EFFECT OF RESIN CEMENT THICKNESS AND CERAMIC THICKNESS ON COMPRESSIVE FRACTURE RESISTANCE OF ENAMEL-BONDED CERAMIC

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A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science Program in Esthetic Restorative and Implant Dentistry
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ผลของความหนาของเรซินซีเมนต์และเซรามิก
ต่อความต้านทานการแตกชนิดแรงอัด
ของเซรามิกที่ยึดกับเคลือบฟัน

นายพิรัตน์ การเที่ยง

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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Thesis Title	EFFECT OF RESIN CEMENT THICKNESS AND CERAMIC THICKNESS ON COMPRESSIVE FRACTURE RESISTANCE OF ENAMEL-BONDED CERAMIC
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Field of Study	Esthetic Restorative and Implant Dentistry
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พิรัตน์ การเที่ยง : ผลของความหนาของเรซินซีเมนต์และเซรามิกต่อความต้านทานการแตกชนิดแรงอัดของเซรามิกที่ยึดกับเคลือบฟัน. (EFFECT OF RESIN CEMENT THICKNESS AND CERAMIC THICKNESS ON COMPRESSIVE FRACTURE RESISTANCE OF ENAMEL-BONDED CERAMIC) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ. ทพ.เฉลิมพล ลี้ไวโรจน์, 36 หน้า.

วัตถุประสงค์ เพื่อศึกษาผลของความหนาของเรซินซีเมนต์และความหนาของเซรามิกต่อความต้านทานการแตกชนิดแรงอัดของเซรามิกที่ยึดกับผิวเคลือบฟัน วิธีการทดลอง ยึดชิ้นเซรามิก ชนิดลูไซต์รีอินฟอร์ซ และลิเธียมไดซิลิเกตที่หนา 0.5 และ 1มม. กับผิวเคลือบฟันมนุษย์ด้วยเรซินซีเมนต์ที่หนาแตกต่างกัน (30 และ 100 ไมโครเมตร) กลุ่มควบคุมคือเซรามิกที่ไม่ได้ยึดกับผิวเคลือบฟัน (n=12) แล้วนำไปทดสอบความต้านทานการแตกชนิดแรงอัดด้วยหัวกดหน้าตัดรูปวงกลมรัศมี 1มม. บันทึกเป็นค่าแรงที่กดจนเซรามิกแตก (นิวตัน) ผลการทดลองที่ได้วิเคราะห์ด้วยสถิติความแปรปรวนแบบสองทางที่ระดับนัยสำคัญ 0.05 ผลการทดลอง ผลของเซรามิกทั้งสองกลุ่มออกมาในแนวทางเดียวกันคือ กลุ่มควบคุมให้ค่าแรงกดที่ต่ำกว่ากลุ่มทดลอง ในพวกกลุ่มเซรามิกที่หนา 0.5มม. ไม่พบความแตกต่างของค่าแรงกดระหว่างกลุ่มซีเมนต์หนา 30 และ 100 ไมโครเมตร (ลูไซต์รีอินฟอร์ซ: 30ไมโครเมตร – 771.56±107.35; 100ไมโครเมตร—810.06±110.26; ลิเธียมไดซิลิเกต: 30ไมโครเมตร—2471.81±339.52; 100ไมโครเมตร—2666.58±245.15) ส่วนกลุ่มที่หนา 1มม. ค่าแรงกดของกลุ่มซีเมนต์ 30ไมโครเมตรสูงกว่าของกลุ่ม 100ไมโครเมตรอย่างมีนัยสำคัญ (ลูไซต์รีอินฟอร์ซ: 30ไมโครเมตร –2666.20±220.46; 100ไมโครเมตร—1748.39±245.24; ลิเธียมไดซิลิเกต: 30ไมโครเมตร—3547.38±310.30; 100ไมโครเมตร—2622.17±256.99) สรุป การยึดเซรามิกกับผิวเคลือบฟันด้วยเรซินซีเมนต์ทำให้ความแข็งแรงของเซรามิกเพิ่มขึ้น เซรามิกที่หนา 0.5มม. ไม่พบความแตกต่างของแรงกดเมื่อซีเมนต์หนาต่างกัน ในขณะที่เซรามิกที่หนา 1มม. ซีเมนต์ที่หนาส่งผลให้ค่าแรงกดลดลงอย่างมีนัยสำคัญ

สาขาวิชา ทันตกรรมบูรณะเพื่อความสวยงามและทันตกรรมรากเทียม ลายมือชื่อนิสิต .....

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ปีการศึกษา 2556

5276155832 : MAJOR ESTHETIC RESTORATIVE AND IMPLANT DENTISTRY
KEYWORDS: LEUCITE-REINFORCED CERAMIC / IPS EMPRESS ESTHETIC / LITHIUM DISILICATE CERAMIC / IPS E.MAX / COMPRESSIVE FRACTURE RESISTANCE / FILM THICKNESS / RESIN CEMENT

PIRAT KARNTIANG: EFFECT OF RESIN CEMENT THICKNESS AND CERAMIC THICKNESS ON COMPRESSIVE FRACTURE RESISTANCE OF ENAMEL-BONDED CERAMIC. ADVISOR: ASSOC. PROF. CHALERMPOL LEEVAILOJ, 36 pp.

