

## All-in-one 접착제에서 초음파진동이 법랑질과 상아질의 결합강도와 레진침투에 미치는 영향

이범의 · 장기택 · 이상훈 · 김종철 · 한세현

서울대학교 치과대학 소아치과학교실

### 국문초록

초기의 접착 시스템은 여러 단계의 술식을 필요로 하였으며 술자의 기술과 재료의 성질에 크게 좌우되었으나 최근 산부식, priming, adhesive를 한번에 적용할 수 있는 all-in-one adhesive system이 등장하였다. 치과에서의 vibration의 이용은 치석의 제거 및 접착제의 점도를 낮추는데 이용되어왔으며 vibration은 접착제의 흐름성을 향상시켜 film thickness를 낮추어 수복물 주위의 미세누출을 줄이는데 도움을 준다. 이에 저자들은 all-in-one adhesive system에서 vibration이 법랑질과 상아질의 접착강도와 레진침투에 미치는 효과를 알아보고자 하였다.

법랑질 시편은 발거 후 실온에서 0.1% thymol 용액에서 보관된 30개의 건전한 사람의 대구치를 무작위로 10개씩 세군으로 나누고 근원심 방향으로 두 부분으로 분리하여 각각은 같은 접착제를 사용하고 초음파진동여부를 다르게 하였고, 아크릴 레진을 이용하여 직경 1-inch의 PVC관에 매몰한 후 협설면이 아크릴봉과 동일한 높이가 되도록 220-, 600-grit 연마지로 순차적으로 연마하였고 군당 10개씩 여섯 군으로 분류하였다. 1군과 2군은 Prompt L-Pop(3M-ESPE, Seefeld, Germany), 3군과 4군은 One-Up Bond F(Tokuyama Corp., Tokyo, Japan), 5군과 6군은 AQ bond(Sun Medical Co., Kyoto, Japan)를 제조사의 지시에 따라 도포하였다. 2군, 4군, 6군은 초음파 치석제거기를 이용하여 치면에 대고 15초간 진동을 가한 후 광중합하였다. 상아질 시편은 치관부 법랑질을 제거한 후 상아질면을 아크릴 봉과 동일한 높이가 되도록 하고 법랑질 시편과 동일하게 처리하였다. 이후 직경 2mm, 높이 3mm의 Teflon mold(Ultradent, U.S.A.)를 이용하여 복합레진을 충전한 후 40초씩 두 번에 나누어 광중합한 후 24시간동안 실온에서 증류수에 보관하였다. 열순환 시행한 후, 만능측정기(Instron 4465)로 전단결합강도를 측정하였으며 Resin tag의 양상을 비교하기 위해 각 군의 시편의 치질을 완전히 용해시킨 후 표면을 주사전자현미경사진으로 관찰하여 다음과 같은 결과를 얻었다.

1. 법랑질에서 초음파 진동을 가한 군(2,4,6군)은 가하지 않은 군(1,3,5군)에 비해 평균 전단결합강도가 높게 나타났다. 그 차이는 AQ bond 군을 제외하고 통계적으로 유의하였다( $p<0.05$ ).
2. 상아질에서 초음파 진동을 가한 군(2,4,6군)은 가하지 않은 군(1,3,5군)에 비해 평균 전단결합강도가 높게 나타났다. 그러나 그 차이는 One-Up Bond F군을 제외하고는 통계적으로 유의한 차이가 없었다.
3. 전자 현미경 관찰에서 초음파 진동을 가한 군에서 더 많은 법랑질의 소실과 상아질에서 resin tag의 길이가 길었고 lateral branch의 수도 많이 관찰되었다.

**주요어** : 초음파진동, All-in-one adhesive, 전단결합강도, 레진침투

교신저자 : Se-Hyun Hahn

28-1 Yeongun-Dong, Chongno-Gu, Seoul, 110-749, Korea  
Dept. of Pediatric Dentistry, College of Dentistry, Seoul National Univ.  
Tel : 02-760-3819  
E-mail : shhan@snu.ac.kr

### I. Introduction

Adhesive dentistry began in 1955, when Buonocore described the acid etching technique on enamel<sup>1)</sup>. Since then, a large number of adhesive systems have been introduced in the market, as new adhesive

philosophies were developed.

A key concept in resin adhesion to dentin is the formation of a hybrid layer immediately after the acid etching. This hybridization occurs following an initial demineralization of the dentin, exposing the collagen fibril network with interfibrillar microporosities that will subsequently be filled with low-viscosity monomers. This bonding mechanism was first described by Nakabayashi et al. in 1982<sup>2)</sup>.

The early generation of adhesive systems involved clinical techniques that were extremely complex for many practitioners. Because bonding procedures require multiple-step clinical approach, clinical success depends on technique-sensitive and material related factors<sup>3-5)</sup>. Simpler adhesive systems have appeared. These simplified systems decrease the number of operative steps during bonding without adversely affecting adhesion of bonding resins to the tooth. Self-etching primers are applied for 20 seconds, air dried, and then covered with a light-cured adhesive layer. Some system requires only one bonding steps, saving clinical time and eliminating several bonding steps in which mistakes could occur. These have been called all-in-one adhesives, because they etch and simultaneously infiltrate resin monomers into dentin<sup>6)</sup>. All-in-one adhesives are applied for 20 to 30 seconds, dried, and light cured. In this system, primer and adhesive are combined.

Theoretically, the acidic all-in-one adhesive dissolves the smear layer, incorporating it into the mixture and demineralizing the superficial dentin. It then hardens after light irradiation<sup>7)</sup>. Since these are recently developed bonding system, more details about bonding to tooth structure needs to be evaluated.

