EFFECT OF ELASTIC CAVITY WALL AND OCCLUSAL LOADING ON MICROLEAKAGE AND BOND STRENGTH OF CLASS V RESTORATIONS

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EFFECT OF ELASTIC CAVITY WALL AND OCCLUSAL LOADING ON MICROLEAKAGE AND BOND STRENGTH OF CLASS V RESTORATIONS

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ABSTRACT

The objective of this study was to evaluate the effect of an unfilled-adhesive resin (Adper™ Single Bond) and a filled-adhesive resin (Adper™ Single Bond 2) with and without a low viscosity resin (Filtek™ Flow) as an elastic cavity wall in class V composite restorations on marginal leakage and ultimate bond strength. V shaped cavities were prepared on buccal surfaces of 64 premolars, lined with either unfilled or filled adhesives with and without low viscosity resin, and restored with a resin composite. The restored teeth in each group were divided into two subgroups for unloaded and loaded conditions. Two specimens from each group of unloaded condition were evaluated for the elastic modulus with nano-indentation test at the layer of dentin, hybrid layer, adhesive resin, low viscosity resin and resin composite. The remaining specimens were subjected for dye leakage test and micro-tensile bond strength test.

The results demonstrated that the elastic moduli were significantly different among layers ($p<0.05$) except between hybrid layers of unfilled and filled adhesive ($p=1.0$). In all groups, dentin margin had significantly higher microleakage than that on enamel margin ($p<0.05$). No statistically significant differences of the enamel microleakage were found between unloaded and loaded groups for all materials ($p=0.512$) but significant differences on the dentin margins were found in groups which low viscosity resin was used ($p<0.05$). Significant differences of the microtensile bond strength were found between unfilled-adhesive and filled-adhesive group with low viscosity resin ($p = 0.016$) under unloaded condition. Under loaded condition, there were no significant differences in bond strength between unfilled and filled adhesive group whether low viscosity intermediate layer was used. The effect of occlusal loading on the bond strength was found in the group using filled adhesive without intermediate layer ($p=0.031$).

The results of this study suggested that the application of filled adhesive or low viscosity resin as elastic cavity wall had no influence on the marginal leakage of both enamel and dentin margins. However, it had an influence on the dentin microtensile bond strength of class V composite restorations.

KEY WORDS : FILLED ADHESIVE / ELASTIC MODULUS / OCCLUSAL
LOADING / BOND STRENGTH / MARGINAL LEAKAGE

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ผลของผนังโพรงฟันยืดหยุ่น และแรงบนด้านบดเคี้ยวต่อ การรั่วซึม และกำลังยึดติดในการบูรณะโพรงฟันคลาสไฟฟ์ (EFFECT OF ELASTIC CAVITY WALL AND OCCLUSAL LOADING ON MICROLEAKAGE AND BOND STRENGTH OF CLASS V RESTORATIONS)

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บทคัดย่อ

วัตถุประสงค์ของการศึกษานี้เพื่อประเมินผลของการใช้สารยึดติดชนิดไม่มีวัสดุอัดแทรก(ซิงเกิลบอนด์) และมีวัสดุอัดแทรก(ซิงเกิลบอนด์ทู) ร่วมกับเรซินชนิดความหนืดน้อย เสมือนผนังโพรงฟันยืดหยุ่นในการบูรณะโพรงฟันคลาสไฟฟ์ด้วยวัสดุคอมโพสิตต่อการรั่วซึมตามขอบและกำลังยึดติด โดยการเตรียมโพรงฟันคลาสไฟฟ์ทางด้านแก้มในฟันกรามน้อยจำนวน 64 ซี่ ทาสารยึดติดชนิดมีวัสดุอัดแทรกหรือไม่มีวัสดุอัดแทรก ร่วมกับการใช้สารคั่นกลาง หรือไม่ใช้สารคั่นกลางที่เป็นเรซินชนิดความหนืดน้อย และอุดด้วยวัสดุเรซินคอมโพสิต ฟันที่ทำการบูรณะแล้วในแต่ละกลุ่มแบ่งเป็นกลุ่มย่อย 2 กลุ่ม คือกลุ่มที่ไม่มีแรงบนด้านบดเคี้ยวและกลุ่มที่มีแรงบนด้านบดเคี้ยว นำฟันในกลุ่มที่ไม่มีแรงบนด้านบดเคี้ยวมา 2 ซี่เพื่อวัดค่ามอดุลัสยืดหยุ่นด้วยวิธีการ ทดสอบนาโนอินเดนเตชั่น บริเวณเนื้อฟัน ชั้นไฮบริด ชั้นสารยึดติด ชั้นวัสดุอุดเรซินชนิดความหนืดน้อย และชั้นวัสดุเรซินอุดคอมโพสิต ฟันที่เหลือนำมาทดสอบการรั่วซึมบริเวณขอบ และทดสอบแรงยึดติดของวัสดุ

ผลการศึกษาพบว่า ค่ามอดุลัสยืดหยุ่นมีความแตกต่างกัน (p<0.05) ยกเว้นระหว่างชั้นไฮบริดของสารยึดติดที่มีวัสดุอัดแทรก และไม่มีวัสดุอัดแทรก (p=1.0) การรั่วซึมบริเวณขอบโพรงฟันด้านเนื้อฟันมากกว่าขอบด้านเคลือบฟัน (p<0.05) ไม่มีความแตกต่างกันของการรั่วซึมบริเวณขอบโพรงฟันด้านเคลือบฟัน ระหว่างกลุ่มที่ไม่ให้แรงและให้แรงในทุกวัสดุ (p=0.512) ทว่าพบความแตกต่างของการรั่วซึมบริเวณขอบโพรงฟันด้านเนื้อฟันได้ ในกลุ่มที่บูรณะร่วมกับเรซินชนิดความหนืดน้อย (p<0.05) ความแตกต่างของกำลังยึดติดพบได้ ระหว่างกลุ่มที่ใช้สารยึดติดที่ไม่มีวัสดุอัดแทรกและมีวัสดุอัดแทรก ร่วมกับการใช้เรซินชนิดความหนืดน้อย (p = 0.016) ได้ในสภาวะไม่มีแรงบดเคี้ยว ภายใต้สภาวะมีแรงบนด้านบดเคี้ยว พบว่าไม่มีความแตกต่างกันของกำลังแรงยึดระหว่างกลุ่มที่ใช้สารยึดติดที่ไม่มีวัสดุอัดแทรก และกลุ่มที่ใช้สารยึดติดที่มีวัสดุอัดแทรกไม่ว่ากลุ่มนั้นจะใช้เรซินชนิดความหนืดน้อยร่วมด้วยหรือไม่ก็ตาม ผลของแรงบนด้านบดเคี้ยวมีผลต่อค่ากำลังแรงยึด พบในกลุ่มที่ใช้สารยึดติดที่มีวัสดุอัดแทรกที่ไม่ได้ใช้เรซินชนิดความหนืดน้อยร่วมด้วย (p=0.031)

จากผลการวิจัยครั้งนี้แสดงให้เห็นว่าการใช้สารยึดติดที่มีวัสดุอัดแทรก หรือเรซินชนิดความหนืดน้อยเพื่อผลของผนังโพรงฟันยืดหยุ่นไม่ได้ช่วยลดการรั่วซึมบริเวณขอบโพรงฟันทั้งด้านเคลือบฟันและเนื้อฟัน อย่างไรก็ตาม วิธีการดังกล่าวสามารถช่วยเพิ่มค่าแรงยึดติดต่อเนื้อฟันในโพรงฟันคลาสไฟฟ์ได้

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CHAPTER I

INTRODUCTION

The demand for restoration of crown-root dentin defects such as cervical erosion and root caries has been significantly increased. Resin composite is one of the materials of choice for this purpose because of high esthetics. The success of resin composite restoration is due to many factors. One of the important factors is the characteristic polymerization of resin-based composite. The shrinkage due to polymerization always causes marginal leakage, tooth fracture, resin composite fracture and dislodgement of the restoration. Contraction stress from polymerization relates to the flow capacity reduction of the composite when it is more constrained (1, 2). An elastic bonding area at tooth/resin interface has been proposed as an inherent buffer to compensate for the polymerization contraction stress of the restorative resin (3). Various materials have been introduced to be used as elastic wall underneath the restorations such as filled adhesive resins, low viscosity resins or flowable composites. However, there is limited information on the performance of these materials.

Clinical success with composite restorations is fundamentally dependent on effective and durable adhesion to enamel and dentin (4, 5, 6) especially under occlusal loading. The occlusal force might be partly responsible for the development of cervical lesion and failure of class V restoration as well.

Bonding to enamel using an acid-etch technique is now accepted as clinically reliable. However, dentin was still an unpredictable substrate for adhesion (7). A large number of literatures concerning filled adhesives indicated that application of these materials or flowable composites underneath the restoration can provide a stress-relief function that compensates for stress resulting from composite polymerization shrinkage and occlusal forces (8, 9). Using these materials for a stress-relief function exhibited significantly increased bond strength and decreased marginal leakage (10).

Because of the limitation of testing under mechanical loading, it was interesting to observe the application of low viscosity resin or filled-adhesive resin as elastic cavity wall on the class V restoration under occlusal loading. These techniques might reduce the degree of marginal leakage and increase the ultimate bond strength under mechanical loading.

The purpose of this study was to evaluate the effectiveness of filled adhesive resin or low viscosity resin as elastic cavity wall on the class V resin composite restoration under mechanical loading by means of the elastic modulus measurement of dentin, hybrid layer, adhesive resin, low viscosity resin and resin composite at resin/dentin interface, the measurement of marginal leakage on enamel and dentin margins and the measurement of microtensile bond strength to human root dentin.

CHAPTER II

OBJECTIVES

The objectives of this study were

1. To compare the elastic moduli of various materials used as intermediate layer
2. To compare the microleakage of class V resin composite restorations with various intermediate layers with and without occlusal load
3. To compare the dentin microtensile bond strength of class V resin composite restorations with various intermediate layers with and without occlusal load

CHAPTER III

HYPOTHESES

Hypothesis

H_0 : There was no significant difference of microleakage among various materials used as intermediate layers of class V composite restorations.

H_1 : There was significant difference of microleakage among various materials used as intermediate layers of class V composite restorations.

H_0 : There was no significant difference of microleakage between with and without occlusal load of class V composite restorations.

H_1 : There was significant difference of microleakage between with and without occlusal load of class V composite restorations.

H_0 : There was no significant difference of microtensile bond strength among various materials used as intermediate layers of class V composite restorations.

H_1 : There was significant difference of microtensile bond strength among various materials used as intermediate layers of class V composite restorations.

H_0 : There was no significant difference of microtensile bond strength between with and without occlusal load of class V composite restorations.

H_1 : There was significant difference of microtensile bond strength between with and without occlusal load of class V composite restorations.

H_0 : There was no significant difference of modulus of elasticity among various materials used as intermediate layers of class V composite restorations..

H_1 : There was significant difference of modulus of elasticity among various materials used as intermediate layers of class V composite restorations.

CHAPTER IV

LITERATURE REVIEW

Non-carious cervical lesions

The classical etiologies of non-carious tooth loss are attrition, erosion, and abrasion. Attrition describes loss of tooth structure arising from tooth to tooth contact in normal or para-functional modes, erosion describes loss of tooth structure due to acid of non-bacterial origin and abrasion describes loss of tooth structure due to wear by other except opposing tooth wear. Abrasion may result from habits, or from an incorrect tooth brushing technique (11). Cervical abrasion is a non-carious cervical lesion caused by abrasive tooth loss.

In an attempt to explain a non-abrasive, non-erosive mechanism of tooth loss, Lee and Eakle described a process whereby occlusal or incisal stresses cause deformation of the tooth crown. If the stress is eccentric, a bending deformation occurs. The deformation causes alternating tensile and compressive stresses at the cervical margin. Basically, enamel is weak in tension. The tensile phase of deformation therefore causes the prism to be disrupted. Ultimately, the enamel breaks away at the cervical margin and progressively exposes the dentin, in which the process continues (12). This process has been termed ‘Abfraction’ by Grippo. He suggested that abfraction is the basic cause of all non-carious cervical lesions (13).

Resin composite restoration

Resin composite is one of the materials of choice for non-carious cervical restorations because of its physical properties, mechanical properties and esthetics. However, current resin composites which have been developed still have a problem on polymerization shrinkage.

Polymerization shrinkage is the shrinkage that occurs during polymerization as monomer molecules are converted into a polymer network. It is occurred when Van Der Waals space is exchanged for shorter covalent bond spaces. This shrinkage is more rapid and greater in magnitude due to the flow capacity reduction of the resin composite when it is more constrained (14). This polymerization shrinkage generates contraction stress especially at tooth/resin interfaces (1, 2, 8, 9, 15). If the contraction stress exceeded the adhesive bond strength, the delamination of the restoration interface might be occurred (16). In the present of high bond strength, the shrinkage stress might cause fracture of the tooth substrate and/or resin composite at the margin (6, 17, 18). These result in marginal gap formation, that allow the ingress of oral fluids and bacteria through the gap named marginal leakage (19).

Many methods have been proposed to reduce the polymerization shrinkage. One approach is to control the components of the composite itself, such as the amount and type of matrix resin (20-22), the filler level (23), the curing chemistry (24, 25), the initiator level (26) and the addition of non-bonded microfiller particles (27). Another is to modify the technique. Examples for this attempt are the use of a sandwich restoration with glass ionomer (28), the use of a resin composite inlay (29), and the altering light energy to control the reaction rate of the material (30, 31). A practically current technique to manage the effect of polymerization shrinkage is to place a layer with relatively low modulus of elasticity as an intermediary between the composite and the tooth. This layer might act as shrinkage stress absorber (8, 9). Low viscosity resin has been suggested to be used as low modulus of elasticity material (32). Additionally, current filled adhesive systems have been advocated to be used as stress absorber layer or elastic cavity wall. As a result, the low viscosity resin might be replaced by this filled adhesive in the attempt to use as intermediate layer (33, 34).

Elastic cavity wall

The hybrid layer, a collagen mesh-work interdiffused with adhesive resin, together with the relatively thick adhesive resin layer forms what was defined by Kemp-Scholte and Davidson as an artificial elastic cavity wall between the shrinking restoration and the rigid dentin substrate. Hence, this elastic bonding area might perform as an inherent buffer and compensate for the polymerization contraction of the resin composite restoration (9). Kemp-Scholte and Davidson proposed that the shrinkage stress should not exceed the dentin bond strength if the adhesive construction possessed sufficient elasticity to cope with the dimensional change of the restorative material during polymerization. Moreover, 20-50% polymerization contraction stress was relieved by the application of an intermediate layer of either a low-viscosity resin or a light-cured glass-ionomer cement between dentin and the restoration (9). Therefore, a sufficiently flexible intermediate resin layer can resist the polymerization shrinkage stress of the restorative composite and also better distribute stresses induced by thermal changes, water absorption, and occlusal loads across the interface (8, 9). A practical approach to manage the effects of resin composite shrinkage is to place a relatively thick layer of adhesive resin as an intermediate layer between the composite and the tooth. Van Meerbeek and coworker (32) confirmed the effectiveness of flexible and low-viscosity intermediate layers. The modulus of elasticity by nano-indentation of dentin, hybrid layer, adhesive layer, intermediate layer and resin composite has been investigated and the relation among these layers was identified. They proposed that the elastic bonding area; adhesive layer and intermediate layer, might have a strain capacity sufficient to relieve stress between the shrinking composite restoration and rigid dentin substrate, as a consequence, the marginal integrity and retention of the restoration. The relation of elastic modulus of these layers is called “Elastic cavity wall concept” (32). The use low-viscosity resin (LVR) will work as shock absorber (34). Additionally, if the elastic modulus of adhesive layer is increased to nearly between hybrid layer and resin composite, use of additional low viscosity resin as intermediate layer is not necessary (32). This adhesive layer might act as the shock absorber layer as the same as LVR performs (32). The relation of this layer to microleakage and bond strength has been investigated. The application of elastic cavity wall concept is not necessary for all composite materials. Since modulus of elasticity of hybrid composite is higher than microfilled resin composite, it might be unnecessary to apply low viscosity resin when microfilled resin composite was used (32, 33, 35), even though volumetric shrinkage of microfilled composite is higher than hybrid composite (33, 36).

Resin/dentin interfaces

The intermediate layer between resin composite and tooth structure is multilayer of hybrid layer, adhesive resin layer and LVR layer.

Hybrid layer

The micromechanical retention between dentin and resin composite is created by hybridization via the application of adhesive systems. The hybridization relies on penetration of adhesive monomer into superficial demineralized dentin and their polymerization to create hybrid layer (37). The thickness or dimension of the hybrid layer varies according to the conditioning agents for dentin demineralization such as acids or acidic monomers and its application time (38). The quality of this layer such as degree of resin penetration and polymerization has more influence on the bonding capacity than it quantity or thickness (39, 40). From the high quality of hybrid layer, tooth preservation and optimal retention without any microleakage can be achieved.

Hybrid layer, the resin polymer coupling zone, has an important function as a layer that compensates for the curing stresses of the restorative material (41). The current concept of collagen removal following acid conditioning and subsequence bonding directly to the partially demineralized dentin layer produce durable adhesion to the dentin substrate. However, by this technique the hybrid layer will not exist. This might affect the buffering capacity of this layer (42).

If collagen fibrils, with an elastic modulus of 5 to 7 MPa (43), are enveloped by resins that have moduli of 2,000 to 4,000 MPa (44), then the collagen fibrils will elongate when the bonded interface undergoes stress-induced strain, and the resin lattice will absorb most of the load and may fail at lower strains than will the collagen.

The modulus of elasticity of hybrid layer was in a range of 4.8-9.7 GPa. Hybrid layer might play a role of stress absorbing in the resin/tooth procedures (32).

Adhesive layer

Function of adhesive layers is upon two factors, thickness and filled or unfilled resins. The thicker adhesive layer was associated with the lower interfacial stresses and the better preserved marginal adaptation (8, 9). In class V restoration, the thicker layers of relatively low-modulus adhesive can significantly reduce the contraction stress of composite restorations and overall degree of microleakage at marginal areas (45). With the multiple coating of adhesive, the bond strength increased with each coating up to four coats. However, bond strength tends to decrease when more than four coats are applied (46, 47). Effect of filled adhesive on bond strength has been established (10). The filled adhesive demonstrated higher bond strength than unfilled adhesive. The effects of filler loading on the rigidity of the adhesives might affect their ability to act as elastic buffers (32). The use of low viscosity resin as the intermediate layer slightly improved the bond strength and a thickness of elastic layer ranking form 200-250 μm. It caused a drastic reduction in cohesive failure in dentin (34).

The efficacy of the resin-tooth interface

Evaluation of the efficacy of resin/tooth interface is generally based on the measurement of bond strength and the degrees of microleakage evaluation.

Bond strength test

This test indicates how the adhesive is likely to perform in vivo. Bond strength test is generally determined by loading bond test specimens in shear or in tension until fracture occurs. The traditional methods test specimens in the large surface area, approximately 7-12 mm^2, and the results frequently show cohesive dentin failure (48, 49). This form of failure does not provide reliable information with regard to the adhesive strength of the bond. Furthermore, high bond strength is virtually impossible to measure by these methods. Since a traditional bond strength test uses large surface area, the interface area might not be a uniform. It might contain air bubbles, phase separation, surface roughness, and non-uniform stress distributions, depending on how the specimens are prepared, which could lead to unreliable results (50). Therefore, a method of bond strength test, so called microtensile test, has been developed.

Generally, the bond strength should be enough to resist polymerization shrinkage stress of resin composite (6, 17). The ability to perform regional bond strength tests on small dentin surfaces is of great importance for the evaluation of the tensile properties of adhesive systems on dentin. Sano and co-worker employed a method called the microtensile technique. This testing method tends to produce higher bond strengths than traditional methods. The primary adhesive failure at bonding interfaces, which are less than 2 mm^2, could be observed (51).

The advantages of this testing method are to perceive more adhesive failures or fewer cohesive failures, to perform higher interfacial bond strengths, to permit measurements of regional bond strengths, to calculate means and variances for single teeth, to permit testing of bonds made to irregular surfaces, to permit testing of very small area and to facilitates SEM examination of the failed bonds since the surface area is approximately 1 mm^2. The disadvantages of this method are labor intensive or technical demanding, difficult to measure bond strengths less than 5 MPa. Additionally, special equipments are required and samples are very small which risk to rapidly dehydrate (52).