Objective This study aimed to evaluate the compressive fracture resistance of enamel-boned ceramic with variation in cement thickness and ceramic thickness. Materials and methods Leucite-reinforced and lithium-disilicate ceramic (0.5 and 1mm thick) were cemented to human enamel using resin composite cement at the thicknesses of 30 and 100μm. Non-cemented ceramic was used as control. Fracture load (Newton) was obtained by pressing a 2mm-diameter indenter rod against ceramic. Two-way ANOVA and two-sample t-tests were used to compare mean fracture loads (MFL). Results The results obtained from both type of ceramic were in the same trend, i.e. for 0.5 thick ceramic, both 30μm and 100μm groups were significantly higher than control group. No difference in MFL between two test groups was found. (leucite-reinforced ceramic: 30μm – 771.56±107.35; 100μm —810.06±110.26; lithium-disilicate ceramic: 30μm —2471.81±339.52; 100μm —2666.58±245.15) On the other hand, when ceramic thickness was 1mm, MFL of both test groups were significantly higher from control group. Also, MFL of 30μm group was significantly higher than that of 100μm group. (leucite-reinforced ceramic: 30μm–2666.20±220.46; 100μm—1748.39±245.24; lithium-disilicate ceramic: 30μm—3547.38±310.30; 100μm—2622.17±256.99) Conclusion Non-cemented PLVs showed significantly lower MFL. The thicker cement group showed a decreased MFL for 1mm PLVs only. No significant difference was found for the 0.5mm groups. These results applied to both types of ceramic.

Field of Study: Esthetic Restorative and Implant Dentistry
Academic Year: 2013

Student's Signature .....

Advisor's Signature .....

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CONTENTS

Page

Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Rationale and Significance of the problem

Nowadays, the need for esthetic dental treatment is continually increasing because more and more people desire a bright, smooth, harmonious smile. Available treatments can include either tooth whitening, orthodontic treatment(1), or minimal reshaping and realignment of anterior teeth. (2-3) However, these treatments have some limitations, such as in cases of patients with an urgent need for treatment, patients with tetracycline-stained teeth,(4) or patients with disproportionate anterior teeth size or multiple diastema.(5) Consequently, porcelain laminate veneers (PLVs) could also be proposed as a treatment plan.(6-9)

Previously, the ceramic used for fabricating PLVs was feldspathic porcelain. This type of porcelain can provide a superior natural look, translucency, and internal characteristics of the restorations.(10) Later, leucite-reinforced and lithium disilicate ceramics were introduced. They possess higher compressive and flexural strength, and esthetics comparable to feldspathic porcelain (11-12) Even in a case of moderate tooth discoloration, these porcelains can acceptably mask the underlying color.(13)

Many reports in the literature have demonstrated an excellent outcome of PLVs.(14-27) Major factors associated with the strength and durability of PLVs include bonding quality of PLVs to the tooth structure,(16) the adhesive cementation, and the thickness of PLVs itself.(28) The use of PLVs has become more reliable as bonding procedure has improved.(29) PLVs are sometimes designed to

cover the occlusal surface of the tooth. That means the restorations have to bear normal chewing forces, which average 400–500 N.(30)

Until today, few studies have investigated ceramic strength in association with tooth structure and cementation. One recent study showed that PLV was more resistant to fracture when adhesively bonded to the enamel surface rather than the dentin surface.(31) Another study concluded that luting film thickness had a significant effect on bond strength(32) and ceramic strength.(28, 33) Nonetheless, no study has yet evaluated the effect of cement thickness on the fracture resistance of a PLV cemented to the enamel surface. Therefore, the aim of this study was to investigate whether resin luting film thickness had a significant effect on the strength of the enamel-bonded PLV, by means of compressive load fracture testing.

Research Question

1. Does resin cement thickness have significant effect on compressive fracture resistance of enamel-bonded PLV?
2. Does ceramic thickness have significant effect on compressive fracture resistance of enamel-bonded PLV?

Objective of the Study

The purpose of this study was to evaluate and compare mean fracture load (MFL) of leucite-reinforced and lithium disilicate PLVs bonded to enamel as a function of resin cement thickness and PLV thickness.

Statement of Hypothesis

Null Hypotheses

1. Resin cement thickness does not have significant effect on MFL of enamel-bonded PLV.
2. PLV thickness does not have significant effect on MFL of enamel-bonded PLV.

Alternative Hypotheses

1. Resin cement thickness has significant effect on MFL of enamel-bonded PLV.
2. PLV thickness has significant effect on MFL of enamel-bonded PLV.

Scope of the Study

This study was an experimental research which evaluated the effect of resin luting film thickness on compressive fracture resistance of PLV bonded to flat-cut enamel surface of human lower third molar, mimicking condition of PLVs adhesively bonded to enamel surface. Therefore, the result might not be generalized to natural anterior teeth which normally receive PLVs in real clinical situation. Moreover, this study utilized only one brand of resin cement and two systems of ceramic, so the results found here may not be able to be extrapolated to resin cement and ceramic of other systems because of different properties in many perspectives.

Basis Assumption

1. All procedures were performed using human lower third molars under well controlled conditions, prepared by one operator and evaluated by one examiner.
2. The widely-used ceramic systems in Thailand with reliable fabrication procedures were chosen this study (IPS Empress Esthetic and IPS e.max, Ivoclar Vivadent, Schaan, Lichtenstein).
3. In order to lessen the effect of several firings, PLVs used in this study were not glazed. Therefore, the result cannot be directly inferred to PLVs in real clinical practice.
4. The specimens were fabricated according to the recommendations of the manufacturers by a single technician. (S&K Dental Lab, Bangkok, Thailand).

Study Limitation

1. There were differences in each tooth collected which can't be controlled. However, the randomized process would reduce systemic bias.
2. Due to a limited budget in this study, all brands cannot be evaluated. As a result, two ceramic systems and one resin cement in common uses were chosen.

