We are IntechOpen, the world's leading publisher of Open Access books
Built by scientists, for scientists

5,000
Open access books available

125,000
International authors and editors

140M
Downloads

Our authors are among the

154
Countries delivered to

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities

BOOK CITATION INDEX
CLARIVATE ANALYTICS
INDEXED

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

Strength of a New All-Ceramic Restorative Material "Turkom-Cera" Compared to Two Other Alumina-Based All-Ceramic Systems

Bandar M. A. AL-Makramani[1], Abdul A. A. Razak[2]
and Mohamed I. Abu-Hassan[3]
[1]Department of Conservative Dentistry, Faculty of Dentistry, Sana'a University,
[2]Department of Conservative Dentistry, Faculty of Dentistry,
University of Malaya, Kuala Lumpur,
[3]Department of Restorative Dentistry, Faculty of Dentistry,
University Teknology MARA, Selangor,
[1]Yemen
[2,3]Malaysia

1. Introduction

Early types of metal-free ceramics did not enjoy success in dentistry, especially in the posterior region (Shimada et al., 2002). The high crystalline content ceramic systems have been developed in an attempt to improve the strength of metal-free restorations as well as deliver more esthetic results than conventional metal-fused-to-ceramic restorations (Ozcan et al., 2001; Valandro et al., 2006). Glass infiltrated alumina ceramic (eg. In-Ceram Alumina, Vita Zahnfabrik, Bad Sackingen, Germany), densely sintered aluminum oxide ceramic (eg, Procera AllCeram, Nobel Biocare AB, Gothenburg, Sweden) and zirconium oxide ceramic (eg, Lava 3M ESPE, St. Paul, MN, USA) are popular oxide-based high-strength ceramic materials that offer favorable esthetic characteristics, mechanical properties and biocompatibility (Blatz et al., 2004; Della Bona et al., 2007).

It is obvious from the different studies in relation to the occlusal fracture resistance of all-ceramic systems that the values reported are highly variable. This is because the testing of the occlusal fracture resistance of crowns is not a standard procedure like a bending test for a geometrically well-defined bar. As reported by some researchers (Webber et al., 2003; AL-Makramani et al., 2008a; Di Iorio et al., 2008), the results of the fracture load of all-ceramic crowns may be influenced by different factors. These include the microstructure of the ceramic material, preparation design, shape and thickness of the restoration, size and distribution of surface flaws, the magnitude, direction and location of the applied load, luting methods, the elastic modulus of the restoration components and storage conditions before loading to fracture.

Regarding the effect of finish line on the occlusal fracture resistance of all-ceramic crowns, it was shown that preparation with a 1.2 mm shoulder finish line and sharp axiogingival line

angle produced the strongest Dicor crowns, while crowns prepared with a chamfer finish line produced the weakest restoration when cemented to metal dies (Doyle et al., 1990a; Doyle et al., 1990b). A similar in-vitro study on Procera AllCeram crowns found that the shoulder finish line showed significantly higher fracture resistance than chamfer finish line (Di Iorio et al., 2008). In contrast, some authors reported that the fracture resistance of Dicor crowns luted with a resin luting cement was unaffected by the type of finish line used (Bernal et al., 1993; Malament and Socransky, 1999).

The present study investigated the effect of three variables on the occlusal fracture resistance of all-ceramic crowns. Attempts were made to standardize the other variables that may have an influence on the results of the fracture load. The studies concerning the effect of ceramic material and margin design on the occlusal fracture resistance of Turkom-Cera restorations are limited. Therefore, the objectives of this study were to:-

1. Determine the occlusal fracture resistance of Turkom-Cera copings compared to In-Ceram and Procera All-Ceram copings cemented to extracted teeth.
2. Examine the effect of finish line design on the occlusal fracture resistance of Turkom-Cera copings.

Null hypotheses
1. There is no difference in the occlusal fracture resistance of Turkom-Cera, In-Ceram and Procera AllCeram copings when cemented to natural teeth.
2. There is no effect of finish line design on the occlusal fracture resistance of Turkom-Cera copings.

2. Materials and methods

2.1 Materials used

40 sound and crack-free maxillary premolar teeth, extracted for orthodontic reasons (the patient's ages ranged from 15-20 years), were used for this study. In addition, three types of all-ceramic systems were used for coping production namely, Turkom-Cera™ (Turkom-Ceramic (M), Puchong, Malaysia), In-Ceram (Vita Zahnfabrik, Bad Sackingen, Germany) and Procera AllCeram (Nobel Biocare, Goteborg, Sweden), and one type of resin luting cement (Panavia-F, Kuraray Medical Inc., Okayama, Japan) with its silane coupling agent (Clearfil Silane Kit, Kuraray), were used in this study.

2.2 Methods
2.2.1 Specimen collection and storage

Based on criteria, the selected teeth were free of cracks and fractures, had no evidence of caries or restorations and had no previous endodontic treatment. The average bucco-lingul, mesio-distal crowns width and teeth length were 9.1 mm, 7.3 mm and 22.3 mm, respectively. The teeth were obtained directly after extraction and stored in 0.5% Chloramine-T trihydrate solution for one week (ISO/TS 11405/2003). Both calculus deposits and residual periodontal tissues were removed by Ultrasonic Scaler (Peizon® Master 400, EMS, Nyon, Switzerland). All teeth were examined under stereo microscope (Olympus SZ61, Olympus Corp., Tokyo, Japan) at 30x to detect cracks before including them in the study. Throughout this study, the teeth were kept hydrated in distilled water as this storage solution does not seem to alter dentine permeability (Goodis et al., 1993). The storage solution was changed every one week and the teeth were stored at 4 degrees Celsius (ISO/TS 11405/2003).

Strength of a New All-Ceramic Restorative Material "Turkom-Cera"
Compared to Two Other Alumina-Based All-Ceramic Systems

261

2.2.2 Preparation of teeth

The teeth were embedded in epoxy resin 2.0 mm below the cemento-enamel junction using a plastic mould with 30 mm diameter and 30 mm height (Fig. 1). Two layers of nail polish were applied to the external surface of the entire roots. A dental surveyor was used to position the long axis of the teeth vertically.
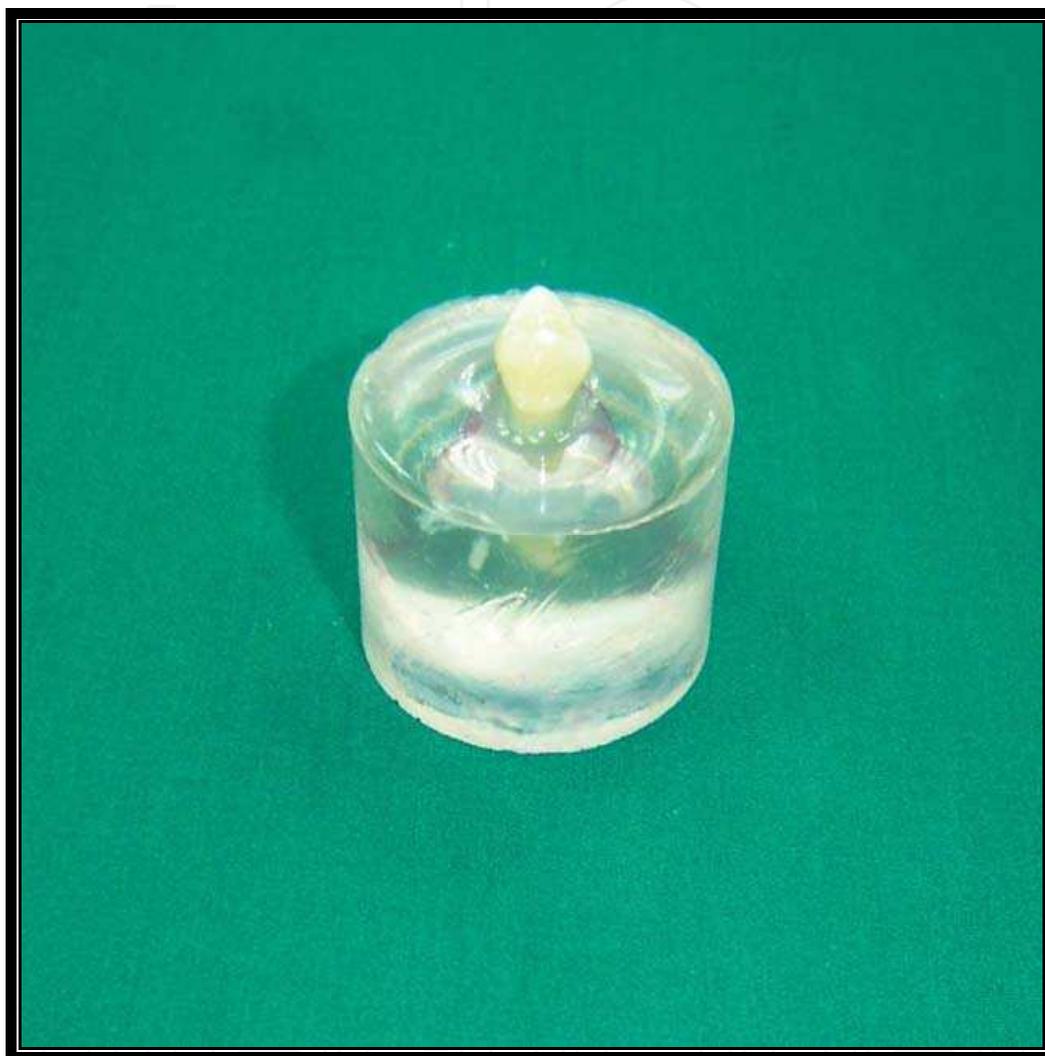