Microleakage test

Microleakage is a clinical problem in which of bacteria and oral fluid penetrate the cavity wall and the restorative material. This results in breakdown and discoloration of margins, secondary caries formation, postoperative sensitivity and pulpal pathology (53). Adhesive systems play an important role for composite restoration (7, 54).

The degree of microleakage at the restoration/tooth interfaces can be evaluated by the penetration of tracers and staining agents. It has been shown that there was not a good correlation between bond strength and microleakage. Nevertheless, the newer systems appear to be superior in inhibiting interfacial leakage with high bond strength (55).

Many laboratory techniques have been developed to investigate marginal leakage at the tooth/restoration interface. One of these test methods is (56, 57, 58) the evaluation of marginal percolation by using of radioisotopes, dyes, bacteria, or air pressure, observation under scanning electron microscopy (SEM), neutron activation analysis and the artificial caries study.

Dye penetration

The use of organic dyes as tracers is one of the oldest and most common methods to detect microleakage involving the placement of a restoration in an extracted tooth, following by immersion of the tooth in a dye solution after the unfilled parts have been coated with a waterproof varnish. After a certain time interval, the specimens are removed, washed, and sectioned for visual examination to measure the extent of dye infiltration around the filling (59). Many dyes can be used with different particle sizes and affinity to substrates, but this does not seem to influence the test results significantly (59).

The use of colored agents to demonstrate microleakage continues to be the most popular of techniques which are currently available. This method allows the production of sections showing leakage in contrasting colors to both tooth and restoration without the need for further chemical reaction or exposure to potentially hazardous radiation (56).

A criticism leveled at microleakage studies using tracer molecules or dyes is the clinical relevance of the dye/tracer molecular size. Since dentin permeability is inversely related to molecular size and weight (60). Some researchers believed that *in vitro* microleakage studies overestimate the amount of leakage that will occur clinically. This is because of the considerably smaller molecular size and weight. The comparative molecular weight and radius of a variety of molecules of clinical relevance, bacteria, viruses and dyes relative to gaps/porosities found in conjunction with restorative materials are presented in Table 1. It is apparent that the more common dye molecules used in microleakage studies are smaller than bacteria, viruses and endotoxin molecules.

Dye penetration studies demand destruction of the specimen and thus make it impossible to use fully quantitative techniques for evaluation. However, others have suggested that dye penetration is nondestructive, thus allowing longitudinal study of restoration margin (61)

The advantage of this method is that it is fully quantitative, and specimens can be followed longitudinally because of its non-destructive nature. A significant is that the specimens are not destroyed each time a leakage assessment is made, allowing specimens to be evaluated over a variety of time and/or experimental conditions. In addition, this technique allows quantification of the leakage assessment. The main disadvantage is that the nominal values are usually very low, so that the actual leakage path is sometimes unclear. Leakage may even occur through the dental substrate itself and so falsely increase the interfacial leakage values. The exact location of the leakage cannot be determined. It is highly technique sensitive and the assessment of results required careful standardization. (59, 62)

Table 1 Comparison of molecular weight and size of molecules, viruses and bacteria relative to size of microporosities and gaps around restorative materials (59)

Substance	Molecular weight	Molecular Radius (nm)
Water	18	0.26
Silver Nitrate ($AgNO_2$)	108	0.50
Glucose	180	0.56
Methylene blue	319	0.68
Fuchsin	585	0.84
Trypan Blue	961	0.99
Myoglobin	17,000	2.60
Albumin	69,000	4.1
Bacterial endotoxin	1,000,000	10.00
Bacterial endotoxin	4,000,000	15.80
Viruses (small)	2,000,000	13
Viruses (large)	25,000,000	45
Bacteria cocci (0.2-1.0 µm diameter)		100-500
Bacteria Rods (0.5 x 7 µm)		250 x 3,500
Microporosities within hybrid layer		20 x 1,000
Gap sizes (0.5 – 20 µm)		250 – 10,000

Dyes most frequently used in dental research are provided as either solutions or particle size dependent upon manufacture and the individual behavior of the dye.

Bacteria and bacterial metabolites

Bacteria have also been used in the study of microleakage. Probably the earliest such study was in 1929 when Fraser tested cements and restorative materials to determine whether they would allow bacteria to pass through or around them (63).

Mortensen and co-worker showed that microorganism penetration might be more appropriate than dye or isotope penetration for studying leakage in vivo (64).

It has been claimed that bacterial penetration studies are more clinically related to leakage because they may be associated with the carious process and recurrent decay. All the bacterial tests described have the disadvantage because the results are described in qualitative rather than quantitative terms. It might also be argued that the microleakage detected is gross if bacterial size is compared with that of the hydrogen ions (58).

Invasion of marginal gaps by bacteria would be expected to be in the region of 0.5 – 1.0 µm or larger. These techniques do not, therefore, take into account for gaps that are smaller than this and the size of bacteria. Such gaps may not allow the diffusion of toxins and other bacterial products that could be harmful to the tooth

However, leakage test involving microbiology is more technically exacting. There is the possibility of contamination and it may be difficult to maintain the viability of some bacteria in an in vitro model (65). The bacteria selected as the leakage marker should preferably be a pathogen, and easy to cultivate. Therefore, bacterial leakage test have not gained popularity despite being more clinically relevant (66)

Occlusal load

Beside the polymerization shrinkage, the occlusal loads have directly affected to the durability of the restoration (8, 9). On the mastication, tooth will be flexed and tensile stresses induced in teeth subjected to a masticatory load may partly be responsible for the development of cervical lesions (12) called “Abfraction” (13). The effect of occlusal loading to the bond strength and marginal adaptation of the restoration has been well documented (67, 68, 69). Seventy-one percent of the restorations placed in molars in occlusion showed evidence of bacterial penetration, while in teeth without antagonists only 28% showed bacterial penetration. Thus, the functional mastication increased the occurrence of marginal leakage along the restorations from 28% to 71% (69). It means the functional stress incurred on the restorations by mastication is one of the important factors for the marginal integrity of optimally composite fillings in the oral environment. A numbers of studies have been made to determine the biting force. The average maximum sustainable biting force is approximately 756 N (170 lbs). For the molar region, bite forces range from 400 to 890 N (90-200 lbs). The premolar area, they range from 222 to 445 N (50-100 lbs). The cuspid region, they vary from 133 to 334N (30-75 lbs). The incisor region, they vary from 89 -111N (20-55 lbs) (14, 70, 71). Application of low modulus resin and restorative materials do partially absorb deformation under loading and limit the stress intensity transmitted to the remaining tooth structure (72).

CHAPTER V

MATERIALS AND METHODS

Materials

1. Scotchbond™ Etchant gel, 3M EPSE, Minnesota, USA.
2. Adper™ Single Bond, 3M ESPE, Minnesota, USA.
3. Adper™ Single Bond 2, 3M ESPE, Minnesota, USA.
4. Filtek™ Flow, shade A4, 3M ESPE, Minnesota, USA.
5. Filtek™ Z250, shade A2, 3M ESPE, Minnesota, USA.
6. Elipar™ Trilight, 3M EPSE, Minnesota, USA.
7. 0.1% Thymol solution.
8. 2% Aqueous Methylene blue dye solution, Fluka, Ec No 2005152, Steinheim, UK.
9. Cylinder diamond bur (D8), Intensive, Lugano-Grancia, Switzerland.
10. Superfine diamond point bur (C16), Intensive, Lugano-Grancia, Switzerland.
11. Soflex™ Disk, 3M ESPE, Minnesota, USA.
12. Self-curing acrylic, Instant Tray Mix, Lang Dental Manufacturing Co., Inc. Wheeling, Illinois, USA.
13. Epoxy resin, Epon 815, Nissin, Tokyo, Japan.
14. Nail varnish, Color Chrome, Revlon, NewYork, USA.
15. Cyanoacrylate adhesive, Model Repair II blue, Dentsply-Sankin, Tokyo, Japan.
16. Silicon carbide paper: 600, 800, 1,000, 1,200 grit, Struers, Ballerup, Denmark.
17. Diamond paste 6, 3, 1, 1/4 micron, DP-Paste, Struers, Ballerup, Denmark.
18. Diamond Wafering Blade 3” Dia. X 0.015”, Isocut™, Buehler, Lake Bluff, Illinois, USA.
19. Low Speed Saw, Isomet™, Buehler, Lake Bluff, Illinois, USA.
20. Nano-hardness testing, ENT-1100 (version 2.100) Elionix, Tokyo, Japan.

21. Argon ion beam etching, EIS-1E, Elionix Ltd., Tokyo, Japan.
22. Universal testing machine, Instron Model 5566, Instron corp., Buckinghamshire, UK.
23. Bencor Multi-T device, Danville Engineering, Danville , California, USA.
24. Gold Sputter Coater, SC-701AT Quick Coater, Elionix Ltd., Tokyo, Japan.
25. Scanning electron microscope, Model JSM 5410 LV, JEOL Company, Tokyo, Japan.
26. Measuring microscope, Measurescope MM-11C, Nikon, Tokyo, Japan.
27. Loading machine

Tooth specimen preparation

Sixty four freshly extracted sound human premolars were used in this study. The inclusion criteria were the teeth with free from decay, cracks or restorations. After extraction, the teeth were cleaned with pumice and stored in 0.1% thymol solution at 4°C before use. V-shaped cavities were prepared with water-cooled high speed handpiece and cylindrical diamond bur (D8) at cemento-enamel junction on buccal surface of the teeth. A bur was used only for preparation of 4 cavities and then replaced by a new bur. The size of cavity was 4.0 x 2.6 mm. The depth of cavity, determined with a periodontal probe, was approximately 2.0 mm. The occlusal margin of cavity was located on enamel and the gingival margin was located on cementum (Figure 1). The prepared teeth were further randomly assigned into 4 groups of 16 teeth each and were kept in normal saline solution (Figure 2).

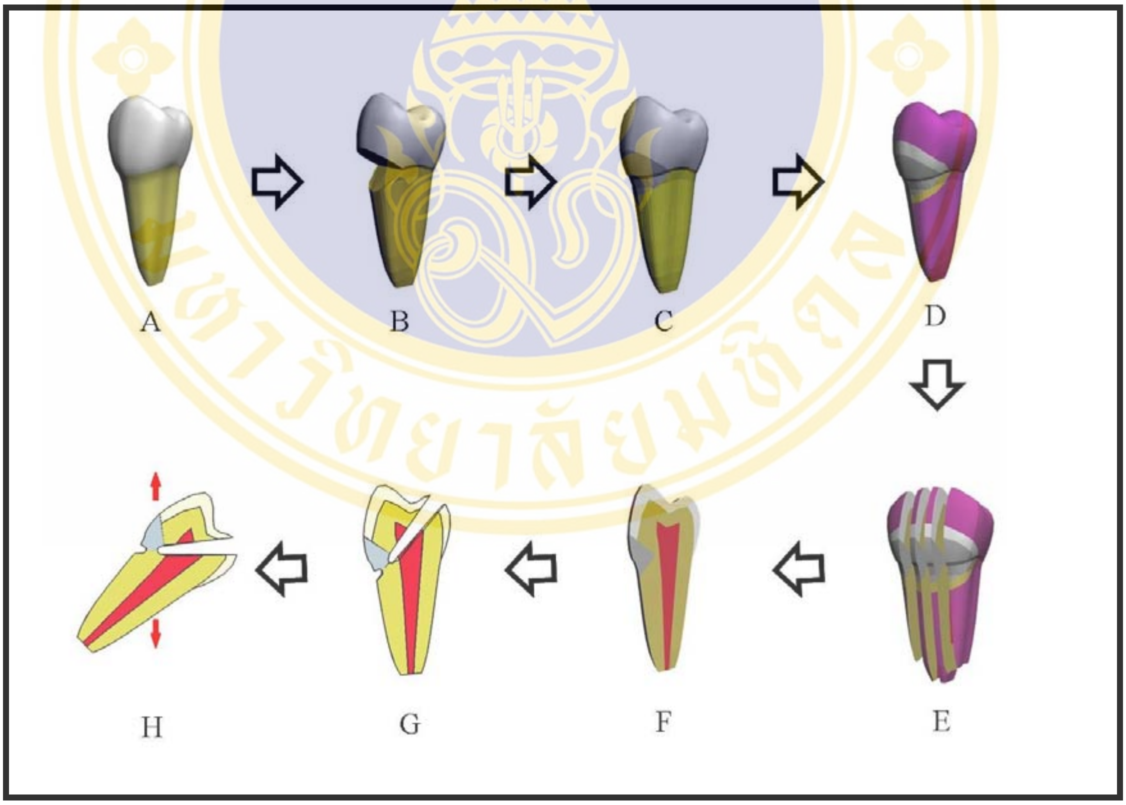

Figure 1. Schematic indication of the methodology (A = sound human premolar tooth, B = classV buccal preparation, C = class V composite restoration, D = application of nail varnish, E = bucco-lingually section, F = specimen for microleakage evaluation, G = dumbell shaped specimen preparation, H = microtensile bond strength evaluation

Restorative procedures

Materials used in this study and their compositions are demonstrated in Table 2. The prepared teeth of each group were restored according to the following conditions.

Group 1: All cavity surfaces were etched with 35% phosphoric acid (Scotchbond™ Etchant gel) for 15 seconds, rinsed for 10 seconds and blot dried with gentle air blow. Bonding (Adper™ Single Bond) was applied for 2 coats onto enamel and dentin. The bonded specimen was gentle dried for 5 seconds and light-cured for 10 seconds with a halogen curing unit (Eliper™ Trilight). A resin composite (Filtek™ Z250) was placed into the cavity with bulk technique and cured for 40 seconds. The finishing and polishing with abrasive disk (Soflex™ Disk) in sequence were performed immediately after polymerization.

Group 2: The restorative procedures were performed as previously described in group 1 except the bonding (Adper™ Single Bond 2) was used.

Group 3: The bonding steps were performed in the same way as previously described in Group 1. Before restoration with the resin composite, the bonded cavity surfaces were applied with a flowable composite (Filtek™ Flow) and gently air blown to obtain a thin layer of the material. This layer was cured for 20 seconds. Then, the cavity was restored with the resin composite in the way as previously mention in group 1 and group 2.

Group 4: The restorative procedures were performed as previously described in group 3 except the bonding (Adper™ Single Bond 2) was used.

The summary of the test groups is demonstrated in Table 3.

After finishing, the specimens were stored in distilled water at 37°C for 24 hours.

Table 2. Compositions of materials used in this study.

Material	Batch No.	Type	Compositions
Scotchbond™ Etchant gel (3M ESPE)	20041126	Etching agent	Water 55-65%, Phosphoric Acid 30-40%, Synthetic amorphous silica 5-10%
Adper™ Single Bond (3M ESPE)	20040527	Primer-adhesive	Ethyl alcohol 30-40%, Bisphenol A diglycidyl ether dimethacrylate 15-25%, 2-hydroxyethyl methacrylate 10-20%, glycerol 1,3-dimethacrylate 5-15%, Copolymer of acrylic and itaconic acids 5-15%, Diurethane dimethacrylate 2-8%, Water 2-8%
Adper™ Single Bond 2 (3M ESPE)	20041016	Primer-adhesive	Ethyl alcohol 25-35%, Bisphenol A diglycidyl ether dimethacrylate 10-20%, Silane treated silica (nanofiller) 10-20%, 2-hydroxyethyl methacrylate 5-15%, Glycerol 1,3-dimethacrylate 5-10%, Copolymer of acrylic and itaconic acids 5-10%, diurethane dimethacrylate 1-5%, Water <5%
Filtek™ Flow (3M ESPE)	20050527	Flowable light cured composite	Silane treated ceramic 55-65%, Bisphenol A diglycidyl ether dimethacrylate 10-20%, Triethylene glycol dimethacrylate 10-20%, Silane treated silica 5-10%, Functionalized dimethacrylate polymer <5%, Water <2%
Filtek™ Z250 (3M ESPE)	20050406	Light cured composite	Silane treated ceramic 75-85%, Bisphenol A polyethylene glycol diether dimethacrylate 5-10%, Diurethane dimethacrylate 5-10%, Bisphenol A diglycidyl ether dimethacrylate <5%, Triethylene glycol dimethacrylate <5%, Water <2%

Table 3. Summary of testing groups.

Group	Conditioner	Adhesive	Intermediate layer	Restoration
1	Scotchbond™ Etchant gel	Adper™ Single Bond	-	Filtek™ Z250
2	Scotchbond™ Etchant gel	Adper™ Single Bond 2	-	Filtek™ Z250
3	Scotchbond™ Etchant gel	Adper™ Single Bond	Filtek™ Flow	Filtek™ Z250
4	Scotchbond™ Etchant gel	Adper™ Single Bond 2	Filtek™ Flow	Filtek™ Z250

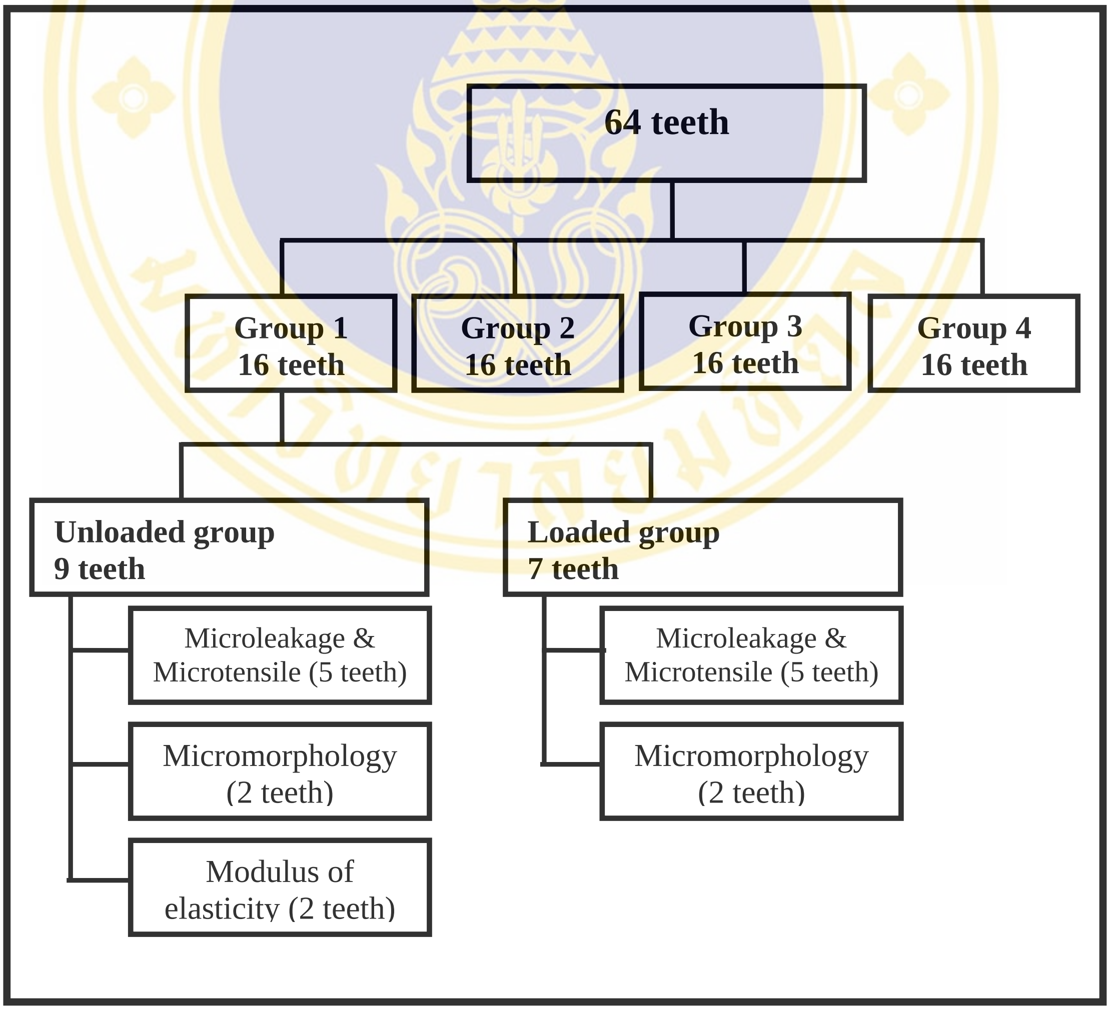

Figure 2. Chart presents the testing groups in this study.

