Influence of different types of resin cement on the fracture resistance of teeth restored with MOD ceramic inlays

Kihyun Kwon

The Graduate School

Yonsei University

Department of Dentistry

Influence of different types of resin cement on the fracture resistance of teeth restored with MOD ceramic inlays

(Directed by Prof. Byoung-Duck Roh,
D.D.S., M.S.D., Ph.D.)

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Of Kihyun Kwon is approved.

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Thesis Supervisor : Byoung-Duck Roh

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Thesis committee : Sung-Ho Park

_____

Thesis committee : Yooseok Shin

The Graduate School

Yonsei University

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감사의 글

보존과에 들어온 날이 어제만 같은데 어느새 3 년이라는 시간이 흘렀습니다. 배움의 길에 첫 발을 디디고 이제 학위논문이라는 작은 결실을 맺게 되어 도움을 주신 분들께 감사의 말을 전하고자 합니다.

먼저 부족함이 많은 저를 여기까지 이끌어주시고 항상 깊이 있는 조언을 아끼지 않으셨던 노병덕 교수님께 특별한 감사의 말씀을 드립니다. 완성도 높은 논문을 위해 학술적인 지도와 관심 가져 주신 박성호 교수님, 그리고 실험에서부터 단어 하나까지 세세하게 검토하고 친형처럼 신경 써주신 신유석 교수님께도 진심으로 감사 드립니다.

수련기간 동안 저를 이끌어주시고 조언해주신 이찬영 교수님, 이승종 교수님, 김의성 교수님, 정일영 교수님께 또한 깊은 감사를 드립니다. 교수님들의 가르침으로 보존과 치과의사로서 성장할 수 있었습니다.

부족한 후배에게 물심 양면으로 도와주시고 관심 갖고 조언해주신 전동근 선생님, 정건석 선생님께도 감사 드립니다. 오랜 시간을 함께 나누며 의지할 수 있게 해준 보존과 수련 동기들과, 후배님들에게도 고마움을 표현하고 싶습니다. 그리고 오랫동안 깊은 애정과 관심으로 제게 힘이 되어주시고, 잊지 못할 큰 가르침을 남겨주신 경희고 이주리 선생님께 뒤늦은 감사와 경애의 마음을 전하고 싶습니다.

마지막으로 세상 누구보다 큰 사랑 주시고 지금까지 뒷바라지 해주신 부모님과, 철없는 동생에게 애정과 관심을 준 누나에게 깊은 고마움과 사랑하는 마음을 전합니다.

2015 년 6 월 권기현

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ABSTRACT

Influence of different types of resin cement on the fracture resistance of teeth restored with MOD ceramic inlays

Kwon Kihyun D.D.S.

(Directed by Prof. Byoung-Duck Roh, D.D.S., M.S.D., Ph.D.)

The purpose of this study was to evaluate the influence of 3 different types of resin cements on the failure of teeth restored with ceramic inlays using a universal testing machine.

Seventy-five intact, caries-free human maxillary premolars were divided into 5 groups (n=15): Group 1, intact teeth as controls; Group 2, Class II mesio-occluso-distal (MOD) cavity preparation and restoration with IPS e.max CAD by Variolink N; Group 3, MOD cavity preparation and restoration with IPS e.max CAD by RelyX Unicem; Group 4, MOD cavity preparation and restoration with IPS e.max CAD by Multilink sprint; and Group 5, MOD cavity preparation and no restoration. Compressive force was loaded only on the cuspal inclination of tooth.

Class II MOD preparation was as follows. The pulpal floor was formed at a depth of 2 mm from the occlusal cavosurface margin of the preparation, and the isthmus was half of

the intercuspal distance. The proximal box width was 1.5 mm, and the axial wall was 2 mm in height. Margins were prepared with 90-degree cavosurface angles.

Specimens were tested with a universal testing machine at 1.0 mm/min using steel sphere plungers (6.0mm in diameter). Peak load to fracture (N) was measured for each specimen. Means were calculated and analyzed with a one-way ANOVA and Tukey's test (α=0.05).

The mean peak fracture loads (N, mean ± S.D.) were as follows: Group 1 - 1371.29 ± 455.86, Group 2 - 1188.18 ± 408.79, Group 3 - 1097.38 ± 443.64, Group 4 - 1134.69 ± 352.13, Group 5 - 624.08 ± 259.03.

Based on the results obtained under *in vitro* experimental conditions, the following conclusions were drawn. There was no statistical difference of fracture load between intact teeth and restored teeth. Although Group 2 (Variolink N) showed superior fracture load than Group 3 (RelyX Unicem) and Group 4 (Multilink speed), no statistical difference was found. Groups 3 and 4, using self adhesive resin cements, showed unfavorable fracture patterns more frequently than Groups 1 and 2. Fracture resistance of teeth restored with ceramic inlays was comparable with that of intact teeth, regardless of the type of resin cements used in this experiment.

Keywords: Ceramic inlay; CAD/CAM; Fracture; IPS e.max; resin cement

Influence of resin cementation method on the fracture resistance of teeth restored with MOD ceramic inlays

(Directed by Prof. Byoung-Duck Roh, D.D.S., M.S.D., Ph.D.)

Department of Dentistry,

Graduate School,

Yonsei University

Kihyun Kwon D.D.S.

I. Introduction

In teeth that need restoration due to caries or fracture, preparation leads to a reduction in fracture resistance. Especially, teeth with MOD cavities show a significant difference in fracture resistance, as compared to intact teeth (Ausiello et al., 2004; Dalpino et al., 2002; Santos and Bezzera, 2005; St-Georges et al., 2003). Generally, teeth get weaker as the amount of preparation for restoration increases (Edelhoff and Sorensen, 2002). The shallower the cavity depth in the enamel layer (Lin et al., 2001), and the wider the remaining axial wall in the dentin layer, leads to greater resistance to stress from fracture

(Lin et al., 2001; Hansen and Asmussen, 1990). When masticatory force is applied on teeth, cusp deformity occurs due to stress (Jagadish and Yogesh, 1990). As the cavity becomes wider, the degree of deformity increases and thus fracture resistance decreases remarkably (Hood, 1991).