Fig. 1. The tooth embedded in the epoxy resin

The preparation of the teeth was carried out using high-speed handpiece attached to a paralleling apparatus (Fig. 2), which allowed standardized preparations. The apparatus consists of a specimen fixture as well as vertical and horizontal arms. The specimen fixture holds the specimen and designed in a way that the fixture can rotate the specimen against a diamond bur (Fig. 3a & b). The vertical arm of the apparatus which holds the handpiece permits vertical as well as rotational movement around the tooth. The high-speed handpiece was attached to the vertical arm of the paralleling apparatus using a custom made jig (Fig. 4). This jig secures the handpiece to the vertical arm in such a manner that the attached bur can be fixed at a set angle to that of the tooth during preparation.
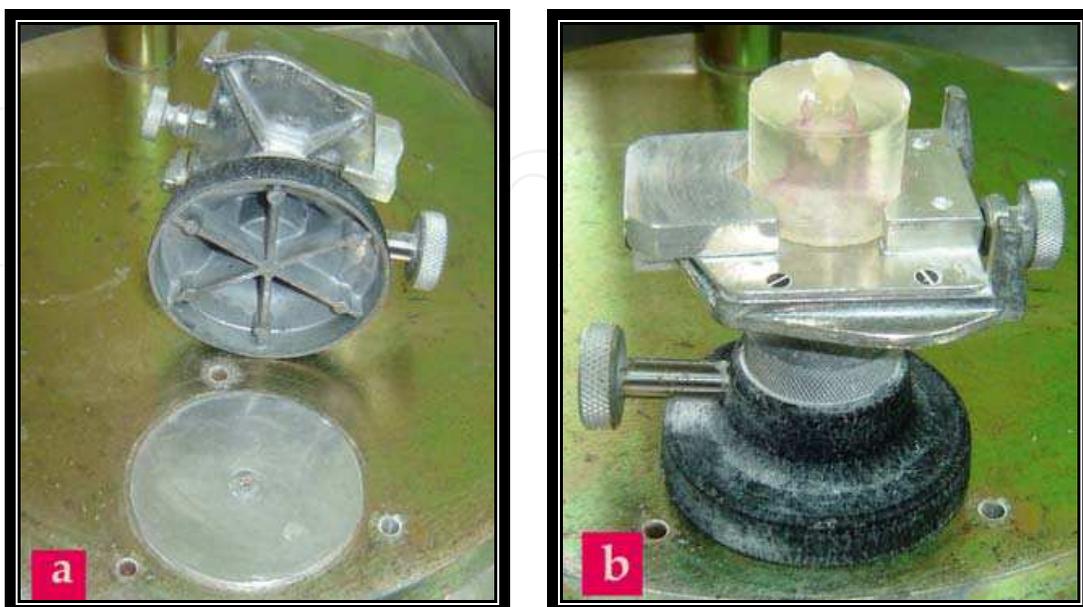
Fig. 2. The paralleling apparatus used

Fig. 3a & b. Two views of the specimen fixture

Strength of a New All-Ceramic Restorative Material "Turkom-Cera"
Compared to Two Other Alumina-Based All-Ceramic Systems

263

Fig. 4. The jig used to fix the handpiece to the vertical arm of the apparatus

The axial taper angle used in the present study was 6°. According to Shillingburg et al., (1997) a tapered bur will impart an inclination of 2-3 degrees to any surface it cuts if the shank of the instrument is held parallel to the intended path of insertion of the preparation. A specially designed jig which consists of a semi-circular transparent Perspex block with a protractor fixed to its side was used to set the degree of taper (Fig. 5). A hole was drilled along the outer side of the perspex block corresponding to a taper angle of 3°.
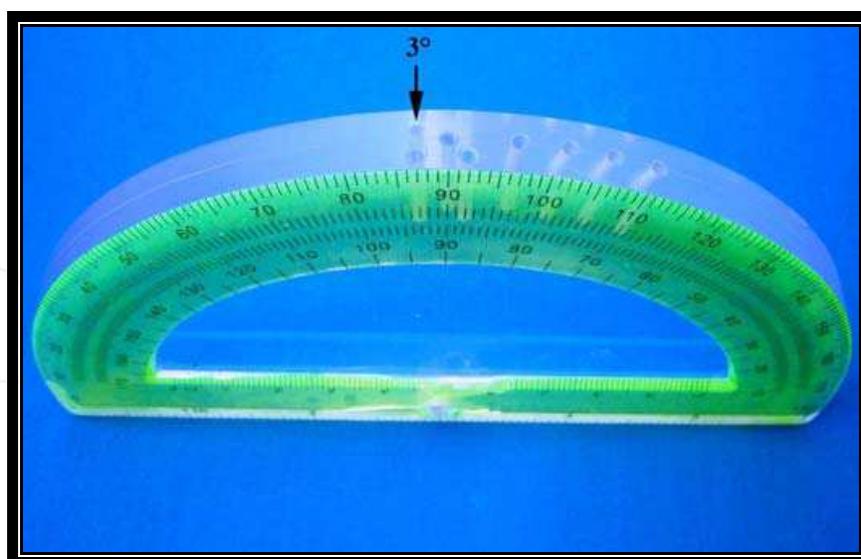

Fig. 5. The jig used to set the degree of taper

Therefore, to achieve a 6° axial taper preparation, the handpiece was secured to the apparatus so that the attached tapered diamond bur was oriented at a 3° angle to the vertical axis of the tooth. This, in additional to the 3° taper of the tapered bur, resulted in a total axial taper angle of 6° corresponding to a convergence angle of 12°.

The axial reduction was performed by rotating the specimen in the fixture against a coarse rotating tapered diamond burs (5856.314.018, chamfer; and 8847KR.314.018, shoulder, Komet GmbH, Lemgo, Germany) as shown in Fig. 6. After that, the preparation surfaces were finished with a fine grit diamond burs (No. 5856.314.018, chamfer; and 8847KR.314.018, shoulder).
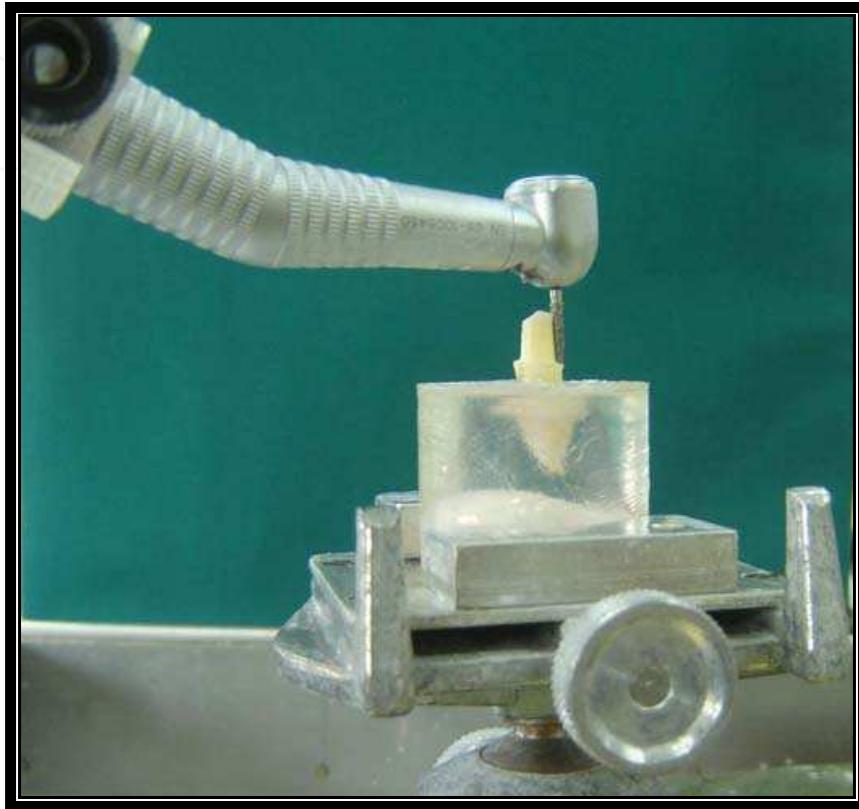
Fig. 6. The tooth during axial preparation

