Influence of Different Cementation Materials and Thermocycling on the Fracture Resistance of IPS e.max Press Posterior Crowns

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Citation

Abstract

Aim: To evaluate the effect of different cementation materials and thermocycling on the fracture resistance of IPS e.max Press posterior crowns.

Materials and methods: Thirty-two sound maxillary molars were subjected to a standardized preparation in order to receive IPS e.max Press (Ivoclar Vivadent) ceramic crowns. Another 16 molars were left unprepared to serve as control (Group I). Both Panavia F2.0 (Kuraray) and Relay X Unicem (3M ESPE) luting cements were used to fix the fabricated crowns (n=16 for each) to their respective prepared teeth (Groups II and III respectively). Eight specimens from each of the 3 test groups were randomly selected for further thermocycling (5000 cycles). All specimens were then vertically pressed using anatomical metal attachment affixed to the upper member of a universal testing machine and running at crosshead speed of 1mm/min. The collected data were statistically analyzed using 2-way analysis of variance (ANOVA) and Student's t-test at 5% level of significance.

Results: The load values that the restored teeth can withstand (From 907 to 986 N) was much lower than that recorded for normal teeth (1279 N) (2-way ANOVA test, p<0.001). No significant difference in the fracture load values was detected among the groups of restored teeth (986 MPa and 974 N for groups II and III) (Student t test, p>0.05). Thermocycled specimens showed lower values of fracture loads in comparison to non-thermocycled ones (Student t test, p<0.001).

Conclusions: Either kinds of cement materials used looks to have no effect on the fracture resistance of IPS e.max crowns to vertical loads. Thermocycling adversely affects the ability of the cemented crowns to resist the applied load. The fracture loads of the tested crowns exceeded the recorded values of normal occlusal forces.

INTRODUCTION

In spite of the amazing success of metal-ceramic crowns, their known drawbacks, such as questionable marginal esthetic and biocompatibility, were directed the attention toward the use of metal-free restorations. In the last 2 decades several manufacturers had introduced new ceramic systems having the ability to overcome the hereditary brittleness and low fracture toughness of early ceramic materials. These features together with excellent esthetic, biocompatibility, resistance to wear and low thermal conductivity nominated many of the current all-ceramic systems to pass the challenge expected to face when applied in the posterior region of the mouth.

Heat-pressing is a process that has been developed to overcome the inhomogeneities and porosity that occur during creaming. The first heat-press ceramic material (IPS Empress, Ivoclar –Vivadent, Schaan, Liechtenstein) is a type of leucite-reinforced glass ceramic and has a flexural strength of 182 MPa. A modified version of this material (IPS Empress 2) having lithium disilicate (2 SiO₂ - Li₂O) crystals could provide an average fracture strength of 350 MPa. Therefore, it was nominated not only for anterior 3 unite bridges, but also for restoration of posterior region which may include a first premolar as a pontic.

An improved press ceramic material called IPS e.max Press (Ivoclar –Vivadent) was recently introduced specially for posterior and bridge applications. The new material consists of lithium disilicate pressed glass ceramic like that of IPS.
Empress 2, but the properties are changed by a different firing process. (Scientific documentation, IPS e.max Press, Ivoclar –Vivadent, Schaan, Liechtenstein) Also, the framework can be veneered with a new type of sintered fluoroapatite porcelain that has nearly the same coefficient of thermal expansion as IPS e.max Press framework has. In comparison with IPS Empress 2, combining the two glass ceramic materials exhibit substantially improved physical properties and greater translucency.

Albakry et al., determined the biaxial flexural strength of different pressable ceramic materials. IPS e.max Press recorded higher flexure strength values in comparison to IPS Empress and Empress 2 materials. Komine et al., examined the static fracture load of three-unit IPS e.max Press frameworks and bridges. Non-veneered and veneered frameworks were also tested. The fracture strength of veneered frameworks was found to be higher than that of those without veneering. Edelhoff et al., discovered that the translucency of IPS e.max Press is so sensitive, dramatically affected by the choice of cementation material and it is better to use translucent cement underneath.