Evaluation of modulus of elasticity

Two specimens of each group were sectioned bucco-lingually with a low speed saw (Isomet™) with diamond wafering blade (Isocut™). The cut specimens were then embedded in epoxy resin (Epon 815) in PVC ring. After the epoxy resin set, the embedded specimens were polished with wet silicon carbide paper of decreasing abrasiveness (600, 800, 1,000, 1,200 grit) and polished with diamond paste down to 0.25 µm grain. The polished specimens were attached into nano-hardness testing (ENT-1100) to measure elastic modulus under 5,000 mgf loading on dentin, adhesive and resin composite and 1,000 mgf loading on hybrid layers. Modulus of elasticity (MPa) were calculated and recorded by an attached computer (Figure 3).

Application of cyclic loading

The remaining 14 teeth of each group were further divided into 2 subgroups of 7 teeth each. One group was used as a control, no mechanical loading. Another group was used as an experimental group with mechanical loading of the specimens. All specimens were embedded in a self-cured acrylic resin (Instant Tray Mix). After the resin set, the specimens in the experimental group were settled on loading machine as shown in figure 1. The mechanical stress stimulated at a frequency of 1.5 Hz for 250,000 cycles on the loading of 50N (73-75) in water under cyclic loading machine (Figure 4). The load force was applied parallel to the long-axis of the tooth. Two teeth of the control group and 2 teeth of the experimental group were randomly selected for evaluation of resin-dentin interfaces. Therefore, the remaining teeth, 5 teeth in each group, were subjected for microleakage and microtensile test.

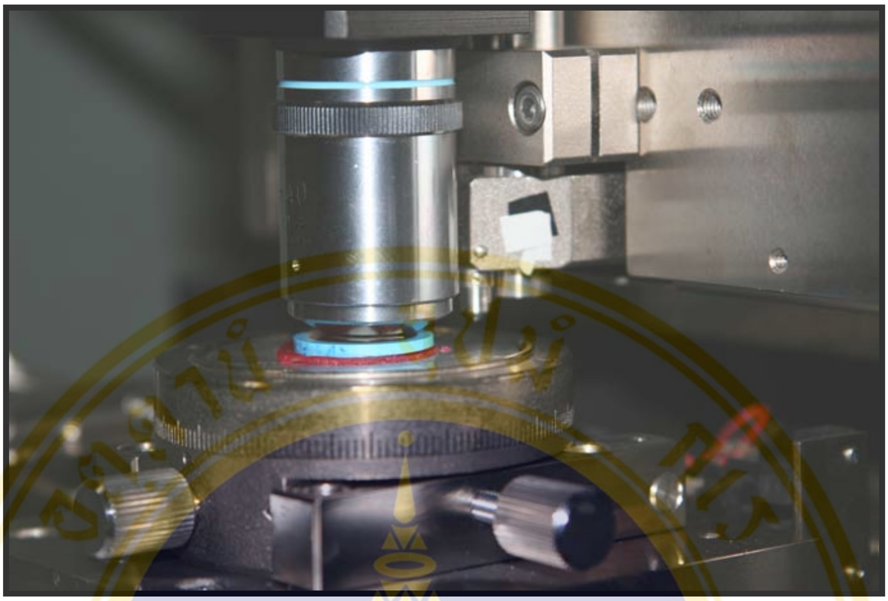

Figure 3. Nano-indentation testing machine.

Figure 4. Occlusal loading machine.

Evaluation of micromorphology of resin-dentin interfaces

The two teeth selected from each group were sectioned bucco-ligually with a low speed saw with diamond wafering blade and kept in 10% buffer formalin for 24 hours. Specimens were then rinsed under tap water and embedded in epoxy resin in PVC ring. After 24 hours, the embedded sections were polished with wet silicon carbide paper of decreasing abrasiveness (600, 800, 1,000, 1,200 grit) and polished with diamond paste down to 0.25 µm grain. The polished specimens were subjected to argon ion beam etching (EIS-1E) for 7 minutes. Operating conditions for the argon ion beam etching were accelerating voltage of 1 kV and an ion current density of 0.2 mA/cm^2 with the ion beam directed perpendicular to the polished surface (76-78). The dried specimens were sputter-coated and observed resin-dentin interface under a scanning electron microscope (JSM 5410 LV) at 1,500 and 3,500 magnifications.

Evaluation of microleakage

The remaining specimens of both control and experimental groups were sealed with two coats of nail-varnish by leaving 1 mm window around the restorations. The sealed specimens were then immersed in 2% methylene blue dye solution at room temperature for 4 hours.

After immersion, the specimens were cleaned by rinsing under tap water and sectioned bucco-lingually into 2 slabs of 0.7 mm thick using low speed diamond saw. The dye penetration at the resin-tooth interfaces were observed and measured under a measuring microscope (Measurescope). Dye penetration was recorded in mm at occlusal and gingival margins. The thickness of bonding and intermediate layer were observed and measured under a measuring microscope (Figure 5).

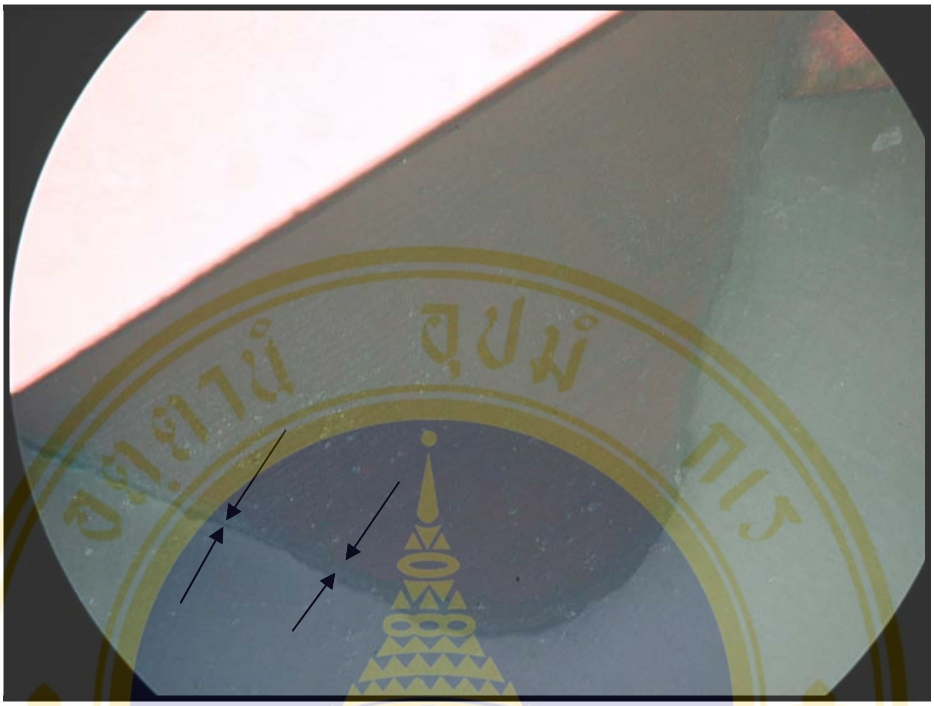

Figure 5. Microscopic image show the thickness of adhesive resin and intermediate resin. The arrow was indicated thickness. (x 25)

Evaluation of microtensile bond strength

After microleakage evaluation, the specimens were subjected for microtensile test. The slabs of specimens were trimmed at gingival wall into dumbbell-shaped by a super-fine diamond point bur (C16) under water coolant. The cross-sectioned area at resin- dentin interface was approximately 1.0 mm^2. The trimmed specimens were attached into a testing apparatus (Bencor-T Multi testing apparatus) with a cyanoacrylate adhesive (Model Repair II Blue) on a universal testing machine (Instron Model 5566). The tensile forces were applied at a crosshead speed of 1 mm/min. The fracture strength were calculated from maximal force with the attached computer and converted into MPa.

Evaluation of fracture mode

Fractured specimens from microtensile bond strength test were kept in 10% buffer formalin for 24 hours. After storage time, the specimens were rinsed under tap water and attached onto the metal stub. The attached specimens were observed for the failure modes under the scanning electron microscope. The failure modes were classified into adhesive failure, cohesive failure in resin and cohesive failure in dentin. The fractured areas were recorded into the percentage of each category of failure modes.

CHAPTER VI

RESULTS

The thickness of adhesive layers and intermediate resin layers are demonstrated in Figure 6 and 7. The statistical analysis was performed using one-way ANOVA. The film thicknesses of Adper™ Single Bond and Adper™ Single Bond 2 for all groups under unloaded and loaded conditions were not significantly different (p=0.079) with the mean value of 0.025 mm. The thickness for Filtek™ Flow in group 3 and group 4 under unloaded and loaded conditions were not significantly different (p=0.49) with mean value of 0.082 mm.

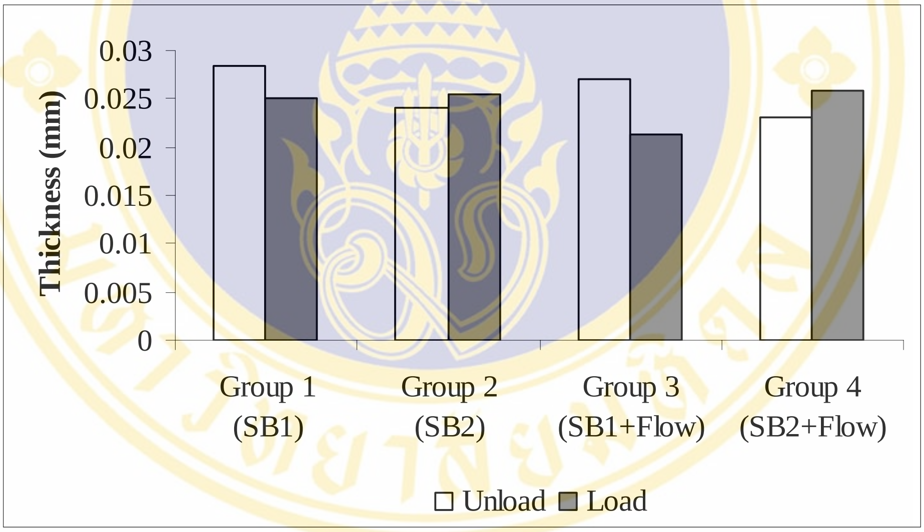

Figure 6. Means thickness of adhesive layers.

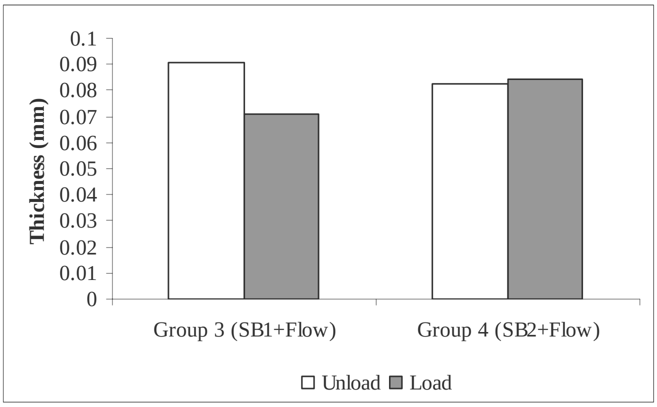

Figure 7. Means thickness of low viscosity resin layers.

Mean values and standard deviations of elastic modulus obtained by nano-indentation are shown in Figure 8. The modulus of elasticity of each layer are 25,111.05 MPa for dentin, 12,243.43 MPa for hybrid layer of Adper™ Single Bond, 11,765.44 MPa for hybrid layer of Adper™ Single Bond 2, 7,594.53 MPa for Adper™ Single bond, 8,430.28 MPa for Adper™ Single bond 2, 13,542.97 MPa for Filtek™ Flow and 24,494.03 MPa for Filtek™ Z250 resin composite. The statistical analysis was performed using one-way ANOVA and Dunnett multiple comparison at 95% confident interval. There were significant differences among layers ($p<0.05$) except between hybrid layer of Adper™ Single Bond and hybrid layer of Adper™ Single Bond 2 ($p=1.0$)

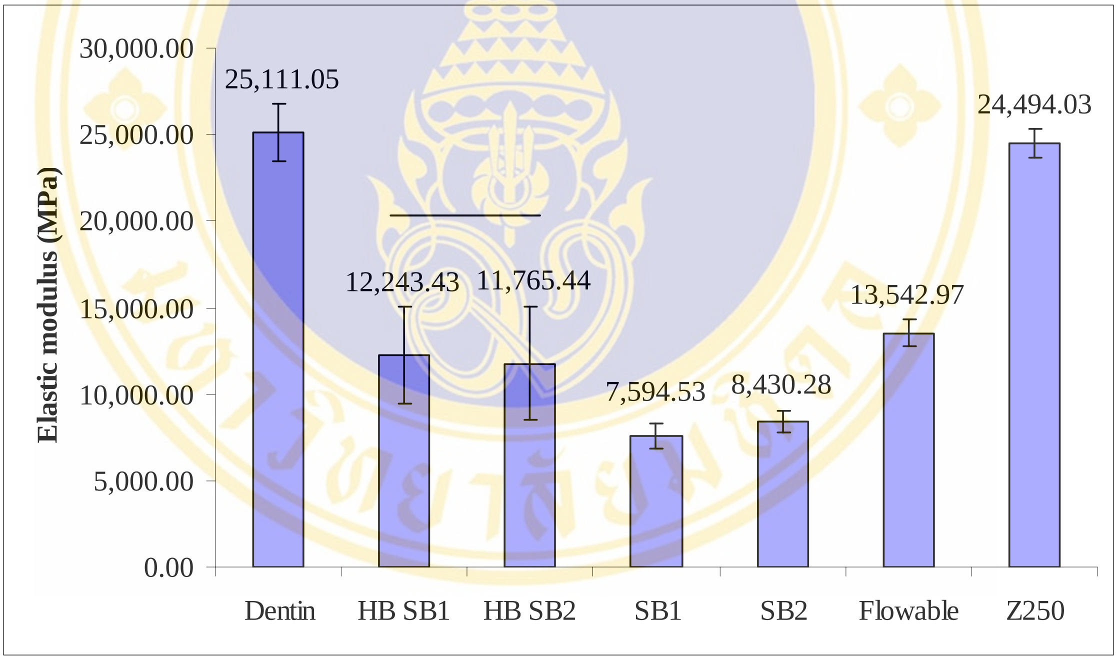

Figure 8. Means elastic modulus of all substrates determined by nano-indentation. Vertical bars represent standard deviations. The horizontal line indicates no significant difference between groups. (HB = Hybrid layer; SB1 = Adper™ Single Bond; SB2 = Adper™ Single Bond 2; Flowable = Filtek™ Flow; Z250 = Filtek™ Z250)

The means of microleakage at enamel margin and dentin margin are shown in Table 4 and 5 and Figure 9 and 10. Statistical analysis was performed using Two-way ANOVA and Dunnett's multiple comparison at 95% confident interval. The Levene's test for homogeneity of variance demonstrated p-value<0.05. There were no significant differences of microleakage among groups on both enamel and dentin margin (p=0.098, p=0.607). No statistically significant differences were found between the microleakage of loaded and unloaded group on enamel margin for all materials (p=0.512). There were statistically significant differences between the microleakage of loaded and unloaded group on dentin margin for group 3 and group 4 (p=0.000, p=0.021)

Table 4. Microleakage (mean ± SD) of unloaded group. E leakage = microleakage at enamel margin; D leakage = microleakage at dentin margin. The data with the same superscript demonstrates no statistically significant differences.

Group (unload)	E Leakage (mm)	D Leakage (mm)
1 (SB1)	0.017 ± 0.03985 ^{a}	0.2849 ± 0.11388 ^{b}
2 (SB2)	0 ± 0 ^{a}	0.3662 ± 0.12821 ^{b}
3 (SB1+Flow)	0.0113 ± 0.0275 ^{a}	0.2724 ± 0.07367 ^{b}
4.(SB2+Flow)	0 ± 0 ^{a}	0.2609 ± 0.15113 ^{b}

Table 5. Microleakage (mean ± SD) of loaded group. E leakage = microleakage at enamel margin; D leakage = microleakage at dentin margin. The data with the same superscript demonstrates no statistically significant differences.

Group (load)	E Leakage (mm)	D Leakage (mm)
1 (SB1)	0.0248 ± 0.0457 ^{a}	0.4084 ± 0.2286 ^{b}
2 (SB2)	0 ± 0 ^{a}	0.4063 ± 0.1041 ^{b}
3 (SB1+Flow)	0.0233 ± 0.0808 ^{a}	0.4544 ± 0.0656 ^{b}
4.(SB2+Flow)	0 ± 0 ^{a}	0.4142 ± 0.1465 ^{b}

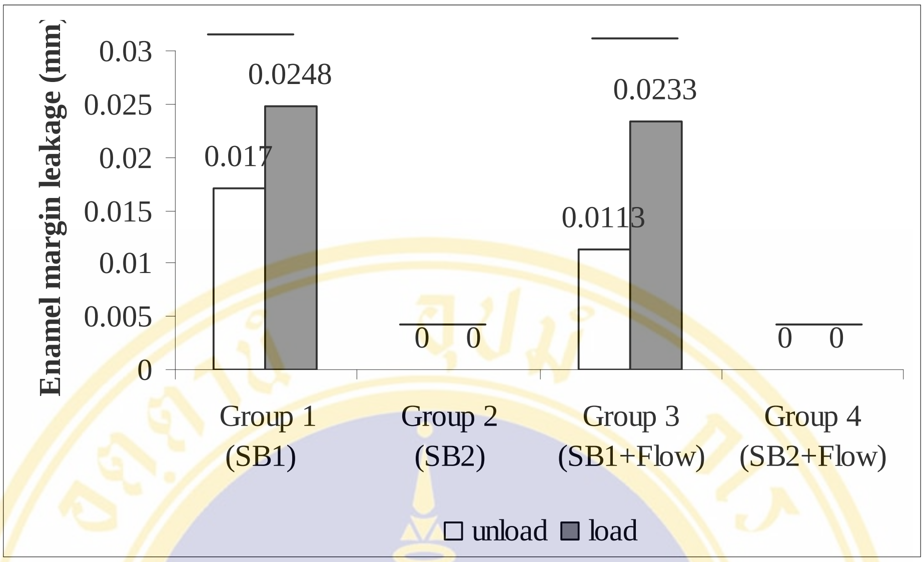

Figure 9. Comparison of microleakage (mean) at the enamel margin of unloaded and loaded class V restorations. The data under the horizontal lines demonstrates no statistically significant difference.

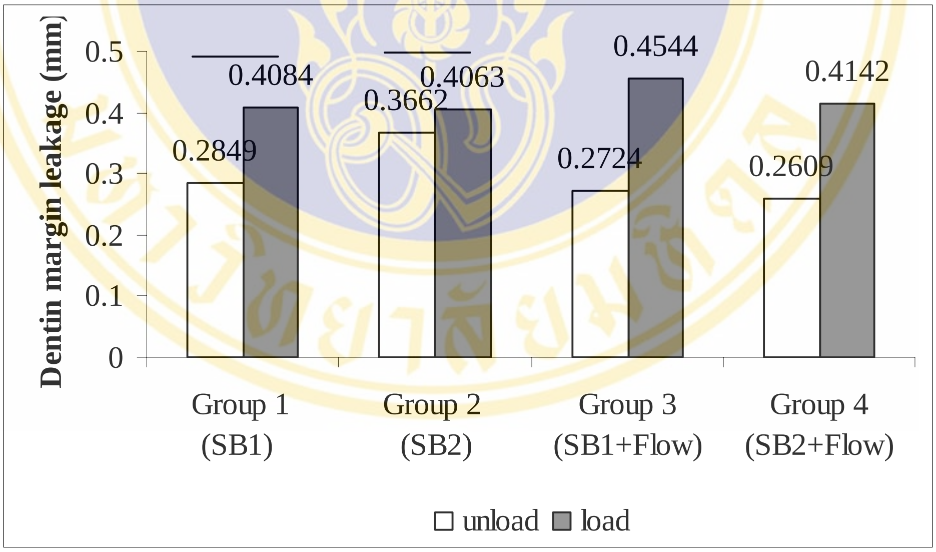

Figure 10. Comparison of microleakage (mean) at the dentin margin of unloaded and loaded class V restorations. The data under the horizontal lines demonstrates no statistically significant difference.

The differences of microleakage between enamel and dentin margin of each group were analyzed using independent student T-test at 95% confident interval. Dentin margins had significantly higher microleakage than enamel margins ($p<0.05$)

The means microtensile bond strengths and standard deviations are shown in Table 6 and Figure 11. The results were statistically analyzed using two-way ANOVA and LSD multiple comparison at 95% confident interval. The Levene’s test for homogeneity of variance demonstrated p-value = 0.366. For unloaded group, there were no significant differences of microtensile bond strengths among group 1,2 and 3 and group 2, 3 and 4. The significant difference was found between group 1 and 4 at p = 0.016. For loaded group, there were no significant differences between group 1 and 2 and group 3 and 4 (Table 6). There were no statistically significant differences of microtensile bond strength between loaded and unloaded groups except for group 2 (p=0.031) (Figure 11).

