〔Original〕

Effects of exposure time and bracket position adjustment under ambient light before light-curing of composite resin adhesives on bracket bond strength to enamel

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Abstract

Background/Objective : The aim of this study was to investigate the effects of exposure time and bracket position adjustment under ambient light (room light) before light-curing of orthodontic light-cured composite adhesive on shear bond strength (SBS) to enamel.

Materials/Methods : Bovine incisors (n=112) were divided randomly into 16 groups. The incisors were encapsulated in epoxy resin and the surfaces were polished with 600-grid silicon carbide paper. The brackets were bonded with two different types of light-cured composite resin adhesives, the self-etching primer type (Transbond Plus) and the etch-and-rinse type (Enlight, Ormco). We compared four exposure times (0.5, 1, 2, and 3 min) under room light with 1,000 lux after resin paste placement on the bracket base, as well as a 45° rotation of the bracket at four working times (0.5, 1, 2, and 3 min) after bracket placement on the tooth. After stored for 24 hours, the SBS of the bracket-bonded specimens was examined (n=7). Data were compared by one-way and two-way ANOVA, and Tukey's test.

Results : The exposure time after resin paste placement on the bracket base did not influence the SBS value for either adhesive. In addition, rotating the bracket position for the working times tested did not influence the values of SBS for either adhesive.

Conclusions/Implications : If it is less than 3 min, exposure to room light in indirect bonding and adjusting the bracket position in direct bonding do not cause bracket bond failure using light-cured composite resin adhesives.

Introduction

Since the direct bonding of orthodontic brackets to enamel was introduced in 1965 by Newman, the direct bonding of fixed appliances has been used widely in clinical orthodontics (Eliades and Eliades, 2001). To achieve precise positioning of brackets, an indirect bonding technique, which was first described in detail in 1972 by Silverman and Cohen, has been developed over the last 40 years. With both direct and indirect bonding techniques, bond failure is a primary concern of both clinicians and researchers. Laboratory tests have been performed to investigate the characteristics of orthodontic bracket bonding adhesives (Eliades and Eliades, 2001). In addition, clinical trials have compared the bond-failure rates associated with the direct and indirect bonding techniques (Zachrisson and Brobakken, 1978 ; Thiyagarajah *et al*., 2006). Currently, light-cured adhesives are more popular for bracket placement than chemical-cured adhesives because they offer a longer working time and immediate archwire placement. Light-cured composite resin adhesives polymerize through a reaction between the catalyst in the adhesive and the photo-activator by blue light (peak wave-

length of about 470 nm) from the light-curing source, such as quartz-tungsten-halogen (QTH), light-emitting diode (LED) and plasma-arc (PAC) (Niepraschk *et al*., 2007). Typically, the syringes of composites are made of opaque plastic to protect the materials from exposure to ambient light, which might advance the polymerization of the composite materials. Within 60 to 90 sec after exposure to ambient light, the surface of the composite may lose its ability to flow readily against tooth structure (Powers, 2002) and long-time exposure may influence bracket bond strength. Little information is available about the relationships between the bonding characteristics and exposure to ambient light during the bracket bonding procedure.

The purpose of this study was to investigate the effect of exposure to ambient light (room light) and bracket position adjustment at extended working time before light-curing of orthodontic composite resin adhesives on the bracket bond strength.

Materials and methods

Materials

A total of 112 bovine incisors were divided randomly into 16 groups. The criteria for tooth selection included the absence of any visible decalcification and cracking of the enamel surface under a stereoscopic microscope (SMZ 1500, Nikon, Tokyo, Japan) at a magnification of ×10. The bovine incisors were encapsulated in epoxy resin and the surfaces were polished with 600-grid silicon carbide paper and then cleaned using non-fluoridated pumice with a rubber cup on a low-speed handpiece for 10 sec. The enamel surface was rinsed with water to remove any pumice or debris and dried with oil-free compressed air. Two types of light-cure composite resin adhesives, a self-etching primer (SEP) adhesive system (Transbond XT + Tarnsbond Plus, 3M Unitek, Monrovia, CA, USA) and an etch-and-rinse adhesive system (Enlight Light Cure adhesive, Ormco, Glendora, CA, USA), were used to bond the brackets. Both adhesive systems were used according to their manufacturers' instructions.

Exposure to Room Light before Light-curing of Composite Resin Adhesive.

