In vitro evaluation of marginal degradation of composite restorations

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Purpose: The purpose of this study was to evaluate the effect of occlusal stressing on marginal integrity of multiple composite restorations in the same tooth.

Materials and Methods: Class V cavities were prepared on buccal and lingual surfaces of 42 extracted human maxillary premolars. Cavo-surface margins were placed in enamel on the incisal wall and in cementum on the gingival wall. Class II (MOD) cavities were also prepared on the same tooth. Class V cavities were restored with a direct composite. For Class II cavities, one-half numbers of the specimens were restored with the direct composite, and the remainders were restored with an indirect composite. The specimens were mounted on two different loading devices (vertical and sliding types) and repetitively loaded with 75 N at 1.2 Hz for 100,000 cycles. Seven specimens were used for each simulation. The tested specimens were immersed into 5% methylene blue solution for two hours, and the lengths of marginal staining and depth of dye penetration were evaluated. The values at each area were averaged, and the data were statistically analyzed by analysis of variance (ANOVA). The differences between gingival and occlusal microleakage; vertical loading and vertical with sliding; and direct and indirect restorations were determined with Fisher's PLSD test ($p<0.05$).

Results: The results indicated that all of the gingival margins on Class V restorations exhibited greater deterioration compared to occlusal margins.

Conclusion: It is suggested that the cementum/restoration interface had less durability compared to enamel/restoration interface. **(Int Chin J Dent 2002; 2: 143-150.)**

Clinical Significance: Clinicians need to realize that cementum margin of Class V composite restoration will be affected by occlusal stress when Class II restoration is placed on the same tooth.

Key words: class V restoration, composite, *in vitro* test, marginal degradation, occlusal stress.

INTRODUCTION

In clinical situations, a single tooth is sometimes restored with resin composite materials via multiple cavity preparations. Although a complete-coverage cast restoration is often recommended as a durable restoration, the cavity preparation is advantageous when minimization of tooth reduction is a primary concern. Therefore, enhancement of longevity is essential to make composite restorations more reliable. Although restorative dentistry has significantly changed since the introduction of enamel etching,[1] polymerization shrinkage of resin composite is still an unsolved problem. Microleakage around restorations needs to be minimized to prevent microbial invasion as well as other clinical problems. Deficiency in perfect sealing of restorative materials to tooth structure leads to gap formation between the restorative material and cavity walls, resulting in postoperative sensitivity, plaque accumulation, recurrent caries, pulpal degeneration and sometimes necrosis.[2,3]

Ongoing development of new adhesive systems and increasing understanding of the dentin substrate[4-6] together with extensive investigation of the smear layer,[7,8] surface phenomenon,[9-12] makes bonding to both enamel and dentin simultaneously possible as evidenced by currently available adhesive systems. The micromechanical interlock of etched enamel with bonding resin has long been established as a major mechanism for enamel bonding.[13] Encapsulation of enamel crystallites of the etched enamel surface with bonding resin, has been reported to be the most significant factor in promoting surface protection from acid dissolution.[14,15] With the advent of newer generation adhesive systems, bonding to tooth structure both enamel and dentin, is attainable.[16-20] *In vitro* study has demonstrated that the marginal sealing ability of current bonding resin composite systems has been improved.[18] While other *in vitro* study has shown that the use of dentin bonding agents reduces the marginal gap formation in composite resin restorations.[19] The dentin hybrid layer resulted from interpenetration of monomers into dentin substrate followed by polymerization and is responsible for a functional monomer group for subsequent chemical bonds of the resin composite.[20] Encapsulation of hydroxyapatite in the hybrid layer by impregnated resin also relates the bonding durability.[21,22]

Extensive and continuous occlusal stresses could possibly create marginal degradation of resin composite restorations. Although several *in vitro* studies on microleakage using occlusal-like loading have been attempted,[24-25] the effect of loading on marginal integrity was not clearly demonstrated. This indicates the difficulty in simulating clinical conditions by an *in vitro* testing system. Therefore, the purpose of this study was to develop a new *in vitro* system to simulate the marginal degradation of resin composite restorations after a long period of masticatory stressing. It was also the purpose of this study to evaluate the effect of occlusal stressing on marginal integrity of resin composite restorations when they were placed in the same tooth.