After the completion of axial preparation, the occlusal surface of the teeth was cut flat. A pencil was used to mark the prepared tooth 4 mm above the margin and the occlusal surface was flattened with a diamond wheel (Komet No. 909.204.055) to the marked line (Fig. 7a), which resulted in a preparation with 4.0 mm height (Fig. 7b).

The preparation was smoothed and all sharp angles or internal line angles were rounded with a fine abrasive disk (Sof-Lex Discs, 3 M Corp., St. Paul, Minn.) connected to a micromotor handpiece. All preparations were made under copious water irrigation by the same investigator.

These series of reductions resulted in a standardized teeth preparation with 6° axial taper, a 1.2 mm circumferential chamfer/shoulder margin, placed 0.5 mm occlusal to the cemento-enamel junction, and total preparation height of 4.0 mm. The finished preparation is illustrated in Fig. 8a &b.

In summary, 30 premolar teeth were prepared with chamfer margin and divided randomly into 3 groups (n=10) for each of the three ceramic systems used (In-Ceram, Procera and Turkom-Cera). In addition, 10 premolars were prepared with round shoulder margin and used to study the effect of finish line design on the fracture resistance of Turkom-Cera all-ceramic copings.
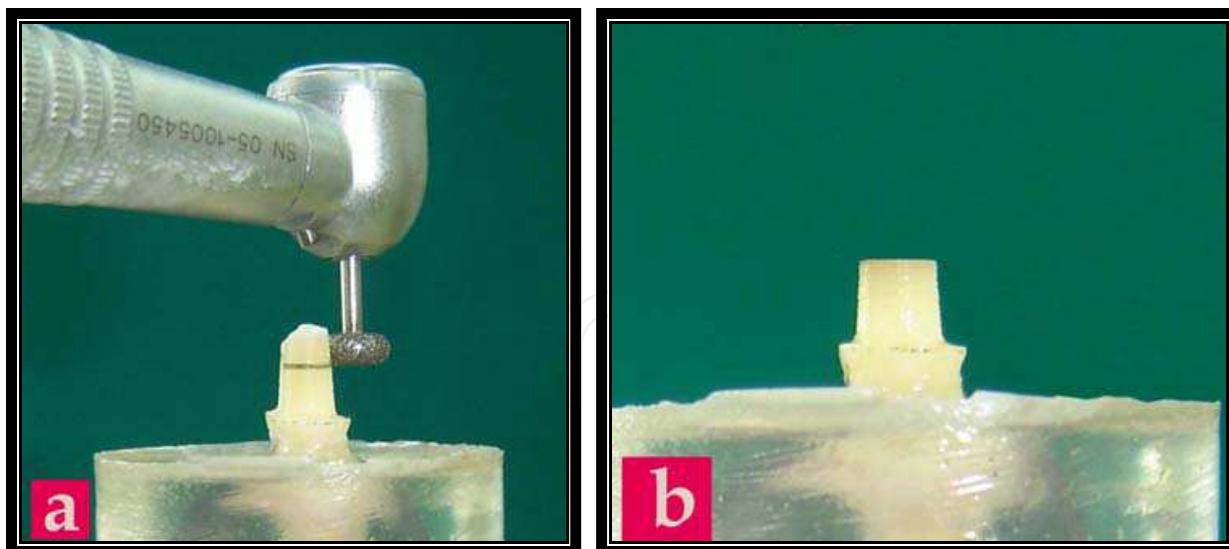
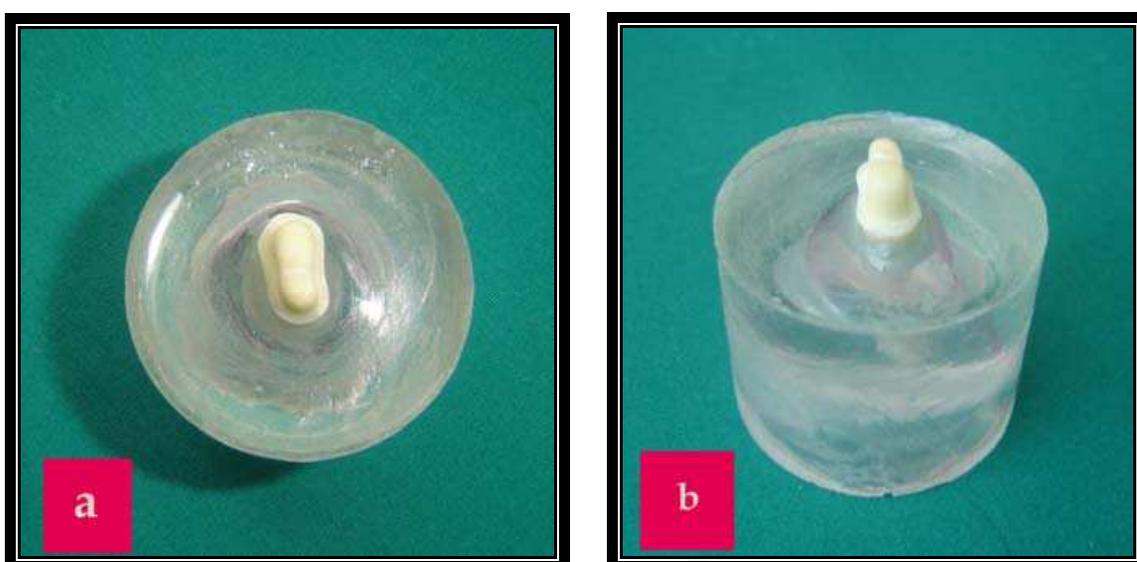Fig. 7a & b. The tooth before (a) and after (b) oclussal reduction

Fig. 8a & b. Occlusal (a) and buccal views (b) of the finished preparation

2.2.3 Impression and die preparation

The teeth were dried with an air/water syringe and impression was taken for each tooth using a bottle cap with pipette which act as an impression tray and silicone impression material (Aquasil Monophase Ultra; Dentsply Caulk, Dentsply International Inc., Milford, Germany) (Fig. 9a & b). The impression material was injected into the cap and placed on the tooth while maintaining finger pressure until setting.

