of all-ceramic crowns bonded to dies or teeth versus nonbonded crowns. The results of this study are in agreement with the results of previous studies;[17,22–24] however, the noticeably higher fracture resistance of Procera AllCeram copings bonded with the resin luting agent (Panavia F) used in this study may be due to: (i) the combination of air particle abrasion, silane coupling agent, and the resin luting agent Panavia F may reduce the stress at the flaw tips;[25] (ii) the Procera core material examined by SEM had very little porosity (Figs 3-5), with complete densely packed alumina particles achieved. This, coupled with the high alumina content, is thought to account for the strengths attained by Procera copings.

In contrast, Casson et al found that the zinc phosphate cement group produced a higher mean fracture strength (1216 N) than glass ionomer cement (754 N) or resin cement (989 N) groups.[26]

Examination of the mode of fracture of specimens revealed that the majority of Procera AllCeram copings cemented with either zinc phosphate or glass ionomer cements exhibited severe fracture of copings. In contrast, Procera AllCeram copings cemented with resin cement (Panavia F) showed minimal fracture without any loss of coping. The retention of resin cement on the internal surface of Procera AllCeram copings provide the

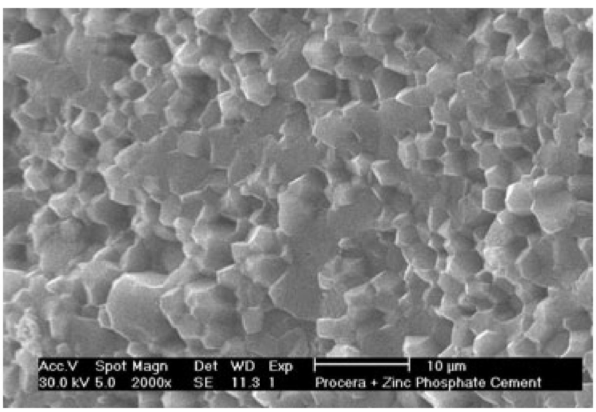

Figure 3 SEM image of Procera AllCeram coping cemented with zinc phosphate cement (Elite) (×2000).

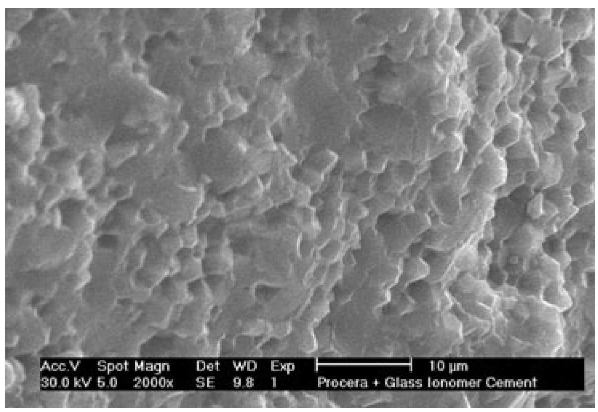

Figure 4 SEM image of Procera AllCeram coping cemented with glass ionomer cement (Fuji I) (×2000).

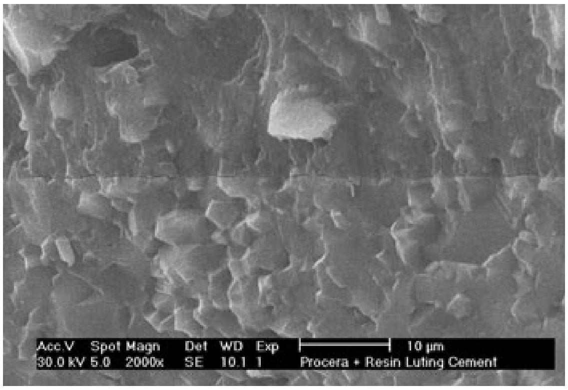

Figure 5 SEM image of Procera AllCeram coping cemented with resin luting cement (Panavia F) (×2000).

reason for the difference in the mode of fracture between the resin group and that of the zinc phosphate and glass ionomer cements groups. In addition to that, the use of silane coupling agent reduces the stress at the flaw tips, which restricts the propagation of crack within the coping.

This study evaluated the effect of luting cements on the fracture strength of Procera AllCeram crown on metal dies only. Therefore, further studies are required to investigate the effect of luting cements on the fracture strength of Procera AllCeram crown (veneered) using different luting cements on tooth structure.