In case of restorations that do not bond to tooth structure, especially with greater amount of tooth loss, fracture resistance does not recover back to its original level (Boyer and Roth, 1994; Trope et al., 1986). However, since the introduction to dentistry of materials that enable micromechanical and chemical bonding with teeth, several researches took to using such materials in restoration of cavities to increase fracture resistance of teeth. Since restoration is bonded to remaining teeth, cusp deformity and bending due to stress decreases (Dalpino et al., 2002). The internal splinting effect of strengthening teeth without cusp capping was the subject of several theses. Direct restoration with resin reportedly has higher fracture resistance, as compared to restoration with material that does not bond to teeth (Hurmuzlu et al., 2003; Mackenzie, 1986). However, when the cavity is wide, fracture resistance of resin restored teeth does not recover to the resistance level of intact teeth (Dalpino et al., 2002; Santos and Bezzera, 2005). In wide cavities, indirect restoration methods are preferred because of the limitations of direct restorations and material properties.

As esthetic needs are increasing in dentistry, the use of ceramic inlays is also increasing (Ferrari et al., 2003). There is a controversy among researchers on the internal splinting effect of ceramic inlays. Some claim that restoring premolar or molar MOD cavities with ceramic inlays can recover fracture resistance to the level that has no significance

difference with intact teeth (Hannig et al., 2005; Dalpino et al., 2002; Bremer and Geurtsen, 2001). On the other hand, some reports indicated that fracture resistance of teeth with ceramic inlay is inferior to that of intact teeth (St-Georges, 2003; Santos and Bezzera, 2005). Since cavity outlines, choice of ceramics, choice of cements, and experiment design of measuring fracture resistance were different among researches, it is difficult to unify the results of different experiments.

Since ceramic inlays can chemically bond to resin through surface preparation using hydrofluoric acid and silane (Blatz et al., 2003), successful bonding to teeth using resin cement is possible (Peumans et al., 2000). Traditional multi-step resin cement is criticized because results may vary depending on the dentist's technique, as pretreatment procedures on teeth are rather complicated and may lead to ineffectiveness (Frankenberger et al., 2008). Recently, self adhesive resin cements that do not need pretreatment of tooth surface have become available. Although the bonding procedure of self adhesive resin cement is simplified and therefore allows quick and simple cementation (Ferracane et al., 2011), it is controversial whether it's adhesive strength is as strong as the previous multi-step resin cement. In addition, there is a lack of research on whether self adhesive resin cement strengthens teeth and prevents tooth fracture as much as the previous multi-step resin cement when ceramic inlays are used in teeth with cavities.

In this study, the strengthening of teeth through internal splinting was evaluated depending on the resin cement type when bonding ceramic inlays. In order to achieve this, the effect of newly developed self adhesive resin cement on fracture resistance of

maxillary premolar with MOD cavities after inlay boding was compared with that of the previously used multi-step, dual cure type resin cement. The hypothesis of this thesis is that the difference in bonding mechanism of resin cement does not affect the fracture resistance of teeth restored with ceramic inlays.

II. Materials & Methods

1. Selection and Preparation of Teeth

Seventy-five, recently extracted caries-free human maxillary premolars of similar size and shape were selected. Any calculus and soft tissue deposits were removed from the selected teeth by the use of a hand scaler (Grace curette SG 17/18, Hu-Friedy, Chicago, IL). Teeth were examined under x10 magnification to detect any preexisting defects. Teeth were stored in normal saline before the experiment began. Before specimens were prepared, the widest bucco-palatal dimension of the crown and intercuspal distance (ICD) of each tooth were measured. Teeth were divided into 5 groups of 15, so that the average tooth size of each group was as equal as possible. The group number, assignment, bucco-palatal dimension of the crown and ICD were shown in Table 1. According to the one-way ANOVA test, there were no statistical differences of bucco-palatal dimension and ICD among groups.

Table 1. Group number, assignment (n = 15 for each group), average bucco-palatal dimension and intercuspal distance for each group.

Group	Assignment	Mean (± SD) of the bucco-palatal dimension(mm)	Mean (± SD) of the Intercuspal distance(mm)
Group 1 (control)	Intact teeth	9.92 ± 0.41	6.17 ± 0.44
Group 2	MOD prep. + e.max CAD + Variolink N	9.91 ± 0.41	6.24 ± 0.53
Group 3	MOD prep. + e.max CAD + RelyX U200(Unicem)	9.93 ± 0.41	6.09 ± 0.48
Group 4	MOD prep. + e.max CAD + Multilink speed	9.92 ± 0.41	6.20 ± 0.54
Group 5	MOD prep. + Unrestored	9.93 ± 0.46 a	6.31 ± 0.59

Class II MOD preparations were made (Figure 1) in 60 premolars of Groups 2-5 with water-cooled high-speed handpiece and diamond burs (#845KR, Brasseler, GmbH, KG). Before testing, teeth were embedded in self curing acrylic resin at a position 1mm below the cement-enamel junction (CEJ) and were surrounded in a plastic tube, following methods reported in several other similar studies (Ausiello et al., 1997; Hannig et al., 2005; St-Georges et al., 2003**).**

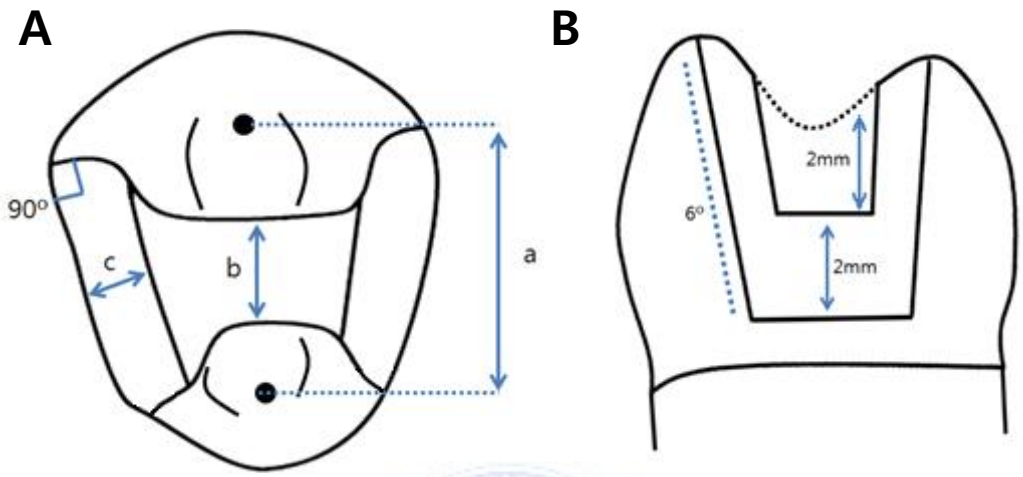

Figure 1. A maxillary premolar with MOD preparation. A, Occlusal view, B, Proximal view