Then, the impressions were boxed (Fig. 10a) using boxing wax (Boxing In Wax, Metrodent Ltd., Huddersfield, Enland). The impressions were then vaporized with a wetting agent and poured in die stone (Densite, Shufo, Kyoto, Japan) (Fig. 10b). The stone was mixed with distilled water in a 20cc liquid to 100 grams of stone ratio as recommended by the manufacturer. After a 4 hours setting time, the dies were trimmed and numbered according to their respective teeth (Fig. 11).
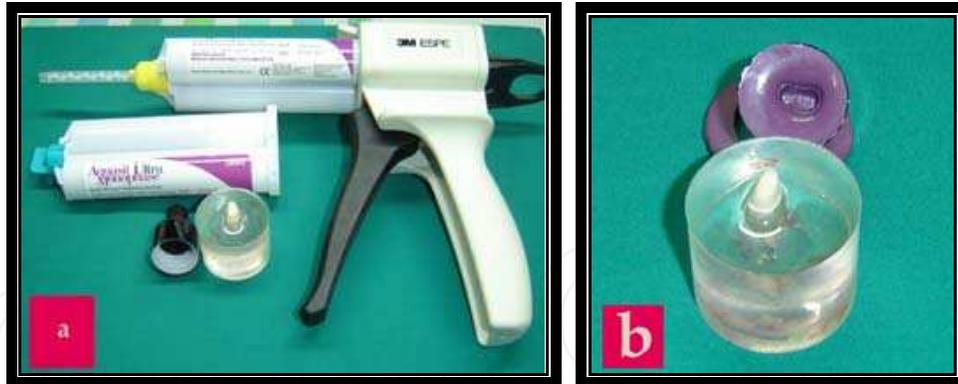
Fig. 9a & b. The impression material, tooth model and plastic cap (a); and impression of the prepared tooth (b)
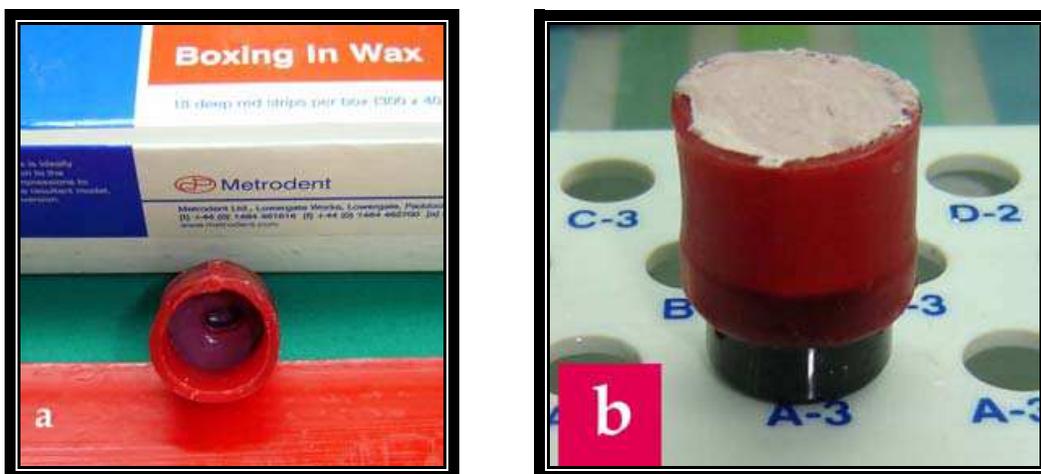

Fig. 10a & b. Boxing of the impression (a) and pouring with die stone (b)

Fig. 11. The die numbered according to its respective tooth

2.2.4 Fabrication of all-ceramic copings

Ten randomly selected stone dies with chamfer margin and the 10 stone dies with shoulder margin were sent to Turkom-Cera dental laboratory and 20 Turkom-Cera copings were fabricated with a thickness of 0.6 mm. The remaining 20 stone dies with chamfer margin were randomly divided into two groups of 10 specimens for In-Ceram (n=10) and Procera (n=10) and sent to other dental laboratories. 10 In-Ceram and 10 Procera copings were fabricated with a thickness of 0.6 mm.

The macroscopic fit of all copings on the corresponding stone dies, and finally on the specimens were visually assessed. Copings that were found to rock or did not seat on the finish line were rejected and refabricated to ensure 10 copings per group.

2.2.5 Cementation

The specimens were identified by their numbers. The teeth were pumiced with a prophylaxis cup mounted on a slow speed handpiece and rinsed with an air/water syringe prior to cementation. The copings were then internally sandblasted with 50 μm aluminium oxide (Al2O3) particles at an air pressure of 2.5 bars for 13s from a distance of 10 mm. After that, the copings were steam cleaned and air dried.

All copings were cemented to their respective teeth using Panavia F resin luting cement. The ED primer was applied to the entire surface of the tooth and allowed to set for 60s before air drying with gentle air flow. 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 5s before air drying with gentle air flow. Sufficient amount of the Panavia F (one complete turn from each cartridge A &B) were dispensed, mixed for 20s and applied to the internal surface of each coping.

Finger pressure was applied to initially seat each coping on its respective tooth, and each coping was held in place while any excess paste remaining at the margins was removed with a disposable brush. A layer of Oxyguard II (Kuraray) was applied for three minutes around the margins of each specimen. The specimens were then placed in a custom-made vertical loading apparatus (Makramani Load) (AL-Makramani et al., 2008a), for 10 minutes under a 5 kg load. Following cementation, the 30 specimens with chamfer margin and the 10 specimens with shoulder margin were placed in a sealed container of distilled water and left in an incubator at a constant temperature of 37°C for 24 hours.

2.2.6 Testing procedure

The tooth with cemented coping was removed from the storage container, secured in a mounting jig and subjected to testing in a universal testing machine (Shimadzu, Shimadzu Corp., Tokyo, Japan) (Fig. 12). A 3 mm stainless steel bar, mounted on the crosshead of the Shimadzu testing machine was used and applied a compressive load at the centre of the occlusal surface, along the long axis of the cemented copings, at a crosshead speed of 1mm/min until failure occurred (Fig. 13). A piece of tin foil 0.7 mm thick was placed between the loading piston and the specimen to distribute the force over a larger area and to avoid loading stress peaks on the coping surface. The maximum force to produce fracture was recorded in Newtons. The failed copings were examined in order to determine the mode of fracture. The mode of fracture was classified using categories as described by Burke & Watts (1994) (Table 1).

Fig. 12. The universal testing machine used

Fig. 13. The specimen during testing

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 1. Modes of fracture (After Burke and Watts, 1994)

2.2.7 Statistical analysis

The first objective was to determine the occlusal fracture resistance of Turkom-Cera copings compared to In-Ceram and Procera AllCeram copings. Descriptive statistics will be recorded for load at fracture of the three groups. The normally distributed data of load at fracture (histogram and Shapiro-Wilk test) will be analyzed by One Way ANOVA to achieve the objective, provided that equal variances will be assumed (Levene's test). Then, Tukey's HSD test will be carried out for post-hoc comparisons.

Whenever assumptions of normal distribution and equal variances of load at fracture between the three groups will not be met, an equivalent nonparametric Kruskal-Wallis test will be conducted. Subsequently, a post hoc test using Mann-Whitney tests with Bonferroni correction will be performed to test which pair of groups differ from each other significantly.

Regarding the second objective, effect of finish line design on load at fracture of Turkom-Cera copings, descriptive statistics will be recorded for load at fracture of each group. Then, independent samples t-test should be used to determine the significant differences in load at fracture between the two groups of Turkom-Cera copings with chamfer and shoulder finish lines. However, this is dependent on the assumptions of normal distribution and equal variances of load at fracture between each two groups to be met.

Whenever assumptions of normal distribution and equal variances of load at fracture between the two groups will not be met, an equivalent nonparametric Mann-Whitney tests will be performed.

In addition, descriptive statistics for modes of fracture and load at fracture will be recorded and the result will be descriptively analyzed. Statistical analysis will be carried out using a computer program (SPSS, SPSS Inc., Chicago, IL). Statistical significance will be set at $\alpha = 0.05$.

3. Results

3.1 Effect of ceramic material on the fracture resistance

The objective is to test if the mean load at fracture of Procera AllCeram, Turkom-Cera, and In-Ceram all-ceramic copings differ from each other. Descriptive analysis was performed

and the mean load at fracture and standard deviation for the three groups are recorded in Table 2.

Ceramic	n	Mean	SD	95% Confidence Interval	
				Lower Bound	Upper Bound
Procera AllCeram	10	975.0	112.7	894.3	1055.6
Turkom-Cera	10	1341.9	216.5	1187.0	1496.8
In-Ceram	10	1151.6	180.1	1022.7	1280.4

Table 2. The mean load at fracture (N) and standard deviation for Procera AllCeram, Turkom-Cera, and In-Ceram copings

Since the assumption of normal distribution was met, the equality of variances (homogeneity) was tested using the Levene's test and showed that there was no significant deviation from homogeneity (p=0.163). Therefore, the parametric One Way ANOVA procedure was used to achieve objective. The results were recorded in Table 3. There was a significant difference in load at fracture between the three groups (p<0.001).

