In vitro study of compressive fracture strength of Empress 2 crowns cemented with various luting agents

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All-ceramic restorations have had a more limited life expectancy than metal ceramic restorations because of their low strength. Their relatively lower strength and resistance to fracture have restricted the use of all-ceramic crowns to anterior applications where occlusal loads are lower. But there has been increasing interest in all-ceramic restorations because patients are primarily concerned with improved esthetics. Many efforts have been made to improve the mechanical properties of dental ceramics.

This study was designed to elucidate the influence of the luting agent on the strength of the Empress 2 crown (staining technique) cemented on human teeth. Seventy extracted human permanent molar teeth were chosen. Teeth were prepared for Empress 2 crowns with milling machine on a surveyor. A dental bur was placed in the mandrel that was positioned so that the long axis of the bur was perpendicular to the surveyor base. Dimensions of the Empress 2 crown preparation were 6° taper on each side, 1.5 ± 0.1mm shoulder margin, and 4mm crown height. The luting cements used in this study were as follow: 1. Uncemented 2. Zinc phosphate cements (Confi-Dental) 3. Conventional glass ionomer cement : Fuji 1 (GC) 4. Resin-modified glass ionomer cements : Fuji plus (GC) 5. Adhesive cements : Panavia F (Kuralay), Variolink Ⅱ (Vivadent), Choice (Bisco).

Fracture test using Instron : The crowns were loaded in compressive force to evaluate the effect of these cements on the breaking strength of these all-ceramic crowns. A steel ball with a diameter of 4mm was placed on the occlusal surface and load was applied to the steel ball by a cylindrical bolt with a crosshead speed of 0.5mm per minute until fracture occurred. The fractured surface was examined using Scanning Electron Microscopic Image (SEM) to discover the correlation between fracture strength and bonding capacity.

Within the limitation of this in vitro study design, the results were as follows :

1. Cementations significantly increased the fracture resistance of Empress ceramic crowns compared to control. Uncemented (206.9 N); ZPC (812.9 N); Fuji 1 (879.5 N); Fuji Plus (937.7 N); Choice (1105.4 N); Variolink Ⅱ (1221.1 N); Panavia F (1445.2 N).
2. Resin luting agent, treated by a silane bond enhancing agents, yielded a significant increase in fracture resistance. In some of the Panavia F group, a fracture extended into dentin.
3. According to SEM images of fractured Empress crowns, the stronger the bond at both interfaces(crown and die), the more fracture strength was acquired.

Key Words

Fracture strength, Empress 2 crown, Human teeth, Cementation method

All-ceramic restorations have had a more limited life expectancy than metal ceramic restorations because of their low strength. Their relatively lower strength and resistance to fracture have restricted the use of all-ceramic crowns to anterior applications where occlusal loads are lower. The use of all-ceramic restoration for posterior crowns or for fixed partial dentures has not been routinely possible because of strength limitations. But there has been increasing interest in all-ceramic restorations[1] because patients are primarily concerned with improved esthetics. In addition, ceramics are regarded as biocompatible and inert material, are resistant to corrosion, and have low temperature and electrical conductivity.[2] Coupled with the esthetic demands for dental restorations, this has resulted in an increased use of dental ceramics and has led to many efforts to improve the mechanical properties of dental ceramics.

In the last few years, several new all-ceramic crown systems with significantly improved strength have been introduced. These newer materials offer the potential for much broader use of the all-ceramic restoration, and increased strength has created a renewed interest in the use of the all-ceramic crown.

Various methods of strengthening are as follows. Increased core strength has been obtained using a shrink-free ceramic core with magnesium aluminate spinel (Cerestore)[3] and an alumina-reinforced core having approximately 40% Al_2O_3 and fabricated directly on the refractory die (Hi-Ceram).[4] Slip casting of alumina ceramics (In-Ceram)[5,6] has been introduced as a method of fabricating a material having a flexural strength of approximately 400 MPa. The highly sintered core is composed of approximately 85% Al_2O_3 and was strengthened by lanthanum silicate glass infiltration in the second firing process. A castable glass-ceramic system using tetrasilicic fluoramica(Dicor) was introduced and was fabricated using a conventional casting procedure. Other strengthening methods have used leucite-reinforced porcelains which is fabricated directly on the refractory die(Optec-HSP) or a heat pressure technique (IPS Empress and Optimal Pressable Ceramics), and recently lithium disilicate (IPS Empress 2) has been introduced. Some of these ceramic materials offer higher strength and are stated as indicated for use as posterior restorations.