The use of vibration to alter thixotropic materials has long been recognized by the industry. However, its active use in dentistry has only recently been documented<sup>8)</sup>. Vibration was first utilized in dental scalers to aid in the removal of plaque and calculus from the teeth. Furthermore, ultrasonic vibration may be used to alter the viscosity of zinc phosphate cement<sup>9)</sup> or composite luting<sup>10,11)</sup> materials during the seating of cast metal and composite inlays. The technique requires the light placement of an ultrasonic scaler against the restoration for a few seconds. The vibration from the tip pass through the restoration

into the underlying material. This changes the viscosity of the cement, and this in turn allows the restoration to slip into place easily<sup>8)</sup>. Using vibration in this manner may have an added advantage: the improved flow characteristics of the material help reduce film thickness, thereby minimizing potential leakages that may occur around the restoration<sup>12)</sup>.

Studies regarding the clinical applications of such vibration on composite restorations have been few. The objective of this study is to compare the bond strength and resin penetration into dentinal tubule and enamel surface achieved with those gained using the conventional technique and vibration technique in all-in-one adhesives.

## II. Materials and Methods

### 1. Shear bond strength

Sixty noncarious extracted human permanent molar teeth were stored in 0.1% thymol solution at room temperature after extraction. The teeth were cleaned by removing the remaining soft tissue and then stored in physiologic saline solution until use.

For enamel specimens, thirty teeth were sectioned mesio-distally at central groove by using a slow-speed saw(Isomet, Buhler Ltd., Evaston, U.S.A.). Sectioned two parts were assigned to the same adhesive system but different treatment(vibration vs. non-vibration). Each specimen was embedded in 1-inch diameter PVC pipe with a cold cured acrylic resin. The buccal and lingual surfaces were placed so that the tooth and the embedding medium were at the same level to form one flat surface. The samples were subsequently polished wet 220-, and 600-grit silicon carbide abrasive papers. Each adhesive system was applied according to its manufacture's instructions.

For dentin specimens, thirty teeth were sectioned to removed the coronal enamel and subsequently sectioned mesio-distally by using a slow-speed saw(Isomet, Buhler Ltd., Evaston, U.S.A.). Sectioned two parts were assigned to the same adhesive system but different treatment(vibration vs. non-vibration). Each specimen was embedded in 1-inch diameter PVC pipe with a cold cured acrylic resin. The exposed dentinal surfaces were placed so that the tooth

**Table 1.** Adhesive systems used in this study

System	Composition	Lot #	Manufacturer
Prompt L-Pop	<b>Compartment1(red blister)</b>	124835	3M-ESPE, U.S.A
	Methacrylated phosphoric esters (di-HEMA-phosphate), Initiators, Stabilizer		
	<b>Compartment 2(yellow blister)</b>		
One-Up bond F	Water, Fluoride complex, Stabilizer	A:547 B:050	Tokuyama Cor., Japan
	<b>Bonding Agent A</b>		
	Methacryloxyalkyl acid phosphate, MAC-10		
AQ bond	<b>Bonding Agent B</b>	FK1	Sun Medical Co., Japan
	Monomer, Water, Fluoro-alumino-silicate glass, Borate catalyst		
	<b>AQ bond base</b>		
AQ bond	Methacrylate monomers(MMA, 4-META, urethane dimethacrylate, 2-hydroxyl methacrylate), Acetone, Water	FK1	Sun Medical Co., Japan
	<b>AQ bond sponge</b>		
	Sodium p-toluenesulfinate		

and the embedding medium were at the same level to form one flat surface. The samples were subsequently polished wet 220-, and 600-grit silicon carbide abrasive papers. Each adhesive system was applied according to its manufacture's instructions.

#### Group 1. Prompt L-Pop

Apply Prompt L-Pop(3M-ESPE, U.S.A.) to enamel and dentin for 15 seconds with moderate finger pressure. Use a stream of air to evenly disperse the material into a thin film. Cure the Prompt L-Pop for 10 seconds.

#### Group 2. Prompt L-Pop with vibration

Apply Prompt L-Pop(3M-ESPE, U.S.A.) to enamel and dentin for 15 seconds with moderate finger pressure. Vibration was applied for 15 seconds using a commercially available ultrasonic scaler(Suprasson P5 Booster, SATELEC, France) without water spray. Use a stream of air to evenly disperse the material into a thin film. Cure the Prompt L-Pop for 10 seconds.

#### Group 3. One-Up Bond F

Apply bonding agent and wait for 20 seconds. Cure the One-Up Bond F for 10 seconds.

#### Group 4. One-Up Bond F with vibration

Apply bonding agent and wait for 20 seconds. Vibration was applied for 15 seconds. Vibration was applied. Cure the One-Up Bond F for 10 seconds.

#### Group 5. AQ bond

Apply bonding agent for 20 seconds. Evaporate the solvent using gentle air blow for 3-5 seconds. And second coat was applied. Blow gently until the coat

dries evenly. Cure for 10 seconds.

#### Group 6. AQ bond with vibration

Apply bonding agent for 20 seconds. Vibration was applied for 15 seconds. Evaporate the solvent using gentle air blow for 3-5 seconds. And second coat was applied. Blow gently until the coat dries evenly. Cure for 10 seconds.