Ceramic	n	Mean (N)	SD	F Statistics (df)	P value[a]
Procera AllCeram	10	975.0	112.7		
Turkom-Cera	10	1341.9	216.5	10.98 (2,27)	<0.001
In-Ceram	10	1151.6	180.1		
[a] One Way ANOVA was used.					
Significant level was set at 0.05.					

Table 3. Comparison of load at fracture between Procera AllCeram, Turkom-Cera and In-Ceram copings by One Way ANOVA

Further analysis using Tukey HSD Post Hoc Test was done to determine the pair of means that differ significantly. Based on Tukey HSD Post Hoc Test (Table 4), the mean load at fracture of Turkom-Cera (1341.9 ± 216.5 N) was significantly more than Procera AllCeram (975.0 ± 112.7 N) (p<0.001). There were no significant differences between the mean load at fracture of In-Ceram (1151.6 ± 180.1 N) and Procera AllCeram (p=0.080) and also between the mean load at fracture of Turkom-Cera and In-Ceram (p=0.056).

Pairewise comparison	Mean (SD)	Mean Difference	P value
Procera AllCeram vs Turkom-Cera	975.0 (112.7) 1341.9 (216.5)	-366.93 366.93	<0.001*
Procera AllCeram vs In-Ceram	975.0 (112.7) 1151.6 (180.1)	-176.60 176.60	0.080
Turkom-Cera vs In-Ceram	1341.9 (216.5) 1151.6 (180.1)	190.33 -190.33	0.056
* 2 pairs of means are significantly different by Tukey HSD Test			

Table 4. Multiple pairwise comparisons of fracture load (N) using Tukey HSD Test

3.1.1 Mode of fracture

A cross-tabulation between treatment groups and modes of fracture was obtained (Table 5). The Chi-square test was used to test if there is any association between treatment groups (Procera, Turkom-Cera and In-Ceram) and modes of fracture. Due to unmet assumption of Chi-Square test and non-meaningful combination of different modes the result can be only descriptively analyzed.

Examination of the mode of fracture of specimens revealed that (70 %) of Turkom-Cera and (80 %) Procera AllCeram copings exhibited minimal fracture. Whereas, only 40 % of In-Ceram copings exhibited minimal fracture.

Ceramic	Mode of Fracture				Total
	Minimal Fracture n (%)	**Less than half of coping lost n (%)**	**More than half of coping lost n (%)**	**Severe fracture of die and/or coping n (%)**	
Procera All-ceram	8 (80%)	1 (10%)	1 (10%)	0 (0%)	10
Turkom-ceram	7 (70%)	2 (20%)	1 (10%)	0 (0%)	10
In-ceram	4 (40%)	1 (10%)	2 (20%)	3 (30%)	10

Table 5. Distribution of modes of fracture in each treatment group (Procera, Turkom-Cera and In-Ceram)

Descriptive summary for modes of fracture and mean load at fracture was recorded (Table 6). The identified modes of fracture were: minimal fracture, less than half of coping lost, more than half of coping lost and severe fracture of die and/or coping.

Mode of Fracture	Procera		Turkom-Ceram		In-Ceram	
	n	Mean LAF (SD)	n	Mean LAF (SD)	n	Mean LAF (SD)
Minimal fracture	8	999.72 (102.67)	7	1344.09 (194.26)	4	1158.32 (245.54)
Less than half of coping lost	1	965.36	2	1233.47 (362.48)	1	1077.61
More than half of coping lost	1	786.51	1	1543.40	2	1159.21 (139.41)
Severe fracture of die and/or coping	0	0	0	0	3	1162.12 (206.71)

(LAF: load at fracture)

Table 6. Descriptive summary for modes of fracture and mean load at fracture (N)

As shown in Table 6, the sever fracture mode was not seen within Procera and Turkom-Cera groups. The minimal fracture mode occurred at a higher load with Turkom-Cera group (1344.09 N) followed by In-Ceram (1158.32 N) and Procera AllCeram (999.72 N) groups.

Furthermore, the minimal fracture mode occurred at a higher load than other modes of fracture in the Procera group. Whereas, in the Turkom-Cera group the minimal fracture mode occurred at a lower load than the more than half of coping lost mode, and at a lower load than the more than half of coping lost mode. Regarding In-Ceram group, the minimal fracture mode occurred at almost similar load to the other modes of fracture.

3.2 Effect of finish line on the fracture resistance of Turkom-Cera

Specimens were divided into two groups according to finish line used; Group 1 (Turkom-Cera with chamfer finish line) and Group 2 (Turkom-Cera with shoulder finish line). The mean and median load at fracture of the two groups are shown in Table 7.

Finish line	n	Mean (SD) (n=10)	Median (IQR) (n=10)	95% CI	
				Lower Bound	Upper Bound
Turkom-Cera (Chamfer)	10	1341.9 (216.5)	1407.38 (343.99)	1187.0	1496.8
Turkom-Cera (Shoulder)	10	1545.2 (186.6)	1549.35 (318.38)	1411.8	1678.7

Table 7. The mean and median load at fracture (N) of Turkom-Cera (Chamfer) and Turkom-Cera (Shoulder) groups

For testing normality, the histogram and Shapiro-Wilk test were used and showed no normal distribution of the mean load at fracture of the two groups. Since the assumption of

Strength of a New All-Ceramic Restorative Material "Turkom-Cera"
Compared to Two Other Alumina-Based All-Ceramic Systems

273

normal distribution was not met, comparison of the load at fracture between the two groups was performed using the nonparametric Mann-Whitney U Test (Table 8). There was no significant difference in the load at fracture between the two groups (p=0.059). Therefore, there was no influence of the finish line on the load at fracture of Turkom-Cera all-ceramic copings.

Variable	Turkom-Cera (Chamfer) (n=10)		Turkom-Cera (Shoulder) (n=10)		P value
	Mean (SD)	Median (IQR)	Mean (SD)	Median (IQR)	
Load at fracture (N)	1341.9 (216.5)	1407.38 (343.99)	1545.2 (186.6)	1549.35 (318.38)	0.059*
* 2 pairs of medians are not significantly different by Mann-Whitney Test.					

Table 8. Comparison of load at fracture (N) between Turkom-Cera (Chamfer) and Turkom-Cera (Shoulder) groups by Mann-Whitney Test

4. Discussion

4.1 Methodology

An ideal experimental model of an in-vivo situation to determine the occlusal fracture resistance of all-ceramic crowns is difficult to achieve. The occlusal fracture resistance of a clinical ceramic crown is influenced by several factors, such as method of luting, loading condition and the elastic modulus of the supporting die (Scherrer and de Rijk, 1993, Webber et al., 2003; AL-Makramani et al., 2008a). However, the so called "crunch-the-crown" mechanical test had been widely used to examine the occlusal fracture resistance of sound and restored teeth (Al-Wahadni et al., 2009).

Mechanical tests on ceramic materials are difficult to carry out because of the presence of several limitations related to specimen preparation (Di Iorio et al., 2008). The present study attempted to isolate the ceramic material, artificial ageing and the finish line as the only variables. Natural teeth with comparable size and length were selected for this study to eliminate a possible effect of variations. In addition, a paralleling apparatus was used to prepare the teeth which allowed standardized preparations for all teeth.

In vivo, the teeth are supported by a visco-elastic periodontal ligament, which was not duplicated in the mounting of the specimens in the current study. The ability of the artificial ligament to reproduce the complex visco-elastic properties exhibited by ligament in vivo is limited (King and Setchell, 1990; Gu and Kern, 2006). In the clinical situation, the periodontal ligament may help to dissipate some of the applied load but at high loads simulation of a periodontal ligament in vitro is not useful as previous work has indicated that the root compresses the simulated ligament and impacts against the rigid mounting system and this might not reflect the clinical reality (Fokkinga et al., 2006; Gu and Kern, 2006; Good et al., 2008).

In the current study, two layers of nail varnish were therefore used for coating the root surfaces prior to embedding them in epoxy resin, which helped to avoid external reinforcement of the root by resin (Gu and Kern, 2006).

