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Distance and Time Effect on Shear Bond Strength of Brackets Cured with a Second-generation Light-emitting Diode Unit

Kimberly Gronberg;[a] P. Emile Rossouw;[b] Barbara H. Miller;[c] Peter Buschang[d]

ABSTRACT

Objective: The aims of this study were to evaluate increasing exposure times and distance between source (light-emitting diode) and adhesive composite on the shear bond strength (SBS) of stainless steel brackets.

Materials and Methods: Stainless steel maxillary incisor brackets (3M Unitek, Monrovia, Calif) were bonded to the facial surfaces of 120 bovine incisors. The bond of each specimen in eight randomly divided groups was tested to failure using an Instron Universal Testing Machine (Instron Corp, Canton, Mass). The mode of failure was evaluated using the adhesive remnant index (ARI).

Results: There were significant SBS differences between exposure times; 5-second exposures were significantly less than at 20-and 40-second exposures; SBS increased in a curvilinear fashion. Significant differences were recorded neither in the frequencies of ARI scores nor the SBS in relation to distance. Significant differences in the frequencies of ARI scores were observed when comparing the 5-second cure time to other time periods, indicating incomplete polymerization in the bracket base.

Conclusions: SBS increased with increasing time periods in a curvilinear fashion, with no difference between the distances evaluated from source to specimen.

KEY WORDS: Orthodontic bonding, LED-curing lights.

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INTRODUCTION Return to TOC

Light-emitting diode (LED)–curing units are promising alternatives for the curing of dental composites.[1] LEDs generate light in very narrow wavelengths[2]; no light in the ultraviolet or infrared range is generated, eliminating the need for filters and preventing excess heat production. No hot filaments are used as in halogen units and thus there is no need for cooling fans, allowing the unit to be cordless. Halogen units work at approximately 1% efficiency compared with LEDs and are approximately 10% efficient in converting electrical current into light.[3] Furthermore, the wavelength of light emitted from LEDs is about 470 nm, ideally matched to the absorption wavelength of the camphorquinone (CQ) photoinitiator used in most composites.[4] Moreover, LEDs are resistant to shock and vibration, require little power to operate, and have longer life spans and more consistent light output than Quartz halogen (QTH) lights.[5]

Numerous factors are involved in the conversion of monomer to polymer in composite resin, including wavelength of light, intensity of irradiation (power density in mW/cm^2), duration of exposure, and distance from source to specimen.[6,7] In evaluating the effect of wavelength, no significant differences were found in depth of cure or Knoop hardness between composite cured with an LED light at 450 nm (100 mW/cm^2) and with a halogen unit (adjusted to 100 mW/cm^2).[8] However, when the wavelength of the LED unit was increased to 470 nm, a greater depth of cure and degree of conversion of monomer to polymer was found in comparison with the QTH when both were adjusted to 100 mW/cm^2.[9] Thus when irradiance is controlled, there is a greater cure with the LED at 470 nm than the QTH. More conversion of monomer to polymer occurs because the wavelength of the LED light is closer to the peak absorption of the CQ photoinitiator.

No differences in shear bond strength (SBS) of orthodontic brackets or in adhesive remnant index (ARI) scores were found among commercial LED units with lower irradiance values (150 mW/cm^2) and conventional halogen units (1030 and 400 mW/cm^2).[10] Recently, LED lights have been designed with irradiance values of up to 1000 mW/cm^2 (3M Unitek, Monrovia, Calif). These changes coupled with proper wavelength of light emission suggest that decreased curing times may be adequate for composite polymerization.