The pulpal floor was formed at a depth of 2mm from the occlusal cavosurface margin of the preparation. The isthmus (Fig.1 A-b) was extended to half of the individual intercuspal distance (Fig.1 A-a) of each tooth. The proximal box width (Fig.1 A-c) was 1.5mm and the axial wall was 2mm in height. Standardized depth was verified with a scaled periodontal probe (instrument number 23/UNC 15, Hu-Friedy, Chicago, IL). The mesial and distal proximal box was extended bucco-palatally to the intercuspal distance. All preparations were completed along the longitudinal axis of each tooth and were free from undercuts. The convergence angle was 6 degree in each buccal and palatal walls. Margins were prepared with 90-degree cavosurface angles.

2. MOD inlay Fabrication

To fabricate ceramic inlays, a CAD/CAM device (CEREC AC, Sirona Dental Systems GmbH, Bensheim, Germany) was used according to the manufacturer's instructions. After preparation, CEREC Omnicam (Sirona Dental Systems GmbH, Bensheim, Germany) was used for the optical impression. After obtaining the images, each inlay was designed by using software package provided (CEREC AC version 4.2).

Inlays were fabricated using lithium disilicate ceramic blocks (IPS e.max CAD, Ivoclar Vivadent, Schaan, Liechtenstein). IPS e.max CAD blocks were milled and then underwent a crystallization process in a Programat P300 furnace (Ivoclar Vivadent, Schaan, Liechtenstein) under the crystallization temperature of 820-840℃ (Program No.81) to precipitate the crystal. The inlays were checked for fit in their preparation.

3. Cementation

For the restorations, the inner surfaces of the inlays were etched with 4% hydrofluoric acid (Porcelain Etchant, Bisco, IL., U.S.A.) for 20 seconds. A silane coupling agent (Monobond N, Ivoclar Vivadent) was applied for 60 seconds. After applying the adhesive system, ceramic restorations were cemented with resin cement.

In Group 2, 37% phosphoric acid (DenFil Etchant-37, Vericom, Chuncheon, Korea) was applied to the prepared enamel for 20 seconds and then onto the prepared dentin for another 10 seconds. The cavities were rinsed for 30 seconds and excess moisture was

removed until a slightly wet dentin surface remained (wet bonding). Then, an adhesive system (Syntac, Ivoclar Vivadent) was applied as directed by the manufacturer, and an adhesive agent (Heliobond, Ivoclar Vivadent) was applied. After applying the adhesive system in Group 2, ceramic restorations were cemented with dual-cured resin cement (Variolink N, Ivoclar Vivadent). The restorations were placed with finger pressure using a brush to remove excess cement.

In Groups 3 and 4, the cavities were rinsed thoroughly with water spray for 30 seconds and then were lightly dried with oil-free air.

In Group 3, inlays were cemented with self adhesive resin cement (RelyX U200 (Unicem), 3M Deutschland GmbH, Germany). Cement was dispensed onto a mixing pad, mixed for 10 seconds, and then applied to inlays.

In Group 4, self adhesive resin cement (Multilink speed, Ivoclar Vivadent) was applied onto inner surfaces of the restorations using automixing syringe.

The restorations were placed with finger pressure, using a brush to remove excess cement. After placement, all inlays were light cured on occlusal, mesial and distal surfaces for 3 minutes in total (1 minute per surface, LED, 500mW/cm^2, Guilin Woodpecker Medical Instrument, Guangxi, China). Teeth were kept in saline at room temperature for 1 week before testing.

Table 2. Ceramic block and resin cements used in this study

Product	Material type	LOT	Manufacturer
IPS e.max CAD	Lithium disilicate glass ceramic	N03151 T15512	Ivoclar Vivadent, Schaan, Liechtenstein
Variolink N	Multi-step dual cure resin cement	Base (S25641) Catalyst (T00902)	Ivoclar Vivadent, Schaan, Liechtenstein
RelyX U200	Self adhesive resin cement	558916	3M Deutschland GmbH, Germany
Multilink speed	Self adhesive resin cement	S05050	Ivoclar Vivadent, Schaan, Liechtenstein

4. Testing

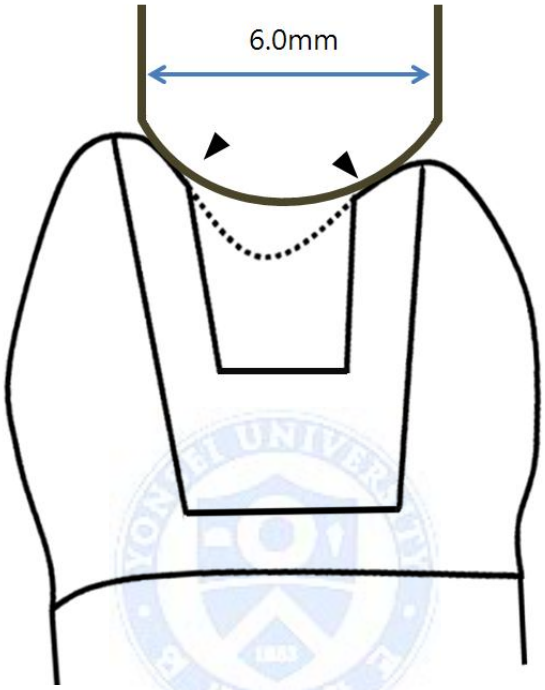

Figure 2. 6.0mm diameter steel sphere plunger in contact with area between buccal and palatal cusp

Specimens were tested in a universal testing machine (model 3366, Instron Corp, Canton, MA, U.S.A.) in which a steel sphere plunger was mounted in the crosshead, moving at a speed of 1.0 mm/min. All specimens were subject to compressive axial load, by means of a 6mm diameter sphere plunger applied centrally to the occlusal surface and parallel to the long axis of the tooth. The plunger was in contact with the area between the buccal and palatal cusp of the tooth (Figure 2). If necessary, the slope of the buccal and

palatal cusps, as well as the anatomy of the restorations, were modified to ensure that the sphere was in contact with only the surface of the tooth beyond the margins. The fracture load and fracture type were recorded for each specimen.