In the present study, the ceramic copings were cemented to natural teeth to replicate fracture load results more related to clinical situations than using ceramic discs (Wakabayashi and Anusavice, 2000; Ku et al., 2002) or crowns cemented to resin or metal die replicas (Neiva et al., 1998; AL-Makramani et al., 2009). Die replicas made of steel or resin fail to reproduce the actual force distribution at the inner surface of the crown or to reliably produce the characteristics of bonding between crowns and prepared teeth (Kelly, 1999; AL-Makramani et al., 2008a). However, die replicas provide a standardized preparation and identical physical qualities of materials used in comparison with natural teeth (Potiket et al., 2004; AL-Makramani et al., 2008b). Natural teeth show a large variation depending on their age, individual structure, and storage time after extraction, thus, causing difficulties in standardization (Strub and Beschnidt, 1998; Potiket et al., 2004).

Since the effect of the veneering porcelain on the load at fracture of high-strength all-ceramic restorations is still debatable, the copings were not veneered with porcelain (Webber et al., 2003; Beuer et al., 2008). In fact, fracturing of multilayer crowns starts at their weakest part. In the case when a stronger and stiffer core substructure is veneered with weaker porcelain, the failure usually occurs in the weak veneering porcelain or at the bond between the core and veneer (Aboushelib et al., 2006; Zahran et al., 2008). In addition, the veneering procedures could actually introduce factors (such as: flaws, cracks, voids, or internal stresses) that influence the results of mechanical tests (Vult von Steyern et al., 2006; Di Iorio et al., 2008). As stated by Miranda et al., (2001) flaws play a crucial role in the fracture resistance of brittle materials. Therefore, all-ceramic copings without porcelain veneering were loaded until fracture in this study.

The most commonly used artificial ageing technique is long-term water storage. Another widely used ageing technique is thermocycling (De Munck et al., 2005). The ISO/TS 11405 standard (2003) indicates that a thermocycling regimen comprised of 500 cycles in water between 5°C and 55°C is an appropriate artificial ageing test. In order to evaluate the effect of water storage and thermocycling on the fracture resistance of Turkom-Cera copings, 10 Turkom-Cera specimens were stored in distilled water for 30 days and subjected to 500 cycles in water between 5°C and 55°C before testing their fracture resistance.

The present study was conducted to evaluate the occlusal fracture resistance of copings fabricated using three ceramic systems and bonded to prepared teeth using resin luting cement. Such an in vitro study does not require natural teeth as a control group for comparison of results (Al-Wahadni et al., 2009; Komine et al., 2004; Potiket et al., 2004) since the stress distribution in restored teeth is different than in unrestored teeth (Arola et al., 2001). Furthermore, studies have found a large variability in the occlusal fracture resistance of extracted unprepared natural teeth (Attia et al., 2004; Attia et al., 2006).

4.2 Discussion of results

In the present study, the load at fracture of Turkom-Cera, In-Ceram and Procera AllCeram all-ceramic copings cemented to extracted teeth using resin luting cement was evaluated. The data showed that the mean load at fracture for Turkom-Cera, In-Ceram and Procera AllCeram were: 1341.9 N, 1151.6 N and 975.0 N, respectively. Statistical analysis showed that the differences were significant between Turkom-Cera and Procera AllCeram ($p < 0.001$).

However, no significant differences were detected between Turkom-Cera and In-Ceram (p=0.056) and also between In-Ceram and Procera AllCeram (p=0.080).

The results of this study for Turkom-Cera and In-Ceram copings were in agreement with those obtained in a previous study (AL-Makramani et al., 2009), which found that Turkom-Cera had a significantly higher load at fracture than Procera AllCeram. Furthermore, the results of this study for In-Ceram and Procera AllCeram copings were in agreement with those obtained in previous studies (Webber et al., 2003; Neiva et al., 1998; Harrington et al., 2003; AL-Makramani et al., 2009), which found no significant differences in load at fracture between Procera AllCeram and In-Ceram copings that were resin cemented.

An in vitro study (AL-Makramani et al., 2009), which evaluated the fracture resistance of Turkom-Cera, In-Ceram and Procera AllCeram copings cemented on a metal master die using resin luting cement, shows that the load necessary to fracture the Turkom-Cera, In-Ceram and Procera AllCeram copings in the current study was less than that reported in that study. In this study, extracted natural teeth were used as abutments. However, metal dies are very rigid and have a higher modulus of elasticity than dentine so that metal dies deform less which results in a lower shear stress at the inner crown surface (Scherrer & de Rijk, 1993). Therefore, the fracture load of all-ceramic restorations may be greater if crowns are supported by dies with a high modulus of elasticity (Scherrer & de Rijk, 1993). This factor should also be considered when interpreting the results of the studies utilizing different die materials.

The results of the present study show that there is no influence of the finish line design on the load at fracture of Turkom-Cera all-ceramic copings. Statistical analysis revealed no significant difference between shoulder (1545.2 N) and chamfer (1341.9 N) margins used in this study (p=0.059). In this study only Turkom-Cera copings were evaluated. Due to this limitation, the load at fracture values obtained in this study should be compared with caution with results obtained in the studies where copings were veneered with feldspathic porcelain.

Results of the present study concurred with other studies on glass-ceramic crowns (Dicor) which did not demonstrate any differences in the loading capacity in relation to the type of finish lines used (Bernal et al., 1993; Malament and Socransky, 1999).

Di Iorio et al., (2008) found that the load at fracture for Procera (alumina-based) crowns with shoulder preparation was significantly higher than the chamfer preparation. In the current study, the load at fracture of Turkom-Cera copings with shoulder margin (1545.2 N) was higher than chamfer margin (1341.9 N), however, statistical analysis revealed no significant difference between them (p=0.059). A possible reason for this may be that the occlusal forces were also borne by the circumferential shoulder margin, and there was less stress concentration on the axial walls compared to chamfer margin (Beuer et al., 2008).

Conversely, a study on ceramic optimized polymer (Ceromer) crowns demonstrated that the fracture resistance of the chamfer finish line specimens was greater than that of the shoulder finish line (Cho et al., 2004).

The classification description of mode of failure by Burke & Watts (1994) was useful in distinguishing between minimal loss of crown material and catastrophic damage (mode II–IV). Examination of the mode of failure of specimens in the current study revealed that Procera AllCeram, Turkom-Cera and In-Ceram copings exhibited (80%), (70%) and (20%) of minimal fracture, respectively. The copings made from Turkom-Cera with shoulder margin and Turkom-Cera with artificial ageing exhibited 50% and 60% of minimal fracture, respectively.

Clinically, dental restorations are subjected to cyclic forces ranging from 60 N to 250 N during normal function and up to 500 N to 800 N for short periods (Zahran et al., 2008; Waltimo and Könönen, 1993; Waltimo and Könönen, 1995). Waltimo & Könönen (1993), reported that the maximum biting force in the molar region was 847 N for men and 597 N for women. The maximum biting force in the premolar region has been reported to be between 181 and 608 N (Widmalm and Ericsson, 1982). However, the normal masticatory forces in human beings have been reported to range from 37% to 40% of the maximum biting force (Lundgren and Laurell, 1986; Gibbs et al., 1981).

Although the results of the present study cannot be directly compared with the in vivo situation, the mean loads at fracture for all groups (ranging from 975.0 to 1545.2 N) exceed the clinically anticipated loads in the molar and premolar regions. However, clinical trials are necessary to validate the results.

Clinically, crown failure usually occurs under a complex type of stresses. However, all specimens in the current study were tested using vertical loads which appear to be appropriate for posterior teeth (Probster, 1992). Therefore, clinical implications of the current study must be limited to that application.

In this study, the specimens were loaded until failure in a single cycle, even though restorations may fail clinically through slow crack growth caused by cyclic fatigue loading (Baran et al., 2001). Subjecting the specimens to cycling fatigue loading could be considered in further investigation to give more information about the longevity and performance of Turkom-Cera crowns in condition relatively resemble the clinical situation.

5. Conclusions

Under the conditions of this study, it was found that:

1. Turkom-Cera copings cemented to extracted teeth using the resin luting cement (Panavia F) provided load at fracture (1341.9 N) that was significantly higher to that obtained by Procera AllCeram (975.0 N) copings tested under the same conditions. However, there was no significant difference between the mean load at fracture of Turkom-Cera and In-Ceram (1151.6 N) and also between In-Ceram and Procera AllCeram copings tested under the same conditions. Thus, the null hypothesis was rejected.

2. There is no influence of the finish line on the load at fracture of Turkom-Cera all-ceramic copings. Thus, the null hypothesis was accepted.