Conclusion

Different luting agents have an influence on the fracture resistance of Procera AllCeram copings.

References

1. Cha Y, Yang J, Lee S, et al: Comparative study on the fracture strength of Empress II ceramic and Targis-Vectris crown. J Korean Acad Prosthodont 2001;39:599-610
2. Harrington Z, McDonald A, Knowles J: An in vitro study to investigate the load at fracture of Procera AllCeram crowns with various thickness of occlusal veneer porcelain. Int J Prosthodont 2003;16:54-58
3. Webber B, McDonald A, Knowles J: An in vitro study of the compressive load at fracture of Procera AllCeram crowns with varying thickness of veneer porcelain. J Prosthet Dent 2003;89:154-160
4. Qualtrough AJE, Piddock V: Dental ceramics: what is new? Dental Update 2002;29:25-33
5. Andersson M, Oden A: A new all-ceramic crown. A dense-sintered high-purity alumina coping with porcelain. Acta Odontol Scand 1993;51:59-64
6. Wagner WC, Chu TM: Biaxial flexural strength and indentation fracture toughness of three new dental core ceramics. J Prosthet Dent 1996;76:140-144
7. Brunton PA, Smith P, McCord JF, et al: Procera all-ceramic crowns: a new approach to an old problem. Br Dent J 1999;186:430-434
8. McLean JW: Evaluation of dental ceramics in the twentieth century. J Prosthet Dent 2001;85:61-66
9. Awliya W, Oden A, Yaman P, et al: Shear bond strength of a resin cement to densely sintered high-purity alumina with various surface conditions. Acta Odontol Scand 1998;56:9-13
10. Blixt M, Adamczak E, Linden LA, et al: Bonding to densely sintered alumina surfaces: effect of sandblasting and silica coating on shear bond strength of luting cements. Int J Prosthodont 2000;13:221-226
11. McComb D: Adhesive luting cements-classes, criteria, and usage. Compend Contin Educ Dent 1996;17:759-762
12. Rosenstiel SF, Land MF, Crispin BJ: Dental luting agents: a review of the current literature. J Prosthet Dent 1999;80:280-301
13. Gu XH, Kern M: Marginal discrepancies and leakage of all-ceramic crowns: influence of luting agents and aging conditions. Int J Prosthodont 2003;16:109-116
14. Riley EJ: Ceramo-metal restoration. State of the science. Dent Clin North Am 1977;21:669-682
15. Josephson BA, Schulman A, Dunn ZA, et al: A compressive strength study of complete ceramic crowns. Part II. J Prosthet Dent 1991;65:388-391
16. Miller A, Long J, Miller B, et al: Comparison of the fracture strength of ceramo-metal crowns versus several all-ceramic crowns. J Prosthet Dent 1992;68:38-41
17. Yoshinari M, Derand T: Fracture strength of all-ceramic crowns. Int J Prosthodont 1994;7:329-338
18. Sobrinho LC, Cattell MJ, Knowles JC: Fracture strength of all-ceramic crowns. J Mater Sci Mater Med 1998;9:555-559
19. Ku CW, Park SW, Yang HS: Comparison of the fracture strengths of metal-ceramic crowns and three ceromer crowns. J Prosthet Dent 2002;88:170-175
20. Burke FJT: Fracture resistance of teeth restored with dentin-bonded crowns constructed in a leucite-reinforced ceramic. Dent Mater 1999;15:359-362
21. Wakabayashi N, Anusavice KJ: Crack initiation modes in bilayered alumina/porcelain disks as a function of core/veneer thickness ratio and supporting substrate stiffness. J Dent Res 2000;79:1398-1404
22. Jensen ME, Sheth JJ, Tolliver D: Etched porcelain resin-bonded full veneer crowns: in vitro fracture resistance. Compend Contin Edu Dent 1989;10:336-341
23. Groten M, Probster L: The influence of different cementation modes on the fracture resistance of feldspathic ceramic crowns. Int J Prosthodont 1997;10:169-177
24. Burke FJT: The effect of variations in bonding procedure on fracture resistance of dentin-bonded all-ceramic crowns. Quintessence Int 1995;26:293-300
25. Blatz MB, Sadan A, Kern M: Resin-ceramic bonding: a review of the literature. J Prosthet Dent 2003;89:268-274
26. Casson AM, Jones JCG, Youngson CC, et al: The effect of luting media on the fracture resistance of a flame sprayed all-ceramic crown. J Dent 2001;29:539-544