Table 6. Microtensile bond strength (mean ± SD) in MPa. The data with the same superscript demonstrate no statistical difference among groups.

Group	Unload	Load
1 (SB1)	22.83 ± 4.61553 ^{a}	19.5475 ± 5.22445 ^{c}
2 (SB2)	23.9403 ± 6.23087 ^{a,b}	18.6792 ± 4.84374 ^{c}
3 (SB1+Flow)	27.2142 ± 4.10959 ^{a,b}	25.98 ± 7.71375 ^{d}
4.(SB2+Flow)	28.3133 ± 6.2499 ^{b}	28.5625 ± 6.43689 ^{d}

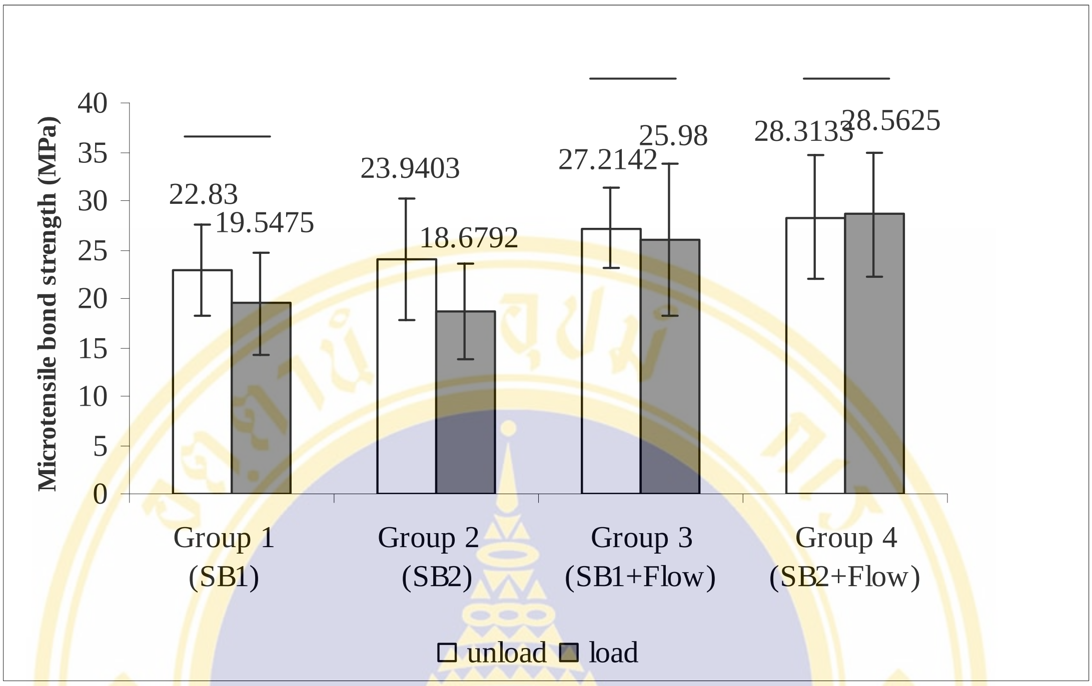

Figure 11. Comparison of microtensile bond strength (mean ± SD) at the dentin wall of unloaded and loaded class V restorations. The data connected with the horizontal line demonstrate no significant difference.

The representative pictures of adhesive, cohesive failure after microtensile bond strength test are shown in Figure 12 and 13 respectively. For statistical analysis, One-way ANOVA and Dunnett's multiple comparison were applied at 95% confident interval. Percentages of failure mode in unloaded and loaded conditions are shown in Figure 14 and 15. Adhesive failure was observed prominently in all groups. There were no significant differences of the percentages of failure among groups under unloaded conditions. Nevertheless, the statistically significant differences of percentages of failure were found under loaded condition.

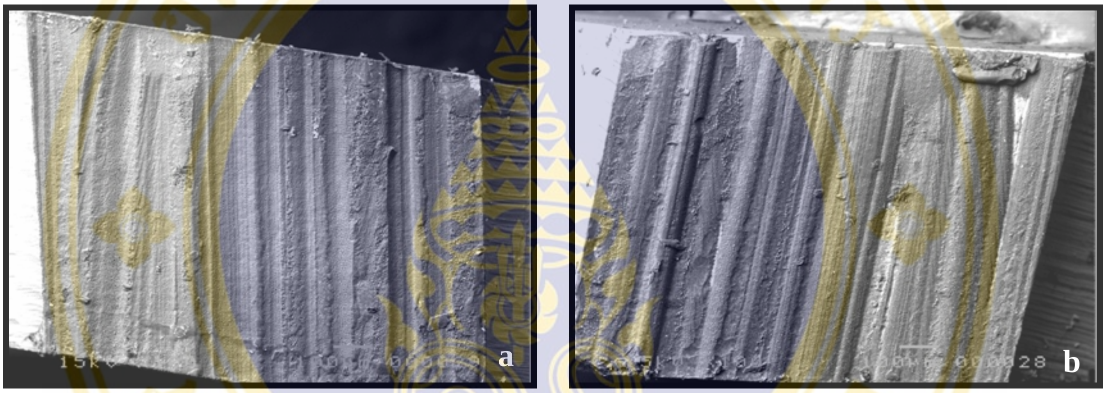

Figure 12. SEM observation of the fractured surface on dentin side (a) and resin side (b). Adhesive fracture occurred within the resin/dentin interface of the specimens (x 100)

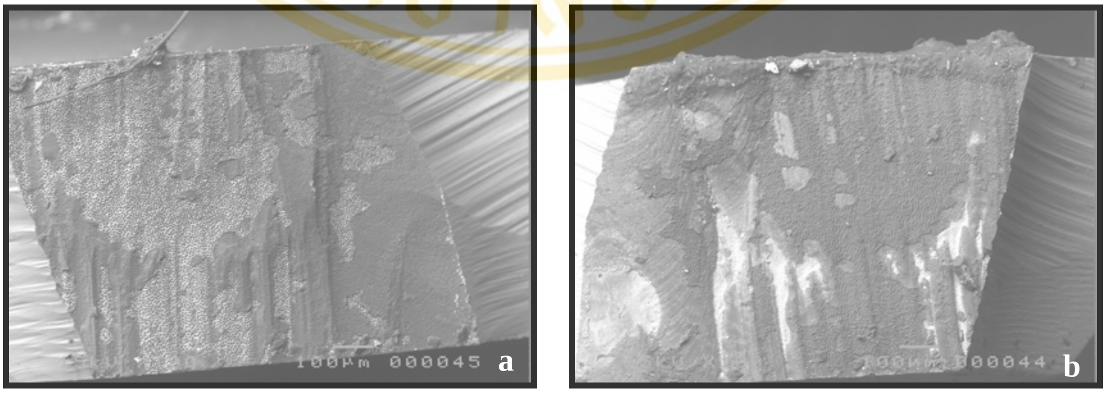

Figure 13 SEM observation of the fractured surface on dentin side (a) and resin side (b). Both adhesive fracture and cohesive fracture within resin was observed (x 100)

In the loaded condition, the groups that flowable composite were applied demonstrated higher percentages of cohesive failure within resin than other groups. Significant difference of percentages of failure were found between SB1 and SB2-Flow groups (p<0.01) and SB2 and SB2-Flow groups (p<0.01).

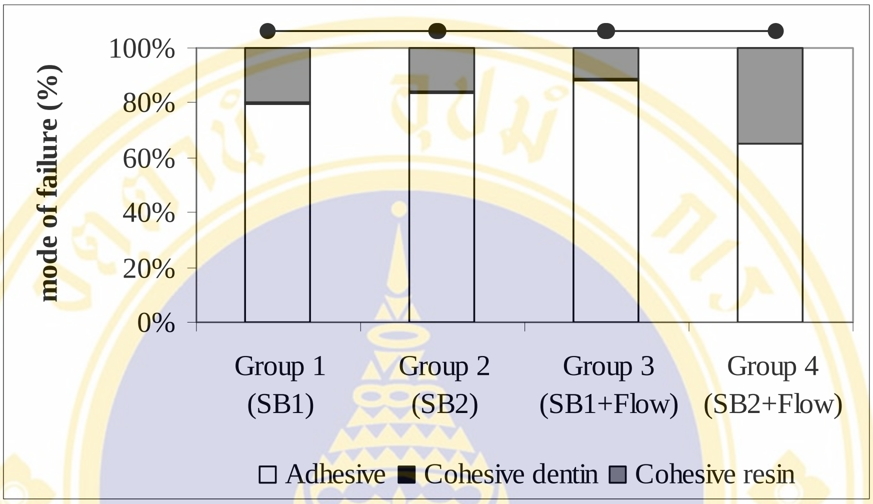

Figure 14. Mode of failure (%) under unloaded conditions. The data connected with the horizontal line demonstrate no statistically significant difference.

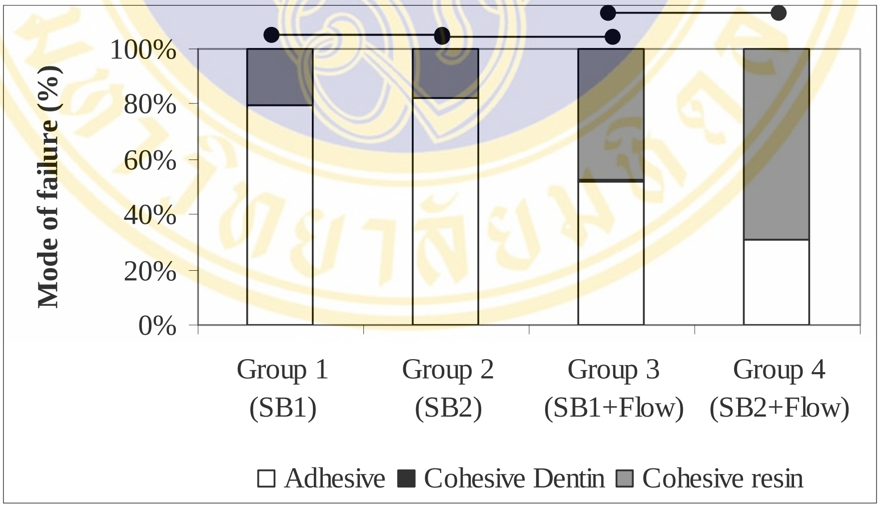

Figure 15. Mode of failure (%) under loaded conditions. The data connected with the horizontal lines demonstrate no statistically significant difference.

When the failure mode of loaded and unloaded groups were compared, statistically significant difference was found only between loaded and unloaded groups of SB1-Flow (p=0.016)

SEM micrographs of the resin-dentin interfaces are demonstrated in Figure 16-23. The penetration of the resin into the dentinal tubules and the formation of a resin-dentin interdiffusion area or hybrid layer were observed for all groups. The thicknesses of hybrid layers were approximately 3-6 µm when SB1 and SB2 were applied. The well defined resin/dentin interface without any separations was observed for both loaded and unloaded groups.

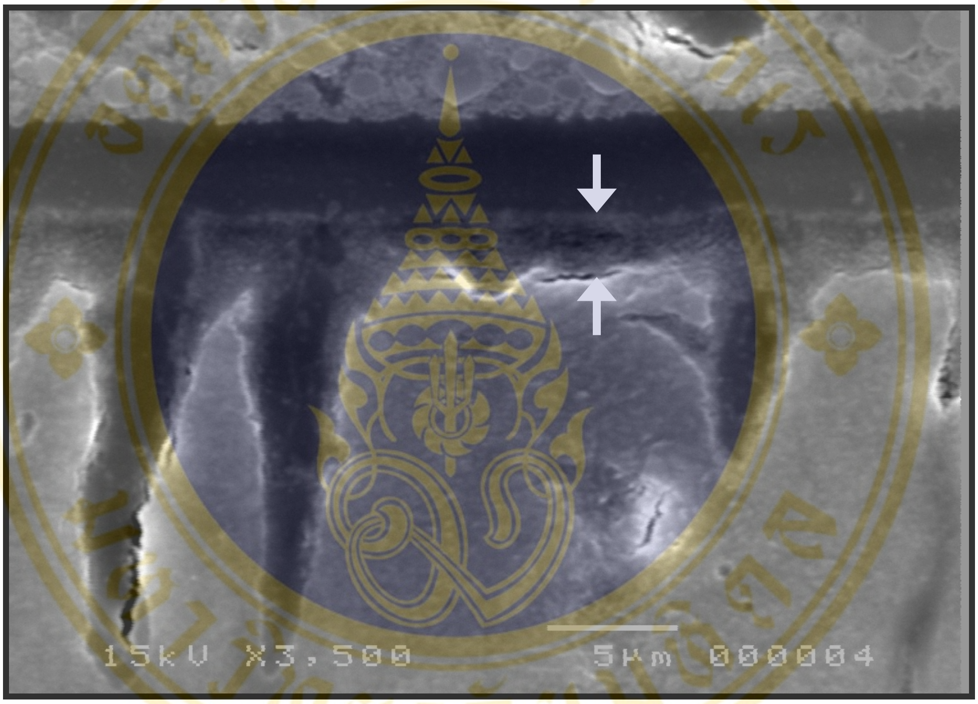

Figure 16. SEM image of the resin-dentin interface at dentin margin of unloaded group 1 (SB1). The arrow indicates thickness of hybrid layer. (x 3,500)

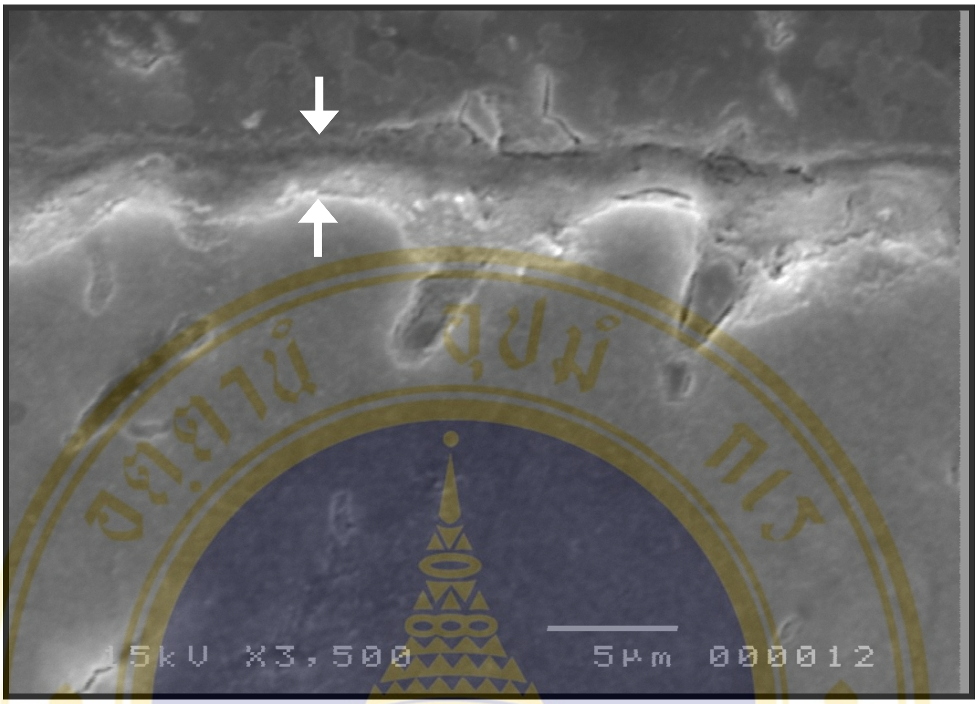

Figure 17. SEM image of the resin-dentin interface at dentin margin of unloaded group 2 (SB2). The arrow indicates thickness of hybrid layer. (x 3,500)

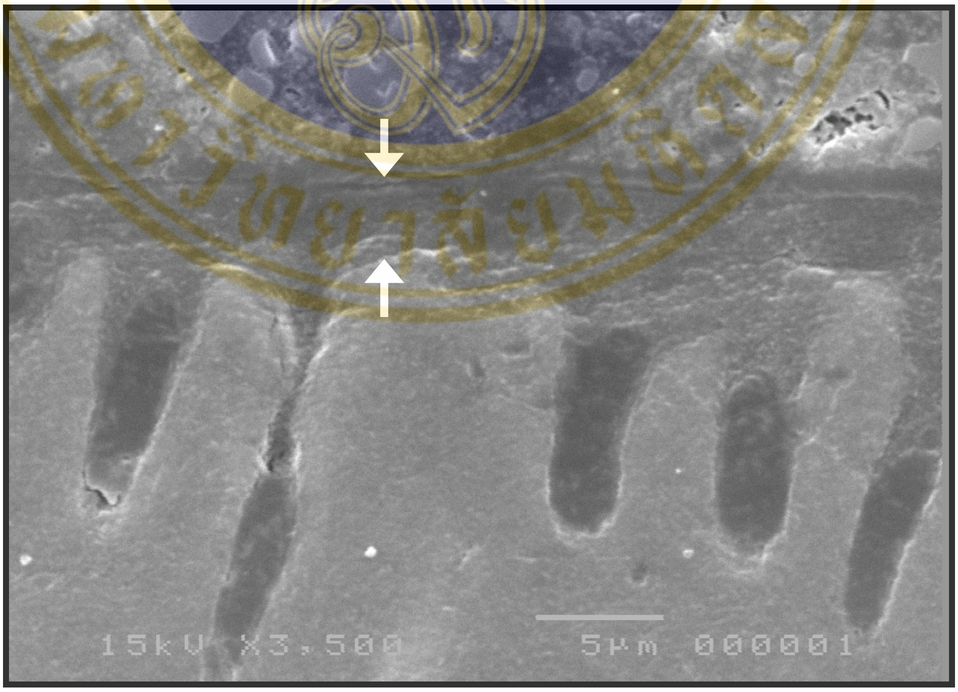

Figure 18. SEM image of the resin-dentin interface at dentin margin of unloaded group 3 (SB1+Flow). The arrow indicates thickness of hybrid layer. (x 3,500)

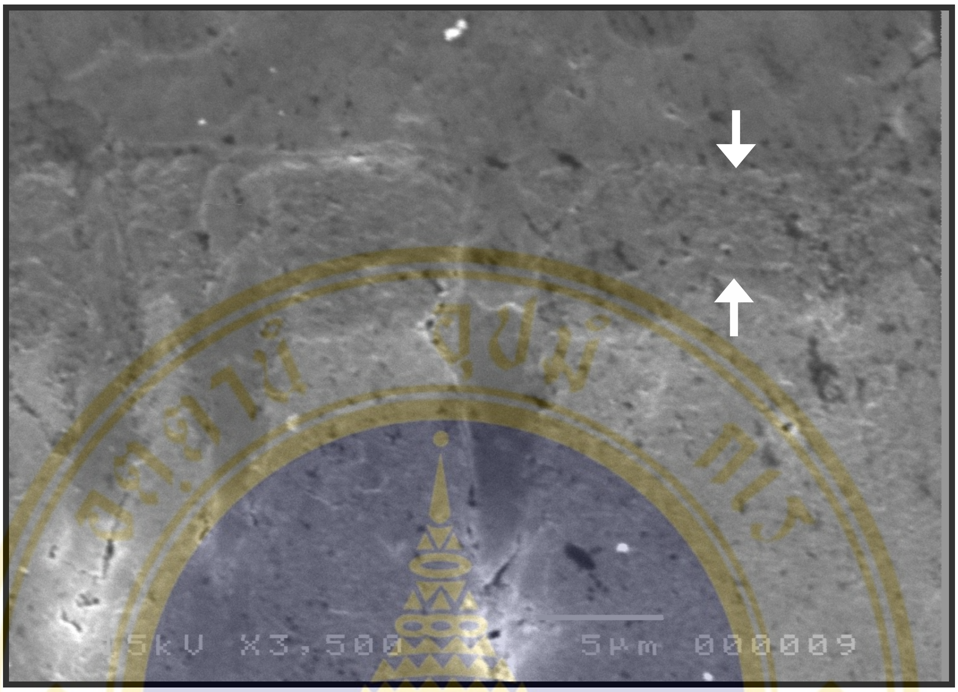

Figure 19. SEM image of the resin-dentin interface at dentin margin of unloaded group 4 (SB2+ Flow). The arrow indicates thickness of hybrid layer. (x 3,500)