On the other hand and as a result of the inherent mechanical characteristics (brittleness, and low flexural and tensile strengths), ceramic materials usually fracture at a fraction of their theoretical strength. To overcome this problem, many authors believe that metal-free ceramic restorations should be bonded to the tooth with a kind of strong cements. Therefore, the purpose of this study was to address the question of whether different types of cementing media in addition to thermocycling significantly influence the fracture resistance of IPS e.max Press posterior crowns.

MATERIALS AND METHODS

TEETH SELECTION AND GROUPING

Extracted maxillary molars were collected at The Department of Oral Surgery, Mansoura University, Faculty of Dentistry. The collected molars were ultrasonically cleaned and stored in 1% chloramines B-hydrate solution for 1 week. For this investigation, only 48 caries and crack-free molars with no hypoplastic defects were visually selected by the aid of x10 magnifying glass.

The selected molars were randomly divided into 3 main groups (n=16) (Table 1). In Group I, the molars were left without any kind of preparation to serve as control. Molars of the other groups were subjected to a standardized preparation to receive IPS e.max press crowns. The fabricated crowns were cemented to their respective molars using either Panavia F2.0 (PF) and Relay X Unicem (Rx) luting cements forming groups II and III. The materials used, their characters and manufacturers were listed in (Table 2).

**Figure 1**

<table>
<thead>
<tr>
<th>Test Groups (n=16 for each)</th>
<th>Test Subgroups (n=8 for each)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 (control)</td>
<td>Subgroup 1: Thermocycled</td>
</tr>
<tr>
<td>Unprepared molars</td>
<td>Subgroup 2: Non thermocycled</td>
</tr>
<tr>
<td>Group II:</td>
<td></td>
</tr>
<tr>
<td>Prepared molars having IPS e.max crown restoration</td>
<td>Subgroup 1: Thermocycled</td>
</tr>
<tr>
<td>Crowns were cemented with Panavia F2.0 (PF)</td>
<td>Subgroup 2: Non thermocycled</td>
</tr>
<tr>
<td>Group III:</td>
<td></td>
</tr>
<tr>
<td>Prepared molars having IPS e.max crown restoration</td>
<td>Subgroup 1: Thermocycled</td>
</tr>
<tr>
<td>Crowns were cemented with Relay X Unicem (Rx)</td>
<td>Subgroup 2: Non thermocycled</td>
</tr>
</tbody>
</table>

**Figure 2**

Table 2: Materials used.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Composition</th>
<th>Manufacturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>IPS e.max press</td>
<td>Lithium silicate reinforced pressable glass ceramic</td>
<td>Ivoclar-Vivadent, Schaan, Liechtenstein</td>
</tr>
<tr>
<td>IPS e.max ceram</td>
<td>Fluoroapatite veneering ceramic</td>
<td>Ivoclar-Vivadent, Schaan, Liechtenstein</td>
</tr>
<tr>
<td>Panavia F2.0</td>
<td>Primer A: HEMA, 10-MCP, 5-NMMA, Primer B: 8-NMMA, water, sodium benzoate, Paste A: silica, dimethacrylate, Paste B: 10% bisphenol, sodium fluoride, dimethacrylate</td>
<td>Kuraray, Medical Inc., Osaka, Japan</td>
</tr>
<tr>
<td>Relay X Unicem</td>
<td>Powder glass powder, silica, calcium hydroxide, Liquid dimethacrylate, phosphoric ester, 3M ESPE, St. Paul, MN</td>
<td></td>
</tr>
</tbody>
</table>

TEETH PREPARATION

All the selected molars were vertically fixed in metal rings using self-cured acrylic resin (Duracrol, Sofa-Dental, Prague, Czech republic) after coating their roots with a 0.25 mm thick layer of low viscosity silicone rubber to represent the periodontal ligament (Imprint II, 3M ESPE, Saint Paul, MN). The roots were embedded in the fixing resin 1mm away from the cervical line. Molars in groups II and III were subjected to a standardize preparation using water-cooled cross slide carbide insert running at 400 rpm on a lathe cutting machine (AB wood Machine tools LTD SGia M/C No.17531, BVC, China). The prepared teeth were adjusted to be 4 mm high with 10o occlusal taper, 1.2 mm shoulder finishing line and flat occlusal surfaces. All the prepared teeth were impressed using medium viscosity vinyl polysiloxane impression material (Imprint II, 3M ESPE, Saint Paul, MN) in custom made acrylic trays and poured in Type IV gypsum (Zeta Muffle, Acrostone, Cairo, Egypt). Both prepared and unprepared teeth were then incubated in
Influence of Different Cementation Materials and Thermocycling on the Fracture Resistance of IPS e.max Press Posterior Crowns

tap water at 37±1°C for 24 h before cementing the fabricated ceramic crowns and testing the resistance of all to fracture under vertical loading.