Resin composite(Z250, 3M, U.S.A.) was condensed on to the prepared surface in two increments using a mold kit for shear bond strength(Ultradent Inc., U.S.A.). Each increments was light-cured for 40 seconds using visible light curing unit(3M dental product, U.S.A.). After 24 hours in tap water at room temperature, the specimens were thermocycled for 1000cycles between 5°C and 55°C. The dwell time in each bath was 30 seconds and the transfer time was 15 seconds. Shear bond strengths were measured with a universal testing machine(Instron 4465, England). A knife edged shearing rod with a crosshead speed of 1.0mm/min was used to load the specimens at the interface between composite and dental surface until fracture occurred. Paired t-test and student-Newman-Keuls test were used to evaluate the statistical significance of the results.

#### 2. Examination of debonded specimens

The debonded enamel and dentin surface were coded and examined in a random sequence using a stereomicroscope at 40X magnification. The mode of failure was recorded as either "adhesive", meaning

none or very little(<30%) composite still remaining on the tooth surface, or "mixed", meaning composite remaining on over 30% of the tooth surface, or "cohesive", meaning fracture occurring in the composite resin itself.

### 3. SEM examination

Infiltration patterns of the adhesive materials were investigated. Dentin discs, 3-4mm in thickness, were prepared from extracted teeth. To avoid morphologic and structural variations of the dentin due to its depth, one half of each specimen was vibrated in each group of each adhesive system, with the second half being kept without vibration. Subsequently, resin composite was placed and polymerized. Sectioned resin-tooth specimens immersed into 6 mol HCl for 24 hours to totally removed the calcified component, washed with distilled water for 5 minutes, then immersed in 5% NaOCl solution for 20 minutes to removed the organic components. After dehydration procedure, the specimens were mounted to aluminum stubs with silver paint and sputter coated with gold-palladium, then examined with scanning electron microscope(JEOL, Tokyo, Japan).

## III. Results

### 1. Shear bond strength

#### a. dentin

The mean and standard deviation values of shear bond strength were  $16.96 \pm 5.91$  Mpa for group 1,  $17.78 \pm 6.52$  Mpa for group 2,  $22.44 \pm 2.08$  Mpa for group 3,  $32.41 \pm 7.37$  Mpa for group 4,  $18.23 \pm 6.37$  Mpa for group 5,  $19.17 \pm 5.86$  Mpa for group 6. In each adhesive system, the mean values of vibration group(group 2, 4, 6) were greater than those of non-vibration group(group 1,3,5). But the differences were not statistically significant except One-Up Bond F group(Table 2).

#### b. enamel

The mean and standard deviation values of shear bond strength were  $25.71 \pm 2.22$  for group 1,  $28.19 \pm 2.79$  for group 2,  $17.23 \pm 2.34$  for group 3,  $19.28 \pm 2.76$  for group 4,  $20.94 \pm 3.86$  for group 5,  $21.88 \pm 3.82$  for group 6. In each adhesive system, the mean values of vibration group(group 2,4,6) were greater than those of non-vibration group(group 1,3,5). The differences were statistically significant except AQ bond group (Table 3).

**Table 2.** Results of dentin shear bond tests(n=10)

Materials Treatment	Prompt L-Pop		One-Up Bond F		AQ bond	
	Non-Vib.	Vib.	Non-Vib.	Vib.	Non-Vib.	Vib.
Mean(Mpa)	16.96	17.78	22.44	32.41	18.23	19.17
SD.	5.91	6.52	2.08	7.37	6.37	5.86
Sig.	NS		S		NS	

\*S means statistically significant( $p < 0.05$ )

\*NS means statistically not significant( $p > 0.05$ )

**Table 3.** Results of enamel shear bond tests(n=10)

Materials Treatment	Prompt L-Pop		One-Up Bond F		AQ bond	
	Non-Vib.	Vib.	Non-Vib.	Vib.	Non-Vib.	Vib.
Mean(Mpa)	25.71	28.19	17.23	19.28	20.94	21.88
SD	2.22	2.79	2.34	2.76	3.86	3.82
Sig.	S		S		NS	

\*S means statistically significant( $p < 0.05$ )

\*NS means statistically not significant( $p > 0.05$ )

**Table 4.** Mode of fracture in dentin

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Cohesive	0	1	1	2	1	2
Adhesive	9	7	7	5	7	5
Mixed	1	2	2	3	2	3

**Table 5.** Mode of fracture in enamel

	Group I	Group II	Group III	Group IV	Group V	Group VI
Cohesive	0	0	0	0	0	0
Adhesive	10	10	9	8	10	9
Mixed	0	0	1	2	0	1

## 2. Examination of debonded specimens

The fracture patterns of bonded dentin and enamel specimens are shown in Table 4, 5. When applied with vibration or non-vibration, failure was mainly adhesive type. More cohesive failures were seen with specimens of vibration groups than non-vibration groups.

## 3. SEM examination

In the SEM examination, resin tag and lateral branches formed a fine resin network than completely infiltrated the intertubular dentin area. Each tubule tag featured an interconnecting network of lateral canals that contained polymerized adhesive. It was shown that variation in resin tag formation among adhesive materials and application methods. For vibration groups, resin tags were found to be greater in length and number of lateral branches.

In enamel, different etching patterns were observed with different adhesive system. Prompt L-Pop appears to have produced the most aggressive etching pattern. AQ bond and One-Up Bond F did not create a deep enamel pattern like phosphoric acid did.

In Dentin-Resin interface, perfect adaptation to the dentin with a thin hybrid layer was observed (Fig. 1~18).

## IV. Discussion

The all-in-one adhesive system is a hydrophilic solution that is effective in wetting the tooth surface<sup>13)</sup>. The etching effect of these systems is related to the

acidic monomers or organic acid solutions that may interact with the mineral component of tooth substrate and enhance monomer penetration<sup>14)</sup>. These one-application adhesives may form a continuum between the tooth surface and adhesive by simultaneous demineralization and resin penetration.