Key words

leucite-reinforced ceramic / IPS Empress Esthetic / lithium disilicate ceramic / IPS e.max / compressive fracture resistance / film thickness / resin cement

Expected Benefit of the study

The results from this study would be a background for a further clinical study in the same field of interest. Moreover, they might indicate whether thin porcelain veneer adhesively cemented to enamel can bear normal occlusal force.

CHAPTER II

REVIEW OF LITERATURES

Up till now, most the publications about success of treatment with ceramic veneers demonstrated high survival rate of ceramic veneers, no less than 90% (16, 18, 20, 23, 34, 35). Though, there was one study demonstrating a high failure rate (22).

Factors causing failure of PLVs include occlusion, preparation design, adhesive used, presence of composite fillings(22), and compromised bonding with dentine.(16, 36) When PLVs are indicated for a patient, primary factors to consider are systematic coverage and reconstitution of the incisal edge. Moreover, the opposing tooth should not contact in centric occlusion if the margin is located directly at the centric stop.(21) Besides, if the enamel surface is compromised, a full-coverage crown should be considered instead.(37)

Focusing on materials widely used to fabricate ceramic veneers in Thailand, there are IPS Empress Esthetic and IPS e.max. IPS Empress Esthetic utilizes custom-made leucite containing ceramic ingots for the hot pressing technique. High translucency enables it to achieve excellent esthetics. Its strengthening mechanism is the difference of coefficients of thermal expansion (CTE) between the glass phase and the crystal phase (leucite). This results in an increase in strength and enables IPS Empress to achieve a flexural strength of 160 MPa and fracture toughness of 1.6-1.8 $MPa.m^{½}$. This material is well indicated for veneers and crown (12, 38).

IPS e.max, on the other hand, is indicated for use in more extensive cases like type III case according to Magne and Belser's classification system (39). IPS

e.max consists of lithium disilicate ($Li_2Si_2O_5$) needle-like crystals approximately 70%. The production process creates ingots in different translucency levels. These ingots feature strength of 400 MPa and fracture toughness of 2.5 – 3.0 MPa.m.$^{1/2}$ (11). Owing to these properties, IPS e.max can be used in monolithic application for inlays, onlays, and posterior crowns or as a core material for crowns and 3-unit FDPs in the anterior region.

General mechanical characteristics of ceramic are hardness, brittleness, high wear resistance, high compressive strength, and low tensile strength (10). Normally, ceramics fracture below their ideal strength because of the internal flaws which accumulate stress under loading. In order to minimize the effect of flaws and increase the strength of the restorations, it is recommended that the all ceramic restorations be adhesively bonded to the tooth structure. (40-41)

As stated earlier, ceramic restorations need to be adhesively bonded to tooth structure to enhance their strength (42), so veneers should be cemented with resin cement used together with adhesive resin. The successful use of resin cements depends on the bonding mechanisms to both toot structures and restorations. Their bonding to tooth structure relies on the use of etch-and-rinse adhesive system, while bonding to porcelain surface needs hydrofluoric etching together with silanizing (43-44) . Since the 1970s, resin cements have been formulated based on dimethacrylate resin chemistry. Focusing on light-cured resin cements, they can be exclusively light-cured. These products offer the clinical advantages of extended working time, snap setting, and color stability, which all are necessary for cementing veneers. Besides, excess composite can be easily removed till the light activation is initiated. This may reduce the finishing time (45).

Adhesive bonding system widely used and considered as a gold standard was an etch-and-rinse system (46-47) . This system consisted of phosphoric acid etchant of 30-40% concentration, primer, and adhesive resin or bonding agent. Etch and rinse procedures would remove smear layer and create micromechanical retention with the enamel surface via a resinous tag-like formation (48). Bond strength was slightly lower if the enamel surface was unground (49). Primer, or so called adhesion promoting agent, turned hydrophilic surface to hydrophobic surface with its bi-functional molecules, made the dentin surface ready to receive following hydrophobic adhesive resin (50). Lastly, adhesive resin, bonding agent in other words, was a mixture of resin in solvent, thin in consistency. This bonding agent would create a so-called hybrid layer consisting of tooth structure gradually changed to resin tag and finally a bonding layer. Bonding to enamel surface was considered more durable and promising compared to dentin bond. As a result of hydrolysis of bonding interphase, dentin bond degraded more easily comparing to enamel bond (50). This was the reason why preparation of PLVs should limit in enamel (14). In addition, better bonding quality affected the strength (51)and durability of bonded PLVs (16)

The use of resin cement in combination with adhesive system and surface treatment of ceramic had many advantage to ceramic restoration. According to Grossman and Nelson, resin cement might reduce the percentage of the failure by changing the flaw geometry as a consequence of the acid-etching procedure and by reducing stress at the flaw tips by transferring stress to the bonding agent (52). A resin layer that is bonded to the flawed surface changes the ceramic material to a ceramic-resin composite. The ability of resin cement to transfer stresses across the

tooth-crown interface was also reported (53). Moreover, Stacey's study reported that a very strong complex was obtained in-vitro by luting the porcelain veneer to enamel with resin composite (44).

There were several studies of resin cement film thickness in relation with fracture resistance of ceramics. Prakki et al studied the effect of resin luting film thickness on fracture resistance of a ceramic adhesively cemented to bovine dentin (28). In that study, there were two thicknesses of ceramic, 1.0 and 2.0 mm and three thicknesses of cement film, 100, 200 and 300 μm including uncemented control group. They found that unluted specimens had the least fracture resistance; thicker cement film resulted in increased fracture resistance for the 1-mm ceramic plates. Though, the film thickness did not influence the fracture resistance of 2-mm ceramic plates.