FABRICATION OF CERAMIC CROWNS
The axial surfaces of the prepared teeth 0.5 mm from the finishing line were coated with die spacer (Tru-Fit, Co. Inc, Jersey City, NJ). Full wax-ups were made for the proposed crowns. Round wax sprues 3 mm in diameter were attached to each of the wax-ups approximately 45° on the long axis before investing in Empress 2 speed investment material (Ivoclar Vivadent, Schaan, Liechtenstein). The preheating cycle was carried out at 850°C for 60 min. The molds were then transferred to the furnace and press-filled with IPS e.max Press ingot material at 915°C for 20 min. After divesting and separation of the restoration the tooth-colored copings were veneered with IPS e.max ceram.

Fitness of the fabricated crowns was checked up on their corresponding prepared teeth. Points of interference on the intaglio surfaces were corrected under water-air cooling, using fine-grit diamond tips in high-speed angled handpiece. The intaglio surfaces of the restorations were then sandblasted (Reco Dental Corp, Wiesbaden, Germany) using 100µm sized Al₂O₃ particles at 1 bar of air pressure and etched with 8% hydrofluoric acid (Choice, Bisco Dental Corp, Itasca, IL) for 20 s before rinsing and air drying for another 30 s each.

CEMENTATION OF CROWNS AND THERMOCYCLING
Silane coating (3M ESPE, St. Paul, MN) was applied to the etched intaglio surfaces, allowed to evaporate for 3 min and air-dried for 30 s immediately before cementation. Sixteen of the constructed crowns (Group II) were cemented to their corresponding molars using Panavia F2.0 (Kuraray Medical Inc., Osaka, Japan) according to the manufacturer's instructions. Equal amounts of ED primer 2.0 A and B was mixed and applied to the dentin surface before the application of cement material. The other 16 crowns (Group III) were cemented to their respective teeth using Rely X Unicem (3M ESPE, St. Paul, MN) and no conditioning step was required for this group according to the manufacturer's instructions.

At the time of cementation, the crowns were secured in place for 1 min using finger pressure and seated under 5 kg constant load for 10 minutes. Half the number of teeth in each group (n=8, subgroup 1) were subjected to thermocycling for 5000 cycle at 5 and 55°C for 60 s each, with an intermediate pause of 12 seconds, while the other half was incubated (Binder Inc, Great river, NY) without thermocycling (subgroup 2) in tap water at 37±1°C. (Table 1).

TESTING THE FRACTURE RESISTANCE
Each specimen was fixed in a specially designed jig mounted to the lower member of the universal testing machine (Type 500, Lloyd instrument, England). Specimens of all groups were compressively loaded until fracture by the aid of anatomical metal attachment representing the opposing contacts and mounted to the moving member of the testing machine (Figure 1). All tests were carried out at crosshead speed of 1mm/ min and the maximum fracture load was recorded when either cracking sounds or visible cracks were noticed.

STATISTICAL ANALYSIS
Two-way analysis of variance (ANOVA, p=0.05) was used to analyze the fracture load values between the three test groups to detect the possibility of differences among the two test variables (types of cement materials and thermocycling). The interaction between both variables was also of concern. Student's t-test was performed to detect which subgroup was exactly differ (p=0.05) from the others.

RESULTS
Mean fracture loads (N) and standard deviations for all test subgroups are shown in table 3. One-way ANOVA test indicated the presence of difference between the test groups. A significant interaction between the tested variables (Type
of cement and thermocycling) was also evident. Test specimens of groups II and III recorded significantly lower fracture loads in comparison to those recorded for natural unprepared teeth (group I) before and after thermocycling (t-test, \( P=0.001 \)). No significant differences was noticed among the fracture loads of groups II (PF) and III (RX) (\( P>0.05 \)). Thermocycling significantly deteriorate the fracture resistance of subgroups independent on the type of luting media (\( P<0.001 \)).