Increasing exposure time with standard QTH light directly increases the cure of composite resins, although in a nonlinear relationship. More polymerization occurs with increases in duration of exposure, with less of an increase between higher time periods.[11–15] LED and QTH units showed higher mean SBS as the curing time is increased (10, 20, or 40 seconds), with less of an increase between higher exposure times.[16]

Distance between composite and light sources could affect composite polymerization because the irradiance of a point light source decreases as an inverse square function of distance. However, dental curing units are collimated and working ranges are small, leading to a less acute decrease in irradiance with increasing distance. LED lights showed significant decreases in power output at 10 mm from the light tip to the radiometer compared with the QTH units.[17] In addition, mean hardness of the composites decreased with increased distance from light tip to composite increased (2 to 9 mm) for both LED and QTH lights.[18] The depth of cure also decreased with increased irradiation distance.[19]

LED light technology has many potential advantages over standard QTH light units including higher irradiance values, and manufacturers (3M Unitek) publicize reduced exposure times for orthodontic bonding. Exposure-time effects in orthodontic bonding are unclear with LED-curing units. Furthermore, because power density decreases with increasing distance from light source to composite, guidelines for the position of the LED light to the resin must be formulated. The aims of this study were to evaluate (1) the effect of increasing LED exposure times on the SBS of orthodontic brackets and (2) the SBS of orthodontic brackets when the LED light source is moved greater distances from the composite/bracket base.

MATERIALS AND METHODS Return to TOC

A total of 135 freshly harvested bovine incisors without visible enamel defects, selected for bonding, were disinfected with 0.5% Chloramine-T solution and stored in a plastic container with deionized water and thymol crystals. The crown specimens, mounted in small epoxy cylinders with the facial surfaces exposed and parallel to the bases of the cylinder, were randomly assigned to one of eight experimental LED groups (Table 1). Each group contained 15 teeth.

Before bonding, the teeth were prepared using the following sequence: (1) sanded with #600-grit silicon carbide paper (Allied High Tech Products Inc, Rancho Dominguez, Calif) to create a flat surface without exposing underlying dentin, (2) polished for 10 seconds with a rubber prophy cup and fluoride-free pumice (Moyco, York, Pa), (3) rinsed for 10 seconds with deionized water, (4) acid etched for 15 seconds as per manufacturers instructions with 37% phosphoric acid (3M Unitek), (5) rinsed for 15 seconds with deionized water, (6) air dried for 5 seconds to produce a chalky enamel surface, and (7) coated with Transbond XT primer (3M Unitek).

Stainless steel maxillary incisor brackets with Transbond XT adhesive composite (3M Unitek) were placed on the bonding surface by hand and fully seated into position using a modified articulator[20] to deliver a standardized pressure (600 g). Excess adhesive was removed with a sharp explorer and then light cured according to the assigned group. Curing was carried out with the tip of the light guide parallel to the base of the bracket with half of the curing time at the mesial of the bracket and half at the distal. Distance from the bracket base (1 or 10 mm) was controlled by a device mounted on the articulator. Each specimen was subsequently stored in deionized water at 37°C for 24 hours. Shear testing to failure, at random with the investigator blinded, occurred using an Instron Universal Testing Machine with a 5-kN load cell (Model 4301, Instron Corp, Canton, Mass). Each bracket base was positioned parallel to the direction of the force with the shear debonding force applied at a crosshead speed of 0.5 mm/minute.

A standard QTH reference group of 15 teeth was prepared using the same protocol, as described previously. Curing occurred with the tip of an Ortholux XT halogen curing light (3M Unitek) parallel to the base of the bracket with 10 seconds of the curing time at the mesial of the bracket and 10 seconds at the distal as per manufacturer's instructions.

After debonding, each specimen was examined, with the investigator blinded to group association, under a light microscope (20×) to determine the mode of bond failure on the basis of the ARI scores[21] (Figure 1). Interoperator agreement was 100% for ARI scoring.

The following statistical analyses were used to evaluate the normally distributed data: two-way analysis of variance (ANOVA) for the effects of distance and time; a post hoc test (Scheffe multiple comparisons) for differences in exposure duration; and chi-square test to determine frequency and significant differences for ARI scores. Significance was determined as $P < .05$.