Penetration of acidic monomer into tooth surface area creates resin tag for enamel<sup>15)</sup> and hybrid layer for dentin with the application of adhesives<sup>16-18)</sup>. The SEM observations of tooth surface treated with one-application adhesives showed some etching of enamel prism. The adhesive etches and penetrates the etched enamel and hardened after evaporation of the solvent and exposure to light. This process creates a mechanical retention between the enamel and adhesive.

From the time that phosphoric acid was introduced as an etching solution for enamel bonding, other etching agents have been investigated for use in clinical dentistry<sup>19,20)</sup>. One recently developed acidic solution is a self-etching primer that contains acidic functional monomers, such as 4-AET<sup>14)</sup>, phenyl-p and MDP<sup>16)</sup>.

There have been few reports dealing with the shear bond strengths of all-in-one adhesive systems used in the present study. Miyazaki et al. obtained, with One-Up bond F, AQ bond, Prompt L P-pop applied both bovine enamel and dentin, each shear bond strength of 13.0 Mpa, 12.1 Mpa, 21.7 Mpa in enamel and 13.9 Mpa, 10.7 Mpa, 12.6 Mpa in dentin<sup>21)</sup>. These systems were relatively new materials, and more studies about the mechanical properties of these systems are needed.

The depth of the etching pattern and the amount

of surface enamel removed during etching depend on the type of acid, acid concentration, duration of acid application and composition of the surface enamel<sup>21)</sup>.

From the morphologic observation by SEM in this study, applying the adhesive did not create a deep enamel pattern like applying phosphoric acid did except Prompt L-Pop. However specific etching pattern may not be a critical factor in determining enamel bond strength<sup>21)</sup>. Creating the etching pattern required for stable enamel bond seems to differ among the bonding systems used and other factors, such as age, site and amount of mineral removed from the tooth<sup>19)</sup>.

In this SEM examination, the vibration group showed rougher enamel surface and more amount of mineral was removed from the tooth in vibration group and this may explain the increase in bond strength.

The dentin bonding mechanism of resin composite is believed to consist of three step-dentin conditioning, priming and adhesive application<sup>22)</sup>. The SEM observation indicates that single application bonding systems have the ability to dissolve the smear layer. Single application bonding systems rely on their adhesives for wetting in order to create good adaptability to the restored tooth. Vibration may influence the wettability of the single application adhesives.

In this study vibration group showed resin tag of greater number and better lateral branch development under SEM examination. This is considered to be the result of ultrasonic vibration used to diminish the viscosity of resin, which in turn aided resin penetration into dentinal tubules.

In Prompt L-Pop, vibration did not affect the shear bond strength of dentin but increased that of enamel. The behavior of Prompt L-Pop on dentin has resulted in a wide range of bond strength<sup>23)</sup>. After applying one coat of material for 15s, Prompt L-Pop has to be dried with air to evaporate the water used as solvent. Even if this procedure is carried out very carefully, dry spot become visible where the material is probably too thin for covering the dentin surface efficiently. Both bond strength testing and interfacial analysis of the specimens bonded with Prompt L-Pop revealed that these dry spots leads to areas without the interfacial characteristics of hybridization<sup>24)</sup>. A TEM investigation disclosed a reduced resin saturation in the upper half of the hybrid layer, which may

be attributed to oxygen inhibition of the thin resin layer after evaporating the water<sup>25)</sup>.

Vibration reduced the film thickness of bonding agent and vibration group may form more dry spot than non-vibration group. If applying multiple coats of Prompt L-Pop until the whole dentin surface became thoroughly glossy as manufacturer's instruction, the observation of dry spots was indeed completely prevented, and the shear bond strength of vibration group may statistically greater than that of the non-vibration group.

In AQ bond, the shear bond strengths of dentin and enamel in vibration group were not statistically greater than those of non-vibration group. According to the manufacturer the thickness of bonding layer in AQ bond was less than 10 $\mu$ m in both cases of mild and intensive air-blow. Because of AQ bond's ultra-thin bonding layer, the effect of vibration was not so great than other adhesive systems. This may explain the no difference in bonding strength both enamel and dentin. And Jacobsen and Sölderholm observed faster acetone evaporation caused by agitation make HEMA to form more or less jelly-like structure, which may not diffuse as easily as a dilute HEMA solution<sup>26)</sup>. In this study, acetone containing AQ bond did not show better shear bond strength after vibration.

In this study, vibration enhanced the resin penetration in dentin by forming more lateral branch and greater resin tag. But the bond strength was not statistically different in AQ bond and Prompt L-Pop. In this study, SEM examination showed longer resin tags and more lateral branches in DEJ but the length of resin tag was shortened toward central portion of the specimens. This might due to the decreased effect of ultrasonic vibration toward central portion. If the vibration methods, for example the frequency and duration and the location of vibration applied, were more defined, more even and stable data could be expected.

## V. Conclusion

1. In enamel, the mean values of shear bond strengths in vibration groups(group 2,4,6) were greater than those of non-vibration group(group 1,3,5). The differences were statistically significant except AQ bond group.

2. In dentin, the mean values of shear bond strengths in vibration groups(group 2, 4, 6) were greater than those of non-vibration groups(group 1,3,5). But the differences were not statistically significant except One-Up Bond F group.
3. The vibration group showed more mineral loss in enamel and longer resin tag and greater number of lateral branches in dentin under SEM examination.