MATERIALS AND METHODS

Materials used in this study are presented in Table 1. They included an enamel/dentin bonding agent (Bond 3), a direct composite restorative (Simile), an indirect composite restorative (Sculpture), and a composite luting cement (Cement-It!). All of the materials were manufactured by Jeneric/Pentron (Wallingford, CT, USA).

Forty-two extracted human maxillary premolars were selected for evaluation. The approval for use of extracted human teeth was obtained from the Institutional Review Board for Human Use (IRB) at the

University of Alabama at Birmingham. Class V cavities (3 mm high, 4 mm wide, and 1.5 mm deep) were prepared on buccal and lingual surfaces of all teeth with a #4 carbide round bur. The cavo-surface margin was placed in enamel on the incisal wall and in cementum on the gingival wall. The margin was beveled (0.5 mm wide) entirely with a white stone (Dura-White Stone, #0244, Shofu Inc, Kyoto, Japan). Class II (MOD) cavities were prepared with a #271 carbide fissure bur on the same tooth. Proximal extension included removal of marginal ridges. The dimension of the cavity was 1.5 mm wide at central fossa, 0.8 mm wide at gingival wall, and 2.5 mm deep at occlusal surface. No bevel was prepared on occlusal margin. The gingival margin was placed in enamel and beveled with 0.5 mm width. Each tooth received a total of three preparations.

Table 1. Materials used.

Material Type	Product Name	Manufacturer	Batch number
Bonding agent	Bond 3	Jeneric/Pentron	59011
Direct composite	Simile	Jeneric/Pentron	S8414
Indirect composite	Sculpture	Jeneric/Pentron	44339
Luting cement	Cement-It!	Jeneric/Pentron	550962

Class V cavities were restored with Simile direct composite with Bond 3 adhesive. The cavities were etched with a 37% phosphoric acid for 20 s, followed by rinsing with tap water for 20 s. Bond 3 adhesive was applied and polymerized by visible light irradiation for 10 s. The cavities were restored with the resin composite with two increments. The resin composite was polymerized by visible light irradiation for 20 s on the first increment and for 40 s on the second increment. Class II cavities were restored with both the direct and indirect composite materials. One-half of the specimens were directly restored with the Simile, and the remainders were restored with Sculpture indirect composite. The direct restorations were restored with three increments. The first and second increments were polymerized for 20 s each, and the third increment was polymerized for 40 s. Sculpture inlays were fabricated by light polymerization, followed by heat polymerized at 110°C for 10 minutes in a vacuum oven (Conquest oven, Jeneric/Pentron). The inlays were cemented with Cement-It! dual-cure composite cement. The cement was polymerized by visible light irradiation for 40 s on each surface.

All restorations were finished and polished with silicon points (Brown point, #0413, and Blue point, #414B, Shofu Inc.) with copious amounts of irrigation. The restored teeth were immersed into 5% methylene blue solution at 37°C for two hours to confirm an intact marginal integrity. They were then cleaned and evaluated for subsequent testing. The completed specimens were secured in specimen holders with an auto-polymerized acrylic resin (Unifast II, GC Corp., Tokyo, Japan) 2 mm below the gingival margin. These specimens were mounted on two different loading devices. A UAB wear simulator[26-29] was used as a vertical loading type, and a modified wear simulator[30] was used as another type of *in vitro* test that has vertical loading with a sliding motion. A custom made stylus was prepared for each individual tooth using two hemi-spherical metal screws (Zinc round-head, Hillman, Cincinnati, OH, USA) and the auto-polymerized acrylic resin (Fig. 1). The screw heads were designed to contact both buccal and lingual triangular ridges, and four contact points were obtained on each specimen. The screw heads were positioned to exclude contact with the restorations. A 75 N load was applied in both simulators (Fig. 2). A schematic illustration of the loading system is presented in Fig. 3. Only vertical loading was employed to the original device (arrow A), and a sliding movement (arrow B) was combined with vertical loading in the modified device. The stylus directly contacted the tooth surface at 1.2 Hz, and the loading was repeated for 100,000 cycles. Seven specimens were used for each condition in each type of loading system.

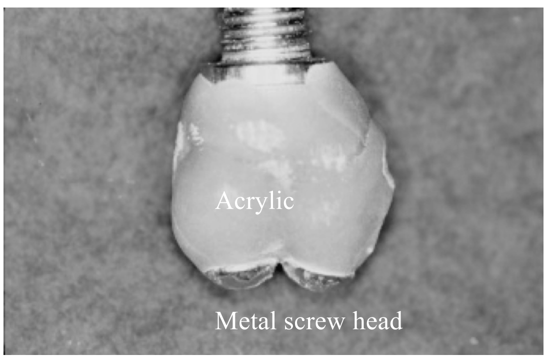

Fig. 1. Custom made stylus for loading.