Another publication by Scherrer et al investigated the effect of cement film thickness on the fracture resistance of ceramic plates against compressive load with a spherical indenter (54). When the resin cement was used, a gradual decrease of the fracture strength was observed and became statistically significant at a cement thickness of 300 μm. Piemjai and Arksornnukit also used this kind of method to measure the compressive strength of porcelain laminates when bonded to enamel or dentin using the following resin cements: All-Bond 2, Panavia 21, and Super-Bond C&B (31). Super-Bond C&B provided a higher fracture resistance of porcelain than the other resin cements. The conclusion drawn from this study was bonding techniques and curing systems of resin cements influenced the fracture resistance of porcelain laminates.

CHAPTER III

MATERIALS AND METHODS

Research Design

Experimental research

Sample Description

1. The population of this study was 144 pieces of human lower third molars with flat-cut enamel surface of the buccal side.

2. Sample size estimation was calculated from this formula;

$$\sigma^2 = \frac{(n_1-1)S_1^2 + (n_2-1)S_2^2}{n_1+n_2-2}$$

Where: $\sigma 2$ represents the variance of the variable as estimated by the data from previous study (28).

n_i represents the required sample size per group (n_1 = 10 and n_2 = 10) Si represent the standard deviation (S_1 = 150 and S_2 = 105)

$$n/group = \frac{2(Z_{\alpha/2}+Z_\beta)^2 \sigma^2}{(\bar{x}_1+\bar{x}_2)^2}$$

Where: Z represents the Z value ($Z_{\alpha/2}$ = 1.96 for type I error (α) equal to 0.05 and Z_β = 1.28 for type II error (β) equal to 0.1)

At 95% confident interval and 90% power of test, the result from sample size estimation was 11.88. Therefore, the number of specimens per group in this study should be 12.

Dental Materials

1. IPS Empress Esthetic Ingots ETC2, Ivoclar Vivadent, Schaan, Liechtenstein (Lot#KM0486) (figure1)
2. IPS e.max Ingot shade LT shade A3, Ivoclar Vivadent, Schaan, Liechtenstein (Lot#M72418) (figure1)
3. NX3 Nexus Third Generation (Light-cured) resin cement, Kerr Corporation, Orange, CA, USA (Lot#4285136)
4. Optibond FL set (including Gel Etchant of 37% phosphoric acid, primer and bonding), Kerr Corporation, Orange, CA, USA (Lot#4346594) (figure2)
5. Silane Primer, Kerr Corporation, Orange, CA, USA (Lot #4403066) (figure2)
6. Porcelain Etchant (4% HF), Bisco, Schaumburg, IL, USA
7. Optidisc, Kerr Corporation, Orange, CA, USA
8. Epoxy resin

Figure 1 IPS Empress Esthetic and IPS e.max ingots

Figure 2 Optibond FL set and Silane Primer

Apparatus

1. Isomet, Buehler, An ITW Company, Illinois, USA
2. Universal Testing Machine, Instron model 5566, Canton, MA, USA (figure3)
3. Optilux radiometer Model 100 P/N 10503, U.S.A.
4. Elipar™ S10 LED Curing Unit, 3M ESPE, Seefeld, Germany
5. Digital Caliper, Mitutoyo, Japan

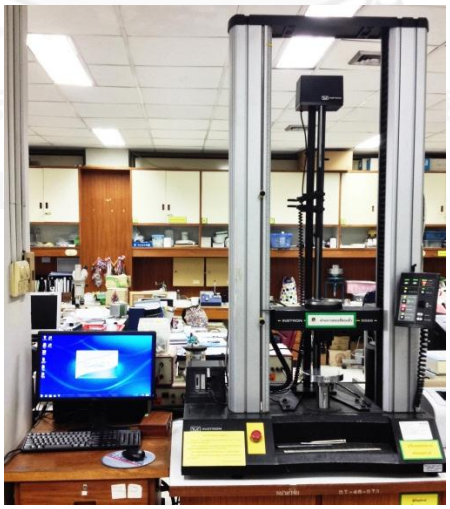


Figure 3 Universal Testing Machine, Instron model 5566, Canton, MA, USA

Fabrication of tooth structure samples

Collected human lower third molars were stored at 4 °C in a solution of 0.1% thymol for 24 h, followed by placing in a solution of normal saline. Only teeth with no cracks, defects and caries on visual examination under a 2.8x magnifying loupe were included. Teeth were cleaned with an ultrasonic scaler, then grinded on the buccal side using a carborundum disc with water coolant in order to achieve a flat area of at least 3 × 6 mm^2. The flat surface was then polished with a series of sandpaper discs (OptiDisc; Kerr Corporation, Orange, CA, USA) from coarse to superfine. If there was dentin exposure, the specimen was excluded from the study.

Next, each tooth was sectioned with an IsoMet low-speed saw (Buehler, Lake Bluff, IL, USA) in order to obtain specimens with dimensions of 3 × 6 × 4 mm^3. Surface grinding was employed to achieve a uniform thickness of 4 mm. The specimens were embedded in unfilled resin, with the flat, polished enamel surface exposed, as shown in figure 4.

Figure 4 Tooth specimen embedded in resin

Fabrication of ceramic specimens

Wax specimens, 0.5 mm and 1 mm thick, were modeled using customized molds in order to ensure that the dimensions of each wax specimen measured 3.5 mm in width and 6.5 mm in length. The final dimensions of every wax

specimen were checked by an individual investigator using a digital caliper (Mitutoyo, Japan). All of the wax patterns were sprued, fabricated using IPS Empress investment material, and pressed by a single lab technician at the S.K. Dental Laboratory, Bangkok, Thailand. Ingots used were IPS Empress Esthetic ETC2 and IPS e.max Press LT shade A3 (Ivoclar Vivadent). Fabrication of the IPS Empress Esthetic and IPS e.max PLVs was undertaken in accordance with the manufacturer's recommendations.