Furthermore, the introduction of bonding procedures and new luting techniques have increased the general acceptance of theses ceramic systems. Various cements have been used for luting all-ceramic crown restorations. Conventional glass ionomer luting agents have an anticariogenic potential through fluoride release, a coefficient of thermal expansion similar to tooth structure, a low in vivo disintegration rate, and adherence to tooth structure. Unfortunately, conventional glass ionomer cements have low tensile strength and fracture toughness, and are susceptible to attack by moisture during the initial setting period. On the other hand, use of resin cements for ceramic restorations in clinical practice is complicated and technique sensitive.

In the late 1980' s, products described as hybrids of glass ionomer cement and composite were introduced to the dental profession and are called resin ionomer.[7,8] Resin-ionomer can be divided into resin-modified glass ionomer cements, polyacid-modified resin cements, and fluoride-releasing resin cements. Resin-modified glass ionomer materials have demonstrated potential in luting of ceramic restorations.[9] It is claimed that these products have advantages of both resin cement and glass ionomer cement. But clinical observations by some practitioners suggest a relation between the fracture of all-ceramic crown and the use of resin-ionomer luting agents. However, a controlled study to answer this question has never been done.

In 1995, a survey of the American Academy of Esthetic Dentistry reported resin cement to be the most popular cement used for cementing all-ceramic crowns(64%),[10] while resin-modified glass ionomer cement, which was introduced only 3 years earlier, was ranked second in popularity (13%) to resin luting agents.

It is difficult to recreate in the laboratory the exact conditions that would cause a fracture in the mouth. All the factors such as occlusion of the patients, shape of the prepared tooth, all-ceramic crown systems, thickness of the porcelain crown, defects within the porcelain, and luting cement systems could be responsible for the clinical fracture of all-ceramic crowns.

This study is designed to elucidate the influence of the luting agent on the strength of all-ceramic crown. Care was taken to standardize production of abutment samples, storage time and conditions, preparation design, crown fabrication technique, porcelain thickness, shape of crowns, and cementation, and finally loading to fracture of the control and test groups to allow relative comparison between the experimental variables under the conditions of the study. Used all-ceramic crown was the Empress 2 crown (staining technique) and human teeth were used as die material.

(1) IPS Empress : The use of a heat-press technique was reported for the fabrication of all-ceramic restorations.[11,12] The technique involves the use of a partially precerammed and precolored glass leucite ingot that is heated and pressed into a phosphate-bonded investment mold. The mold is heated to 850 ℃ in a burnout oven. A ceramic ingot is then placed in the open end of the mold, followed by a push rod. The mold is held in the automatic pressing furnace at 1,150℃ for 20 minutes prior to pressing. Following divestment, the restoration is completed by the addition of surface colorants as needed and a surface glaze. The final crystal growth takes place during the pressing and firing steps of fabrication. The IPS Empress material is feldspathic porcelain with the crystalline phase consisting of leucite crystals. The technique of heat pressing produces a restoration with good marginal adaptation because additional shrinkage is minimized.

(2) IPS Empress 2 : As the flexural strength of IPS Empress is below 200 MPa, the material is not suitable for the fabrication of bridges. A material that can be used with the IPS Empress hot press technique to fabricate esthetic all-ceramic bridges was demanded. In response to this demand, the new high-strength IPS Empress 2 layering ceramic has been developed.[13] The new material has replaced the conventional IPS Empress layering ceramic. The system components for the IPS Empress staining technique, however, remain unchanged.

MATERIAL AND METHODS

Selection of teeth

Seventy extracted human permanent molars were chosen, having first been examined visually to be sound and free from hypoplastic defects and having been found to be free from cracks when examined with ×10 optical microscope. Calculus deposits and soft tissues were removed from the selected teeth with a hand instrument. Following postextraction storage in 10% formalin for 2 weeks, the teeth were cleaned in NaOCl for 2 hours. They were divided at random into seven equal groups.

The teeth were stored in 0.9% normal saline at room temperature (20℃) except when the experimental procedure required isolation from moisture. Each tooth was fixed, crown uppermost and long axis vertical, in a square shaped acrylic resin mold with 40mm width and length, with a self-curing resin that extended to approximately 3mm below the cementoenamel junction. After mounting, the teeth were stored in 0.9% normal saline at room temperature until they were used.

Preparation of teeth

A preparation design was considered to fabricate equal size of Empress 2 crown. Preparation of teeth were divided into two steps.

First step : Prepared the teeth to 8×8mm square form size to standardize crown size and shape on milling machine.