6. Acknowledgment

7. References

Aboushelib, M.N.; Kleverlaan, C.J. & Feilzer, A.J. (2006). Microtensile bond strength of different components of core veneered all-ceramic restorations. Part II: zirconia veneering ceramics. *Dental Materials*; Vol. 22, No. 9, (September 2006) 857-863, ISSN 0109-564.

Strength of a New All-Ceramic Restorative Material "Turkom-Cera"
Compared to Two Other Alumina-Based All-Ceramic Systems

277

AL-Makramani , B.M.A.; Razak, A.A.A. & Abu-Hassan, M.I. (2008a). Evaluation of Load at Fracture of Procera AllCeram Copings Using Different Luting Cements. *Journal of Prosthodontics*, Vol. 17, No. 2, (February 2008) 120-124, ISSN 1532-849X.

AL-Makramani, B.M.A.; Razak, A.A.A. & Abu-Hassan, M.I. (2008b). Effect of luting cements on the compressive strength of Turkom-Cera all-ceramic copings. *The Journal of Contemporary Dental Practice*, Vol. 9, No. 2, (February 2008), 33-40, ISSN 1526-3711.

AL-Makramani, B.M.A.; Razak, A.A.A. & Abu-Hassan, M.I. (2009). Comparison of the load at fracture of Turkom-Cera to Procera AllCeram and In-Ceram all-Ceramic restorations. *Journal of Prosthodontics*, Vol. 18, No. 6, (August 2009) 484-488, ISSN 1532-849X.

Al-Wahadni, A.M.; Hussey, D.L.; Grey, N. & Hatamleh, M.M. (2009). Fracture Resistance of Aluminium Oxide and Lithium Disilicate-based Crowns using Different Luting Cements: An in vitro Study. *J Contemp Dent Pract*, Vol. 10, No. 2, (March 2009) 051-058, ISSN 1526-3711.

Arola, D.; Galles, L.A. & Sarubin, M.F. (2001). A comparison of the mechanical behavior of posterior teeth with amalgam and composite MOD restorations. *Journal of Dentistry*, Vol. 29, No. 1, (January 2001) 63-73, ISSN 0300-5712.

Attia, A. & Kern, M. (2004). Fracture strength of all-ceramic crowns luted using two bonding methods. *The Journal of Prosthetic Dentistry,* Vol. 91, No. 3, (March 2004) 247-252, ISSN 0022-3913.

Attia, A.; Abdelaziz, K.M.; Freitag, S. & Kern, M. (2006). Fracture load of composite resin and feldspathic all-ceramic CAD/CAM crowns. *The Journal of Prosthetic Dentistry,* Vol. 95, No. 2, (February 2006) 117-123, ISSN 0022-3913.

Baran, G.; Boberick, K. & McCool, J. (2001). Fatigue of restorative materials. *Critical Reviews in Oral Biology & Medicine*, Vol. 12, No. 4, (July 2001) 350-360, ISSN 1544-1113.

Bernal, G.; Jones, R.M.; Brown, D.T.; Munoz, C.A. & Goodacre, C.J. (1993). The effect of finish line form and luting agent on the breaking strength of Dicor crowns. *The International Journal of Prosthodontics*, Vol. 6, No. 3, (May-June 1993) 286-290, ISSN 0893-2174.

Beuer, F.; Aggstaller, H.; Edelhoff, D. & Gernet, W. (2008). Effect of Preparation Design on the Fracture Resistance of Zirconia Crown copings. *Dental Materials Journal*, Vol. 27, No. 3, (May 2008) 362-367, ISSN 0287-4547.

Blatz, M.B.; Richter, C.; Sadan, A. & Chiche, G.J. (2004). Critical appraisal. Resin bond to dental ceramics, Part II: high-strength ceramics. *Journal of Esthetic and Restorative Dentistry*, Vol. 16, No. 5, (September 2004), 324-328, ISSN 1708-8240.

Burke, F.J.T. & Watts, D.C. (1994). Fracture resistance of teeth restored with dentin-bonded crowns. *Quintessence International*, Vol. 25, No. 5, (May 1994) 335-340, ISSN 0033-6572.

Cho, L.; Choi, J.; Yi, Y.J.; Park, C.J. (2004). Effect of finish line variants on marginal accuracy and fracture strength of ceramic optimized polymer/fiber-reinforced composite crowns. *The Journal of Prosthetic Dentistry,* Vol. 91, No. 6, (June 2004) 554–560, ISSN 0022-3913.

De Munck, J.; Van Landuyt, K.; Peumans, M.; Poitevin, A.; Lambrechts, P.; Braem, M. & Van Meerbeek, B. (2005). A critical review of the durability of adhesion to tooth tissue: methods and results. *Journal of Dental Research*, Vol. 84, No. 2, (February 2005) 118-132, ISSN 1544-0591.

Della Bona, A.; Borba, M.; Benetti, P. & Cecchetti, D. (2007). Effect of surface treatments on the bond strength of a zirconia-reinforced ceramic to composite resin. *Brazilian Oral Research*, Vol. 21, No. 1, (January-March 2007) 10-15, ISSN 1806-8324.

Di Iorio, D.; Murmura, G.; Orsini, G.; Scarano, A. & Caputi, S. (2008). Effect of Margin Design on the Fracture Resistance of Procera® All Ceram Cores: An in vitro Study. *The Journal of Contemporary Dental Practice*, Vol. 9, No. 2, (February 2008), 001-008, ISSN 1526-3711.

Doyle, M.G.; Goodacre, C.J.; Munoz, C.A. & Andres, C.J. (1990a). The effect of tooth preparation design on the breaking strength of Dicor crowns: 3. *The International Journal of Prosthodontics*, Vol. 3, No. 4, (July-August 1990) 327-340, ISSN 0893-2174.

Doyle, M.G.; Munoz, C.A.; Goodacre, C.J.; Friedlander, L.D. & Moore, B.K. (1990b). The effect of tooth preparation design on the breaking strength of Dicor crowns: 2. *The International Journal of Prosthodontics*, Vol. 3, No. 3, (May-June 1990) 241-248, ISSN 0893-2174.

Fokkinga, W.A.; Kreulen, C.M.; Le Bell-Rönnlöf, A.M.; Lassila, L.V.; Vallittu, P.K. & Creugers, N.H. (2006). In vitro fracture behavior of maxillary premolars with metal crowns and several post-and-core systems. *European Journal of Oral Sciences*, Vol. 114, No. 3, (June 2006) 250-256, ISSN 0909-8836.

Gibbs, C.H.; Mahan, P.E.; Lundeen, H.C.; Brehnan, K.; Walsh, E.K, and Holbrook, W.B. (1981). Occlusal forces during chewing and swallowing as measured by sound transmission. *The Journal of Prosthetic Dentistry*, Vol. 46, No. 4, (October 1981) 443-449, ISSN 0022-3913.

Good, M.L.; Orr, J.F. & Mitchell, C.A. (2008). In vitro study of mean loads and modes of failure of all-ceramic crowns cemented with light-cured or dual-cured luting cement, after 1 and 30 d of storage. *European Journal of Oral Sciences*, Vol. 116, No. 1, (February 2008) 83-88, ISSN 0909-8836.

Goodis, H.E.; Marshall, G.W. Jr.; White, J.M.; Gee, L.; Hornberger, B. & Marshall, S.J. (1993). Storage effects on deiitin permeability and shear bond strengths. *Dental Materials*; Vol. 9, No. 2, (March 1993) 79-84, ISSN 0109-564.

Gu, X.H. & Kern, M. (2006). Fracture resistance of crowned incisors with different post systems and luting agents. *Journal of Oral Rehabilitation*, Vol. 33, No. 12, (December 2006) 918-923, ISSN 13652842.

Harrington, Z.; McDonald, A. & Knowles, J. (2003). An in vitro study to investigate the load at fracture of Procera Allceram crowns with various thickness of occlusal veneer porcelain. *The International Journal of Prosthodontics*, Vol. 16, No. 1, (January-February 2003) 54-58, ISSN 0893-2174.

International Organization for Standardization. ISO/TS 11405:2003. *Dental materials–testing of adhesion to tooth structure*, 2nd ed. Geneva, Switzerland: ISO; 2003.

Kelly, J.R. (1999). Clinically relevant approach to failure testing of all-ceramic restorations. *The Journal of Prosthetic Dentistry*, Vol. 81, No. 6, (June 1999) 652-661, ISSN 0022-3913.