Figure 3 showed each fracture patterns. Cuspal fracture included fracture of enamel or dentin with intact restorations and cementation layer. Unfavorable fracture included the propagation of fracture line beyond CEJ, along with the long axis of tooth. Other cases including fracture of restoration were classified as Fracture of restoration and part of teeth.

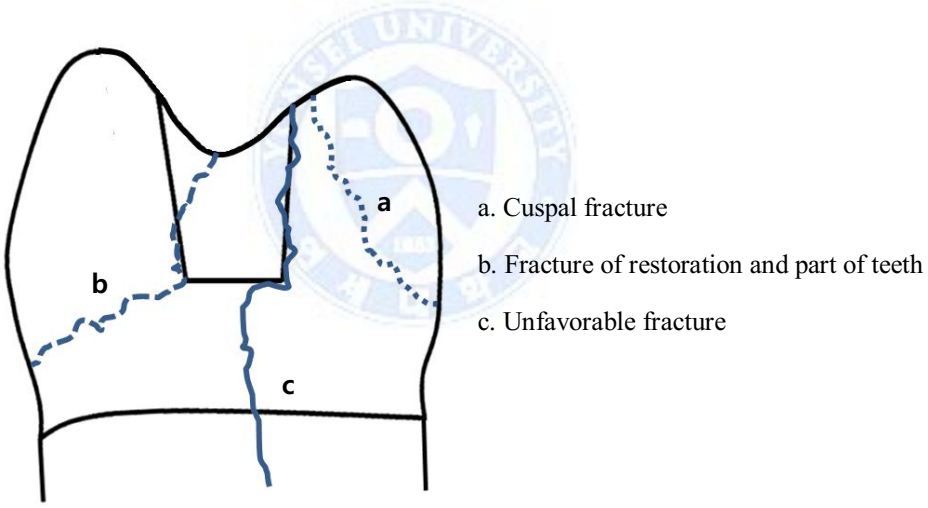

Figure 3. Fracture types from proximal view

5. Statistical analysis

In this experiment, Tukey's test and one-way ANOVA were used to analyze the bucco-palatal dimension, ICD, and fracture load. The fracture load of Groups 1-5 were compared. The number of unfavorable fractures between groups was analyzed by chi-square test. Statistical analysis was carried out using SPSS 21 for Windows (SPSS Inc., Chicago, IL, USA).

III. Results

1. Fracture load

Measurement results showed that there was no significant statistical difference of bucco-palatal dimension and ICD among all groups ($p > 0.05$). In addition, there was no significant statistical difference of ICD among all groups ($p > 0.05$).

Table 3. Mean and standard deviation of fracture load (N) for each group: same superscript letters represent statistically equivalent mean values.

Group	Number of specimens	Mean (± SD) of Fracture load (N)
Group 1	15	1371.29 ± 455.86 a
Group 2	15	1188.18 ± 408.79 a
Group 3	15	1097.38 ± 443.64 a
Group 4	15	1134.69 ± 352.13 a
Group 5	15	624.08 ± 259.03 b

Fracture load among experimental groups was compared in Table 3. Groups 1-4 did not show a significant statistical difference ($p > 0.05$). Group 5 (unrestored teeth) showed a significantly lower fracture load, as compared to that of the other 4 groups. ($p < 0.05$).

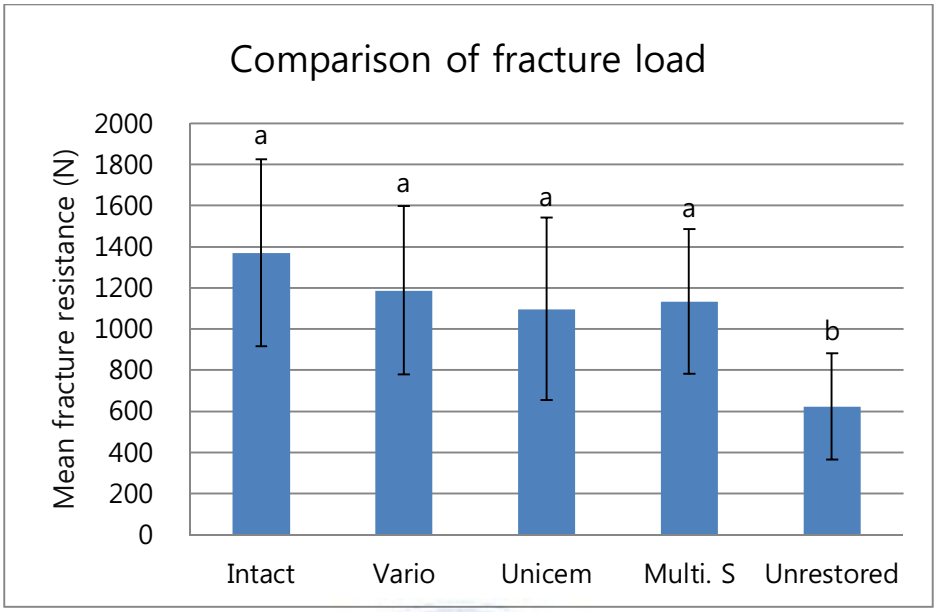

Figure 4. Comparison of fracture load: same superscript letters represent statistically equivalent mean values.

Comparison of the fracture load of Groups 2, 3, 4, indicated that the fracture load of Variolink N group was higher than Unicem and MultiInk speed groups without statistically significant difference ($p > 0.05$).

2. Fracture type evaluation

Table 4. Fracture types

Group	Cuspal fracture	Restoration + Part of teeth	Unfavorable Fractures
Group 1	13	n-s	2
Group 2	3	10	2
Group 3	6	4	5
Group 4	7	3	5
Group 5	8	n-s	7

The comparison of fracture types was shown in Table 4. The frequency of unfavorable fracture was lowest in Group 1 (Intact teeth) and Group 2 (Variolink N), each with 2 incidences, followed by Group 3 (Unicem) and Group 4 (Multilink speed) each with 5 incidences. Group 5 (Unrestored teeth) showed the most frequent unfavorable fractures with 7 incidences. However, there was no statistical difference of unfavorable fractures between all groups by chi-square test ($p > 0.05$).