After the PLVs were divested, their dimensions were measured with a digital caliper to ensure the desired size and uniform thickness of each specimen. Then, specimens were kept at room temperature until they were surface-treated.

Surface Treatment of ceramic specimen

The inner surface of each PLV was first etched with porcelain etchant: 1 min for IPS Empress Esthetic, and 20 sec for IPS e.max. After the ceramic surface was washed and dried, silane primer was applied once on the etched surface with a microbrush. Excess silane primer was removed by a dry microbrush. While waiting to be cemented, the treated ceramic specimens were kept away from light to avoid premature setting of the silane primer.

Preparation of enamel surface

The enamel surface was etched with a microbrush dipped in gel etchant for 30 sec. Next, the gel was rinsed-off with copious water from 3-way syringe for 10 seconds. A piece of gauze was pressed on the rinsed surface for 5 seconds to remove water and dry the surface. A microbrush was dipped in Optibond FL Adhesive for a second. Then the adhesive was applied 3 strokes in the same direction, followed by 3 strokes thinning with another dry microbrush in the same

way (figure 5-9). To make sure the adhesive was cured and to reduce the effect of incomplete cure adhesive, the adhesive was light-cured with an Elipar™ S10 LED curing light.

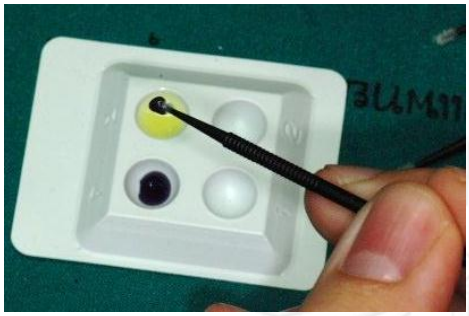


Figure 9 37% Phosphoric Acid

Figure 9 Application of gel etchant

Figure 9 A once- bonding-dipped microbrush

Figure 9 Application of bonding agent

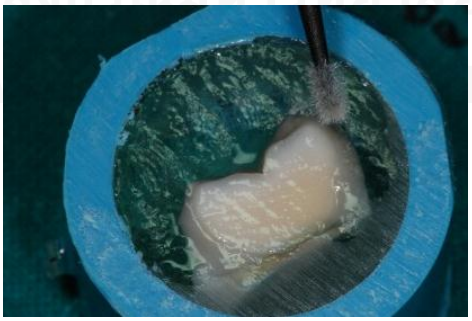


Figure 9 A new microbrush used to thin bonding agent

Cementation Process

The prepared enamel and ceramic samples were randomly assigned to 12 control and test groups as shown in table 1. NX3 Nexus Third Generation (light-cured) resin cement was applied approximately 2 mm in diameter on the prepared enamel surface. Then a prepared PLV treated surface down was vertically pressed with a 1,000-gram durometer for 10 sec as shown in figure10; meanwhile, excess cement oozed out. If the sample belonged to the 30 μm group, the PLV was placed on the cement without any spacer. If the sample belonged to the 100 μm group, two folds of a 50-μm-thick celluloid strip were placed between the enamel surface and the PLV at both ends as a spacer to control cement thickness. After removal of excess cement with a dry microbrush, light-activation was performed with an Elipar S10 curing light five times per specimen: directly on top, and at a 45° angle on each of the four sides. The tip of the light-curing unit was separated from the specimen by a celluloid strip. Light intensity was checked by an Optilux radiometer (figure11) to ensure constant light intensity (600 mW/cm^2) for every specimen.

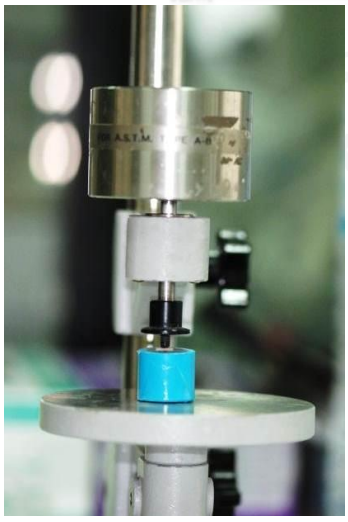


Figure 11 Specimen being pressed with durometer

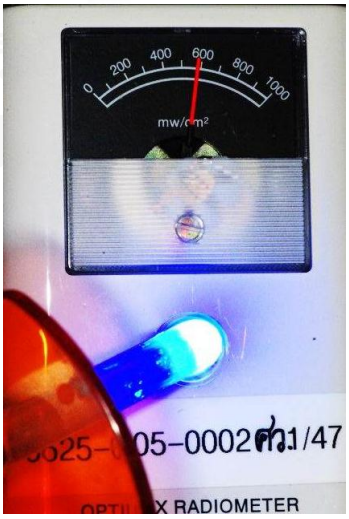


Figure 11 Light intensity checked with radiometer

Table 1 Studied Groups

Group number	Materials	Ceramic thickness	Cement thickness
Group1	IPS Empress Esthetic	0.5 mm	no cement
Group2			30 μm
Group3			100 μm
Group4		1 mm	no cement
Group5			30 μm
Group6			100 μm
Group7	IPS e.max	0.5 mm	no cement
Group8			30 μm
Group9			100 μm
Group10		1 mm	no cement
Group11			30 μm
Group12			100 μm

All specimens were stored in 37 ˚C deionized water for 24 h before testing to allow possible post-cure polymerization of the luting cement.