**Figure 4**

Table 3: Means fracture loads (N) of different test groups before and after thermocycling.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Group I</th>
<th>Group II</th>
<th>Group III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unprepared teeth</td>
<td>( X^* )</td>
<td>( \pm SD )</td>
<td>( X^* )</td>
</tr>
<tr>
<td>Thermocycled</td>
<td>1043*</td>
<td>261</td>
<td>921**</td>
</tr>
<tr>
<td>Non-thermocycled</td>
<td>1279**</td>
<td>190</td>
<td>906**</td>
</tr>
</tbody>
</table>

* Significantly different from the control
For each group, different superscripts indicating significant differences (t-test, \( P<0.05 \))

**DISCUSSION**

Strength of ceramic crowns is a multifactorial property that governed by the strength properties and thickness of selected ceramic material as well as the configuration of the constructed crowns. Cement’s interfacial properties and the elastic moduli of different components of the adhesive junction (Ceramic, cement and tooth) have also been reported to have close association with both crack initiation and propagation in dental ceramic restorations.

In practice crown failure usually occurs under a complex type of stresses, however, this in vitro study addressed only the resistance on compression which appears to be appropriate for posterior teeth. Metal-ceramic crowns were used in certain studies to compare the performance of all-ceramic ones. However, the unprepared natural teeth looked to be the commonly nominated reference because the main restorative goal of fixed prosthodontics is not to improve the nature, but to restore the function and esthetic.

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Laboratory teeth preparation usually follows the clinically established reduction criteria for all-ceramic crowns. The low angle of tapering (10°) may have caused the increased dependence of cement layer thickness on the fitness of the prosthesis. The increase in cement thickness would accordingly increase the volume of materials with lower modulus of elasticity and strength within the adhesive junction. This study tried to fix this annoying variable through controlling the cement film thickness. The application of definite number of uniform coats of die spacer and the use of constant value of pressure at the time of cement setting, did help regarding this issue.

A number of investigators showed differences in the fracture resistance of cemented crowns using a wide variety of cementing media. Their results suggest that certain combinations of materials (Ceramic systems and cement) may have some beneficial effect on the value of fracture strength. In this in vitro study the fracture strength of e. max Press crowns were not affected by the type of cement used. These findings are not directly transferable to the clinical situation, but the followed testing protocol has been shown to correlate well with clinical studies assessing the performance of restorations over 5-years.

Panavia F and Rely X Unicem both consist of multifunctional phosphoric acid dimethacrylate modified monomers, such as Bis-GMA, and inorganic fillers of fine glass and silica. The current study did not discover any significant difference in the values of fracture resistance among the non-thermocycled crowns of in groups II and III, is spite of the conflict with some previously recorded data. It may be assumed that the ductile resin cement functions as a shock absorber so that it can distribute the force during the fracture resistance test at the tooth-cement-ceramic interfaces. Certain studies proved that the use of dentin bonding agents improve the fracture resistance of cemented crowns simply because it perfectly seals dentinal tubules and thus prevents fluid outflow from the pulp that could affect the setting of the cement material and its adaptation to the dentin surface.

Thermocycling is a way to expose materials to thermal stresses as a result of abrupt changes in temperature and to simulate aging of the retentive system of crowns. Thermocycling has been found to have an adverse influence on the fracture resistance of cemented crowns. This reduction could be the result of deteriorating cement material underneath. Waltimo and Konenen found that the maximum biting force in the molar region was 847 N for men and 597 N for women. Although the results of the current study cannot be directly compared with the in vivo situation, the mean load at fracture was far greater than the
clinically anticipated load.

Subjecting the specimens to cycling loading could be considered in further investigation to give more information about the longevity and performance of IPS e.max crowns in situation relatively resemble the clinical situation.

CONCLUSIONS

Within the limitations of this in-vitro study the following conclusions could be deduced; there is no significant influence of the cement type, either Panavia F2.0 or Relay X Unicem, media on the fracture resistance of IPS e.max posterior crowns. Thermocycling has an adverse effect on the fracture resistance of cemented IPS e.max Press crowns.

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