IV. Discussion

Ceramic inlay has been widely used for indirect restoration of premolar MOD cavity as it has high mechanical strength, marginal adaptability, wear resistance, and excellent biocompatibility (Ferrari et al., 2003). Some researches showed that restoring molar MOD cavities with ceramic inlays recovered fracture resistance to the level similar to that of intact teeth (Hannig et al., 2005; Dalpino et al., 2002; Bremer and Geurtsen, 2001). However, it is also argued that despite an increase in fracture resistance, it is difficult to obtain a fracture resistance similar to intact teeth (St-Georges et al., 2003; Santos and Bezzera, 2005). The former researches made a cavity of 1.5-2.0mm depth with an isthmus dimension that was 1/2 of the intercuspal dimension. The latter researches made a cavity of 4.0mm depth with an isthmus dimension that was 1/2 of the intercuspal dimension or 3.0mm. It seems that there is a controversy on the internal splinting effect since it is difficult to unify contradicting results due to the differences in cavity design and restoration methods among experiments.

Results of previous experiments that used relatively small cavities showed that fracture resistance recovered to the level of intact teeth while experiments that used wider cavities did not show such results. In this experiment, 2.0mm deep occlusal cavity was prepared. This size is similar to the cavity size used in experiments that showed that fracture resistance of maxillary premolars with bonded ceramic inlays was similar to that of intact teeth (Hannig et al., 2005; Dalpino et al., 2002). To even out the cavity size and remaining teeth amount among groups, teeth were divided into groups depending on the

maximum bucco-palatal dimension and ICD that were measured before the experiment. In all groups, average bucco-palatal dimension and ICD did not have a statistically significant difference (Table 1).

The aim of this experiment was to compare the resistance level of teeth due to internal splinting effect when cusp deformity and fracture occurs due to stress depending on the cement's bonding mechanism. Therefore, sphere plunger was controlled to contact just the cusp inclination and not the restoration. This was similar to the method used in other research that compared premolar fracture resistance (Dalpino et al., 2002; Hannig et al., 2005; St-Georges et al., 2003; Santos and Bezzera, 2005). As a result, fracture of restoration only was not observed in any of the groups but cuspal fracture, restoration and cusp fracture, and unfavorable vertical fracture were observed (Table 4).

Regardless of the type of resin cement used in the experiment, the fracture resistance of groups 2-4 with inlay restoration was not significantly different to that of Group 1 (intact teeth). Moreover, unrestored teeth of Group 5 showed a significantly low fracture resistance, as compared to all other groups (Table 3). This result was similar to those of previous studies that used similar cavity designs (Hannig et al., 2005; Dalpino et al., 2002; Bremer and Geurtsen, 2001).

Variolink N is a dual cure type resin cement of multistep, total etching method. According to its manufacturer (Ivoclar Vivadent), there is no difference in components or bonding mechanism when compared to Variolink II. Variolink II showed a significantly higher bond strength to enamel, as compared to Unicem (Hikita et al., 2007; Abo-Hamar

et al., 2005). Comparison of shear bond strength to dentin indicated a significantly higher bond strength, as compared to Unicem (Farrokh et al., 2012; Piwowarczyk et al., 2007), and shear bond strength of lithium disilicate to dentin was also higher than that of Unicem or Multilink sprint (Toman et al., 2008; Yin et al., 2009). Results of numerous experiments indicated that Variolink II has a higher bond strength to enamel and a similar or higher bond strength to dentin than most self adhesive resin cements. It is known as the gold standard of resin cement (Ferracane et al. 2010; Radovic et al., 2008). However, even though Variolink N showed a higher bond strength than self adhesive resin cements in the experiments described above, group 2 did not show a significant difference in fracture resistance, as compared to groups that used self adhesive resin cements. Therefore, the hypothesis of this thesis is accepted.

Unicem is the first commercialized self adhesive resin cement that is used in several research studies, as compared to multistep resin cements. Unicem could achieve a stabilized chemical bond to calcium of hydroxyapatite in teeth by chelation due to its multifunctional phosphoric acid group (Duarte et al., 2008; Gerth et al., 2006). Despite its relatively low bond strength to enamel, as compared to multistep resin cement (Hikita et al., 2007; Abo-Hamar et al., 2005), some studies indicated that it has a similar shear bond strength to dentin (Abo-Hamar et al., 2005), and some indicated that it had a rather higher bond strength to dentin, as compared to Variolink II (Hikita et al., 2007). Hikita's experimental results were contradictory to those of Farrokh et al. (2012) and Piwowarczyk et al. (2007), due to differences in experiment design. Hikita did not measure the shear bond strength of cement to dentin but rather measured the microtensile

bond strength of resin cement between resin disc and dentin. Bonding to dentin is known as an important factor in restoration bonding success, as it is more difficult than bonding to enamel due to structural characters (D'Arcangelo et al., 2009). This was the possible reason for the high fracture resistance in group 3 with Unicem. Moreover, there is reportedly no significant difference in bond strength, as compared to Variolink II, when Unicem is used to bond composite resin to lithium disilicate (Piwowarczyk et al., 2004). When comparing push-out bond strength of leucite-based ceramic on dentin, it showed higher bond strength, as compared to Variolink II (Simon et al., 2010).

When evaluating the marginal adaptability of ceramic restoration, Unicem showed similar results to multi-step resin cement (Behr et al., 2009; Rosentritt et al., 2004) and proper marginal integrity has a compensatory action to polymerization shrinkage (Feilzer et al., 1989). For these properties, Unicem showed clinical results similar to Variolink II after 1-2 years of in vivo evaluation (Taschner et al., 2009; Taschner et al., 2012).

Multilink speed is a self adhesive resin cement that is very similar to Multilink sprint in terms of components and mechanism and only differs in product name, according to the manufacturer (Ivoclar Vivadent). According to Hooshmand et al. (2012), Multilink sprint does not show a significant difference in fracture toughness, as compared to Variolink II when bonded to lithium disilicate disc treated with hydrofluoric acid. This is because of the action of adhesive phosphate monomer included in Multilink sprint. Manso et al. (2011) reported that Multilink sprint shows no significant difference in push out bond strength after bonding lithium disilicate ceramic to dentin, as compared to Variolink II.

Even though some experimental research showed that Unicem and Multilink speed both have a relatively lower bond strength, as compared to Variolink II, both self adhesive resin cements are expected to have a stable bond strength to teeth and ceramic, according to the above mentioned studies . In this study, groups with self adhesive resin cements showed a recovery of fracture resistance that was similar to Variolink N.