A small amount of composite resin paste was placed on mesh processed bracket base surface of the stainless steel bracket (One Piece Bracket, Shofu, Kyoto, Japan) and it was exposed under a desk lamp with fluorescent light for four working times (0.5, 1, 2, and 3 min). The distance between the working environment and desk lamp was adjusted to obtain an illumination of 1,000 lux, measured using an illuminometer (LX1010BS, Yueqing Hecheng Electrical, Yueqing, China). Next, the bracket was placed on polished bovine incisors and then a force of 0.98 N was applied using a custom-made device (Figure 1a), which was used previously to mount brackets for friction testing (Muguruma *et al*., 2011). Excess bonding material was removed with a small scaler. All samples were light-cured for 20 sec at a distance of 3 mm (10 sec from each proximal side) using a light-emitting diode (LED) curing unit (Mocha, Pierce, Tokyo, Japan) with 1,600 mW/cm^2.

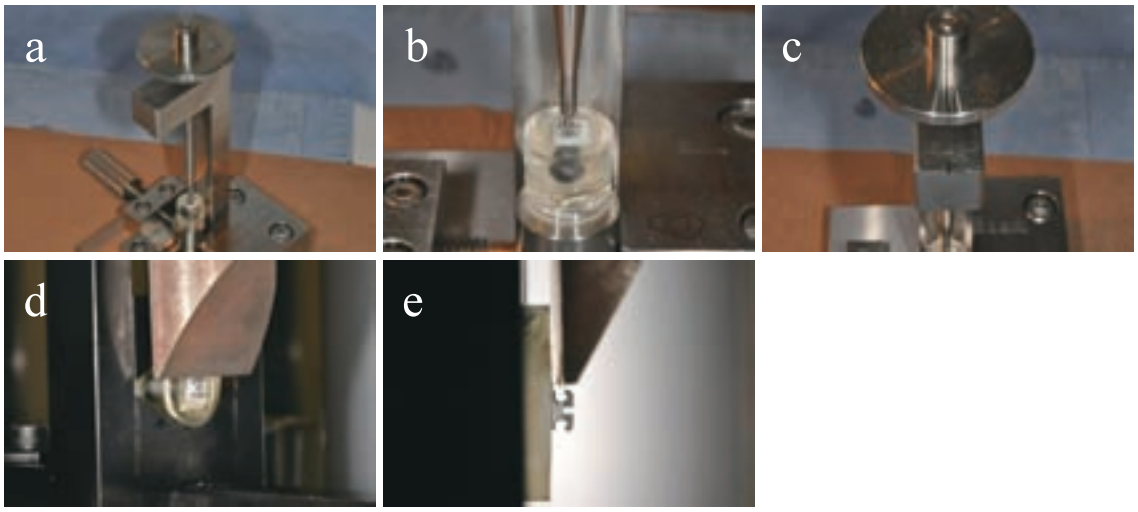

Figure 1 (a, b, c) Custom-made device for applying force to the bracket-slot and rotating of the bracket. (d, e) Custom-made device for holding encapsulated bovine incisors. The device is fixed to a universal testing machine, and a knife-edged shearing blade is secured to the crosshead with the direction of force parallel to the buccal surface and the bracket base.

Bracket Position Adjustment before Light-curing of Composite Resin.

A small amount of composite resin paste was placed on the bracket base (One Pierce Bracket, Shofu) and the bracket was placed on polished bovine incisors. A force of 0.98 N was applied ; as described above and excess bonding material was removed with a small scaler. After four different working times (0.5, 1, 2, and 3 min) under desk light with 1,000 lux, the bracket was rotated 45° using a custom-made device (Figure 1b, c). The samples were light-cured for 20 sec at distance of 3 mm (10 sec from each proximal side) using the LED curing unit (Mocha, Pierce).

Measurement of the Shear Bond Strength (SBS)

Following the bonding procedures, the specimens were stored in artificial saliva at 37° C for 24 hours. Next, the specimens were fixed to a custom-made device connected to a universal testing machine (EZ Test, Shimadzu, Kyoto, Japan) (Figure 1d, e). A knife-edged shearing blade was secured to the crosshead with the direction of force parallel to the buccal surface and the bracket base. Force was applied directly to the bracket wings. The brackets were debonded at a crosshead speed of 0.5 mm/min.

Adhesive Remnant Index

After bond failure, the bracket bases and enamel surfaces were examined under a stereoscopic microscope at a magnification of ×10. Adhesive remnant index (ARI) scores were used to assess the amount of adhesive remaining on the enamel surface (Artun and Bergland, 1984). The ARI scores ranged from 0 to 3, as follows : 0 = no adhesive left on the tooth surface, that is, the failure site was between the adhesive and enamel ; 1 = less than half of the adhesive was left on the tooth surface ; 2 = half or more of the adhesive was left on the tooth ; 3 = all of the adhesive was left on the tooth surface, that is, the failure site was between the adhesive and bracket base.