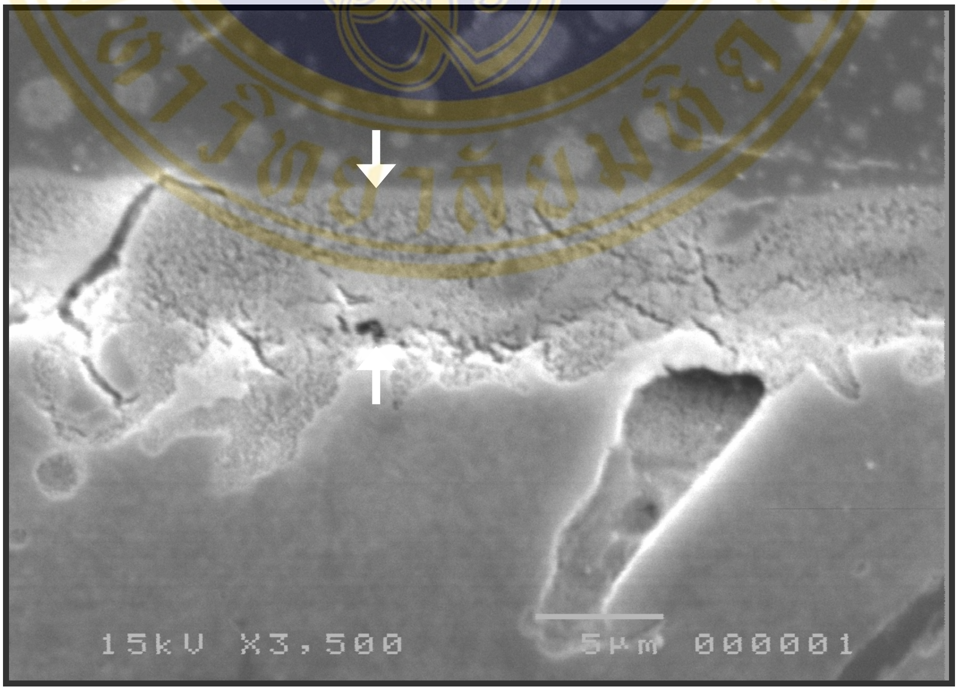

Figure 20. SEM image of the resin-dentin interface at dentin margin of loaded group 1 (SB1). The arrow indicates thickness of hybrid layer. (x 3,500)

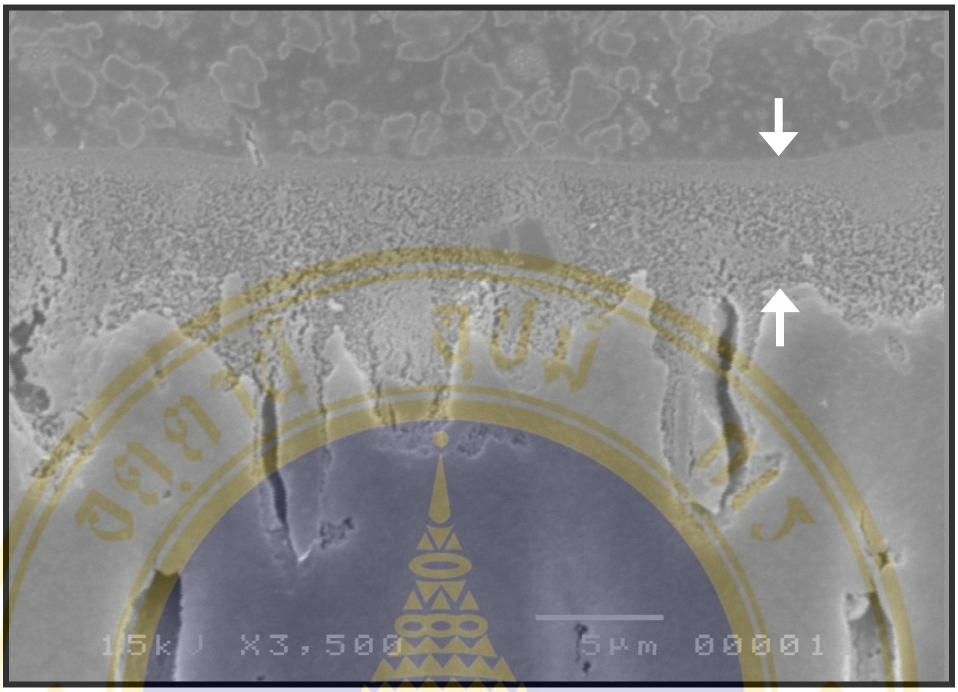

Figure 21. SEM image of the resin-dentin interface at dentin margin of loaded group 2 (SB2). The arrow indicates thickness of hybrid layer. (x 3,500)

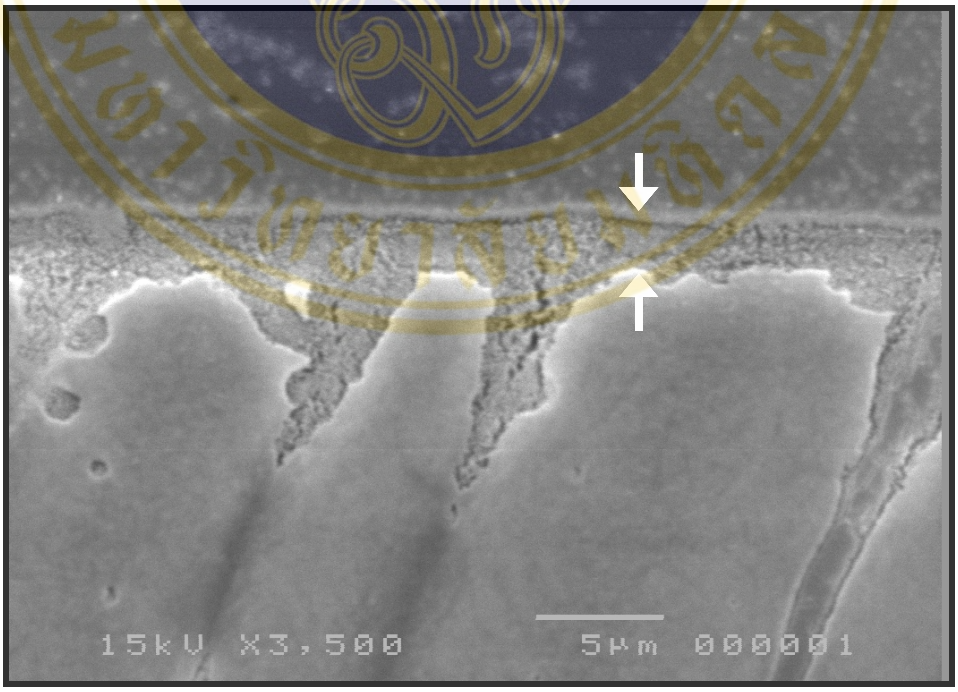

Figure 22. SEM image of the resin-dentin interface at dentin margin of loaded group 3 (SB1+ Flow). The arrow indicates thickness of hybrid layer. (x 3,500)

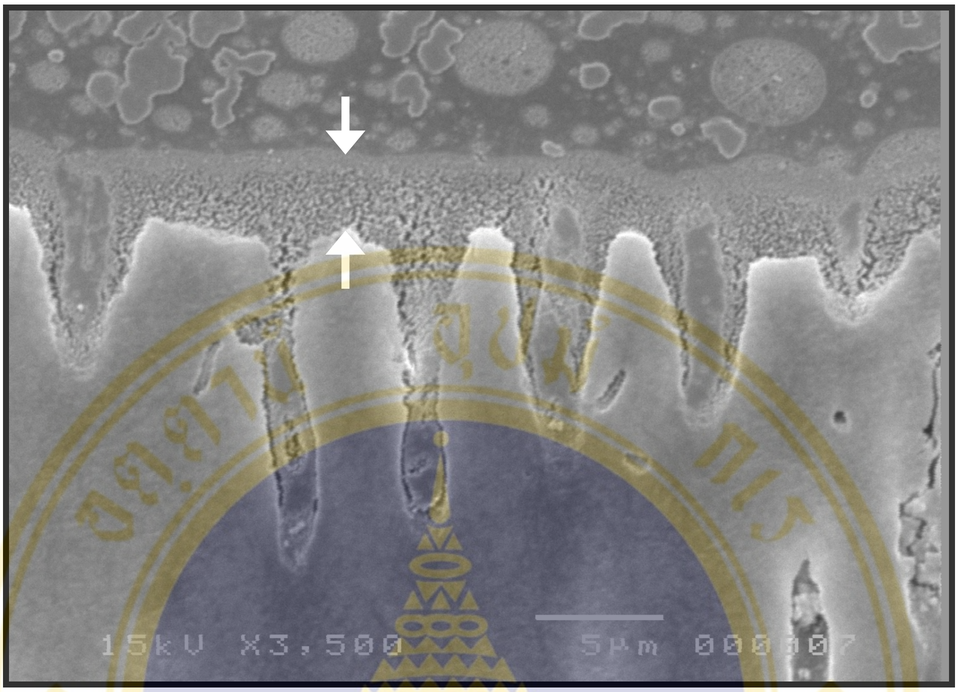

Figure 23. SEM image of the resin-dentin interface at dentin margin of loaded group 4 (SB2+Flow). The arrow indicates thickness of hybrid layer. (x 3,500)

CHAPTER VII

DISCUSSIONS

Elastic cavity wall created by the application of either a low viscosity resin (9) or filled adhesive resin (33, 34) has been proved. This wall acts as an inherent buffer to compensate for the polymerization contraction of resin composite (9) and transfer occlusal stress to the underneath tooth structure. Therefore, the reduction of the failure rate of composite restoration can be obtained (72). Two testing conditions were performed in this study. First, unloading condition was used to evaluate the effect of contraction stress of resin composite to the bond strength and microleakage and used control. Second, loading condition was used to evaluate the effect of occlusal loading to bond strength and leakage and used as experimental group to simulate the clinical situation. In this study, 50 N occlusal force was applied parallel to the long axis of the tooth for 250,000 cycles under 100% humidity. This loading condition has been verified as one year of clinical wear (79-80).

In class V restoration, the thicker layers of relatively low modulus resin or adhesive can significantly reduce the contraction stress of composite restorations and consequently reduce the overall degree of microleakage at the marginal areas (45 - 47). The thickness of these layers were measured and statistically analyzed. The statistical analysis confirmed no significant difference of thickness. Thus the effect of thickness of adhesive layers and low viscosity layers could be excluded from this study. The thicknesses were approximately 0.025 mm for adhesive layer and 0.082 mm for low viscosity resin layer as presents in Figure 6, 7. Zheng and coworker (2001) proposed that the thickness of adhesive layer in the range of 0.007 to 0.025 mm provided the highest tensile bond strength (47).

The evaluation of elastic modulus at the successive layer across the resin dentin interface has been studies and demonstrated the strain capacity of elastic buffer layer (32). Because a small area of resin/dentin interface was evaluated, the nano-indentation technique with a small three-sided pyramid probe under 5,000 mgf loading on dentin, adhesive and resin composite and 1,000 mgf loading on hybrid layers was used. This method was performed in an isolation chamber with a temperature controller on an anti-vibration isolator in order to minimize the influence of environmental condition such as room temperature, floor vibration and noise (81). The size of an imprint after indentation test was approximately 1 µm in diameter that was small enough to evaluate the modulus of elasticity at the small explicit area such as adhesive layer and hybrid layer at resin dentin interface (32). In this study the elastic modulus of dentin was 25,111.05 MPa. This value was higher than that in the study of Van Meerbeek and coworker (32). However, it was in the line with the studies of Urabe and coworker (81) and Senawongse and coworker (82). In addition, elastic modulus of hybrid layer, adhesive layer, low viscosity resin and resin composite were lower than that of dentin was similar to a previous study (32). At the resin/dentin interface, a gradient of elasticity was observed from the relatively stiff dentin, over the more elastic hybrid layer, the adhesive layer, and the low viscosity resin to the resin composite restoration (Figure 8). Such a gradient elastic bonding area might have a strain capacity to relieve stresses from polymerization shrinkage and occlusal loading between composite restoration and the rigid dentin substrate. This area has been proved to resist the stress induced by thermal change and water sorption (32).

Two adhesive resins were employed in this study. There were an unfilled adhesive resin (Adper™ Single Bond) and a filled adhesive resin (Adper™ Single Bond 2). Effect of filler content in resin-based materials to modulus of elasticity was observed. The filled adhesive had significantly higher modulus of elasticity than the unfilled adhesive. This finding is in agreement with the result of a previous study (33). The size of filler (approximately 5 nm) in adhesive resin should penetrate into the larger into interfibrillar space of 20 nm (83) to form hybrid layer. Since, in this study, the filler content in adhesive resin had no effect on the elastic modulus of hybrid layer, the further study should be performed to explain about this result.

The elastic modulus of adhesive layers and hybrid layers infiltrated with both filled adhesive and unfilled adhesive in the present study was higher than those in the previous study (32). The differences of testing conditions and materials used might be responsible for this result.

For the microleakage test, the methylene blue was used because of its contrasting color. Additionally, the dye has been proved to have no chemical reaction or no destruction to the specimen (56 - 59, 61).

Marginal seal is one of the most important factors for the success of a restoration. Many studies have shown that bonding of restorative material to enamel is adequate to resist contraction stress (5). In this investigation, all restorations demonstrated less microleakage at the occlusal margins than at the dentin margins because of the effectiveness of the acid-etch technique in sealing cavity margins on enamel. Various degrees of microleakage occurred along the gingival margins that were placed on dentin. Currently, the resin composite restorations of the cavities having margins partly or totally located in the dentin are still an unsolved problem.

The efficiency of filler containing in adhesive or the low viscosity layer to reduce the microleakage on both enamel and dentin margins was not exhibited in this study. No significant differences of microleakage among groups were found. This indicated that the filled-adhesive and flowable composite resin could not decrease the microleakage caused by polymerization contraction of resin composite in all groups. The result of this study was comparable to the study by Cardoso and coworker who compared the microleakage performance of filled and unfilled adhesive with the use of hybrid resin composite and they found no significantly less leakage in Class V cavities when filled adhesive was applied (85). In contrast, several authors have reported encouraging results in reducing microleakage with the use of flowable composite restorative materials (84). When loading force was applied, increase of marginal leakage was exhibited only at dentin margin. There were no statistical significant differences of microleakage at enamel margin for all materials (Figure 9). The explanation might be due to the highly effective enamel bond of total-etching adhesive system (5) even under occlusal loading. There was a statistically significant difference of the microleakage at dentin margin between unloaded and loaded condition in group 3 and group 4 (Figure 10). Use of flowable composite in group 3 and 4 in loaded condition demonstrated higher microleakage at the dentin margin compared with unloaded condition. It seems that, low viscosity resin had negative effect on the marginal leakage at dentin margin. The thick layers of low viscosity resin with low elastic modulus might present the defect within the thick layers after occlusal loading that caused high degree of marginal leakage compared with other groups. Further study may be necessary to confirm this result.

When comparing the leakage between enamel and dentin margins, the leakage at dentin margin was higher than at enamel margin for both loaded and unloaded condition that confirmed the previous results (86, 87). It indicated that all enamel margins were fairly well sealed. The enamel roughness created by acid etching might be sufficiently pronounced to offer adequate micromechanical retention and sealing ability.

For bond strength test, microtensile bond strength method was used in this study. This method has been developed and demonstrated advantages over the traditional test method. The microtensile test enables more accurate in measurement because the hourglass design of the specimen imposes the highest uniform distributions of stress during testing. The uniform stress distribution has been claimed to reduce the scatter of bond values and achieve high bond strength (48-50). In addition, this method permits the investigation of interfacial bond strength on area smaller than 1 mm^2 that is very practical in this study especially for Class V restoration (52).

For unloaded condition, there were no significant differences of microtensile bond strength among group 1, 2 and 3 and group 2, 3 and 4. However, there was significant difference between group 1 and 4 (Table 5). It means that the application of only filled adhesive resin or the application of low viscosity resin onto unfilled adhesive resin as stress absorber could not improve microtensile bond strength. The application of both filled adhesive together with flowable composite could improve the microtensile bond strength of resin composite to dentin and has benefit over other groups.

The microtensile bond strength for loaded group demonstrated no significant differences between group 1 and 2 and group 3 and 4 (Table 5). The application of low viscosity resin resulted in increasing of dentin bond strength at dentin margin of class V restoration. This result indicated that flowable composite could improve microtensile bond strength by resist the force from occlusal loading. The use of low viscosity resin combination with adhesive system might have a higher strain capacity to relieve stresses between composite restoration and the rigid dentin substrates due to occlusal loading (32).

Application of filled adhesive both under unloaded and loaded conditions did not improve the bond strength when compared to the unfilled adhesive group that was in the line with previous studies (88, 89). The improvement of bond strength by application of filled adhesive that was proposed by Fanning and coworker (10) could not observe in this study.

The effect of loading to the bond strength also was investigated. It had an influence when the filled adhesive was applied. Further study may be necessary to find the explanation of this result.

After bond strength test, the fractured specimens were further observed under the SEM. Application of low viscosity resin as stress absorber tended to increase bond strength and increase the percentage of cohesive failure in resin. The increasing of cohesive failure in resin was observed clearly in group 4 especially under loaded condition (Figure 14, 15). The thick layers of low viscosity resin with low elastic modulus might be damaged and present the defect after occlusal loading, caused increasing of percentage of cohesive failure in this thick layer. Further study may be necessary to confirm this result.

The SEM micrographs of all groups demonstrate in Figure 16-23. The thickness of hybrid layers were approximately 3-6 µm both for Adper™ Single Bond and Adper™ Single Bond 2 that was similar to a previous studies (90). The resin dentin interfaces might have the ability to resist the contraction stress generated by polymerization shrinkage and occlusal loading, thereby, establishing a good bond to dentin without any gap formation that confirmed a previous study (6). The addition of fillers into adhesive system had no effect to the micromorphology of hybrid layer under the SEM.

From the results of this study, the application of filled adhesive combination with low viscosity resin might be recommended because it presented the highest bond strength and comparable leakage to other groups under unloaded and loaded conditions.

CHAPTER VIII

CONCLUSIONS

Within the limitation of this experiment, it can be concluded that:

1. The modulus of elasticity of resin dentin interface; hybrid layer, adhesive layer, low viscosity layer, was less than those of dentin and resin composite.
2. Application of filled adhesive did not increase the elastic modulus of hybrid layer when comparing with the unfilled adhesive resin, even though, the modulus of filled adhesive was significantly higher than that of unfilled adhesive.
3. The application of filled adhesive or low viscosity resin had no influence on marginal leakage both at enamel and dentin margin.
4. Occlusal loading significantly increased degree of marginal leakage at dentin margin when low viscosity was applied in combination with two adhesive systems.
5. The application of filled adhesive or low viscosity resin had an influence on microtensile bond strength to dentin of class V restoration.
6. Occlusal loading significantly decreased dentin bond strength the group that was treated by only filled adhesive.