The remaining amount of teeth after cavity preparation is the most important factor in fracture resistance and has a greater effect than the restoration material itself (Dalpino et al., 2002). In this experiment, inlay was cemented on maxillary premolars with isthmus dimension of 1/2 of ICD. In addition, occlusal cavity depth was 2.0mm, which was shallower than cavities in studies that reported teeth weakening after inlay restoration (St-Georges, 2003; Santos and Bezzera, 2005). Thus, as there is a relatively sufficient amount of teeth remaining, differences of bond strength between resin cements might have been reduced (Dalpino et al., 2002). Results were expected to differ when wider cavities with isthmus width that exceeds 1/2 of ICD were prepared in the experiment.

When comparing the fracture types (Table 4), Group 2 (Variolink N) showed fewer (2 incidences) unfavorable fractures than self adhesive resin cements. This is the same frequency as Group 1 (intact teeth). Unfavorable fractures were most frequent in Group 5 (unrestored teeth) with 7 incidences. The frequency in Group 3 (5 incidences) and Group 4 (5 incidences) were lower than Group 5 but higher than Groups 1and 2.

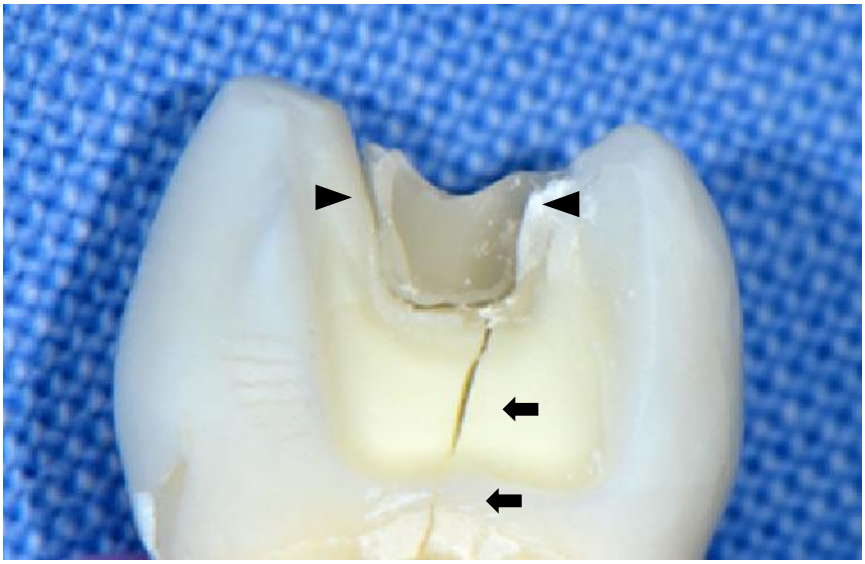

Figure 5. Unfavorable fracture of a specimen (arrows) showing failure of cementation layer (triangles)

As shown in Figure 5, bonding failure was observed in the cementation layer of inlay and teeth when unfavorable fracture occurs. Since load was applied on just the cusp inclination of teeth and not on restoration, fractures on restoration only were not observed. When vertical load is applied on teeth, stress is focused on the cementation layer of the cusp and axial wall (Ausiello et al., 2004). In unfavorable fractures, when load is applied, the cement layer is destroyed before cohesive fracture within the cusp (cuspal fracture). When failure in cement layer occurs less frequently when load is applied, bonding between axial walls and inlay is retained. This reduces the possibility of unfavorable fracture as adhesive layer and rigidity of cement prevents focusing of stress and reduces the risk of fracture (Ausiello et al., 2004). The low frequency of unfavorable fracture in Group 2 indicates that even though there was no statistically significant difference of

fracture load among cements, the frequency of adhesive failure at the moment of fracture was lower in Variolink N than self adhesive resin cements. Past research also showed similar results. Variolink II showed fewer adhesive failure than Unicem (Hikita et al., 2007; Piwowarczyk et al., 2007) or Multilink sprint (Hooshmand et al., 2012). In addition, Luhrs et al. (2010) and Viotti et al. (2009) showed that higher rate of adhesive failure with teeth occurred in self adhesive resin cement. This is because self adhesive resin cement has a lower wettability to teeth (Viotti et al., 2009) and because incomplete hybrid layer is formed in dentin (De Munck et al., 2004; Monticelli et al., 2008).

Specimens used in the experiment were kept at room temperature in saline solution for 1 week after cementation, and then fracture load was measured. According to Piwowarczyk et al. (2004), the bond strength of Unicem on ceramic surface increases when kept in saline solution for 2 weeks after cementation and on 1000 repetitions of thermocycling. Others have (Piwowarczyk et al., 2007; Abo-Hamar et al., 2005) reported an increase in bond strength of resin cement after thermocycling. This may due to continuation of the polymerization process of resin cement for a certain amount of time after light curing(Sabatini et al., 2013). Therefore, measuring fracture resistance after 1 week rather than immediate fracture resistance can be a more reliable method.

In this experiment, thermocycling and dynamic loading was not applied on specimens and this showed limited reenactment of in vivo environment. Additional research is needed in order to analyze the long-term internal splinting effect of inlays depending on different cement types in the actual oral environment.

Our experiment results suggest that restoring premolar MOD cavities with isthmus dimension that is 1/2 of ICD with lithium disilicate inlays, causes recovery of fracture resistance to a level that is comparable to that of intact teeth regardless of the resin cement used.

However, Variolink N showed lower frequency of unfavorable fracture, as compared to other 2 types of self adhesive resin cements, and the same frequency with that of the intact teeth group.

V. Conclusion

1. When restoring maxillary premolar MOD cavities with lithium disilicate ceramic inlay (e.max CAD), groups that used Variolink N and groups that used self adhesive resin cement (RelyX Unicem, Multilink speed) showed a fracture load that is similar to that of intact teeth.

2. Unfavorable fractures occurred at similar frequencies in groups that used conventional multi-step resin cement and the intact teeth group. Groups that used self adhesive resin cement showed higher frequencies of unfavorable fractures, as compared to the intact teeth group, but there was no statistical difference.

VI. References

1. Abo-Hamar, S. E., K. A. Hiller, H. Jung, M. Federlin, K. H. Friedl and G. Schmalz (2005). "Bond strength of a new universal self-adhesive resin luting cement to dentin and enamel." Clin Oral Investig 9(3): 161-167.