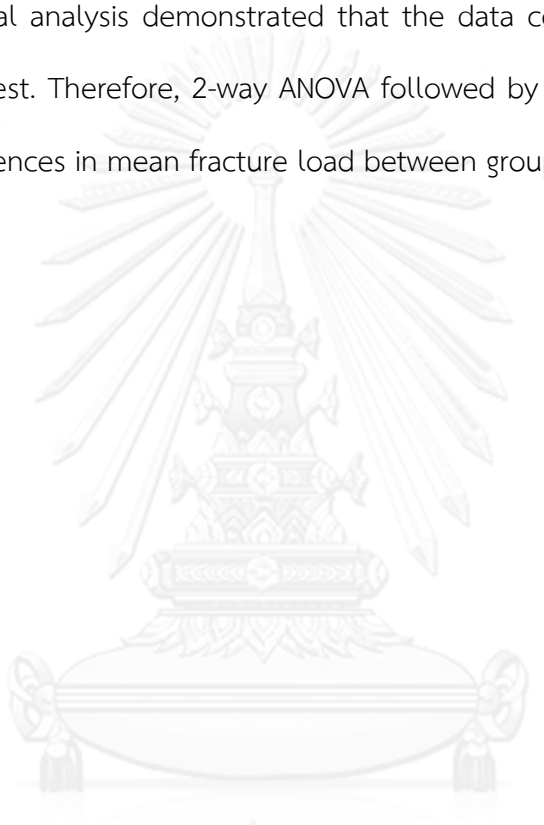
Compressive Fracture Resistance Testing

A unit of PLV cemented on the enamel surface was subjected to a compressive test using a universal testing machine at a crosshead speed of 0.5 mm/min. The crosshead surface was circular, 2 mm in diameter. The crosshead of

the testing machine stopped when a sudden drop appeared on the recording chart as a result of catastrophic failure. All fracture loads were recorded in newtons (N).

Statistical Analysis

Descriptive statistics were computed using SPSS version 16 for Windows. Statistical analysis demonstrated that the data collected met the criteria for a parametric test. Therefore, 2-way ANOVA followed by two-sample *t*-tests were used to find differences in mean fracture load between groups.



CHAPTER IV

RESULTS

Descriptive analysis of the data, mean fracture load and standard deviations of every group were calculated using SPSS for windows version 16, followed by normal distribution test and homogeneity of variance. The data met the criteria of parametric test. Consequently, 2-way ANOVA and two-sample t-test were used to find difference in mean fracture load between groups. Mean fracture load of IPS Empress Esthetic and IPS e.max were listed in the table 2 and 3 respectively.

For IPS Empress Esthetic 0.5 mm, MFL of the control (non-cement) group and groups with cement thicknesses of 30 μm and 100 μm were 15.51 ± 2.97, 771.56 ± 107.35 and 810.06 ± 110.26, respectively. MFL of both test groups were significantly different from the control group. However, there was no statistical difference in MFL between the 30 μm and 100 μm groups ($p>0.05$). For IPS Empress Esthetic 1 mm, MFL of non-cement, 30 μm and 100 μm groups were 58.02 ± 15.33, 2,666.20 ± 220.46 and 1,748.39 ± 245.24, respectively. Both test groups were also significantly different from the control group. Plus, the mean fracture load of the 30 μm group was significantly higher than that of the 100 μm group ($p<0.05$). The group with a 1.0 mm PLV using 30 μm cement exhibited the highest MFL among all the IPS Empress Esthetic groups. Also, it was significantly higher than other groups of the same material ($p<0.05$).

Table 2 Mean Load to Fracture (N), Standard Deviation, and Statistical Analysis for IPS Empress Esthetic PLV Groups

Group	Ceramic thickness	Cement thickness	MFL (SD)
1	0.5 mm	Control (no cement)	15.51 (2.97)
2		30 μm	771.56 (107.35)
3		100 μm	810.06 (110.26)
4	1.0 mm	Control (no cement)	58.02 (15.33)
5		30 μm	2666.20 (220.46)
6		100 μm	1748.39 (245.24)

MFL; mean fracture load(N), SD; standard deviation, vertical line indicated significant difference between groups.

The results obtained from testing IPS e.max groups were in accordance with those from IPS Empress Esthetic groups, i.e. there was no significant difference between the 0.5-mm test groups, while the 1-mm test groups exhibited a significant difference. For IPS e.max 0.5 mm, MFL of non-cement, 30 μm and 100 μm groups were 47.09 ± 7.02, 2,471.81 ± 339.51 and 2,666.58 ± 245.15, respectively. For IPS e.max 1 mm, MFL for non-cement, 30 μm and 100 μm groups were 145.88 ± 25.01, 3,547.38 ± 310.30 and 2,830.50 ± 245.04, respectively. MFL of the control groups were significantly different from both 0.5 mm and 1 mm test groups. MFL of both cement thickness test

Table 3 Mean Load to Fracture (N), Standard Deviation, and Statistical Analysis for IPS e.max PLV Groups

Group	Ceramic thickness	Cement thickness	MFL (SD)
7	0.5 mm	Control (no cement)	47.09 (7.02)
8		30 μm	2471.81 (339.51)
9		100 μm	2666.58 (245.15)
10	1.0 mm	Control (no cement)	145.88 (25.01)
11		30 μm	3547.38 (310.30)
12		100 μm	2830.50 (245.04)

MFL; mean fracture load(N), SD; standard deviation, vertical line indicated significant difference between groups.

groups were also significantly different from the control group. Plus, for both types of ceramic with a thickness of 1 mm, the mean fracture load of the 30 μm group was significantly higher than that of the 100 μm group ($p<0.05$).