Statistical Analysis

Statistical analysis was performed using the Statistical Package for Social Science software (version 22 for Windows, IBM SPSS, Chicago, Ill). The bond strength data were tested for normality with the Kolmogorov-Smirnov test. The mean SBS for each adhesive obtained at the four exposure times under room light and with bracket rotation at four working times were compared by two- and one-way analyses of variance (ANOVA), followed by the Tukey-Kramer honestly significant difference test. The chi-square test was used to evaluate the significance of differences in ARI scores among the different groups. For the purpose of statistical analysis, ARI scores of 0 and 1, as well as 2 and 3 were combined. Statistical significance was defined as $P < 0.05$.

Results

The SBS results are illustrated in Figures 2 and 3. Exposure to desk light after resin paste placement on the bracket base did not affect the SBS of either bracket bonding adhesive ($p=0.733$ for SEP adhesive ; $p=0.959$ for etch-and-rinse adhesive). Similarly, adjusting the bracket position by 45° after bracket placement on the tooth did not influence the SBS in with either bracket bonding adhesive ($p=0.680$ for SEP adhesive ; $p=0.674$ for etch-and-rinse adhesive).

A chi-square analysis that compared the ARI scores for the 2 adhesives revealed no significant difference in the distribution of frequencies among the ARI categories for the 8

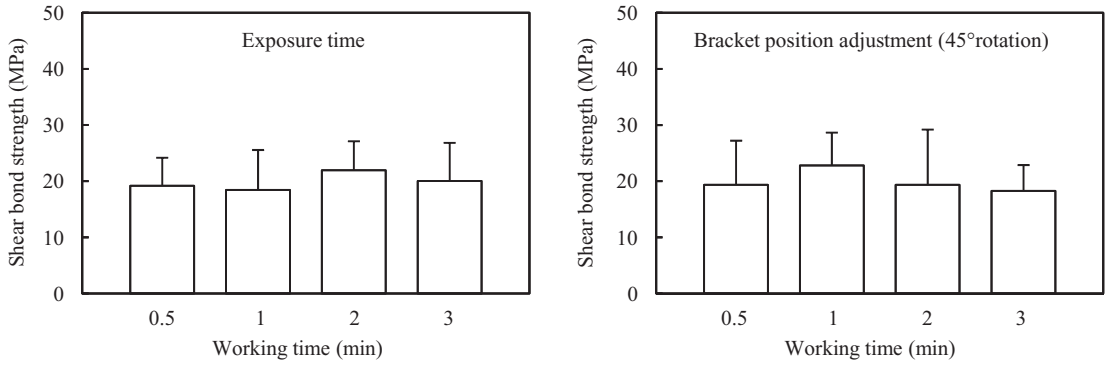

Figure 2 Mean and standard deviation of the shear bond strength (MPa) for the SEP adhesive system. There was no significant difference in shear bond strength as a function of exposure time ($P=0.733$) or bracket position adjustment ($P=0.959$).

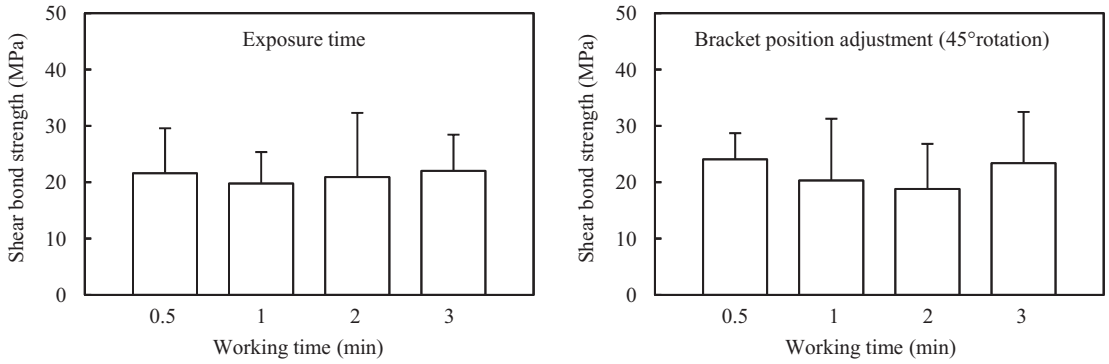

Figure 3 Mean and standard deviation of the shear bond strength (MPa) for the etch-and-rinse adhesive system. There was no significant difference in shear bond strength as a function of exposure time (P=0.680) or bracket position adjustment (P=0.674).