2. Ausiello, P., S. Rengo, C. L. Davidson and D. C. Watts (2004). "Stress distributions in adhesively cemented ceramic and resin-composite Class II inlay restorations: a 3D-FEA study." Dent Mater 20(9): 862-872.

3. Behr, M., M. Hansmann, M. Rosentritt and G. Handel (2009). "Marginal adaptation of three self-adhesive resin cements vs. a well-tried adhesive luting agent." Clin Oral Investig 13(4): 459-464.

4. Blatz, M. B., A. Sadan and M. Kern (2003). "Resin-ceramic bonding: a review of the literature." J Prosthet Dent 89(3): 268-274.

5. Boyer, D. B. and L. Roth (1994). "Fracture resistance of teeth with bonded amalgams." Am J Dent 7(2): 91-94.

6. Bremer, B. D. and W. Geurtsen (2001). "Molar fracture resistance after adhesive restoration with ceramic inlays or resin-based composites." Am J Dent 14(4): 216-220.

7. Dalpino, P. H., C. E. Francischone, A. Ishikiriama and E. B. Franco (2002). "Fracture resistance of teeth directly and indirectly restored with composite resin and indirectly restored with ceramic materials." Am J Dent 15(6): 389-394.

8. D'Arcangelo, C., F. De Angelis, M. D'Amario, S. Zazzeroni, C. Ciampoli and S. Caputi (2009). "The influence of luting systems on the microtensile bond strength of dentin to indirect resin-based composite and ceramic restorations." Oper Dent 34(3): 328-336.

9. De Munck, J., M. Vargas, K. Van Landuyt, K. Hikita, P. Lambrechts and B. Van Meerbeek (2004). "Bonding of an auto-adhesive luting material to enamel and dentin." Dent Mater 20(10): 963-971.

10. Duarte, S., Jr., A. C. Botta, M. Meire and A. Sadan (2008). "Microtensile bond strengths and scanning electron microscopic evaluation of self-adhesive and self-etch resin cements to intact and etched enamel." J Prosthet Dent 100(3): 203-210.

11. Edelhoff, D. and J. A. Sorensen (2002). "Tooth structure removal associated with various preparation designs for posterior teeth." Int J Periodontics Restorative Dent 22(3): 241-249.

12. Farrokh, A., M. Mohsen, S. Soheil and B. Nazanin (2012). "Shear bond strength of three self-adhesive resin cements to dentin." Indian J Dent Res 23(2): 221-225.

13. Feilzer, A. J., A. J. De Gee and C. L. Davidson (1989). "Increased wall-to-wall curing contraction in thin bonded resin layers." J Dent Res 68(1): 48-50.

14. Ferracane, J. L., J. W. Stansbury and F. J. Burke (2011). "Self-adhesive resin cements - chemistry, properties and clinical considerations." J Oral Rehabil 38(4): 295-314.

15. Ferrari, M., A. Dagostin and A. Fabianelli (2003). "Marginal integrity of ceramic inlays luted with a self-curing resin system." Dent Mater 19(4): 270-276.

16. Flury, S., A. Lussi, A. Peutzfeldt and B. Zimmerli (2010). "Push-out bond strength of CAD/CAM-ceramic luted to dentin with self-adhesive resin cements." Dent Mater 26(9): 855-863.

17. Frankenberger, R., U. Lohbauer, R. B. Schaible, S. A. Nikolaenko and M. Naumann (2008). "Luting of ceramic inlays in vitro: marginal quality of self-etch and etch-and-rinse adhesives versus self-etch cements." Dent Mater 24(2): 185-191.

18. Gerth, H. U., T. Dammaschke, H. Zuchner and E. Schafer (2006). "Chemical analysis and bonding reaction of RelyX Unicem and Bifix composites--a comparative study." Dent Mater 22(10): 934-941.

19. Hannig, C., C. Westphal, K. Becker and T. Attin (2005). "Fracture resistance of endodontically treated maxillary premolars restored with CAD/CAM ceramic inlays." J Prosthet Dent 94(4): 342-349.

20. Hansen, E. K. and E. Asmussen (1990). "In vivo fractures of endodontically treated posterior teeth restored with enamel-bonded resin." Endod Dent Traumatol 6(5): 218-225.

21. Hikita, K., B. Van Meerbeek, J. De Munck, T. Ikeda, K. Van Landuyt, T. Maida, P. Lambrechts and M. Peumans (2007). "Bonding effectiveness of adhesive luting agents to enamel and dentin." Dent Mater 23(1): 71-80.

22. Hood, J. A. (1991). "Biomechanics of the intact, prepared and restored tooth: some clinical implications." Int Dent J 41(1): 25-32.

23. Hooshmand, T., G. Rostami, M. Behroozibakhsh, M. Fatemi, A. Keshvad and R. van Noort (2012). "Interfacial fracture toughness of different resin cements bonded to a lithium disilicate glass ceramic." J Dent 40(2): 139-145.

24. Hurmuzlu, F., A. Kiremitci, A. Serper, E. Altundasar and S. H. Siso (2003). "Fracture resistance of endodontically treated premolars restored with ormocer and packable composite." J Endod 29(12): 838-840.

25. Jagadish, S. and B. G. Yogesh (1990). "Fracture resistance of teeth with Class 2 silver amalgam, posterior composite, and glass cermet restorations." Oper Dent 15(2): 42-47.

26. Lin, C. L., C. H. Chang and C. C. Ko (2001). "Multifactorial analysis of an MOD restored human premolar using auto-mesh finite element approach." J Oral Rehabil 28(6): 576-585.

27. Luhrs, A. K., S. Guhr, H. Gunay and W. Geurtsen (2010). "Shear bond strength of self-adhesive resins compared to resin cements with etch and rinse adhesives to enamel and dentin in vitro." Clin Oral Investig 14(2): 193-199.

28. Mackenzie, D. F. (1986). "The reinforcing effect of mesio-occlusodistal acid-etch composite restorations on weakened posterior teeth." Br Dent J 161(11): 410-414.

29. Manso, A. G., S. Gonzalez-Lopez, V. Bolanos-Carmona, P. J. Mauricio, S. A. Felix and P. A. Carvalho (2011). "Regional bond strength to lateral walls in class I and II ceramic inlays luted with four resin cements and glass-ionomer luting agent." J Adhes Dent 13(5): 455-465.