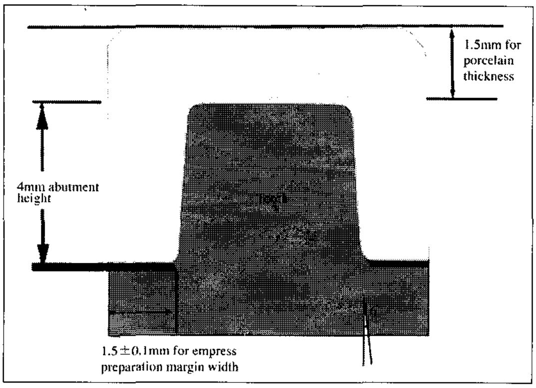

Fig. 1. Dimension of preparation and fabricated crown.

Next step : Prepared the teeth to 4mm height and 1.5mm marginal width (Fig. 1).

Teeth were prepared for Empress 2 crowns with milling machine on a surveyor. A diamond bur (No. 585.8, Premier) was placed in the mandrel that was positioned so that the long axis of the bur was perpendicular to the surveyor base.

Cusps were removed and a pencil was used to mark the tooth approximately 4.0±0.05mm below the flat occlusal surface. The long axis of tooth was positioned vertically, and then the screw was tightened.

The straight cylindrical diamond bur (No. 585.8, Premier) was attached to milling machine. The vertical spindle of the surveyor was adjusted until the tip of the diamond bur was at the level of the pencil mark. The operator moved the engine to flatten all lateral convex surfaces level with the cervical mark. Water was used as coolant.

The straight diamond bur was changed to a diamond wheel bur (No. 863, Premier) for the Empress preparations. A 1.5±0.1mm shoulder depth cut was created 4mm below the occlusal surface with the diamond wheel bur.

Then taper of 6° was applied to the preparation with 1mm safe tip, round-end tapered diamond bur (No. S79, Premier). This safe tip prevented ledging and overcutting. The diamonds were held in a laboratory handpiece operated at 25,000rpm with intermittent water spray. Any sharp preparation angles were rounded with a tapered diamond bur at 3,000rpm without water spray. Final dimension of the Empress 2 crown preparation was 6° taper on each side, 1.5±0.1mm shoulder margin, and 4mm crown height.

Fabrication of crowns

Impressions of the prepared teeth were made with a hydrophilic polyvinyl siloxane impression material, putty and light bodied paste (Examix cartridges, GC America Inc., Chicago, Ill.) in a stock plastic tray painted with tray adhesive.

The impressions were cast with type 4 stone to fabricate working die. IPS Empress crowns were fabricated in the following manner. Wax patterns of the crown were fabricated on the stone. All the procedure was done on surveyor to confirm the size and width of wax pattern. 1.5±0.05mm Duralay pattern resin plates were used for even occlusal thickness. These wax patterns were invested with special investment and the heat-pressed ceramic crowns were fabricated according to the manufacturer' s instructions.

After the ring had bench set for 1 hour, the ring and base were separated, making certain that the ends and sides were at 90° angles. The ring was then placed into the burnout furnace along with the AlOx plunger. The burnout temperatures were as follows: stage 1-room temperature to 250℃ at 5℃ per minute with a 30 minutes hold; stage 2- 250℃ to 850℃ at 5℃ per minute with a 60 minutes hold. After burnout, the ring, cold ingot and AlOx plunger were placed together into the EP 500 pressing furnace. A program with a high temperature(920℃) was installed and held for 20 minutes at pressure of 5 bars. Vacuum was initiated at 500℃ and at 920℃ with no press time. After pressing, the ring was immediately removed and placed on an elevated ring stand.

After the ring had cooled, it was separated with a large disc at the junction of the plunger and the ingot. Most of the investment could be blasted off of

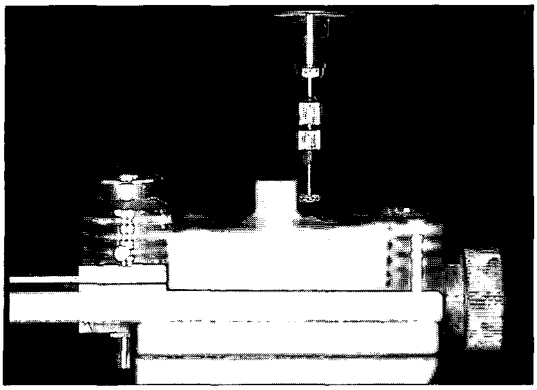

Fig. 2. Preparation of the teeth Ⅰ.