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APPENDIX

Data of adhesive thickness

				BONDING THICKNESS
GROUP1	SB1	1		.03
		2		.02
		3		.03
		4		.03
		5		.03
		6		.03
		7		.03
		8		.03
		9		.02
		10		.03
		11		.03
		12		.03
		Total	N	12
			Mean	.0284
			Std. Deviation	.00511
			Minimum	.02
			Maximum	.03
GROUP2	SB2	1		.02
		2		.02
		3		.02
		4		.03
		5		.03
		6		.04
		7		.03
		8		.02
		9		.02
		10		.02
		11		.02
		12		.03
		Total	N	12
			Mean	.0240
			Std. Deviation	.00655
			Minimum	.02
			Maximum	.04

				BONDING THICKNESS
GROUP3	SB1+Flow	1		.03
		2		.02
		3		.03
		4		.02
		5		.02
		6		.04
		7		.02
		8		.04
		9		.03
		10		.02
		11		.03
		12		.03
		Total	N	12
			Mean	.0271
			Std. Deviation	.00714
			Minimum	.02
			Maximum	.04
GROUP4	SB2+Flow	1		.02
		2		.03
		3		.02
		4		.02
		5		.03
		6		.02
		7		.02
		8		.02
		9		.02
		10		.03
		11		.02
		12		.04
		Total	N	12
			Mean	.0231
			Std. Deviation	.00605
			Minimum	.02
			Maximum	.04

				BONDING THICKNESS
GROUP1	Load SB1	1		.03
		2		.03
		3		.02
		4		.02
		5		.02
		6		.03
		7		.02
		8		.02
		9		.03
		10		.03
		11		.03
		12		.02
		Total	N	12
			Mean	.0250
			Std. Deviation	.00463
			Minimum	.02
			Maximum	.03
GROUP2	Load SB2	1		.01
		2		.02
		3		.02
		4		.03
		5		.02
		6		.04
		7		.03
		8		.02
		9		.03
		10		.03
		11		.04
		12		.03
		Total	N	12
			Mean	.0255
			Std. Deviation	.00636
			Minimum	.01
			Maximum	.04

				BONDING THICKNESS
GROUP3	Load SB1+Flow	1		.02
		2		.02
		3		.03
		4		.02
		5		.02
		6		.03
		7		.02
		8		.02
		9		.02
		10		.02
		11		.03
		12		.02
		Total	N	12
			Mean	.0213
			Std. Deviation	.00422
			Minimum	.02
			Maximum	.03
GROUP4	Load SB2+Flow	1		.02
		2		.02
		3		.02
		4		.02
		5		.03
		6		.03
		7		.04
		8		.03
		9		.03
		10		.03
		11		.02
		12		.02
		Total	N	12
			Mean	.0259
			Std. Deviation	.00470
			Minimum	.02
			Maximum	.04
	Total	N		96
		Mean		.0250
		Std. Deviation		.00587
		Minimum		.01
		Maximum		.04

Statistical analysis of adhesive thickness

Test of Homogeneity of Variances

BONDING

Levene Statistic	df1	df2	Sig.
.733	7	88	.645

ANOVA

BONDING

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.000	7	.000	1.901	.079
Within Groups	.003	88	.000		
Total	.003	95			

Data of flowable thickness

				FLOWABLE THICK
GROUP3	SB1+Flow	1		.19
		2		.10
		3		.09
		4		.08
		5		.04
		6		.14
		7		.05
		8		.08
		9		.15
		10		.05
		11		.06
		12		.07
		Total	N	12
			Mean	.0908
			Std. Deviation	.04539
			Minimum	.04
			Maximum	.19
GROUP4	SB2+Flow	1		.03
		2		.05
		3		.04
		4		.14
		5		.08
		6		.11
		7		.07
		8		.06
		9		.08
		10		.09
		11		.13
		12		.13
		Total	N	12
			Mean	.0828
			Std. Deviation	.03753
			Minimum	.03
			Maximum	.14

				FLOWABLE THICK
GROUP3	Load SB1+Flow	1		.07
		2		.08
		3		.08
		4		.06
		5		.06
		6		.09
		7		.07
		8		.08
		9		.08
		10		.07
		11		.06
		12		.07
		Total	N	12
			Mean	.0708
			Std. Deviation	.00889
			Minimum	.06
			Maximum	.09
GROUP4	Load SB2+Flow	1		.06
		2		.06
		3		.06
		4		.09
		5		.05
		6		.10
		7		.08
		8		.10
		9		.10
		10		.09
		11		.12
		12		.09
		Total	N	12
			Mean	.0842
			Std. Deviation	.02193
			Minimum	.05
			Maximum	.12
	Total	N		48
		Mean		.0821
		Std. Deviation		.03155
		Minimum		.03
		Maximum		.19

Statistical analysis of flowable thickness

Test of Homogeneity of Variances

FLOW

Levene Statistic	df1	df2	Sig.
6.291	3	44	.001

ANOVA

FLOW

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.002	3	.001	.820	.490
Within Groups	.044	44	.001		
Total	.047	47			

Data of elastic modulus at resin-dentin interface

			MODULUS
DENTIN	1		23990.30
	2		23519.14
	3		23460.24
	4		23470.06
	5		24029.57
	6		26787.86
	7		24225.89
	8		23440.61
	9		27101.98
	10		26140.01
	11		26787.86
	12		23528.95
	13		27563.33
	14		23067.60
	15		24186.62
	16		27160.87
	17		26630.81
	18		23195.21
	19		26768.23
	20		23087.23
	21		26944.92
	22		27082.34
	23		26630.81
	24		22390.30
	25		26346.14
	26		27268.85
	27		24373.13
	28		26169.46
	29		23313.00
	30		23587.85
	31		26218.54
	32		25973.14
	33		24540.00
	34		26925.29
	35		27327.74
	36		26571.91
	37		27092.16
	38		25030.80
	39		27013.63
	40		25953.50

	41		28073.76
	42		25629.58
	43		24569.45
	44		23617.30
	45		23607.48
	46		24932.64
	47		25266.38
	48		25030.80
	49		23587.85
	50		23283.55
	51		25079.88
	52		25364.54
	53		23617.30
	54		25541.23
	55		26277.43
	56		23725.27
	57		24412.39
	58		23342.45
	59		25933.87
	60		24088.46
	61		25070.06
	62		26454.12
	63		23519.14
	64		29065.18
	65		24785.40
	66		25982.95
	67		26454.12
	68		23705.64
	69		27533.88
	70		24481.10
	71		25982.95
	72		26630.81
	73		23332.63
	74		20181.70
	75		25276.20
	76		24392.76
	77		23450.42
	78		24373.13
	79		24697.06
	80		28594.01
	81		23195.21
	82		22910.54
	83		25747.37
	84		24225.89

	85		25747.37
	86		24471.29
	87		24657.79
	88		22939.99
	89		26866.39
	90		27337.56
	91		24382.94
	92		25757.18
	93		27425.90
	94		25344.91
	95		26218.54
	96		26552.28
	97		25452.89
	98		25178.04
	99		26316.70
	100		22851.65
	101		24765.77
	102		22851.65
	103		24765.77
	104		24716.69
	105		23803.80
	106		27524.06
	107		28868.86
	108		24824.66
	109		26149.82
	110		24657.79
	111		24716.69
	112		26778.05
	113		21830.78
	114		21673.73
	115		24059.02
	116		26571.91
	117		24343.68
	118		25776.82
	119		23411.16
	120		23813.62
	Total	N	120
		Mean	25111.0458
		Std. Deviation	1633.00390
		Std. Error of Mean	149.07218
		Kurtosis	-.255

			MODULUS
HYBRID SINGLE BOND	1		11504.35
	2		10022.14
	3		11347.30
	4		10198.82
	5		12270.00
	6		9729.62
	7		8998.33
	8		10758.34
	9		11023.37
	10		12103.13
	11		12760.80
	12		12142.39
	13		11818.46
	14		13241.78
	15		9518.58
	16		12112.94
	17		14439.34
	18		10493.30
	19		13987.80
	20		14085.96
	21		13909.27
	22		12917.86
	23		12377.98
	24		11739.94
	25		10758.34
	26		10512.94
	27		11867.54
	28		12976.75
	29		11720.30
	30		10709.26
	31		12338.71
	32		12191.47
	33		16000.08
	34		17551.01
	35		8762.74
	36		9408.64
	37		18414.82
	38		9128.88
	39		9248.64
	40		15097.01
	41		12073.68
	42		19808.69

	43		10414.78
	44		18434.45
	45		11867.54
	46		10238.09
	47		11435.64
	48		11946.07
	49		19092.12
	50		19396.42
	51		15784.13
	52		11337.48
	53		10611.10
	54		10630.73
	55		9791.46
	56		8642.01
	57		10208.64
	58		10866.31
	59		13281.05
	60		8556.61
	Total	N	60
		Mean	12243.4314
		Std. Deviation	2773.41832
		Std. Error of Mean	358.04677
		Kurtosis	1.093

			MODULUS
HYBRID SINGLE BOND 2	1		15882.29
	2		14704.37
	3		14213.57
	4		8892.31
	5		7913.66
	6		7969.61
	7		8043.23
	8		9665.82
	9		12574.30
	10		9992.69
	11		9646.18
	12		13114.18
	13		8640.04
	14		9865.08
	15		14350.99
	16		8245.44
	17		12760.80
	18		12466.32
	19		10296.98
	20		7308.01
	21		10316.62
	22		9224.10
	23		14557.13
	24		14439.34
	25		16647.94
	26		11759.57
	27		8021.64
	28		9098.45
	29		10650.36
	30		10316.62
	31		7862.62
	32		6902.61
	33		8495.75
	34		7758.57
	35		7362.00
	36		11160.79
	37		11219.69
	38		9482.26
	39		10002.50
	40		7347.28
	41		17639.35
	42		18984.14

	43		14252.83
	44		12643.01
	45		14144.86
	46		14458.97
	47		12152.21
	48		10807.42
	49		15352.22
	50		11710.49
	51		15293.33
	52		12888.41
	53		10208.64
	54		14036.88
	55		19327.70
	56		15234.43
	57		19906.85
	58		10100.66
	59		13742.40
	60		13870.01
	Total	N	60
		Mean	11765.4412
		Std. Deviation	3260.10056
		Std. Error of Mean	420.87717
		Kurtosis	-.332

			MODULUS
ADPER™ SINGLE BOND	1		9545.08
	2		8033.41
	3		10365.70
	4		7666.30
	5		9050.35
	6		7302.12
	7		7989.24
	8		7347.28
	9		7732.06
	10		7030.22
	11		7062.61
	12		7244.21
	13		7089.12
	14		6944.82
	15		6838.81
	16		7297.21
	17		6910.46
	18		7057.70
	19		6925.19
	20		6851.57
	21		7396.36
	22		7136.23
	23		7321.75
	24		9444.96
	25		7064.58
	26		6876.11
	27		6995.86
	28		7533.78
	29		7506.30
	30		6752.43
	31		8536.98
	32		8232.68
	33		7432.68
	34		7138.20
	35		7525.93
	36		7413.04
	37		7262.86
	38		7287.40
	39		7253.04
	40		7224.58
	41		8551.70
	42		8205.19

	43		7363.96
	44		7361.02
	45		7489.61
	46		7211.82
	47		7599.55
	48		7622.12
	49		7378.69
	50		7547.52
	51		7246.17
	52		7380.65
	53		7779.18
	54		8785.32
	55		7630.96
	56		7582.86
	57		7518.07
	58		7577.95
	59		8541.88
	60		7678.08
	Total	N	60
		Mean	7594.5247
		Std. Deviation	709.78683
		Std. Error of Mean	91.63309
		Kurtosis	4.030

			MODULUS
ADPER™ SINGLE BOND 2	1		8080.53
	2		8002.00
	3		8900.17
	4		8598.82
	5		8706.79
	6		7430.71
	7		7832.19
	8		8505.56
	9		8905.08
	10		8235.62
	11		7997.10
	12		8765.69
	13		7668.26
	14		7945.07
	15		8736.24
	16		7972.56
	17		8210.10
	18		8224.83
	19		8642.99
	20		8375.01
	21		8402.50
	22		8451.58
	23		8584.09
	24		8298.45
	25		8376.97
	26		9282.99
	27		8893.30
	28		8563.48
	29		8451.58
	30		8465.32
	31		8485.93
	32		8119.80
	33		7957.83
	34		8181.64
	35		8640.04
	36		8775.50
	37		8055.99
	38		9017.96
	39		9332.07
	40		8853.05
	41		9096.49
	42		8394.64

	43		7638.81
	44		9142.62
	45		9074.89
	46		8495.75
	47		7430.71
	48		9006.18
	49		7206.91
	50		8319.06
	51		7587.77
	52		7543.60
	53		7933.29
	54		8257.22
	55		7903.84
	56		8029.49
	57		8412.31
	58		8666.55
	59		10355.88
	60		10395.14
	Total	N	60
		Mean	8430.2753
		Std. Deviation	603.95400
		Std. Error of Mean	77.97013
		Kurtosis	2.141

			MODULUS
FILTEK™ FLOW	1		13516.63
	2		13791.48
	3		13281.05
	4		12917.86
	5		12750.98
	6		13732.58
	7		13074.91
	8		11965.70
	9		14360.81
	10		12809.88
	11		12574.30
	12		14429.52
	13		14331.36
	14		14301.91
	15		13555.90
	16		13654.06
	17		13192.70
	18		13624.61
	19		13997.62
	20		13654.06
	21		14213.57
	22		13438.10
	23		13428.29
	24		13899.46
	25		13850.38
	26		14233.20
	27		14174.30
	28		13389.02
	29		14125.22
	30		12525.22
	31		14017.25
	32		13182.89
	33		14370.62
	34		13938.72
	35		14164.49
	36		13791.48
	37		14174.30
	38		14272.46
	39		11396.38
	40		13516.63
	41		13035.65
	42		13281.05

	43		13438.10
	44		13762.03
	45		14085.96
	46		14154.67
	47		11651.59
	48		13585.34
	49		10915.39
	50		14125.22
	51		13938.72
	52		13860.19
	53		14213.57
	54		13330.13
	55		14125.22
	56		13870.01
	57		13614.79
	58		14203.75
	59		11828.28
	60		13938.72
	Total	N	60
		Mean	13542.9716
		Std. Deviation	771.81838
		Std. Error of Mean	99.64132
		Kurtosis	2.346

			MODULUS
FILTEK™ Z250	1		24863.93
	2		24913.01
	3		23450.42
	4		23195.21
	5		24186.62
	6		24687.24
	7		23911.78
	8		24687.24
	9		22223.42
	10		23754.72
	11		24157.18
	12		25128.96
	13		24225.89
	14		24824.66
	15		23489.69
	16		24962.09
	17		24647.98
	18		25452.89
	19		26208.72
	20		24294.60
	21		25344.91
	22		22822.20
	23		24677.42
	24		25011.17
	25		23597.66
	26		24176.81
	27		23990.30
	28		25217.30
	29		25590.31
	30		24559.63
	31		24402.58
	32		24127.73
	33		23322.82
	34		24471.29
	35		23097.05
	36		23528.95
	37		22154.71
	38		23872.51
	39		23617.30
	40		23764.54
	41		24844.30
	42		24471.29

	43		23057.78
	44		24736.32
	45		24029.57
	46		24284.78
	47		25020.98
	48		23047.97
	49		24942.46
	50		24000.12
	51		24540.00
	52		23607.48
	53		24245.52
	54		24127.73
	55		23951.04
	56		24706.87
	57		25070.06
	58		26670.07
	59		25462.70
	60		25580.50
	61		25305.65
	62		23970.67
	63		24942.46
	64		24854.11
	65		23646.74
	66		24775.58
	67		24962.09
	68		24569.45
	69		24628.34
	70		25482.34
	71		26620.99
	72		22939.99
	73		24726.50
	74		24913.01
	75		23303.18
	76		25276.20
	77		24186.62
	78		24559.63
	79		25227.12
	80		23774.35
	81		25472.52
	82		25236.94
	83		25943.69
	84		23499.50
	85		24873.74
	86		24971.90

	87		24716.69
	88		23362.08
	89		24049.20
	90		25246.75
	91		24844.30
	92		23597.66
	93		24932.64
	94		25217.30
	95		25384.18
	96		24353.50
	97		25629.58
	98		23754.72
	99		24147.36
	100		24971.90
	101		25030.80
	102		24569.45
	103		24382.94
	104		24471.29
	105		23313.00
	106		22959.62
	107		25325.28
	108		24343.68
	109		25001.35
	110		24893.38
	111		24059.02
	112		24461.47
	113		25236.94
	114		25079.88
	115		26297.06
	116		25178.04
	117		24746.14
	118		24775.58
	119		25187.86
	120		24088.46
	Total	N	120
		Mean	24494.0284
		Std. Deviation	836.95140
		Std. Error of Mean	76.40286
		Kurtosis	.309

Statistical analysis for elastic modulus at resin-dentin interface

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	ELASTIC	Statistic	df	Sig.	Statistic	df	Sig.
MODULUS	dentine	.062	120	.200*	.983	120	.140

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	ELASTIC	Statistic	df	Sig.	Statistic	df	Sig.
MODULUS	hybrid layer single bon	.181	60	.000	.879	60	.000

a. Lilliefors Significance Correction

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	ELASTIC	Statistic	df	Sig.	Statistic	df	Sig.
MODULUS	hybrid layer single bon	.122	60	.027	.950	60	.016

a. Lilliefors Significance Correction

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	ELASTIC	Statistic	df	Sig.	Statistic	df	Sig.
MODULUS	single bond1	.220	60	.000	.810	60	.000

a. Lilliefors Significance Correction

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	ELASTIC	Statistic	df	Sig.	Statistic	df	Sig.
MODULUS	single bond2	.067	60	.200*	.948	60	.013

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	ELASTIC	Statistic	df	Sig.	Statistic	df	Sig.
MODULUS	filtek flow	.141	60	.005	.851	60	.000

a. Lilliefors Significance Correction

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	ELASTIC	Statistic	df	Sig.	Statistic	df	Sig.
MODULUS	z250	.070	120	.200*	.986	120	.239

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Test of Homogeneity of Variances

MODULUS

Levene Statistic	df1	df2	Sig.
49.730	6	533	.000

ANOVA

MODULUS

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.8E+10	6	4677737442	1590.100	.000
Within Groups	1.6E+09	533	2941788.260		
Total	3.0E+10	539			

Dunnett T3 Multiple Comparisons

			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
	(I) ELASTIC	(J) ELASTIC				Lower Bound	Upper Bound
Dunnett T3	dentine	hybrid layer single bond1	12867.6144	387.84017	.000	11656.0307	14079.1982
		hybrid layer single bond2	13345.6046	446.49760	.000	11947.4272	14743.7819
		single bond1	17516.5211	174.98325	.000	16978.8125	18054.2298
		single bond2	16680.7705	168.23155	.000	16163.4808	17198.0602
		filtek flow	11568.0742	179.30674	.000	11017.1733	12118.9751
		z250	617.0174	167.51093	.006	102.3537	1131.6811
	hybrid layer single bond1	dentine	-12867.6144	387.84017	.000	-14079.1982	-11656.0307
		hybrid layer single bond2	477.9901	552.57134	1.000	-1232.3715	2188.3517
		single bond1	4648.9067	369.58640	.000	3487.3383	5810.4751
		single bond2	3813.1561	366.43803	.000	2660.1145	4966.1976
		filtek flow	-1299.5402	371.65290	.017	-2466.7391	-132.3414
		z250	-12250.5970	366.10775	.000	-13402.7026	-11098.4915
	hybrid layer single bond2	dentine	-13345.6046	446.49760	.000	-14743.7819	-11947.4272
		hybrid layer single bond1	-477.9901	552.57134	1.000	-2188.3517	1232.3715
		single bond1	4170.9166	430.73683	.000	2815.5492	5526.2839
		single bond2	3335.1660	428.03847	.000	1987.0590	4683.2729
		filtek flow	-1777.5304	432.51126	.002	-3137.6942	-417.3666
		z250	-12728.5872	427.75576	.000	-14075.9075	-11381.2668
	single bond1	dentine	-17516.5211	174.98325	.000	-18054.2298	-16978.8125
		hybrid layer single bond1	-4648.9067	369.58640	.000	-5810.4751	-3487.3383
		hybrid layer single bond2	-4170.9166	430.73683	.000	-5526.2839	-2815.5492
		single bond2	-835.7506	120.31610	.000	-1208.1618	-463.3394
		filtek flow	-5948.4469	135.36992	.000	-6367.2934	-5529.6004
		z250	-16899.5037	119.30641	.000	-17267.5561	-16531.4514
	single bond2	dentine	-16680.7705	168.23155	.000	-17198.0602	-16163.4808
		hybrid layer single bond1	-3813.1561	366.43803	.000	-4966.1976	-2660.1145
		hybrid layer single bond2	-3335.1660	428.03847	.000	-4683.2729	-1987.0590
		single bond1	835.7506	120.31610	.000	463.3394	1208.1618
		filtek flow	-5112.6963	126.52167	.000	-5504.5745	-4720.8182
		z250	-16063.7531	109.16381	.000	-16399.7955	-15727.7107
	filtek flow	dentine	-11568.0742	179.30674	.000	-12118.9751	-11017.1733
		hybrid layer single bond1	1299.5402	371.65290	.017	132.3414	2466.7391
		hybrid layer single bond2	1777.5304	432.51126	.002	417.3666	3137.6942
		single bond1	5948.4469	135.36992	.000	5529.6004	6367.2934
		single bond2	5112.6963	126.52167	.000	4720.8182	5504.5745
		z250	-10951.0568	125.56190	.000	-11338.9353	-10563.1783
	z250	dentine	-617.0174	167.51093	.006	-1131.6811	-102.3537
		hybrid layer single bond1	12250.5970	366.10775	.000	11098.4915	13402.7026
		hybrid layer single bond2	12728.5872	427.75576	.000	11381.2668	14075.9075
		single bond1	16899.5037	119.30641	.000	16531.4514	17267.5561
		single bond2	16063.7531	109.16381	.000	15727.7107	16399.7955
		filtek flow	10951.0568	125.56190	.000	10563.1783	11338.9353

* The mean difference is significant at the .05 level.