## References

1. Buonocore MG : A simple method of increasing the adhesion of acrylic filling materials to enamel surface. *J Dent Res*, 34:849-853, 1955.
2. Nakabayashi N, Kojima K, Masuhara E : The promotion of adhesion by the infiltration of monomers into tooth substrate. *J Biomed Mater Res*, 16:265-273, 1982.
3. Sano H, Kanemura N, Burrow MF, et al. : Effect of operator variability on dentin adhesion : Students vs dentists. *Dent mater J*, 17:51-58, 1998.
4. Finger J, Balkenhol M : Practitioner variability effects on dentin bonding with an acetone-based one-bottle adhesive. *J Adhe Dent*, 1:311-314, 1999.
5. Miyazaki M, Onose H, Moore BK : Effect of operator variability on dentin bond strength of two-step bonding systems. *Am J Dent*, 13:101-104, 2000.
6. Nakabayashi N, Pashley DH : Hybridization of Dental Hard Tissues. Quintessence Chicago: 129, 1998.
7. Watanabe I, Nakabayashi N : Bonding durability of photocured phenyl-P in TEGDMA to smear layer-retained bovine dentin. *Quintessence Int*, 24:335-342, 1993.
8. Walmsley AD, Lumley PJ : Applying composite luting agent ultrasonically: A successful alternative. *J Am Dent Assoc*, 126:1125-1129, 1995.
9. Mutlu G, Harrison A, Draughn RA : Effect of ultrasonic instrumentation on film thickness of dental cements(Abstract885). *J Dent Res*, 71:626, 1992.
10. Noack MJ, Roulet JF, Bergmann P : A new method to lute tooth colored inlays with highly filled composite resins(Abstract 1528). *J Dent Res*, 70:457, 1991.
11. Kuenzelmann K-H, Deigner R, Hickel R : Three-body wear of composite luting material(Abstract 59). *J Dent Res*, 71:113, 1992.
12. Peutzfeldt A : Effect of the ultrasonic insertion technique on the seating of composite inlays. *Acta Odontol Scand*, 52:51-54, 1994.
13. Kitasako T, Nakajima M, Pereira PN et al. : Monkey pulpal response and microtensile strength beneath a one-application resin bonding system in vivo. *J Dent*, 28:193-198, 2000.
14. Ikemura K, Kouro Y, Endo T : Effect of 4-acryloxyethyltrimellitic acid in a self-etching primer on bonding to ground dentin. *Dent Mater J*, 15:132-143, 1996.
15. Gwinnett AJ, Matsui A : A study of enamel adhesives. The physical relationship between enamel and adhesive. *Arch Oral Biol*, 12:1615-1620, 1967.
16. Nakabayashi N, Kojima K, Matsumura E : The promotion of adhesion by the infiltration of monomers into tooth substrates. *J Biomed Mater Res*, 16:265-273, 1982.
17. Van Meerbeek B, Inokoshi S, Braem M et al. : Morphological aspects of the resin-dentin inter-diffusion zone with different dentin adhesive systems. *J Dent Res*, 71:1530-40, 1992.
18. Inokoshi, Hosoda H, Harnirattisai C et al. : Interfacial structure between dentin and seven dentin bonding system revealed using argon ion beam etching. *Oper Dent*, 18:8-16, 1993.
19. Shaffer SE, Barkmeier WW, Kelsey WP III : Effect of reduced acid-containing time on enamel microleakage. *Gen Dent*, 35:278-280, 1987.
20. Blosser RL : Time dependence of 2.5% nitric acid solution as an etchant on human dentin and enamel. *Dent Mater*, 6:83-87, 1990.
21. Miyazaki M, Iwasaki K, Onose H : Adhesion of single application bonding systems to bovine enamel and dentin. *Oper Dent*, 27:88-94, 2002.
22. Barkmeier WW, Los SA, Triolo PT Jr : Bond strengths and SEM evaluation of Clearfill Liner Bond 2. *Am J Dent*, 8:289-293, 1995.
23. Van Meerbeek B, Perdigao J, Lambrechts P, et al. : The clinical performance of adhesives. *J Dent*, 26:1-20, 1998.

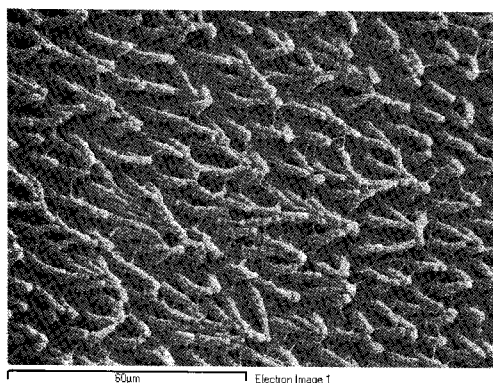
24. Perdigao J, Frankenberger R, Rosa BT : New trend in dentin/enamel adhesion. Am J Dent, 13:25-30, 2000.
25. Frankenberger R, Perdigao J, Rosa BT : "No-bottle" vs "Multi-bottle" dentin adhesives. A microtensile bond strength and morphological study. Dent Mater, In press.
26. Jacobson T, Söderholm KM : Effect of primer solvent, primer agitation, and dentin dryness on the shear bond strength to dentin. Am J Dent, 11:225-228, 1998.