CHAPTER V

DISCUSSION, CONCLUSION, IMPLICATION OF THE RESULT

Discussion

This study tested the mean fracture load of two ceramics cemented to human enamel tooth surfaces with light-cured resin cement. There were two thicknesses of each ceramic type: 0.5 mm and 1 mm. Also, there were two thicknesses of cement film: 30 μm and 100 μm. Only human lower third molars of similar size were included, so that the thickness of the remaining enamel after being flattened down would be comparable. In this study, the enamel surface of the buccal side was flattened to a size of 3 × 6 mm^2; the thickness of the enamel-dentin piece cut out of the crown was 4 mm. Although the precise thickness of the enamel and dentin could not be controlled, the tooth selection procedure helped lessen the variation in thickness. The tooth specimen was then embedded in molding resin, exposing the flat enamel surface on top.

The fabricated PLV was 3 × 6 mm^2 in size, rectangular-shaped, and either 0.5 mm or 1 mm in thickness. These thicknesses were chosen according to Magne and Belser(55), in order to get a good tooth-restoration complex, a sufficient ceramic thickness was needed to provide the restoration with some intrinsic mechanical resistance. They recommended the thickness of approximately 0.3-0.5 mm in the cervical area, 0.7 mm in the middle and incisal thirds. These recommendations were in accordance with enamel thicknesses derived from different location measurement, which can be 0.3-0.5 mm at the gingival third, 0.6-1.0 at the middle third, and 1.0-2.1 at the incisal third(56). This PLV was cemented with light-cured resin cement to simulate a PLV cemented on human tooth. Prakki et al. (28) and Scherrer et al (33) also utilized the similar specimen design in their study.

According to Christensen and Christensen (15), an acceptable resin cement film thickness should be no more than 120 μm. The present study chose thicknesses of 30 μm and 100 μm because these thicknesses were reproducible in the pilot experiment. The pilot study was carried out to determine if the constant thickness of cement could be met. The authors found that a thickness of 30 μm was reproducible if the ceramic plate was pressed with 1000g-durometer for 10 sec. Meanwhile, the cement film thickness of 100 μm was controlled by inserting a spacer between the enamel surface and the ceramic plate while cementing with a pressing force of 1000g-durometer for 10 sec. The spacer used was two folds of a celluloid strip of known thickness (50 μm). These methods of cementation ensured a constant cement thickness. To verify the thickness of the cement, the specimens were cross-sectioned and observed under a stereomicroscope. However, the thickness of the cement was found to differ from the thickness claimed by the manufacturer. This might be caused by the different force and time used for pressing in order to obtain a film thickness in accordance with the ISO 4049 standard (150 N, 180 sec).

The chosen method of testing the strength of the samples was compressive fracture resistance. The crosshead used was a flat-ended circular rod, 2 mm in diameter. This kind of crosshead was also used in the study by Prakki et al. (28), while a spherical crosshead of 12.7 mm in diameter was used by Scherrer et al. (33). However, a spherical crosshead makes it difficult to calculate the stress correctly if needed because as the crosshead presses more, the contact area increases.

In the non-cement groups, the mean fracture loads were significantly lower due to the fact that ceramic was strong to compression, weak to tension, and

brittle. This finding was in accordance with Prakki et al. (28), who found that unluted groups had lower fracture loads compared with luted groups, and that thin ceramic groups had lower fracture loads compared with thick ceramic groups. Scherrer et al. (33) also gave additional reasons for this finding. They stated that treating the ceramic surface with hydrofluoric acid and the silanization process, together with cementation with resin cement, smoothed out the sharp edges and roughness of the surface flaws. Moreover, Flemming suggested that resin cement shrinkage strengthened porcelain (57).

This study evaluated two types of ceramic, leucite-reinforced ceramic and lithium disilicate ceramic (Empress Esthetic and e.max), fabricated into two thicknesses and cemented with two film thicknesses of cement. The control groups were unluted. In this study, the fracture loads of Empress Esthetic groups (group 0.5 mm: 15.51 N; group 1 mm: 58.02 N) were lower than e.max groups (group 0.5 mm: 47.09 N; group 1 mm: 145.88 N). There was no significant difference found for 0.5 mm Empress Esthetic between the 30 μm cement group (771.56 N) and the 100 μm cement group (810.06 N). Likewise, for 0.5 mm e.max groups there was no significant difference in fracture load between the 30 μm cement group (2,471.81 N) and the 100 μm cement group (2,666.58 N). The reason for these findings might be that the PLV was so thin that the effect of the different cement film thickness was not easily observed. However, at a ceramic thickness of 0.5 mm, e.max demonstrated a higher fracture load compared with Empress Esthetic.

On the contrary, when the ceramic sample thickness was increased to 1 mm, mean fracture load significantly increased in both Empress Esthetic and e.max groups. Within the same ceramic group, the mean fracture load of the 100 μm

cement group was significantly lower than that of the 30 μm cement group for both Empress Esthetic (1,748.39 N and 2,666.20 N, respectively) and e.max (2,830.50 N and 3,547.38 N, respectively). When the PLV is thicker, it possibly can better tolerate the tension generated at the opposite side of the compression. Moreover, with a more flexible cement supporting layer, when the cement is thicker, the PLV is able to subside more. This finding may be in accordance with the report of B. Kim, et.al stated that a hard metal substructure could prevent radial fracture at the lower surface of veneering porcelain. In other words, yield of the metal substructure facilitated flexure of the overlying porcelain veneer (58). These factors may explain why the effect of thicker cement can be clearly seen in the 1 mm PLV groups. According to a report by Thompson and Rekow, when the ceramic thickness is less than 1 mm, flexural radial cracking becomes predominant (59). Stiffness of the substrates, which in this case were resin cement and the supporting tooth structure, played a major role in the failure of the ceramic. (The resin cement used in the present study, NX3, had a compressive strength of 406 MPa.)