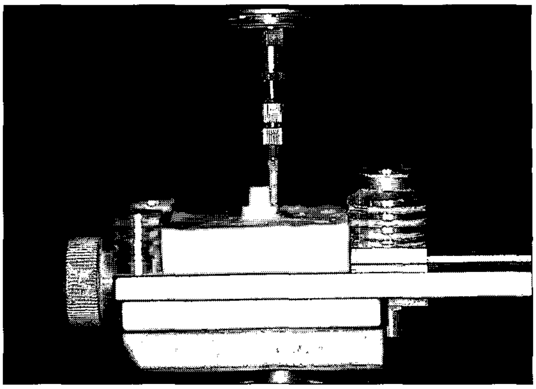

Fig. 3. Preparation of the teeth Ⅱ.

the specimen with 50 micron alumina powder at 4 bars of pressure; the pressure was reduced to 2 bars for the final investment. The specimen was then rinsed with water and air dried. The sprues were removed according to the manufacturer' s recommendation prior to the finishing steps.

The specimen was cleaned with steam, dried with oil-free air, applied glazing material using the glazing liquid. Then the final firing was done.

Placement of crowns

The marginal fit of each crown was examined on the tooth. If the fit was considered unsatisfactory, a new impression was taken and a new crown was constructed. When the fit was considered adequate, the fitting surface of the crown was washed with water and dried.

Cementation

For the load-to-fracture evaluation, control and test crowns were seated on the abutment samples according to several categories.

The luting cements used in this study are shown in Table Ⅰ.

1. Uncemented
2. Zinc phosphate cemented
3. Conventional glass ionomer cemented
4. Modified glass ionomer cemented
5. Adhesively bonded

Zinc phosphate cement was used as follows : The inner surfaces of crowns were cleaned and dried with flush of water. The dies were also cleaned with water only and gently dried with cotton pellet. 8 drops of phosphoric acid were mixed with 0.7g zinc oxide powder on a cooled glass plate for 1.5 minutes. The cement was applied to the inner crown surface using a brush, and gross excess was removed. A constant pressure of 50 N was applied for 10 minutes by a metallic weight.

Fuji 1 was used as follows : The inner surfaces of crowns were cleaned and dried with flush of water. The dies were also cleaned with water only and gently dried with cotton pellet. Powder to liquid ratio was 1.8/1.0g. Using the plastic spatula, powder and liquid were mixed for 20 seconds. Internal surface of restoration was coated with 1mm of cement and restorations were seated within 30 seconds of completing mix.

Fuji Plus was used as follows : The inner surfaces of crowns were cleaned and dried with flush of water. The dies were applied GC Fuji Plus conditioner for 20 seconds using a cotton pellet. Then dies were cleaned with flush of water, gently dried with cotton pellet. Powder to liquid ratio was 2.0g/1.0g. Using the plastic spatula, powder and liquid were mixed for 20 seconds. Internal surface of restoration was coated with 1mm of cement and restorations were seated within 30 seconds of completing mix.

Table Ⅰ. Luting cement systems

Cements	Type	Manufacturer
ZPC	Zinc phosphate cement	Confi-Dental products co.
Fuji 1	Conventional glass ionomer cement	GC America Inc., Chicago
Fuji plus	Resin-modified glass ionomer cement	GC America Inc., Chicago
Panavia F	Dual / light-polymerized resin cement	Kuraray Co., LTD, Japan
Vairolink Ⅱ	Dual / light-polymerized resin cement	Ivoclar Liechtenstein
Choice	Dual / light-polymerized resin cement	Bisco Inc., U.S.A

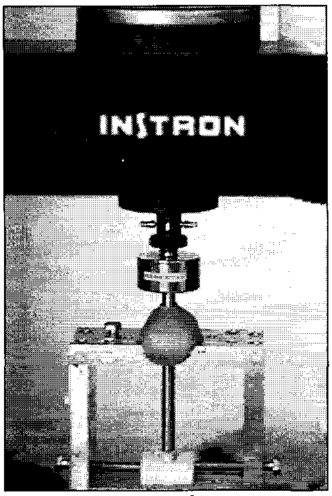

Fig. 4. Loading test on the Instron machine.

For adhesive bonding, three products were used.

Panavia F TC was used as follows. The inner surfaces of the crowns were etched for 60 seconds with a 4% hydrofluoric acid gel, rinsed for 60 seconds and air dried for 20 seconds. Thereafter a silane was applied for 60 seconds and air dried for 20 seconds. The dies were etched with 37% phosphoric acid, rinsed with flush of water, and gently dried with cotton pellet. A bonding agent was then brushed on dies and crowns in a thin layer and gently dried to avoid pooling.

Composite luting material was mixed for 30 seconds according to the manufacturer' s instructions and applied to the inner crowns. Crowns were then placed on dies using finger pressure, and immediately 50 N of load was applied for 10 minutes by a metallic weight Excess luting composite was removed using a probe tip. To avoid polymerization inhibition at the surface of the adhesive interface, Oxyguard was applied for 10 minutes.