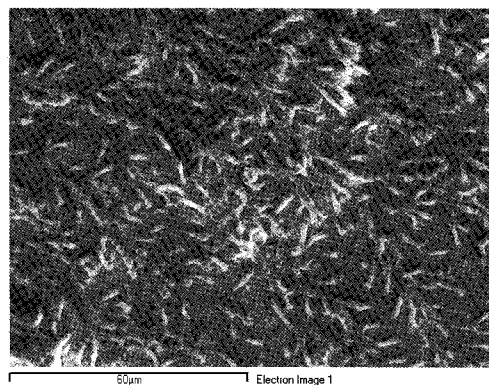
## Appendix

- Fig. 1. SEM of demineralized non-vibration dentin surface for Prompt-L-Pop( $\times 1000$ ).
- Fig. 2. SEM of demineralized vibration dentin surface for Prompt-L-Pop( $\times 1000$ ).
- Fig. 3. SEM of demineralized non-vibration dentin surface for One-Up Bond F( $\times 1000$ ).
- Fig. 4. SEM of demineralized vibration dentin surface for One-Up Bond F( $\times 1000$ ).
- Fig. 5. SEM of demineralized non-vibration dentin surface for AQ Bond( $\times 1000$ ).
- Fig. 6. SEM of demineralized vibration dentin surface for AQ Bond( $\times 1000$ ).
- Fig. 7. SEM of demineralized non-vibration enamel surface for Prompt-L-Pop( $\times 1000$ ).
- Fig. 8. SEM of demineralized vibration enamel surface for Prompt-L-Pop( $\times 1000$ ).
- Fig. 9. SEM of demineralized non-vibration enamel surface for One-Up Bond F( $\times 1000$ ).
- Fig. 10. SEM of demineralized vibration enamel surface for One-Up Bond F( $\times 1000$ ).
- Fig. 11. SEM of demineralized non-vibration enamel surface for AQ Bond( $\times 1000$ ).
- Fig. 12. SEM of demineralized vibration enamel surface for AQ Bond( $\times 1000$ ).
- Fig. 13. SEM of non-vibration resin-dentin interface for Prompt-L-Pop( $\times 2000$ ).
- Fig. 14. SEM of vibration resin-dentin interface for Prompt-L-Pop( $\times 2000$ ).
- Fig. 15. SEM of non-vibration resin-dentin interface for One-Up Bond F( $\times 2000$ ).
- Fig. 16. SEM of vibration resin-dentin interface for One-Up-Bond F( $\times 2000$ ).
- Fig. 17. SEM of non-vibration resin-dentin interface for AQ Bond( $\times 2000$ ).
- Fig. 18. SEM of vibration resin-dentin interface for AQ Bond( $\times 2000$ ).

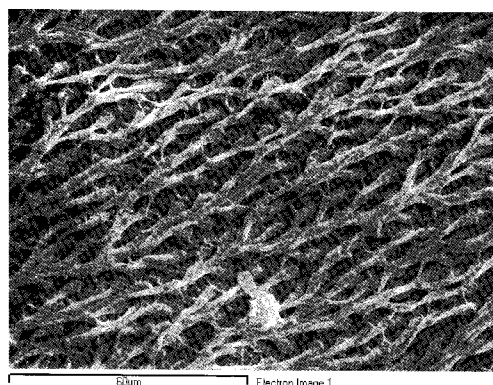
Appendix(Figures)



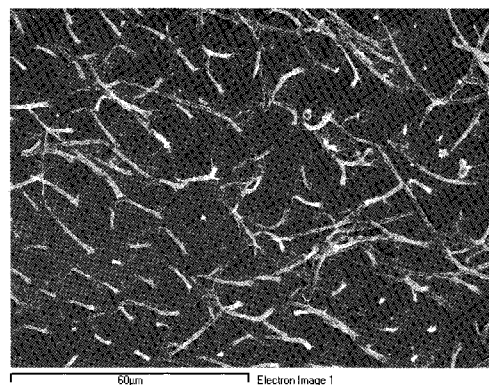
**Fig. 1.** Non-vibration dentin surface for Prompt-L-Pop.



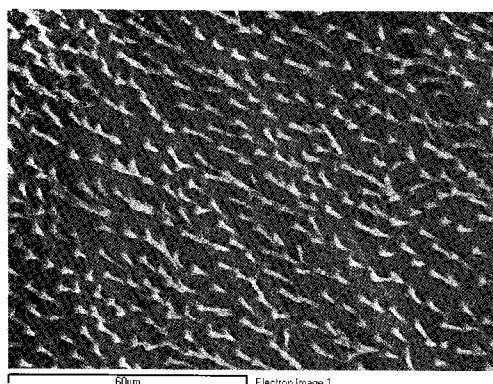
**Fig. 4.** Vibration dentin surface for One-Up bond F.



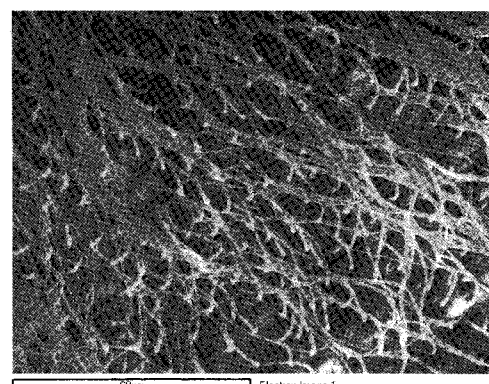
**Fig. 2.** Vibration dentin surface for Prompt-L-Pop.