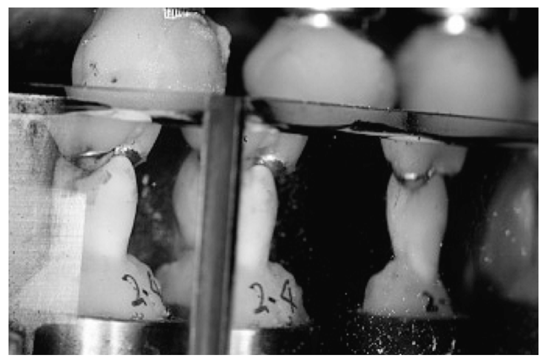

Fig. 2. Cyclic loading.

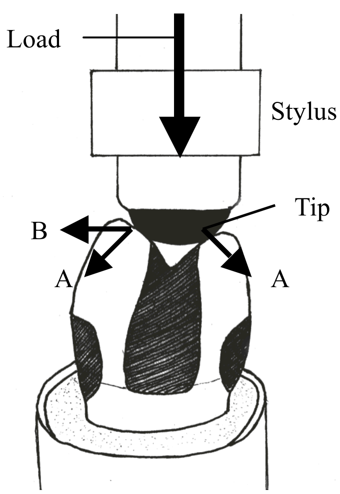

Fig. 3. Illustration of loading system. A: Vertical loading; B: Sliding.

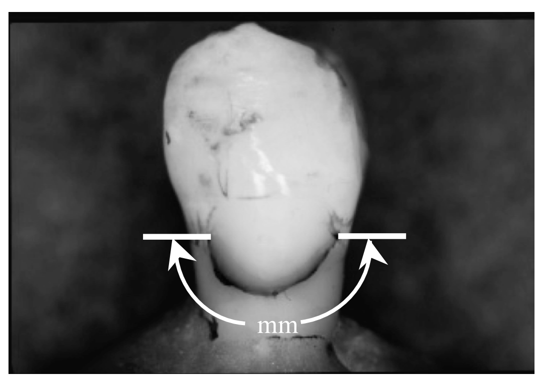

Fig. 4. Measurement of marginal staining length.

The tested specimens were immersed into 5% methylene blue solution at 37°C for two hours to evaluate marginal leakage. Fourteen specimens without the stressing were used as control groups. The lengths of marginal staining at both gingival and occlusal margins of Class V restorations were evaluated (Fig. 4).

The values of respective sites were averaged independently. The gingival margins of both mesial and distal proximal surfaces of Class II restorations were also evaluated on each restoration, and the values on each condition were averaged.

After the measurements of staining length were made, the specimens were sectioned buccolingually along the tooth axis. However, the control groups were not sectioned, as they exhibited no marginal staining. Depth of dye penetration along the cavity wall was then evaluated. The deepest dye penetrations were measured in millimeter by a light microscope. The values at each area were averaged, and the data were statistically analyzed by three-way analysis of variance (ANOVA). The differences between gingival and occlusal margins, vertical loading and vertical with sliding, direct and indirect Class II restorations were determined with Fisher's PLSD test ($p<0.05$).

RESULTS

Table 2. Results of marginal stain lengths in mm with standard deviations in parentheses.

	Direct class II group			Indirect class II group		
	No stressing	Vertical	Vertical/Sliding	No stressing	Vertical	Vertical/Sliding
Bucco-gingival	0	4.43 (1.10)	5.00 (0.96)	0	5.93 (0.93)	4.50 (1.78)
		a, *	c		e, *, #	g, #
Bucco-occlusal	0	2.43 (1.90)	1.64 (1.38)	0	2.21 (2.48)	1.71 (2.58)
		a,	c		e	g
Linguo-gingival	0	4.43 (1.34)	4.43 (0.84)	0	5.50 (1.04)	4.64 (0.85)
		b	d		f	h
Linguo-occlusal	0	2.00 (2.25)	0.29 (0.76)	0	0.57 (1.13)	0
		b	d		f	h
Proximal-gingival	0	3.09 (1.13)	2.44 (1.53)	0	2.11 (1.31)	1.21 (0.76)

Values with the same letters and symbols indicate significant differences ($p<0.05$).
a-h: gingival/occlusal, *: direct/indirect, #: vertical/vertical + sliding.