Variolink Ⅱ was used as follows. The inner surfaces of the crowns were treated in the same manner as Panavia F group (etched and air dried). Then silane (Monobond S) was applied for 60 seconds and air dried for 20 seconds. The dies were etched with 37% phosphoric acid, rinsed with flush of water, and then gently dried with cotton pellet. After primer was applied on die, a bonding agent (Heliobond) was then brushed on dies and crowns in a thin layer and then gently dried to avoid pooling.

Composite luting material was mixed for 30 seconds according to the manufacturer' s instructions and applied to the inner crowns. Crowns were then placed on dies using finger pressure, and immediately 50 N of load was applied for 10 minutes by a metallic weight Excess luting composite was removed using a probe tip.

Choice was use as follows. The inner surfaces of the crowns were treated in the same manner as Panavia F group (etched and air dried and silaned with All-bond 2). The dies were etched with 37% phosphoric acid, rinsed with flush of water. Then gently dried with cotton pellet. A bonding resin was then brushed on dies and crowns in a thin layer and gently dried to avoid pooling.

Composite luting material was mixed according to the manufacturer' s instructions and applied to the inner crowns. Crowns were then placed on dies using finger pressure, and immediately 50 N of load was applied for 10 minutes by a metallic weight Excess luting composite was removed using a probe tip.

Fracture test using Instron

After storage of the abutment samples in water for 1 week, the crowns were loaded in compressive force to failure to evaluate the effect of these cements on the breaking strength of these all-ceramic crowns. A steel ball with a diameter of 4 mm was placed on the occlusal surface and load was applied to the steel ball by a cylindrical bolt with a crosshead speed of 0.5mm per minute until fracture occurred. Load was transmitted vertically to the surface of the die support. The fracture load values were recorded in newtons.

After fracture test, the fractured surfaces were examined using SEM(Scanning Electron Microscopic Image) to discover the correlation between fracture strength and bonding capacity.

Statistical analysis

The fracture load values were statistically tested by a one way analysis of variance using SPSS/PC+software (SPSS, Chicago, IL.). Duncan' s multiple comparison test was used to compare the correlations among the cement variables.

RESULTS

The main outcome variable was the fracture resistance measured as the maximal fracture load by progressive occlusal loading until catastrophic failure.

All the cement (ZPC, Fuji 1, Fuji plus, Panavia F and Variolink Ⅱ, and Choice) remained attached to the tooth structure. But ZPC easily detached from the tooth. in contrast to other cement.

A small amount of cement remained in the crowns luted using ZPC and G.I.C. In this study, conventional glass ionomer and resin modified glass ionomer luting cements behaved similarly. As for adhesive cements group, crowns were completely covered with cement.

Even though adhesive cements remained at-

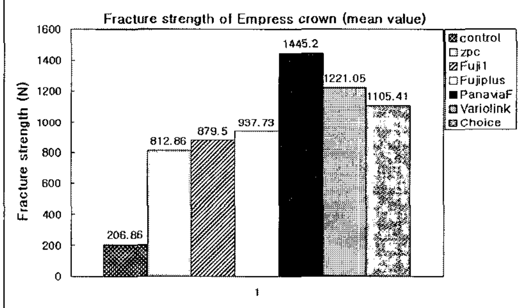

Fig. 5. Fracture strength of Empress 2 crown.

Table Ⅱ. ANOVA(Analysis of Variance) Results(Alpha=0.05)

Cements	N	Mean Fracture Load (N)	SD	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Min	Max
Control	10	206.9	56.86	166.2	247.5	151.1	303.7
ZPC	10	812.9	106.43	736.7	889.0	670.1	1015.0
Fuji Ⅰ	10	879.5	114.27	797.8	961.2	759.0	1117.0
Fuji Plus	10	937.7	114.78	855.6	1019.8	808.3	1175.0
Panavia F	10	1445.2	197.82	1303.7	1586.7	1067.0	1699.0
Variolink Ⅱ	10	1221.1	188.60	1086.1	1356.0	968.5	1612.0
Choice	10	1105.4	223.19	945.8	1265.1	867.1	1484.0

Table Ⅲ. Duncan's 95% Confidence test

Cements	N	Subset for alpha = .05			
Control	10	206.9			
ZPC	10		812.9		
Fuji Ⅰ	10		879.5		
Fuji Plus	10		937.7		
Choice	10			1105.4	
Variolink Ⅱ	10			1221.1	
Panavia F	10				1445.2

tached to both the porcelain crown and the tooth structure, they tended to be attached more to the porcelain crowns than to the tooth structure. The fracture loads of the ceramic crowns are given in Table Ⅱ. The influence of luting agents on the strength of Empress 2 crown is shown in Fig. 5. When the fracture strength of Empress crown according to the cements. There was significant difference in the fracture strength of Empress crowns between Panavia F and other luting agents.