**Fig. 5.** Non-vibration dentin surface for AQ bond.

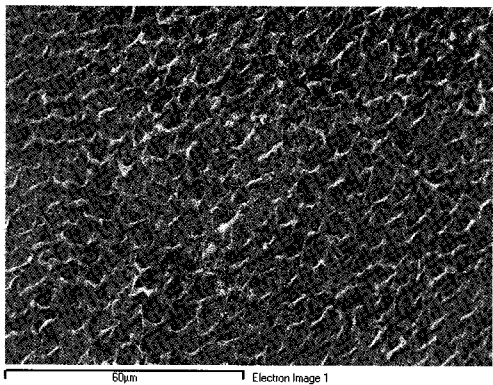


**Fig. 3.** Non-vibration dentin surface for One-Up bond F.

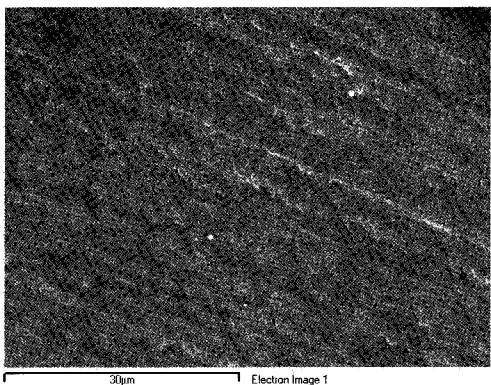


**Fig. 6.** Vibration dentin surface for AQ bond F.

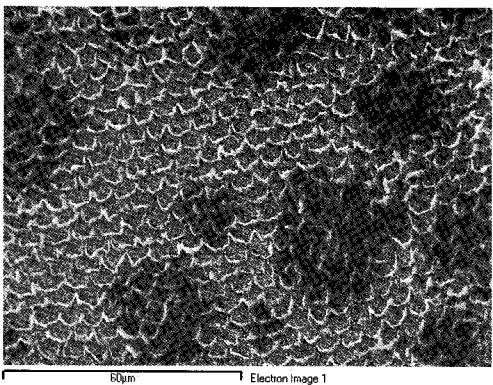
Appendix(Figures)



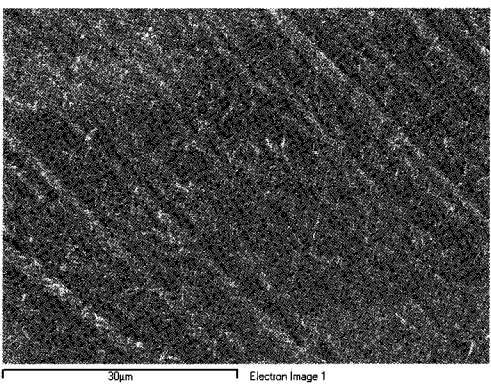
**Fig. 7.** Non-vibration enamel surface for Prompt-L-Pop.



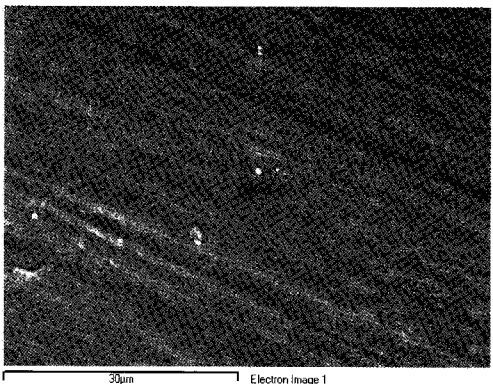
**Fig. 10.** Vibration enamel surface for One-Up Bond F.



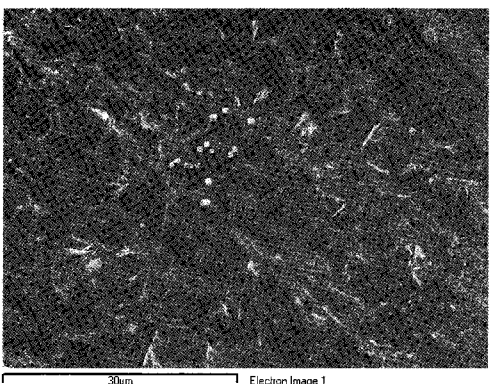
**Fig. 8.** Vibration enamel surface for Prompt-L-Pop.



**Fig. 11.** Non-vibration enamel surface for AQ bond.

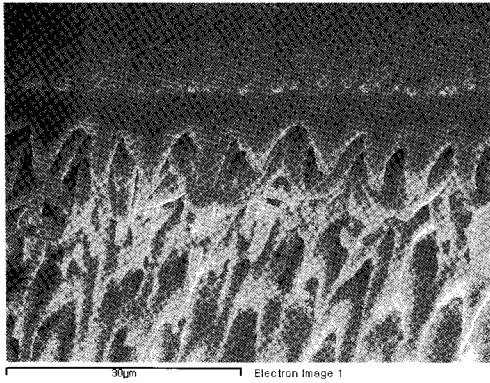


**Fig. 9.** Non-vibration enamel surface for One-Up Bond F.

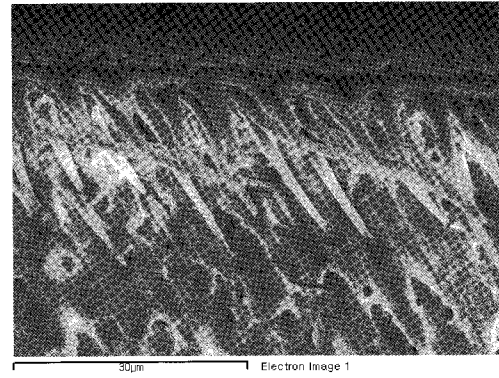


**Fig. 12.** Vibration enamel surface for AQ bond.

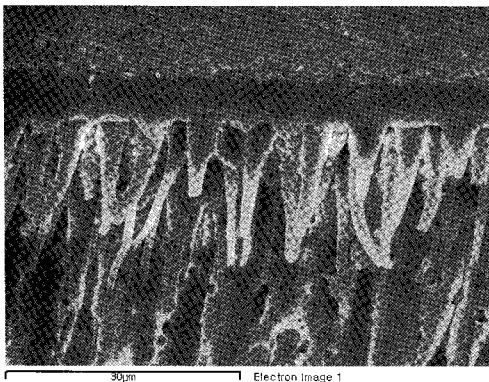
Appendix(Figures)