Table 1 Frequency Distribution of ARI Score of the SEP adhesive.

Condition	Working time	ARI scores			
		0	1	2	3
Exposure time	0.5 min	0	5	2	0
	1 min	0	5	0	2
	2 min	0	6	1	0
	3 min	0	7	0	0
45-degree rotation	0.5 min	0	4	2	1
	1 min	0	5	2	0
	2 min	0	4	3	0
	3 min	0	6	1	0

Table 2 Frequency Distribution of ARI score of the etch-and-rinse adhesive.

Condition	Working time	ARI scores			
		0	1	2	3
Exposure time	0.5 min	0	3	2	2
	1 min	0	1	3	3
	2 min	0	1	5	1
	3 min	0	2	3	2
45-degree rotation	0.5 min	0	5	2	0
	1 min	0	3	2	2
	2 min	0	1	5	1
	3 min	0	2	4	1

adhesive groups (Tables 1 and 2).

Discussion

Bond failure of bracket bonding to teeth is a primary concern in clinical orthodontics. As described in a textbook on restorative dental materials (Powers, 2002), the surface of the composite may lose its capability to flow readily against tooth structure within 60 to 90 sec after exposure to ambient light, suggesting that light-cured composite resin adhesive may start to polymerize under room light, and this exposure may influence the bracket bond strength. However, this procedure may take a few minutes in the clinical setting because the transfer tray for the indirect bonding technique usually contains multiple brackets and it is necessary to apply composite resin paste to multiple brackets at the same time (Siliverman and Cohen, 1972 ; Zachrisson and Brobakken, 1978 ; Thiyagarajah *et al*., 2006). For this reason, we investigated a working time of 3 min in the current study. Similarly, we used an extended working time of 3 min before light-curing with the direct bonding technique. The mean SBS of the two light-cured composite resin adhesives ranged from 18.3 to 24.0 MPa. These values are well above the clinically acceptable bond strength (6-8 MPa) described by Reynolds (1975). In addition, the measured bond strengths were not influenced by exposure time or adjusting the bracket position under ambient light (1,000 lux) prior to light-curing of the resin.

The human eye can discern wavelengths from 380-780 nm, which are interpreted as a range of colors comprised of violet, blue, cyan, green, yellow, orange and red. Visible light is derived primarily from artificial sources, such as fluorescent and incandescent lights. Most composite adhesives are designed to cure by irradiation in the blue spectrum (440-480 nm) ; thus, the composite paste may be polymerized by general room light. The European standard (SS -EN 12464-1) recommends that ambient light (illuminance) in a dental practice be 1,000 lux. Therefore, we selected an illumination of 1,000 lux as the test environment in which composite resin paste would be applied to the bracket base. On the other hand, the International Organization for Standardization (ISO Standard 9690) describes that the level of illuminance for operating light should be adjustable with a minimum level <8,000 lux and a maximum >20,000 lux. These operating light sources, powered by either halogen or

LED, should not be use during composite resin paste placement on the bracket base because such high illumination would advance the polymerization of the composite paste. The use of operating light is assumed in the direct bonding technique. Because the direct bonding procedure under high-illumination operating light may influence the polymerization of the composite paste, further investigation is needed to investigate the effects of bonding characteristics with operating light 8,000 lux.

In the current study, bovine incisors were used as a substitute for human teeth. Most bracket bonding studies used human premolars that were extracted for orthodontic treatment. However, the morphology of human premolars varies widely, which can influence the thickness of the adhesive layer between the enamel surface and bracket base. Previous studies have reported that the bond strength to bovine enamel is less than that to human enamel (Barkmeier and Erikson, 1994 ; Oesterle *et al*., 1998). In this study, the surfaces of bovine enamel were ground and polished as reported previously (Attin *et al*., 2012 ; Parrish *et al*., 2012).[13,14] This polishing procedure of bovine enamels removed approximately 200 μm of the tooth surface ; the use of such flattened enamel is advantageous for the standardization of specimens.

Conclusion

Based on the current findings, we can conclude that when the working time is less than 3 min, the bracket bond failure using light-cured composite resin adhesives is influenced by neither exposure to room light at 1,000 lux in indirect bonding, nor bracket position adjustment in direct bonding.

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