The present results reflected a similar trend to the findings of Scherrer et al. (33), who demonstrated a lower fracture load for ceramics cemented with thicker cement (297 μm: 2.02 kN) compared with ceramics cemented with thinner cement (26 μm: 2.30 kN). In that study, Macor glass-ceramic plates (Corning Incorporated, Corning, NY, USA) were fabricated and cemented to a Silar block (3M ESPE Dental Products, St. Paul, MN, USA) using Dicor MGC cement (Dentsply, Konstanz, Germany) and zinc phosphate cement. Also, Tuntipraworn, whose study results showed a similar trend, concluded that the thicker the cement, the lower the fracture strength of a porcelain jacket crown (60). In that experiment, a porcelain

crown was fabricated with Vitadur-N (Vita, Bad Säckingen, Germany) and cemented to a metal die using Phosphacap (Ivoclar Vivadent, Lichtenstein). The fracture load was applied at the lingual fossa with a steel ball point.

The study by Prakki et al. (28) though, did not show precisely the same results. However, there were many differences in the materials and methods used. Ceramic was cemented to bovine dentin with RelyX ARC (3M ESPE, St. Paul, MN, USA). Ceramic plates were fabricated from Duceram Plus (Degussa, Rosbach, Germany). The thicknesses of the ceramic were 1 and 2 mm. Cement thicknesses were 100, 200, and 300 μm. The study demonstrated that the fracture load of the 300 μm group was statistically lower than that of the 100 μm group. Nevertheless, the differences in setting, as stated earlier, made it difficult to directly compare the results from that study with the current study.

From what we have found in this study, there should be further studies about the exact thickness which give the highest strength to enamel-bonded ceramic or the effect of different cement type to strength of enamel-bonded ceramic.

Conclusions

Non-cemented PLV showed a significantly lower mean load to fracture than cemented PLV. This was the case for both types of ceramics tested. The thicker cement group (100 μm) showed a decreased mean fracture load for the 1-mm-thick PLV only. On the contrary, no significant difference was found for the 0.5 mm group. These results were also found in both types of ceramics tested.

Implication of the Result

This study result implies that ceramic restorations should be adhesively cemented to tooth structure to strengthen the restorations. Moreover, any procedures associated with the cement thickness should be taken into consideration as thicker cement might affect the strength of ceramic restoration.

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APPENDIX

Appendix A. Raw Data – Fracture resistance of IPS Empress Esthetic (N)

Sample number	Empress					
	0.5mm			1mm		
	no cement	30 μm	100 μm	no cement	30 μm	100 μm
1	10.56	593.09	623.83	39.53	2250.06	1352.46
2	12.31	662.13	693.8	33.54	2467.59	1505.27
3	13.55	688.81	716.7	41.8	2535.99	1543.65
4	14.05	718.83	758.89	48.47	2546.08	1652.03
5	14.21	747.45	780.73	56.88	2631.64	1667.25
6	14.32	750.28	801.55	57.35	2647.64	1701.13
7	15.78	770.33	803.59	61.05	2659.06	1738.85
8	16.09	781.28	816.27	61.83	2701.58	1755.1
9	19.51	796.48	849.41	64.43	2712.12	1801.3
10	17.2	846.44	912.38	71.01	2856.45	1947.44
11	17.61	929.62	948.69	74.2	2859.49	2097.06
12	20.94	973.97	1014.86	86.15	3126.74	2219.11
Ave	15.51	771.56	810.06	58.02	2666.20	1748.39
Min	10.56	593.09	623.83	33.54	2250.06	1352.46
Max	20.94	973.97	1014.86	86.15	3126.74	2219.11
S.D.	2.97	107.35	110.26	15.33	220.46	245.24

Appendix B. Raw Data – Fracture resistance IPS e.max (N)

Sample number	e.max					
	0.5mm			1mm		
	no cement	30 μm	100 μm	no cement	30 μm	100 μm
1	35.26	1838.72	2273.18	107.01	2978.63	2389.59
2	38.77	2071.73	2349.89	109.4	3198.02	2546.42
3	40.22	2218.45	2411.91	125.59	3322.22	2613.43
4	42.77	2254.58	2558.39	130.83	3368.51	2726.34
5	45.66	2485.55	2576.12	133.51	3461.7	2801.29
6	45.96	2493.56	2609.13	141.59	3468.21	2803.75
7	46.62	2508.44	2715.49	156.3	3597.74	2823.25
8	51.29	2545.19	2785.43	157.43	3620.61	2855.32
9	52.11	2601.31	2809.48	163.46	3735.4	2968.95
10	53.32	2669.49	2935.72	166.84	3845.62	3085.32
11	55.25	2965.8	2947.88	177.22	3970.28	3143.64
12	57.82	3008.92	3026.38	181.34	4001.57	3208.7
Ave	47.0875	2471.8117	2666.58333	145.87667	3547.3758	2830.5
Min	35.26	1838.72	2273.18	107.01	2978.63	2389.59
Max	57.82	3008.92	3026.38	181.34	4001.57	3208.7
STD	7.01909749	339.51787	245.145876	25.011341	310.30187	245.042238

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