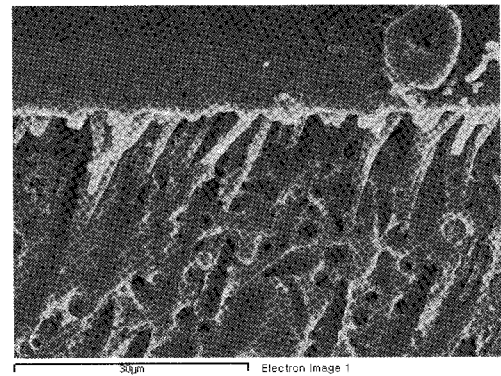
**Fig. 13.** Non-vibration dentin-resin interface of Prompt-L-Pop.



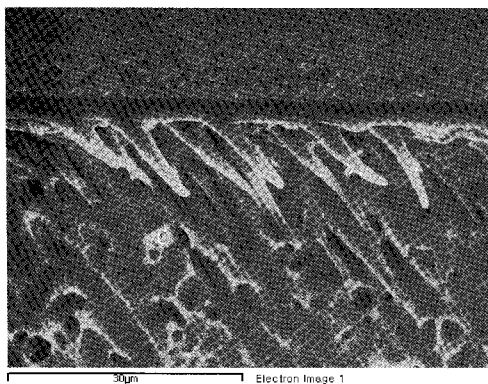
**Fig. 16.** Vibration dentin-resin interface of One-Up Bond F.



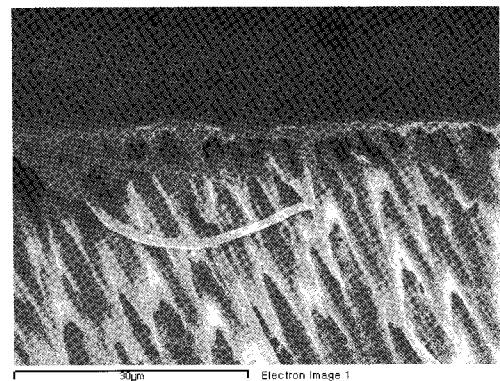
**Fig. 14.** Vibration dentin-resin interface of Prompt-L-Pop.



**Fig. 17.** Non-vibration dentin-resin interface of AQ bond.



**Fig. 15.** Non-vibration dentin-resin interface of One-Up Bond F.



**Fig. 18.** Vibration dentin-resin interface of AQ bond.

## Abstract

### EFFECT OF ULTRASONIC VIBRATION ON ENAMEL AND DENTIN BOND STRENGTH AND RESIN INFILTRATION IN ALL-IN-ONE ADHESIVE SYSTEMS

Bum-Eui Lee, D.D.S., Ki-Taeg Jang, D.D.S., M.S.D., Ph.D., Sang-Hoon Lee, D.D.S., M.S.D., Ph.D.,  
Chong-Chul Kim, D.D.S., M.S.D., Ph.D., Se-Hyun Hahn, D.D.S., M.S.D., Ph.D.

*Department of Pediatric Dentistry, College of Dentistry, Seoul National University*

The objective of this study was to apply the vibration technique to reduce the viscosity of bonding adhesives and thereby compare the bond strength and resin penetration in enamel and dentin achieved with those gained using the conventional technique and vibration technique.

For enamel specimens, thirty teeth were sectioned mesio-distally. Sectioned two parts were assigned to same adhesive system but different treatment(vibration vs. non-vibration). Each specimen was embedded in 1-inch inner diameter PVC pipe with a acrylic resin. The buccal and lingual surfaces were placed so that the tooth and the embedding medium were at the same level. The samples were subsequently polished silicon carbide abrasive papers. Each adhesive system was applied according to its manufacture's instruction. Vibration groups were additionally vibrated for 15 seconds before curing. For dentin specimen, except removing the coronal part and placing occlusal surface at the mold level, the remaining procedures were same as enamel specimen. Resin composite(Z250. 3M. U.S.A.) was condensed on to the prepared surface in two increments using a mold kit(Ultradent Inc., U.S.A.). Each increments was light cured for 40 seconds. After 24 hours in tap water at room temperature, the specimens were thermocycled for 1000cycles. Shear bond strengths were measured with a universal testing machine(Instron 4465, England). To investigate infiltration patterns of adhesive materials, the surface of specimens was examined with scanning electron microscope.

The results were as follows:

1. In enamel, the mean values of shear bond strengths in vibration groups(group 2,4,6) were greater than those of non-vibration group(group 1,3,5). The differences were statistically significant except AQ bond group.
2. In dentin, the mean values of shear bond strengths in vibration groups(group 2, 4, 6) were greater than those of non-vibration groups(group 1,3,5). But the differences were not statistically significant except One-Up Bond F group.
3. The vibration group showed more mineral loss in enamel and longer resin tag and greater number of lateral branches in dentin under SEM examination.

**Key words** : Ultrasonic vibration, All-in-one adhesive, Shear bond strength, Resin penetration