SEM images of fractured Empress crowns with different magnifications of the same specimen are shown in Figures 6~11. It was observed that the cement layers fractured in different patterns.

Statistical analysis by one way analysis of variance showed that the fracture values for resin-bonded all-ceramic crowns were significantly greater ($P<0.05$) than the other crowns (see also Table Ⅱ).

DISCUSSION

Several factors can contribute to the clinical variation in fracture strength of ceramic crowns, such as the crown thickness, porosity, shape of the prepared tooth, the luting agent, direction of the applied force, and location of the applied load.[14] Porosities and large flaws are also responsible for failure, especially in crowns with reduced occlusal thickness. Although there are many ways to simulate the clinical environment in vitro. In vitro reports concerning the natural human teeth are few. So it is difficult to use theoretical considerations to estimate the fracture strength of all-ceramic crowns.

The purpose of this study was to assess the effect of the luting agent on the fracture strength of the crown. In order to do this, all ceramic crowns were placed on standardized preparations on extracted molar using various luting agents and their fracture resistance was measured.

In other fracture studies, resin or steel has been used for die material. When resin was used, it was intended to imitate the modulus of elasticity. When fracture study was designed, the effect of the elastic modulus of the supporting substrate under an all-ceramic crown was significant. A large increase in the fracture strength occurred when the elastic modulus of the substrate increased from 2.9 GPa to 14.0 GPa (fracture strength increased 0.96 kN to 2.8 kN).[15] According to the literature, the elastic modulus of dentin ranges from 5.2 GPa to 19 GPa.[16,17] But, when adhesive technology is used to seat the crowns the fine hybrid composite resin has the potential of a strong bond between abutments and ceramic that may not be attained in the same consistent strength in clinical situations.[18] In case of steel die, cementation on metal die requires special treatment method, even though it is easy to fabricate standardized abutment. It is reasonable to use human molar teeth as die material for the assessment of the fracture strength of all-ceramic crown. Milling machine was used for preparation and the ceramic crown form was controlled by using surveyor.

Empress crown has following characteristics. The industrially manufactured ceramic has a consistent material quality with a high degree of homogeneity and only sparse single fine pores. The flexural strength of its pre-cerammed ingot (74 MPa) is different from that of a heat pressed test bar (126 MPa). Dong et al.[12] attributed this difference to the more homogeneous distribution of the leucite crystals which they observed under scanning electron microscope.

Dolye et al.[20] reported that increasing the occlusal convergence angle of the abutment increased the fracture load of zinc phosphate cemented Dicor crowns in vitro.[19] For the preparation of adhesively luted Dicor crowns, a convergence angle of 20° was recommended. However, the dentin should not be reduced to less than a minimum dentin thickness of 0.7mm to avoid pulp damage.[20] A convergence angle of 6 to 10° seemed to provide the best combination of all-ceramic crown strength and remaining dentin thickness.[21] In this study, dimensions of the Empress 2 crown preparation were 6° taper on each side, 1.5 ± 0.1mm shoulder margin and 4mm crown height.

According to McLean, strength tests for porcelain can produce scattered, inconsistent results.[22] This finding is consistent with those reported by other clinicians and this study. these values and rankings are similar to another study that evaluated compressive strengths of posterior crowns by vertical loading Instron machine.

When uncemented crowns were loaded, the abutment samples remained undamaged. A study using finite element analysis has shown that in uncemented glass ceramic crowns the maximum stresses occurred at or near the crown margin and decreased when the ratio of occlusal ceramic thickness to crown length was increased.[23] In contrast to this, in this study fractures occurred at occlusal surface. Abutment height and margin width were relatively sufficient and this is thought to show different fracture type.