30. Monticelli, F., R. Osorio, C. Mazzitelli, M. Ferrari and M. Toledano (2008). "Limited decalcification/diffusion of self-adhesive cements into dentin." J Dent Res 87(10): 974-979.

31. Peumans, M., B. Van Meerbeek, P. Lambrechts and G. Vanherle (2000). "Porcelain veneers: a review of the literature." J Dent 28(3): 163-177.

32. Piwowarczyk, A., R. Bender, P. Ottl and H. C. Lauer (2007). "Long-term bond between dual-polymerizing cementing agents and human hard dental tissue." Dent Mater 23(2): 211-217.

33. Piwowarczyk, A., H. C. Lauer and J. A. Sorensen (2004). "In vitro shear bond strength of cementing agents to fixed prosthodontic restorative materials." J Prosthet Dent 92(3): 265-273.

34. Radovic, I., F. Monticelli, C. Goracci, Z. R. Vulicevic and M. Ferrari (2008). "Self-adhesive resin cements: a literature review." J Adhes Dent 10(4): 251-258.

35. Rosentritt, M., M. Behr, R. Lang and G. Handel (2004). "Influence of cement type on the marginal adaptation of all-ceramic MOD inlays." Dent Mater 20(5): 463-469.

36. Sabatini, C., M. Patel and E. D'Silva (2013). "In vitro shear bond strength of three self-adhesive resin cements and a resin-modified glass ionomer cement to various prosthodontic substrates." Oper Dent 38(2): 186-196.

37. Santos, M. J. and R. B. Bezerra (2005). "Fracture resistance of maxillary premolars restored with direct and indirect adhesive techniques." J Can Dent Assoc 71(8): 585.

38. St-Georges, A. J., J. R. Sturdevant, E. J. Swift, Jr. and J. Y. Thompson (2003). "Fracture resistance of prepared teeth restored with bonded inlay restorations." J Prosthet Dent 89(6): 551-557.

39. Taschner, M., R. Frankenberger, F. Garcia-Godoy, S. Rosenbusch, A. Petschelt and N. Kramer (2009). "IPS Empress inlays luted with a self-adhesive resin cement after 1 year." Am J Dent 22(1): 55-59.

40. Taschner, M., N. Kramer, U. Lohbauer, M. Pelka, L. Breschi, A. Petschelt and R. Frankenberger (2012). "Leucite-reinforced glass ceramic inlays luted with self-adhesive resin cement: a 2-year in vivo study." Dent Mater 28(5): 535-540.

41. Toman, M., S. Toksavul and A. Akin (2008). "Bond strength of all-ceramics to tooth structure: using new luting systems." J Adhes Dent 10(5): 373-378.

42. Trope, M., I. Langer, D. Maltz and L. Tronstad (1986). "Resistance to fracture of restored endodontically treated premolars." Endod Dent Traumatol 2(1): 35-38.

43. Viotti, R. G., A. Kasaz, C. E. Pena, R. S. Alexandre, C. A. Arrais and A. F. Reis (2009). "Microtensile bond strength of new self-adhesive luting agents and conventional multistep systems." J Prosthet Dent 102(5): 306-312.

44. Yin, M., X. P. Luo, H. Yao and X. Liu (2009). "[Comparison of shear bond strength of different resin cements to ceramic and dentin]." Zhonghua Kou Qiang Yi Xue Za Zhi 44(2): 113-116.

국문요약

근원심면 와동을 갖는 상악 소구치의 세라믹 인레이 접착시 레진 시멘트의 종류가 파절 강도에 미치는 영향

연세대학교 대학원 치의학과

(지도교수 노 병 덕)

권 기 현

이 연구의 목적은 사용되는 시멘트의 종류와 접착 기전에 따라 Class II MOD 세라믹 인레이로 수복한 치아의 실패에 어떤 영향을 미치는지 인스트론을 이용하여 평가하는 것이다.

75 개의 건전한, 우식이 없는 상악 소구치를 15 개씩 5 개의 군으로 나누었다. 1 군은 양성대조군으로 와동 형성하지 않은 건전한 상태로 두고 압축력을 치아에 가한다. 2 군은 Class II MOD 와동형성 후 e.max CAD 로 inlay 를 제작하여 Variolink N 를 이용해 접착시킨다. 3 군은 MOD 와동형성 후 e.max CAD 로 inlay 를 제작하여 RelyX Unicem 를 이용해 접착시킨다. 4 군은 MOD 와동형성 후 e.max CAD 로 inlay 를 제작하여 Multilink sprint 를 이용해 접착시킨다. 5 군은 음성대조군으로 와동형성만 하였다. 압축력은 치아의 교두 사면에만 가해지도록 설정하였다.

와동 형성의 규격은 다음과 같다. 치수저는 교합면에서 2 mm 깊이로 형성하고 isthmus 는 교두간 거리의 1/2, 인접면 박스의 넓이는 1.5 mm, 축벽은 2 mm 높이로 한다. 변연은 모두 90 도로 형성했다.

시편들은 1.0 mm/min 으로 움직이는 직경 6 mm 의 강철구를 이용하여 만능시험기로 시험했다, 최대 파절값 (N)을 측정했고 평균을 계산하였으며 one-way ANOVA and Tukey test 로 95%의 유의수준으로 통계분석을 하였다.

평균 파절값 (N, mean ± S.D.)은 1 군 - 1371.29 ± 455.86, 2 군 - 1188.18 ± 408.79, 3 군 - 1097.38 ± 443.64, 4 군 - 1134.69 ± 352.13, 5 군 - 624.08 ± 259.03 으로 나왔다.

이번 실험의 결과로 다음의 결론을 내릴 수 있었다. 파절시 강도는 건전한 치아를 사용한 그룹과 세라믹 인레이로 수복한 그룹에서 유의차가 없었다. Variolink N 을 사용한 군에서 self adhesive resin cement 을 사용한 군에서보다 파절 강도가 높았으나 통계적인 유의차는 발생하지 않았다. Variolink N 을 사용한 군에서 unfavorable fracture 의 빈도가 self adhesive resin cement 을 사용한 군에서보다 낮았다. 세라믹 인레이 수복시, 레진 시멘트의 종류의 기전에 관계없이 건전한 치아와 같은 수준으로 파절 강도가 회복되는 것으로 생각된다.

핵심이 되는 말 : 세라믹 인레이; CAD/CAM; 파절; IPS e.max; 레진 시멘트