The results of marginal staining lengths are presented in Table 2. The control groups exhibited no marginal staining at all, while occlusally stressed groups showed various amount of staining. The values of Class V gingival margins (cementum margins) ranged 4.43 to 5.93 mm, while those of occlusal margins (enamel margins) ranged 0 to 2.43 mm. The values of Class II gingival margins (enamel margins) ranged 1.21 to 3.09 mm. The statistical analysis indicated that all of the gingival margins exhibited greater deterioration as compared to occlusal margins on Class V restorations regardless of stressing modes. The difference between direct and indirect Class II restoration groups was only detected at bucco-gingival margin when they were subjected to vertical stressing. The difference between vertical loading group and vertical with sliding movement group was only seen at bucco-gingival margin of Class V restorations when teeth were restored with indirect Class II restoration. Class II gingival margins showed no differences regardless of the restoration modes.

The results of dye penetration along the cavity wall are presented in Table 3. The values of Class V gingival margins ranged 0.85 to 1.25 mm, while those of occlusal margins ranged 0 to 0.46 mm. The values of Class II gingival margins ranged 0.14 to 0.60 mm. The statistical analysis demonstrated that all of the values for gingival margin on Class V were significantly greater than those of occlusal margin. There were no differences between vertical loading and vertical with sliding motion. The differences between direct restoration and indirect inlay were only seen at the gingival margin of Class II restorations. The inlay groups showed less dye penetrations compared to the direct restoration groups.

Table 3. Results of dye penetration (mm).

	Direct class II group		Indirect class II group	
	Vertical	Vertical/Sliding	Vertical	Vertical/Sliding
Bucco-gingival	1.25 (0.43) a	0.92 (0.49) c	0.97 (0.34) e	0.90 (0.36) g
Bucco-occlusal	0.32 (0.47) a	0.32 (0.58) c	0.10 (0.19) e	0.20 (0.52) g
Linguo-gingival	1.03 (0.46) b	0.85 (0.58) d	1.12 (0.13) f	1.12 (0.21) h
Linguo-occlusal	0.30 (0.54) b	0.06 (0.16) d	0.46 (0.61) f	0 (0) h
Proximal-gingival	0.48 (0.25) *	0.60 (0.31) **	0.14 (0.12) *	0.18 (0.23) **

Values with the same letters and symbols indicate significant differences ($p<0.05$).
a-h: gingival/occlusal, *, **: direct/indirect.

DISCUSSION

There are many clinical problems of Class V composite restorations. One of them is the interfacial debonding that is provoked by numerous factors including the polymerization shrinkage of composite, contamination by oral fluids, failure of polymerization, operator error, and longitudinal degradation.[31] The degradation of tooth/restoration interface is inevitable under a functional oral environment even with the appropriate clinical procedures. The results indicated that all of the gingival margins on Class V restorations were deteriorated after cyclic loading regardless of the type of loading. This was probably due to fatigue of bonding interface by the continuous stressing created by this cyclic loading system. The most stress is perhaps concentrated at the tooth/restoration interface of gingival margins as can be speculated from the mechanism of abfraction defects.[32] The results also indicated that the cementum/restoration interface had less durability compared to the enamel/restoration interface. It can be speculated that the bond strengths of the adhesive system to cementum could be weaker than to enamel. This assumption is supported by the results of other in vitro studies, showing dentin or cementum margins exhibited weaker bonding compared to enamel.[23-25,33,34] From the results of this study, it can be concluded that the *in vitro* system used in this study may simulate the clinical situation in terms of marginal breakdown by long-term occlusal stressing.

Although the marginal integrity of the Class V restorations was significantly deteriorated by the cyclic loading, little influence was obtained under different loading modes. Therefore, further research is warranted to investigate the improved experimental designs to simulate the clinical conditions more precisely.

CONCLUSIONS

Based upon the results of this study, it is concluded that the *in vitro* cyclic loading system used in this study has a potential to simulate the marginal degradation of resin composite restorations by means of continuous occlusal stressing. It is concluded that occlusal stressing considerably affected the gingival marginal integrity of resin composite restorations, and the cementum/restoration interface had less durability as compared to enamel/restoration interface.

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Received on October 9, 2002. Revised on October 22, 2002. Accepted on November 19, 2002.