Data of microleakage and microtensile bond strength

					ELEAKAGE	DLEAKAGE	BONDSTR
GROUP1	SB1	unload	1		.00	.20	17.41
			2		.57	.17	16.12
			3		.58	.15	27.31
			4		.00	.48	20.45
			5		.00	.13	24.35
			6		.00	.47	27.59
			7		.00	.30	19.57
			8		.00	.31	25.97
			9		.00	.27	30.22
			10		.62	.27	18.93
			11		.09	.39	26.09
			12		.11	.30	19.95
			Total	N	12	12	12
				Mean	.1651	.2849	22.8300
				Std. Deviation	.26036	.11388	4.61553
				Std. Error of Mean	.07516	.03287	1.33239
				Maximum	.62	.48	30.22
				Minimum	.00	.13	16.12
		load	1		.00	.33	22.44
			2		.00	.42	13.43
			3		.00	.26	15.55
			4		.12	.13	13.83
			5		.00	.20	22.64
			6		.00	.15	22.16
			7		.09	.24	18.24
			8		.00	.10	31.13
			9		.00	.11	21.29
			10		.00	.09	14.03
			11		.08	.20	16.77
			12		.00	.02	23.06
			Total	N	12	12	12
				Mean	.0248	.1880	19.5475
				Std. Deviation	.04575	.11211	5.22445
				Std. Error of Mean	.01321	.03236	1.50817
				Maximum	.12	.42	31.13
				Minimum	.00	.02	13.43

					ELEAKAGE	DLEAKAGE	BONDSTR
GROUP2	SB2	unload	1		.00	.62	23.38
			2		.00	.59	32.56
			3		.00	.47	23.04
			4		.00	.17	25.43
			5		.00	.27	19.33
			6		.00	.19	13.29
			7		.00	.35	20.72
			8		.00	.26	22.34
			9		.00	.53	15.80
			10		.00	.41	31.01
			11		.00	.35	32.12
			12		.00	.40	28.26
			Total	N	12	12	12
				Mean	.0000	.3828	23.9403
				Std. Deviation	.00000	.14728	6.23087
				Std. Error of Mean	.00000	.04252	1.79870
				Maximum	.00	.62	32.56
				Minimum	.00	.17	13.29
		load	1		.00	.45	13.29
			2		.00	.31	16.57
			3		.00	.39	13.19
			4		.00	.25	22.44
			5		.00	.22	26.56
			6		.00	.51	14.83
			7		.00	.33	19.43
			8		.00	.37	26.08
			9		.00	.35	16.52
			10		.00	.55	14.11
			11		.00	.18	17.79
			12		.00	.20	23.34
			Total	N	12	12	12
				Mean	.0000	.3418	18.6792
				Std. Deviation	.00000	.11845	4.84374
				Std. Error of Mean	.00000	.03419	1.39827
				Maximum	.00	.55	26.56
				Minimum	.00	.18	13.19

					ELEAKAGE	DLEAKAGE	BONDSTR
GROUP3	SB1+Flow	unload	1		.00	.24	21.89
			2		.05	.22	29.66
			3		.00	.21	22.63
			4		.09	.26	28.27
			5		.00	.45	25.81
			6		.00	.40	25.36
			7		.00	.46	25.32
			8		.00	.26	29.73
			9		.00	.21	29.34
			10		.00	.25	27.05
			11		.00	.27	37.25
			12		.00	.46	24.26
			Total	N	12	12	12
				Mean	.0113	.3057	27.2142
				Std. Deviation	.02756	.10164	4.10959
				Std. Error of Mean	.00796	.02934	1.18634
				Maximum	.09	.46	37.25
				Minimum	.00	.21	21.89
		load	1		.28	.44	24.37
			2		.00	.43	23.36
			3		.00	.40	32.59
			4		.00	.72	30.30
			5		.00	.45	18.84
			6		.00	.53	13.83
			7		.00	.46	35.97
			8		.00	.44	24.42
			9		.00	.51	25.44
			10		.00	.32	19.77
			11		.00	.57	21.85
			12		.00	.79	41.01
			Total	N	12	12	12
				Mean	.0233	.5044	25.9800
				Std. Deviation	.08083	.13295	7.71375
				Std. Error of Mean	.02333	.03838	2.22677
				Maximum	.28	.79	41.01
				Minimum	.00	.32	13.83

					ELEAKAGE	DLEAKAGE	BONDSTR
GROUP4	SB2+Flow	unload	1		.00	.28	28.94
			2		.00	.43	21.89
			3		.00	.14	24.03
			4		.00	.22	28.45
			5		.00	.55	29.31
			6		.00	.06	29.89
			7		.00	.18	31.61
			8		.00	.46	21.57
			9		.00	.32	26.97
			10		.00	.11	22.29
			11		.00	.18	44.70
			12		.00	.20	30.11
			Total	N	12	12	12
				Mean	.0000	.2609	28.3133
				Std. Deviation	.00000	.15113	6.24990
				Std. Error of Mean	.00000	.04363	1.80419
				Maximum	.00	.55	44.70
				Minimum	.00	.06	21.57
		load	1		.00	.33	23.91
			2		.00	.26	19.89
			3		.00	.43	34.19
			4		.00	.38	36.70
			5		.00	.39	30.73
			6		.00	.83	21.30
			7		.00	.34	34.36
			8		.00	.38	32.52
			9		.00	.52	33.32
			10		.00	.38	18.29
			11		.00	.34	25.16
			12		.00	.36	32.38
			Total	N	12	12	12
				Mean	.0000	.4124	28.5625
				Std. Deviation	.00000	.14652	6.43689
				Std. Error of Mean	.00000	.04230	1.85817
				Maximum	.00	.83	36.70
				Minimum	.00	.26	18.29

Tests of normal of distribution

Tests of Normality[b,c]

	MATERIAL	Kolmogorov-Smirnov[a] Statistic	df	Sig.	Shapiro-Wilk Statistic	df	Sig.
ELEAKAGE	SB1	.498	12	.000	.479	12	.000
	SB1+Flow	.492	12	.000	.484	12	.000
DLEAKAGE	SB1	.177	12	.200*	.933	12	.410
	SB2	.104	12	.200*	.974	12	.944
	SB1+Flow	.363	12	.000	.742	12	.002
	SB2+Flow	.187	12	.200*	.932	12	.400
BONDSTR	SB1	.197	12	.200*	.932	12	.405
	SB2	.122	12	.200*	.956	12	.731
	SB1+Flow	.187	12	.200*	.907	12	.196
	SB2+Flow	.220	12	.112	.831	12	.021

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

b. ELEAKAGE is constant when MATERIAL = SB2. It has been omitted.

c. ELEAKAGE is constant when MATERIAL = SB2+Flow. It has been omitted.

Statistical analysis of enamel microleakage

Levene's Test of Equality of Error Variances[a]

Dependent Variable: ELEAKAGE

F	df1	df2	Sig.
5.199	7	88	.000

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept+MATERIAL+LOAD+MATERIAL * LOAD

Tests of Between-Subjects Effects

Dependent Variable: ELEAKAGE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power[a]
Corrected Model	.010[b]	7	.001	1.058	.397	7.408	.432
Intercept	.009	1	.009	6.386	.013	6.386	.705
MATERIAL	.009	3	.003	2.167	.098	6.501	.534
LOAD	.001	1	.001	.434	.512	.434	.100
MATERIAL * LOAD	.001	3	.000	.158	.924	.473	.078
Error	.121	88	.001				
Total	.140	96					
Corrected Total	.131	95					

a. Computed using alpha = .05

b. R Squared = .078 (Adjusted R Squared = .004)

Statistical analysis of dentin microleakage

Levene's Test of Equality of Error Variances[a]

Dependent Variable: DLEAKAGE

F	df1	df2	Sig.
3.231	7	88	.004

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept+MATERIAL+LOAD+MATERIAL * LOAD

Tests of Between-Subjects Effects

Dependent Variable: DLEAKAGE

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power[a]
Corrected Model	.471[b]	7	.067	3.676	.002	25.735	.967
Intercept	12.320	1	12.320	672.570	.000	672.570	1.000
MATERIAL	.034	3	.011	.615	.607	1.845	.174
LOAD	.371	1	.371	20.233	.000	20.233	.994
MATERIAL * LOAD	.067	3	.022	1.219	.308	3.656	.316
Error	1.612	88	.018				
Total	14.404	96					
Corrected Total	2.083	95					

a. Computed using alpha = .05

b. R Squared = .226 (Adjusted R Squared = .165)

Statistical analysis of dentin microleakage between unloaded and loaded

T-Test Group 1

Group Statistics

	LOAD	N	Mean	Std. Deviation	Std. Error Mean
DLEAKAGE	unload	12	.2849	.11388	.03287
	load	12	.4084	.22860	.06599

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DLEAKAGE	Equal variances assume	4.959	.037	-1.675	22	.108	-.1235	.07373	-.27640	.02940
	Equal variances not assumed			-1.675	16.143	.113	-.1235	.07373	-.27968	.03268

T-Test Group 2

Group Statistics

	LOAD	N	Mean	Std. Deviation	Std. Error Mean
DLEAKAGE	unload	12	.3662	.12821	.03701
	load	12	.4063	.10412	.03006

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DLEAKAGE	Equal variances assume	.473	.499	-.841	22	.410	-.0401	.04768	-.13896	.05880
	Equal variances not assumed			-.841	21.112	.410	-.0401	.04768	-.13921	.05904

T-Test Group 3

Group Statistics

	LOAD	N	Mean	Std. Deviation	Std. Error Mean
DLEAKAGE	unload	12	.2724	.07367	.02127
	load	12	.4544	.06561	.01894

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DLEAKAGE	Equal variances assume	.011	.917	-6.391	22	.000	-.1820	.02848	-.24106	-.12294
	Equal variances not assumed			-6.391	21.711	.000	-.1820	.02848	-.24110	-.12290

T-Test Group 4

Group Statistics

	LOAD	N	Mean	Std. Deviation	Std. Error Mean
DLEAKAGE	unload	12	.2609	.15113	.04363
	load	12	.4124	.14652	.04230

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
DLEAKAGE	Equal variances assumed	.599	.447	-2.493	22	.021	-.1515	.06077	-.27752	-.02548
	Equal variances not assumed			-2.493	21.979	.021	-.1515	.06077	-.27753	-.02547

Statistical analysis of microleakage between enamel and dentin margins

T-Test Group 1 unload

Group Statistics

	TOOTH	N	Mean	Std. Deviation	Std. Error Mean
LEAKAGE	enamel	12	.0170	.03985	.01150
	dentin	12	.2849	.11388	.03287

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
LEAKAGE	Equal variances assumed	7.232	.013	-7.692	22	.000	-.2679	.03483	-.34015	-.19569
	Equal variances not assumed			-7.692	13.654	.000	-.2679	.03483	-.34280	-.19304

T-Test Group 2 unload

Group Statistics

	TOOTH	N	Mean	Std. Deviation	Std. Error Mean
LEAKAGE	enamel	12	.0000	.00000	.00000
	dentin	12	.3662	.12821	.03701

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
LEAKAGE	Equal variances assumed	24.029	.000	-9.894	22	.000	-.3662	.03701	-.44292	-.28941
	Equal variances not assumed			-9.894	11.000	.000	-.3662	.03701	-.44763	-.28471

T-Test Group 3 unload

Group Statistics

	TOOTH	N	Mean	Std. Deviation	Std. Error Mean
LEAKAGE	enamel	12	.0113	.02756	.00796
	dentin	12	.2724	.07367	.02127

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
LEAKAGE	Equal variances assumed	3.757	.066	-11.502	22	.000	-.2612	.02271	-.30826	-.21408
	Equal variances not assumed			-11.502	14.019	.000	-.2612	.02271	-.30986	-.21247

T-Test Group 4 unload

Group Statistics

	TOOTH	N	Mean	Std. Deviation	Std. Error Mean
LEAKAGE	enamel	12	.0000	.00000	.00000
	dentin	12	.2609	.15113	.04363

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
LEAKAGE	Equal variances assumed	27.150	.000	-5.980	22	.000	-.2609	.04363	-.35140	-.17044
	Equal variances not assumed			-5.980	11.000	.000	-.2609	.04363	-.35694	-.16489

T-Test Group 1 load

Group Statistics

	TOOTH	N	Mean	Std. Deviation	Std. Error Mean
LEAKAGE	enamel	12	.0248	.04575	.01321
	dentin	12	.4084	.22860	.06599

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
LEAKAGE	Equal variances assumed	14.283	.001	-5.700	22	.000	-.3836	.06730	-.52315	-.24401
	Equal variances not assumed			-5.700	11.880	.000	-.3836	.06730	-.53038	-.23679

T-Test Group 2 load

Group Statistics

	TOOTH	N	Mean	Std. Deviation	Std. Error Mean
LEAKAGE	enamel	12	.0000	.00000	.00000
	dentin	12	.4063	.10412	.03006

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
LEAKAGE	Equal variances assumed	25.772	.000	-13.516	22	.000	-.4063	.03006	-.46859	-.34391
	Equal variances not assumed			-13.516	11.000	.000	-.4063	.03006	-.47241	-.34009

T-Test Group 3 load

Group Statistics

	TOOTH	N	Mean	Std. Deviation	Std. Error Mean
LEAKAGE	enamel	12	.0233	.08083	.02333
	dentin	12	.4544	.06561	.01894

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
LEAKAGE	Equal variances assumed	.048	.828	-14.344	22	.000	-.4311	.03005	-.49341	-.36876
	Equal variances not assumed			-14.344	21.107	.000	-.4311	.03005	-.49356	-.36861

T-Test Group 4 load

Group Statistics

	TOOTH	N	Mean	Std. Deviation	Std. Error Mean
LEAKAGE	enamel	12	.0000	.00000	.00000
	dentin	12	.4124	.14652	.04230

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
LEAKAGE	Equal variances assumed	8.081	.009	-9.751	22	.000	-.4124	.04230	-.50013	-.32470
	Equal variances not assumed			-9.751	11.000	.000	-.4124	.04230	-.50551	-.31932

Statistical analysis of microtensile bond strength on dentin

Levene's Test of Equality of Error Variances[a]

Dependent Variable: BONDSTR

F	df1	df2	Sig.
1.108	7	88	.366

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept+MATERIAL+LOAD+MATERIAL * LOAD

Tests of Between-Subjects Effects

Dependent Variable: BONDSTR

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power[a]
Corrected Model	1224.063[b]	7	174.866	5.224	.000	36.571	.997
Intercept	57076.653	1	57076.653	1705.251	.000	1705.251	1.000
MATERIAL	983.829	3	327.943	9.798	.000	29.393	.997
LOAD	136.191	1	136.191	4.069	.047	4.069	.514
MATERIAL * LOAD	104.043	3	34.681	1.036	.381	3.108	.272
Error	2945.459	88	33.471				
Total	61246.175	96					
Corrected Total	4169.522	95					

a. Computed using alpha = .05

b. R Squared = .294 (Adjusted R Squared = .237)

Statistical analysis of dentin bond strength on unloaded groups

ANOVA

BONDSTR

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	244.713	3	81.571	2.811	.050
Within Groups	1276.845	44	29.019		
Total	1521.558	47			

Multiple Comparisons

Dependent Variable: BONDSTR

	(I) MATERIAL	(J) MATERIAL	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
LSD	SB1	SB2	-1.1102	2.19921	.616	-5.5425	3.3220
		SB1+Flow	-4.3842	2.19921	.052	-8.8164	.0481
		SB2+Flow	-5.4833*	2.19921	.016	-9.9156	-1.0511
	SB2	SB1	1.1102	2.19921	.616	-3.3220	5.5425
		SB1+Flow	-3.2739	2.19921	.144	-7.7061	1.1583
		SB2+Flow	-4.3731	2.19921	.053	-8.8053	.0591
	SB1+Flow	SB1	4.3842	2.19921	.052	-.0481	8.8164
		SB2	3.2739	2.19921	.144	-1.1583	7.7061
		SB2+Flow	-1.0992	2.19921	.620	-5.5314	3.3331
	SB2+Flow	SB1	5.4833*	2.19921	.016	1.0511	9.9156
		SB2	4.3731	2.19921	.053	-.0591	8.8053
		SB1+Flow	1.0992	2.19921	.620	-3.3331	5.5314

*. The mean difference is significant at the .05 level.

BONDSTR

	MATERIAL	N	Subset for alpha = .05	
			1	2
Duncan[a]	SB1	12	22.8300	
	SB2	12	23.9402	23.9402
	SB1+Flow	12	27.2142	27.2142
	SB2+Flow	12		28.3133
	Sig.		.065	.066

Means for groups in homogeneous subsets are displayed.

[a] Uses Harmonic Mean Sample Size = 12.000.

Statistical analysis of dentin bond strength on loaded groups

ANOVA

BONDSTR

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	843.159	3	281.053	7.411	.000
Within Groups	1668.614	44	37.923		
Total	2511.773	47			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: BONDSTR

	(I) MATERIAL	(J) MATERIAL	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
LSD	SB1	SB2	.8683	2.51406	.731	-4.1984	5.9351
		SB1+Flow	-6.4325*	2.51406	.014	-11.4993	-1.3657
		SB2+Flow	-9.0150*	2.51406	.001	-14.0818	-3.9482
	SB2	SB1	-.8683	2.51406	.731	-5.9351	4.1984
		SB1+Flow	-7.3008*	2.51406	.006	-12.3676	-2.2341
		SB2+Flow	-9.8833*	2.51406	.000	-14.9501	-4.8166
	SB1+Flow	SB1	6.4325*	2.51406	.014	1.3657	11.4993
		SB2	7.3008*	2.51406	.006	2.2341	12.3676
		SB2+Flow	-2.5825	2.51406	.310	-7.6493	2.4843
	SB2+Flow	SB1	9.0150*	2.51406	.001	3.9482	14.0818
		SB2	9.8833*	2.51406	.000	4.8166	14.9501
		SB1+Flow	2.5825	2.51406	.310	-2.4843	7.6493

*. The mean difference is significant at the .05 level.

Homogeneous Subsets

BONDSTR

	MATERIAL	N	Subset for alpha = .05	
			1	2
Duncan[a]	SB2	12	18.6792	
	SB1	12	19.5475	
	SB1+Flow	12		25.9800
	SB2+Flow	12		28.5625
	Sig.		.731	.310

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 12.000.

Statistical analysis of dentin bond strength between unloaded and loaded

T-Test Group 1

Group Statistics

	LOAD	N	Mean	Std. Deviation	Std. Error Mean
BONDSTR	unload	12	22.8300	4.61553	1.33239
	load	12	19.5475	5.22445	1.50817

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
BONDSTR	Equal variances assume	.024	.877	1.631	22	.117	3.2825	2.01242	-.89101	7.45601
	Equal variances not assumed			1.631	21.671	.117	3.2825	2.01242	-.89469	7.45969

T-Test Group 2

Group Statistics

	LOAD	N	Mean	Std. Deviation	Std. Error Mean
BONDSTR	unload	12	23.9402	6.23087	1.79870
	load	12	18.6792	4.84374	1.39827

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
BONDSTR	Equal variances assume	.521	.478	2.309	22	.031	5.2611	2.27826	.53627	9.98590
	Equal variances not assumed			2.309	20.738	.031	5.2611	2.27826	.51955	10.00262

T-Test Group 3

Group Statistics

	LOAD	N	Mean	Std. Deviation	Std. Error Mean
BONDSTR	unload	12	27.2142	4.10959	1.18634
	load	12	25.9800	7.71375	2.22677

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
BONDSTR	Equal variances assume	3.874	.062	.489	22	.630	1.2342	2.52307	-3.99836	6.46670
	Equal variances not assumed			.489	16.779	.631	1.2342	2.52307	-4.09440	6.56273

T-Test Group 4

Group Statistics

	LOAD	N	Mean	Std. Deviation	Std. Error Mean
BONDSTR	unload	12	28.3133	6.24990	1.80419
	load	12	28.5625	6.43689	1.85817

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
BONDSTR	Equal variances assume	1.133	.299	-.096	22	.924	-.2492	2.58996	-5.62042	5.12208
	Equal variances not assumed			-.096	21.981	.924	-.2492	2.58996	-5.62069	5.12235

Data of Failure modes

				ADHESIVE	CODENTIN	CORESIN
GROUP1	SB1	1		72.00	.00	28.00
		2		92.00	.00	8.00
		3		95.00	.00	5.00
		4		12.00	4.00	84.00
		5		92.00	.00	8.00
		6		93.00	.00	7.00
		7		100.00	.00	.00
		8		40.00	.00	60.00
		9		90.00	.00	10.00
		10		90.00	.00	10.00
		11		92.00	.00	8.00
		12		87.00	3.00	10.00
		Total	N	12	12	12
			Mean	79.5833	.5833	19.8333
			Std. Deviation	26.56196	1.37895	25.73584
			Minimum	12.00	.00	.00
			Maximum	100.00	4.00	84.00
GROUP2	SB2	1		100.00	.00	.00
		2		76.00	2.00	22.00
		3		100.00	.00	.00
		4		100.00	.00	.00
		5		20.00	.00	80.00
		6		100.00	.00	.00
		7		100.00	.00	.00
		8		100.00	.00	.00
		9		100.00	.00	.00
		10		80.00	.00	20.00
		11		70.00	.00	30.00
		12		60.00	.00	40.00
		Total	N	12	12	12
			Mean	83.8333	.1667	16.0000
			Std. Deviation	24.75272	.57735	24.70186
			Minimum	20.00	.00	.00
			Maximum	100.00	2.00	80.00

ADHESIVE = Adhesive failure at resin-dentin interface, CODENTIN = Cohesive failure in dentin, CORESIN= Cohesive failure in resin.