King, P.A. & Setchell, D.J. (1990). An in vitro evaluation of a prototype CFRC prefabricated post developed for the restoration of pulpless teeth. *Journal of Oral Rehabilitation*, Vol. 17, No. 6, (November 1990) 599-609, ISSN 13652842.

Komine, F.; Tomic, M.; Gerds, T. & Strub, J.R. (2004). Influence of different adhesive resin cements on the fracture strength of aluminum oxide ceramic posterior crowns. *The Journal of Prosthetic Dentistry*, Vol. 92, No. 4, (October 2004) 359-364, ISSN 0022-3913.

Ku, C.W.; Park, S.W. & Yang, H.S. (2002). Comparison of the fracture strengths of metal-ceramic crowns and three ceromer crowns. *The Journal of Prosthetic Dentistry*, Vol. 88, No. 2, (August 2002) 170-175, ISSN 0022-3913.

Lundgren, D. & Laurell, L. (1986). Occlusal force pattern during chewing and biting in dentitions restored with fixed bridges of cross-arch extension. I. Bilateral end abutments. *Journal of Oral Rehabilitation*, Vol. 13, No. 1, (January 1986) 57-71, ISSN 13652842.

Malament, K. & Socransky, S. (1999). Survival of Dicor glassceramic dental restorations over 14 years. Part II: Effect of thickness of Dicor material and design of tooth preparation. *The Journal of Prosthetic Dentistry*, Vol. 81, No. 6, (June 1999) 662-667, ISSN 0022-3913.

Miranda, P.; Pajares, A.; Guiberteau, F.; Cumbrera, F.L. & Lawn, B.R. (2001). Role of flaw statistics in contact fracture of brittle coatings. *Acta Materialia*, Vol. 49, No. 18, (October 2001) 3719-3726, ISSN 1359-6454.

Neiva, G.; Yaman, P.; Dennison, J.B.; Razzoog, M.E. & Lang, B.R. (1998). Resistance to fracture of three all-ceramic systems. *Journal of Esthetic and Restorative Dentistry*, Vol. 10, No. 2, (March 1998) 60-66, ISSN 1708-8240.

Ozcan, M.; Alkumru, H.N. & Gemalmaz, D. (2001). The effect of surface treatment on the shear bond strength of luting cement to a glass-infiltrated alumina ceramic. *The International Journal of Prosthodontics*, Vol. 14, No. 4, (July-August 2001) 335-339, ISSN 0893-2174.

Potiket, N.; Chiche, G. & Finger, I.M. (2004). In vitro fracture strength of teeth restored with different all-ceramic crown systems. *The Journal of Prosthetic Dentistry,* Vol. 92, No. 5, (November 2004) 491-495, ISSN 0022-3913.

Probster L. (1992). Compressive strength of two modern all-ceramic crowns. *The International Journal of Prosthodontics*, Vol. 5, No. 5, (September-October 1992) 409-414, ISSN 0893-2174.

Scherrer, S.S. & de Rijk, W.G. (1993). The fracture resistance of all-ceramic crowns on supporting structures with different elastic moduli. *The International Journal of Prosthodontics*, Vol. 6, No. 5, (September-October 1993) 462-467, ISSN 0893-2174.

Shillingburg, H.T.; Hobo, S.; Whitsett, L.D.; Jacobi, R. & Brackett, S.E. (1997). *Fundamentals of fixed prosthodontics*. 3rd ed., Quintessence Publishing Co, Inc, 0-86715-201-X, Chicago.

Shimada, Y.; Yamaguchi, S. & Tagami, J. (2002). Micro-shear bond strength of dual-cured resin cement to glass ceramics. *Dental Materials*; Vol. 18, No. 5, (July 2002) 380-388, ISSN 0109-564.

Strub, J.R. & Beschnidt, S.M. (1998). Fracture strength of five different all-ceramic crown systems. *The International Journal of Prosthodontics*, Vol. 11, No. 6, (November-December 1998) 602-609, ISSN 0893-2174.

Valandro, L.F.; Ozcan, M.; Bottino, M.C.; Bottino, M.A.; Scotti, R. & Della Bona, A. (2006). Bond strength of a resin cement to high-alumina and zirconia-reinforced ceramics: the effect of surface conditioning. *The Journal of Adhesive Dentistry*, Vol. 8, No. 3, (June 2006) 175-181, ISSN 1461-5185.

Vult von Steyern, P.; Ebbesson, S.; Holmgren, J.; Haag, P. & Nilner, K. (2006). Fracture strength of two oxide ceramic crown systems after cyclic pre-loading and thermocycling. *Journal of Oral Rehabilitation*, Vol. 33, No. 9, (September 2006) 682-689, ISSN 13652842.

Wakabayashi, N. & Anusavice, K. (2000). Crack initiation modes in bilayered alumina/porcelain disks as a function of core/veneer thickness ratio and supporting substrate stiffness. *Journal of Dental Research*, Vol. 79, No. 6), (June 2006) 1398-1404, ISSN 1544-0591.

Waltimo, A. & Könönen, M. (1993). A novel bite force recorder and maximal isometric bite force values for healthy young adults. *Scandinavian Journal of Dental Research*, Vol. 101, No. 3, (June 1993) 171-175, ISSN 0029-845X.

Waltimo, A. & Könönen, M. (1995). Maximal bite force and its association with signs and symptoms of craniomandibular disorders in young Finnish non-patients. *Acta Odontologica Scandinavica*, Vol. 53, No. 4, (August 1995) 254-258, ISSN 1502-3850.

Webber, B.; McDonald, A. & Knowles, J. (2003). An in vitro study of the compressive load at fracture of procera allceram crowns with varying thickness of veneer porcelain. *The Journal of Prosthetic Dentistry*, Vol. 89, No. 2, (February 2003) 154-160, ISSN 0022-3913.

Widmalm, S.E. & Ericsson, S.G. (1982). Maximal bite force with centric and eccentric load. *Journal of Oral Rehabilitation*, Vol. 9, No. 5, (September 1982) 445-450, ISSN 13652842.

Zahran, M.; El-Mowafy, O.; Tam, L.;Watson, P.A. & Finer, Y. (2008). Fracture strength and fatigue resistance of all-ceramic molar crowns manufactured with CAD/CAM technology. *Journal of Prosthodontics*, Vol. 17, No. 5, (July 2008) 370-377, ISSN 1532-849X.
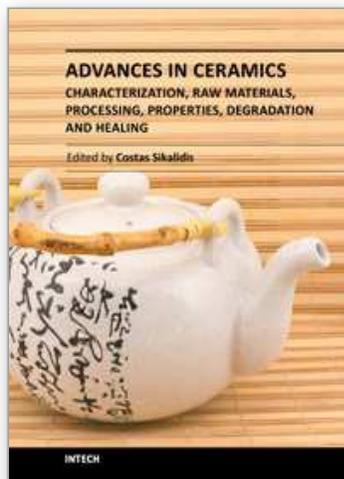
Advances in Ceramics - Characterization, Raw Materials,
Processing, Properties, Degradation and Healing
Edited by Prof. Costas Sikalidis

ISBN 978-953-307-504-4

Hard cover, 370 pages

Publisher InTech

Published online 01, August, 2011

Published in print edition August, 2011

The current book consists of eighteen chapters divided into three sections. Section I includes nine topics in characterization techniques and evaluation of advanced ceramics dealing with newly developed photothermal, ultrasonic and ion spattering techniques, the neutron irradiation and the properties of ceramics, the existence of a polytypic multi-structured boron carbide, the oxygen isotope exchange between gases and nanoscale oxides and the evaluation of perovskite structures ceramics for sensors and ultrasonic applications. Section II includes six topics in raw materials, processes and mechanical and other properties of conventional and advanced ceramic materials, dealing with the evaluation of local raw materials and various types and forms of wastes for ceramics production, the effect of production parameters on ceramic properties, the evaluation of dental ceramics through application parameters and the reinforcement of ceramics by fibers. Section III, includes three topics in degradation, aging and healing of ceramic materials, dealing with the effect of granite waste addition on artificial and natural degradation bricks, the effect of aging, micro-voids, and self-healing on mechanical properties of glass ceramics and the crack-healing ability of structural ceramics.

INTECH
open science | open minds