Adhesively seated crowns had the highest fracture load values compared to uncemented and zinc phosphate-cemented crowns. Stress distribution and initiation of fracture were not specifically examined in this study. Uncemented crowns were included in the study as a control group for the effects of luting agents. Groten et al. found that the fracture load of Empress crowns luted with composite resin to steel dies was significantly higher than when using phosphate cement or glass ionomer cement,[24] indicating a strengthening effect of the interfacial bond. The strengthening effect of adhesive placement was clearly confirmed by the present fracture load data, as reported in other studies.[25]

In resin cements, the differences in the filler-matrix bond can lead to large differences in water uptake and strength between proprietary composites made from methyl methacrylate.[26] Coupling agents, such as silane and 4-META, have been used to improve the filler matrix bond, which can lower the rate of water uptake by reducing interfacial water diffusion. The filler component in Panavia is treated with coupling agents, which may be related to the low rate of water uptake and expansion reported by Hollis et al.[27]

Several strengthening techniques and principles were developed and investigated. There are two concepts behind the clinical use of adhesive techniques: (1) the more effective stress transfer by the creation of strong bonding forces at the enamel-resin-ceramic interfaces analogous to principles of compound systems, and (2) the strengthening effect resulting from resin coatings following the principles of surface modification to inhibit crack initiation.[28,29]

Micromechanical retention of the luting material to the restoration is obtained by etching the fitting surface of the crown with hydrofluoric acid in a manner similar to that used in the porcelain veneer technique.[30]

In a study by Giordano et al., it was shown that the flexural strength of ceramics could be affected by the surface finish.[31] Additionally, the porcelain surface is treated by a silane bond enhancing agents. Such agents have been shown to improve the bond strength to a resin composite based luting material by about 20%.[32] The beneficial effect of surface treatment and bonding technique for ceramics has been demonstrated on bonded Dicor crowns[33,34] and bonded Ceramco crowns.

Grossman reported that the strong chemical bond of the light-activated cement to the etched-silanized porcelain surface is thought to better distribute the stresses and leads to a 28% increase in the characteristic fracture resistance.[35] The reasons for such effects are (a) a reduction of the stress associated with an increased radius of curvature at the flaw tip in the ceramic surface by the acid etching treatment, (b) a reduction of stress at the flaw tips by completely coating these areas with a silane bonding agent and resin cement, and (c) a decrease in the strain (deflection) along the internal surface of the crowns, the area subjected to the highest tensile stress, through a chemical bond between the cement, crown, and prepared tooth. Following finite element analysis, it was also reported that the stress reduction was not the result of the low elastic modulus of the luting material but the complete adhesion between the restoration and the tooth structure. Fracture strength improvement resulting from adhesion was observed in an other study.[36] Fracture resistance has been considered to be improved because the plane of fracture was continuous through dentin, luting material, and crown.

Beside the increase in fracture strength, adhesive bonding systems has other advantages. By using this luting procedure, the need for conventional means of retention, with respect to both the taper and the height of the preparation, will be reduced.[37] Further esthetic advantages may also accrue because light transmission is better than it is with metal ceramic crowns or those luted with a non-translucent cement.[38]

The mean maximal posterior occlusal biting force may vary between 200 and 540 N. In this study, all luting system exceeded 540 N. The difference between the fracture rates may have a clinical significance. But Initial fracture strength itself is not main issue in clinical situation, However, for example, the halfmoon gingival fracture, which is often seen in the all-ceramic crown, is considered to be the end result of chronic stresses and strains related to occlusal forces, thermal shocks,[39] aqueous degradation,[40] and flaws in the ceramic microstructure. So the risk of fractures has to be taken into consideration when placing crowns on teeth that are likely to be subjected to high stress levels.

CONCLUSION

Empress pressed ceramic crowns were luted to prepared natural teeth using several types of luting agents and varied luting procedures. Within the limitation of this in vitro study design, the following conclusions may be made:

1. The use of zinc phosphate or glass ionomer cement had no significant influence on the fracture resistance of Empress ceramic crowns.
2. Resin luting agent, treated by a silane bond enhancing agents, yielded a significant increase in fracture resistance. In some of the Panavia F group, a fracture extended into dentin.
3. Complete adhesive bonding using a resin luting agent yielded a considerable increase of the in vitro fracture resistance of all-ceramic crowns. According to SEM images of fractured Empress crowns, this effect is ascribed to a strong bond at both interfaces, the crown-resin and the die-resin interface, simulated by tooth conditioning.

The results of this study indicates that a luting procedure that includes dentinal bonding in conjunction with a composite resin-based luting material and an etched fitting surface of ceramic provides superior resistance to fracture in all-ceramic crowns compared to crowns luted with other luting cement such as zinc phosphate cement, G.I.C. or modified G.I.C.

It therefore appears that the resin based luting material may play an important role in improving fracture resistance, either by its better physical properties or by prevention of crack propagation.