				ADHESIVE	CODENTIN	CORESIN
GROUP3	SB1+Flow	1		65.00	.00	35.00
		2		50.00	.00	50.00
		3		100.00	.00	.00
		4		96.00	4.00	.00
		5		95.00	5.00	.00
		6		97.00	3.00	.00
		7		100.00	.00	.00
		8		95.00	.00	5.00
		9		98.00	.00	2.00
		10		70.00	.00	30.00
		11		88.00	.00	12.00
		12		100.00	.00	.00
		Total	N	12	12	12
			Mean	87.8333	1.0000	11.1667
			Std. Deviation	16.71055	1.85864	17.32488
			Minimum	50.00	.00	.00
			Maximum	100.00	5.00	50.00
GROUP4	SB2+Flow	1		15.00	.00	85.00
		2		30.00	.00	70.00
		3		.00	.00	100.00
		4		95.00	.00	5.00
		5		.00	.00	100.00
		6		100.00	.00	.00
		7		100.00	.00	.00
		8		50.00	.00	50.00
		9		100.00	.00	.00
		10		100.00	.00	.00
		11		92.00	.00	8.00
		12		100.00	.00	.00
		Total	N	12	12	12
			Mean	65.1667	.0000	34.8333
			Std. Deviation	42.80364	.00000	42.80364
			Minimum	.00	.00	.00
			Maximum	100.00	.00	100.00

ADHESIVE = Adhesive failure at resin-dentin interface, CODENTIN = Cohesive failure in dentin, CORESIN= Cohesive failure in resin.

				ADHESIVE	CODENTIN	CORESIN
GROUP1	Load SB1	1		85.00	.00	15.00
		2		75.00	.00	25.00
		3		80.00	.00	20.00
		4		60.00	.00	40.00
		5		70.00	.00	30.00
		6		90.00	.00	10.00
		7		85.00	.00	15.00
		8		85.00	.00	15.00
		9		85.00	.00	15.00
		10		90.00	.00	10.00
		11		99.00	.00	1.00
		12		50.00	.00	50.00
		Total	N	12	12	12
			Mean	79.5000	.0000	20.5000
			Std. Deviation	13.76095	.00000	13.76095
			Minimum	50.00	.00	1.00
			Maximum	99.00	.00	50.00
GROUP2	Load SB2	1		85.00	.00	15.00
		2		80.00	.00	20.00
		3		95.00	.00	5.00
		4		90.00	.00	10.00
		5		50.00	.00	50.00
		6		80.00	.00	20.00
		7		95.00	.00	5.00
		8		60.00	.00	40.00
		9		80.00	.00	20.00
		10		100.00	.00	.00
		11		100.00	.00	.00
		12		70.00	.00	30.00
		Total	N	12	12	12
			Mean	82.0833	.0000	17.9167
			Std. Deviation	15.73334	.00000	15.73334
			Minimum	50.00	.00	.00
			Maximum	100.00	.00	50.00

ADHESIVE = Adhesive failure at resin-dentin interface, CODENTIN = Cohesive failure in dentin, CORESIN= Cohesive failure in resin.

				ADHESIVE	CODENTIN	CORESIN
GROUP3	Load SB1+Flow	1		50.00	.00	50.00
		2		60.00	.00	40.00
		3		10.00	.00	90.00
		4		30.00	.00	70.00
		5		15.00	.00	85.00
		6		85.00	.00	15.00
		7		60.00	.00	40.00
		8		30.00	5.00	65.00
		9		80.00	5.00	15.00
		10		70.00	.00	30.00
		11		50.00	.00	50.00
		12		80.00	5.00	15.00
		Total	N	12	12	12
			Mean	51.6667	1.2500	47.0833
			Std. Deviation	25.61368	2.26134	26.32475
			Minimum	10.00	.00	15.00
			Maximum	85.00	5.00	90.00
GROUP4	Load SB2+Flow	1		25.00	.00	75.00
		2		30.00	.00	70.00
		3		20.00	.00	80.00
		4		20.00	5.00	75.00
		5		10.00	.00	90.00
		6		.00	.00	100.00
		7		35.00	.00	65.00
		8		15.00	.00	85.00
		9		20.00	.00	80.00
		10		40.00	.00	60.00
		11		75.00	.00	25.00
		12		80.00	.00	20.00
		Total	N	12	12	12
			Mean	30.8333	.4167	68.7500
			Std. Deviation	24.29303	1.44338	24.13268
			Minimum	.00	.00	20.00
			Maximum	80.00	5.00	100.00

ADHESIVE = Adhesive failure at resin-dentin interface, CODENTIN = Cohesive failure in dentin, CORESIN= Cohesive failure in resin.

Statistical analysis of failure mode

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
ADHESIVE	5.182	7	88	.000
CODENTIN	10.570	7	88	.000
CORESIN	5.136	7	88	.000

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
ADHESIVE	Between Groups	32771.46	7	4681.637	7.325	.000
	Within Groups	56240.17	88	639.093		
	Total	89011.63	95			
CODENTIN	Between Groups	19.740	7	2.820	1.751	.108
	Within Groups	141.750	88	1.611		
	Total	161.490	95			
CORESIN	Between Groups	32461.91	7	4637.415	7.250	.000
	Within Groups	56288.08	88	639.637		
	Total	88749.99	95			

Dunnett T3 Multiple Comparisons

Adhesive failure

			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
	(I) GROUP	(J) GROUP				Lower Bound	Upper Bound
Dunnett T3	SB1	SB2	-4.2500	10.48107	1.000	-40.8999	32.3999
		SB1+Flow	-8.2500	9.05897	1.000	-40.5838	24.0838
		SB2+Flow	14.4167	14.54215	1.000	-37.5444	66.3777
		Load SB1	.0833	8.63569	1.000	-31.2447	31.4114
		Load SB2	-2.5000	8.91196	1.000	-34.4646	29.4646
		Load SB1+Flow	27.9167	10.65207	.299	-9.3159	65.1492
		Load SB2+Flow	48.7500	10.39106	.003	12.4027	85.0973
	SB2	SB1	4.2500	10.48107	1.000	-32.3999	40.8999
		SB1+Flow	-4.0000	8.62139	1.000	-34.6079	26.6079
		SB2+Flow	18.6667	14.27366	.988	-32.6312	69.9645
		Load SB1	4.3333	8.17547	1.000	-25.1464	33.8131
		Load SB2	1.7500	8.46677	1.000	-28.4456	31.9456
		Load SB1+Flow	32.1667	10.28250	.111	-3.7735	68.1068
		Load SB2+Flow	53.0000	10.01186	.001	18.0090	87.9910
	SB1+Flow	SB1	8.2500	9.05897	1.000	-24.0838	40.5838
		SB2	4.0000	8.62139	1.000	-26.6079	34.6079
		SB2+Flow	22.6667	13.26460	.874	-26.5818	71.9151
		Load SB1	8.3333	6.24904	.988	-13.5967	30.2633
		Load SB2	5.7500	6.62558	1.000	-17.4146	28.9146
		Load SB1+Flow	36.1667	8.82847	.016	4.7441	67.5892
		Load SB2+Flow	57.0000	8.51173	.000	26.8217	87.1783
	SB2+Flow	SB1	-14.4167	14.54215	1.000	-66.3777	37.5444
		SB2	-18.6667	14.27366	.988	-69.9645	32.6312
		SB1+Flow	-22.6667	13.26460	.874	-71.9151	26.5818
		Load SB1	-14.3333	12.97920	.998	-63.1638	34.4971
		Load SB2	-16.9167	13.16463	.988	-66.0091	32.1758
		Load SB1+Flow	13.5000	14.39969	1.000	-38.1040	65.1040
		Load SB2+Flow	34.3333	14.20769	.431	-16.8081	85.4748
	Load SB1	SB1	-.0833	8.63569	1.000	-31.4114	31.2447
		SB2	-4.3333	8.17547	1.000	-33.8131	25.1464
		SB1+Flow	-8.3333	6.24904	.988	-30.2633	13.5967
		SB2+Flow	14.3333	12.97920	.998	-34.4971	63.1638
		Load SB2	-2.5833	6.03394	1.000	-23.7130	18.5464
		Load SB1+Flow	27.8333	8.39357	.091	-2.5215	58.1881
		Load SB2+Flow	48.6667	8.05975	.000	19.6504	77.6829
	Load SB2	SB1	2.5000	8.91196	1.000	-29.4646	34.4646
		SB2	-1.7500	8.46677	1.000	-31.9456	28.4456
		SB1+Flow	-5.7500	6.62558	1.000	-28.9146	17.4146
		SB2+Flow	16.9167	13.16463	.988	-32.1758	66.0091
		Load SB1	2.5833	6.03394	1.000	-18.5464	23.7130
		Load SB1+Flow	30.4167	8.67755	.058	-.6148	61.4481
		Load SB2+Flow	51.2500	8.35509	.000	21.4958	81.0042
	Load SB1+Flow	SB1	-27.9167	10.65207	.299	-65.1492	9.3159
		SB2	-32.1667	10.28250	.111	-68.1068	3.7735
		SB1+Flow	-36.1667	8.82847	.016	-67.5892	-4.7441
		SB2+Flow	-13.5000	14.39969	1.000	-65.1040	38.1040
		Load SB1	-27.8333	8.39357	.091	-58.1881	2.5215
		Load SB2	-30.4167	8.67755	.058	-61.4481	.6148
		Load SB2+Flow	20.8333	10.19073	.682	-14.7926	56.4593
	Load SB2+Flow	SB1	-48.7500	10.39106	.003	-85.0973	-12.4027
		SB2	-53.0000	10.01186	.001	-87.9910	-18.0090
		SB1+Flow	-57.0000	8.51173	.000	-87.1783	-26.8217
		SB2+Flow	-34.3333	14.20769	.431	-85.4748	16.8081
		Load SB1	-48.6667	8.05975	.000	-77.6829	-19.6504
		Load SB2	-51.2500	8.35509	.000	-81.0042	-21.4958
		Load SB1+Flow	-20.8333	10.19073	.682	-56.4593	14.7926

Cohesive failure in dentin

			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
	(I) GROUP	(J) GROUP				Lower Bound	Upper Bound
Dunnett T3	SB1	SB2	.4167	.43155	1.000	-1.1770	2.0103
		SB1+Flow	-.4167	.66809	1.000	-2.7737	1.9404
		SB2+Flow	.5833	.39807	.952	-.9713	2.1380
		Load SB1	.5833	.39807	.952	-.9713	2.1380
		Load SB2	.5833	.39807	.952	-.9713	2.1380
		Load SB1+Flow	-.6667	.76459	1.000	-3.4025	2.0692
		Load SB2+Flow	.1667	.57626	1.000	-1.8477	2.1810
	SB2	SB1	-.4167	.43155	1.000	-2.0103	1.1770
		SB1+Flow	-.8333	.56183	.953	-2.9514	1.2847
		SB2+Flow	.1667	.16667	.999	-.4842	.8176
		Load SB1	.1667	.16667	.999	-.4842	.8176
		Load SB2	.1667	.16667	.999	-.4842	.8176
		Load SB1+Flow	-1.0833	.67373	.912	-3.6490	1.4823
		Load SB2+Flow	-.2500	.44876	1.000	-1.9131	1.4131
	SB1+Flow	SB1	.4167	.66809	1.000	-1.9404	2.7737
		SB2	.8333	.56183	.953	-1.2847	2.9514
		SB2+Flow	1.0000	.53654	.786	-1.0955	3.0955
		Load SB1	1.0000	.53654	.786	-1.0955	3.0955
		Load SB2	1.0000	.53654	.786	-1.0955	3.0955
		Load SB1+Flow	-.2500	.84499	1.000	-3.2156	2.7156
		Load SB2+Flow	.5833	.67933	1.000	-1.8073	2.9739
	SB2+Flow	SB1	-.5833	.39807	.952	-2.1380	.9713
		SB2	-.1667	.16667	.999	-.8176	.4842
		SB1+Flow	-1.0000	.53654	.786	-3.0955	1.0955
		Load SB1	.0000	.00000	.	.0000	.0000
		Load SB2	.0000	.00000	.	.0000	.0000
		Load SB1+Flow	-1.2500	.65279	.757	-3.7995	1.2995
		Load SB2+Flow	-.4167	.41667	.999	-2.0440	1.2106
	Load SB1	SB1	-.5833	.39807	.952	-2.1380	.9713
		SB2	-.1667	.16667	.999	-.8176	.4842
		SB1+Flow	-1.0000	.53654	.786	-3.0955	1.0955
		SB2+Flow	.0000	.00000	.	.0000	.0000
		Load SB2	.0000	.00000	.	.0000	.0000
		Load SB1+Flow	-1.2500	.65279	.757	-3.7995	1.2995
		Load SB2+Flow	-.4167	.41667	.999	-2.0440	1.2106
	Load SB2	SB1	-.5833	.39807	.952	-2.1380	.9713
		SB2	-.1667	.16667	.999	-.8176	.4842
		SB1+Flow	-1.0000	.53654	.786	-3.0955	1.0955
		SB2+Flow	.0000	.00000	.	.0000	.0000
		Load SB1	.0000	.00000	.	.0000	.0000
		Load SB1+Flow	-1.2500	.65279	.757	-3.7995	1.2995
		Load SB2+Flow	-.4167	.41667	.999	-2.0440	1.2106
	Load SB1+Flow	SB1	.6667	.76459	1.000	-2.0692	3.4025
		SB2	1.0833	.67373	.912	-1.4823	3.6490
		SB1+Flow	.2500	.84499	1.000	-2.7156	3.2156
		SB2+Flow	1.2500	.65279	.757	-1.2995	3.7995
		Load SB1	1.2500	.65279	.757	-1.2995	3.7995
		Load SB2	1.2500	.65279	.757	-1.2995	3.7995
		Load SB2+Flow	.8333	.77443	.999	-1.9277	3.5944
	Load SB2+Flow	SB1	-.1667	.57626	1.000	-2.1810	1.8477
		SB2	.2500	.44876	1.000	-1.4131	1.9131
		SB1+Flow	-.5833	.67933	1.000	-2.9739	1.8073
		SB2+Flow	.4167	.41667	.999	-1.2106	2.0440
		Load SB1	.4167	.41667	.999	-1.2106	2.0440
		Load SB2	.4167	.41667	.999	-1.2106	2.0440
		Load SB1+Flow	-.8333	.77443	.999	-3.5944	1.9277

Cohesive failure in resin

			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
	(I) GROUP	(J) GROUP				Lower Bound	Upper Bound
Dunnett T3	SB1	SB2	3.8333	10.29771	1.000	-32.1621	39.8287
		SB1+Flow	8.6667	8.95584	1.000	-23.1352	40.4685
		SB2+Flow	-15.0000	14.41783	.999	-66.6488	36.6488
		Load SB1	-.6667	8.42465	1.000	-31.1463	29.8130
		Load SB2	1.9167	8.70762	1.000	-29.2343	33.0676
		Load SB1+Flow	-27.2500	10.62750	.330	-64.3933	9.8933
		Load SB2+Flow	-48.9167	10.18463	.002	-84.5266	-13.3067
	SB2	SB1	-3.8333	10.29771	1.000	-39.8287	32.1621
		SB1+Flow	4.8333	8.70983	1.000	-26.0060	35.6727
		SB2+Flow	-18.8333	14.26632	.987	-70.1136	32.4470
		Load SB1	-4.5000	8.16265	1.000	-33.9284	24.9284
		Load SB2	-1.9167	8.45439	1.000	-32.0633	28.2300
		Load SB1+Flow	-31.0833	10.42103	.151	-67.5195	5.3528
		Load SB2+Flow	-52.7500	9.96899	.001	-87.5919	-17.9081
	SB1+Flow	SB1	-8.6667	8.95584	1.000	-40.4685	23.1352
		SB2	-4.8333	8.70983	1.000	-35.6727	26.0060
		SB2+Flow	-23.6667	13.33011	.842	-73.0227	25.6893
		Load SB1	-9.3333	6.38693	.968	-31.7837	13.1171
		Load SB2	-6.7500	6.75580	1.000	-30.3848	16.8848
		Load SB1+Flow	-35.9167	9.09736	.021	-68.2750	-3.5584
		Load SB2+Flow	-57.5833	8.57583	.000	-87.9015	-27.2652
	SB2+Flow	SB1	15.0000	14.41783	.999	-36.6488	66.6488
		SB2	18.8333	14.26632	.987	-32.4470	70.1136
		SB1+Flow	23.6667	13.33011	.842	-25.6893	73.0227
		Load SB1	14.3333	12.97920	.998	-34.4971	63.1638
		Load SB2	16.9167	13.16463	.988	-32.1758	66.0091
		Load SB1+Flow	-12.2500	14.50616	1.000	-64.1198	39.6198
		Load SB2+Flow	-33.9167	14.18490	.447	-85.0047	17.1714
	Load SB1	SB1	.6667	8.42465	1.000	-29.8130	31.1463
		SB2	4.5000	8.16265	1.000	-24.9284	33.9284
		SB1+Flow	9.3333	6.38693	.968	-13.1171	31.7837
		SB2+Flow	-14.3333	12.97920	.998	-63.1638	34.4971
		Load SB2	2.5833	6.03394	1.000	-18.5464	23.7130
		Load SB1+Flow	-26.5833	8.57494	.138	-57.6670	4.5004
		Load SB2+Flow	-48.2500	8.01951	.000	-77.1052	-19.3948
	Load SB2	SB1	-1.9167	8.70762	1.000	-33.0676	29.2343
		SB2	1.9167	8.45439	1.000	-28.2300	32.0633
		SB1+Flow	6.7500	6.75580	1.000	-16.8848	30.3848
		SB2+Flow	-16.9167	13.16463	.988	-66.0091	32.1758
		Load SB1	-2.5833	6.03394	1.000	-23.7130	18.5464
		Load SB1+Flow	-29.1667	8.85311	.090	-60.8967	2.5633
		Load SB2+Flow	-50.8333	8.31627	.000	-80.4344	-21.2323
	Load SB1+Flow	SB1	27.2500	10.62750	.330	-9.8933	64.3933
		SB2	31.0833	10.42103	.151	-5.3528	67.5195
		SB1+Flow	35.9167	9.09736	.021	3.5584	68.2750
		SB2+Flow	12.2500	14.50616	1.000	-39.6198	64.1198
		Load SB1	26.5833	8.57494	.138	-4.5004	57.6670
		Load SB2	29.1667	8.85311	.090	-2.5633	60.8967
		Load SB2+Flow	-21.6667	10.30930	.641	-57.7263	14.3930
	Load SB2+Flow	SB1	48.9167	10.18463	.002	13.3067	84.5266
		SB2	52.7500	9.96899	.001	17.9081	87.5919
		SB1+Flow	57.5833	8.57583	.000	27.2652	87.9015
		SB2+Flow	33.9167	14.18490	.447	-17.1714	85.0047
		Load SB1	48.2500	8.01951	.000	19.3948	77.1052
		Load SB2	50.8333	8.31627	.000	21.2323	80.4344
		Load SB1+Flow	21.6667	10.30930	.641	-14.3930	57.7263

* The mean difference is significant at the .05 level.

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