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FIGURES ①

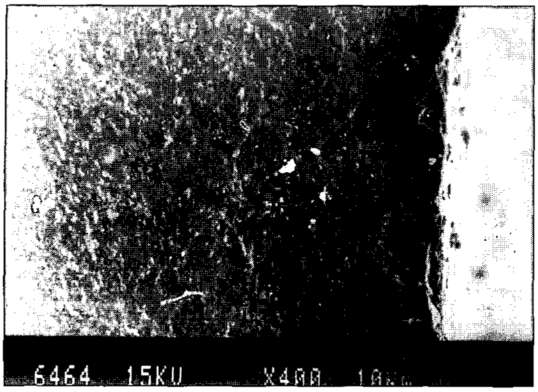

Fig. 6. SEM of fracture surface of Empress crown cemented with ZPC (× 400).

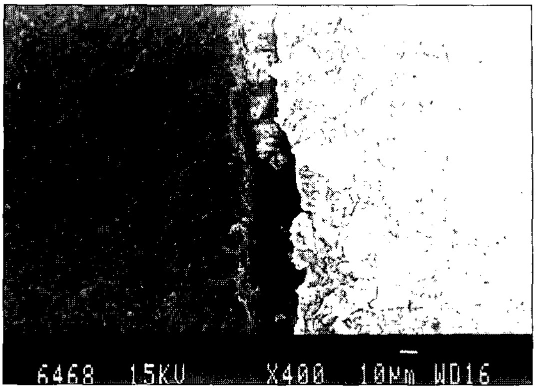

Fig. 7. SEM of fracture surface of Empress crown cemented with Fuji 1(Conventional G.I.C.) (× 400).

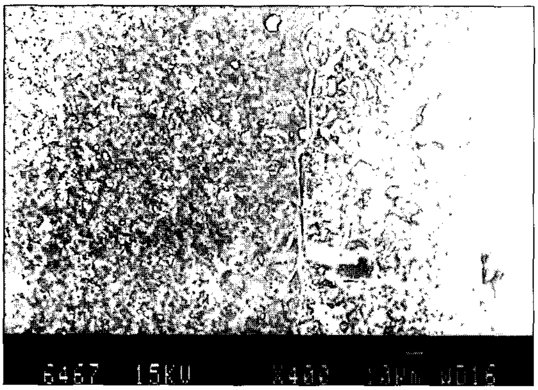

Fig. 8. SEM of fracture surface of Empress crown cemented with Fuji Plus (Modified G.I.C.) (× 400).

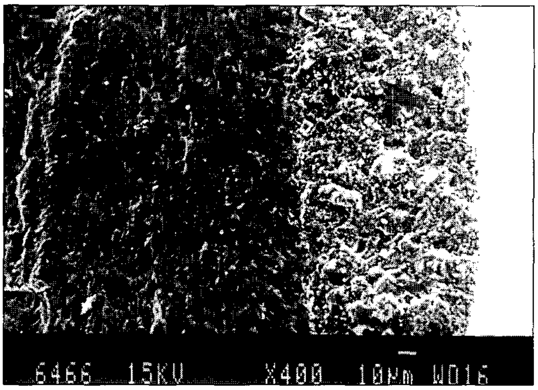

Fig. 9. SEM of fracture surface of Empress crown cemented with Panavia F (× 400).

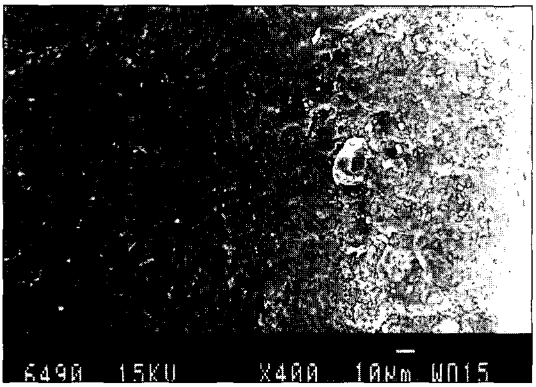

Fig. 10. SEM of fracture surface of Empress crown cemented with Variolink Ⅱ (× 400).

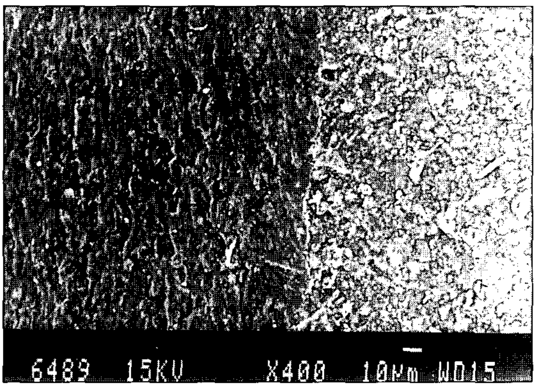

Fig. 11. SEM of fracture surface of Empress crown cemented with Choice (× 400).