RESULTS Return to TOC

Table 1 describes the distribution of tested specimens. The mean SBS for each of the four LED-curing times and two distances are shown in Table 2. Mean SBS increased with increasing exposure time periods in a curvilinear relationship, with the greatest increases in bond strength occurring at the lowest exposure times (Figure 2). Two-way ANOVA revealed, with respect to SBS, no significant interaction between time and distance ($F = 1.903$, $P = .133$); no significant differences between the 1 and 10 mm distances ($F = 0.079$, $P = .779$); significant differences among time groups ($F = 15.847$, $P < .001$). Bond strengths at 5 seconds were significantly less than those at 20 seconds ($P < .001$) and 40 seconds ($P < .001$) (Table 3). In addition, SBS at 10 seconds were significantly less than those at 40 seconds ($P = .004$). A control group, cured with a QTH light for a total of 20 seconds, tested with a mean SBS of 20.6 ± 4.0 MPa.

No significant differences in ARI scores were shown in relation to distance ($P = .454$) (Figure 3; Table 4); however, the ARI scores were significantly different in relation to time ($P = .001$) (Figure 4; Table 5). Significant differences in frequencies of ARI scores were seen between 5 and 10 seconds ($P = .018$), 5 and 20 seconds ($P = .026$), and 5 and 40 seconds ($P = .033$). No significant differences were seen for any other time periods in relation to frequencies of ARI scores. No enamel fractures were detected under 20× magnification.

DISCUSSION Return to TOC

The present study assessed an LED light-curing unit with an irradiance value much higher than standard QTH lights. SBS were evaluated at lower and higher than recommended exposure times to describe fully the relationship of time and SBS at varying time periods. The present data show less increase between the means of SBS at increasing time periods as seen in the curvilinear relation in Figure 2. Mean SBS at 5 seconds were significantly less than at 20 and 40 seconds. The difference between 5 and 10 seconds ($P = .059$) would probably become significant with a greater sample size. No significant differences were found between higher exposure time periods (Table 2), supporting a curvilinear function of increasing cure with increasing time periods; other bonding studies show the same general trend[14,16] (Figure 5). It is also notable that above 5 seconds of total exposure time, all mean SBS in this study were greater than 8 MPa, a level which may be sufficient to withstand normal orthodontic force.[22] None of the previous studies evaluated bond strength down to this low time period.

Although there were no significant differences in ARI scores in relation to light source to resin distance, the ARI scores were significantly different in relation to exposure time. The 5-second cure group showed a significantly higher frequency of ARI scores of 3 (all composite left on the tooth instead of the bracket). In addition, at this lowest time period, almost twice as many ARI scores of 3 at 10 mm were recorded compared with 1 mm. These results may be because of a lack of cured adhesive in the metal mesh of the bracket bases.

A scanning electron micrograph image of a representative sample cured for 5 seconds showed that an adhesive failure occurred between the bracket mesh and composite (Figure 1, ARI 3). Transillumination through enamel would allow the light to reach the interface between the tooth and composite easier than the junction of composite to bracket. This is supported by other studies[15,23] in which brackets irradiated for the shortest time period left a higher percentage of adhesive on the tooth surface. Maximum conversion of monomer to polymer allows composites to achieve optimal physical properties.[24,25] Stronger bonds may have been due not only to greater polymerization of the overall adhesive but also specifically to greater polymerization of the adhesive in the mesh of the metal bracket. For the samples with greater polymerization, this would give a stronger interlocking of the composite in the bracket base mesh and lead to increased fractures within the adhesive (cohesive fracture) rather than at the junction of bracket and adhesive (adhesive fracture).

No significant difference was found in SBS in the present study for samples cured at 1 or 10 mm from the LED light source. With increased source to specimen distance, power output has been shown to decrease in a linear relationship for LED lights.[13] Therefore, a linear decrease in bond strength as distance increase is expected. However, Bennett and Watts[13] showed that even at the greatest source to specimen distance of 8 mm, the lowest depth of cure for all lights was greater than 1 mm deep. The adhesive thickness used in the bonding of orthodontic brackets is 1 mm or less, and the latter may prove to be clinically insignificant. The thin adhesive layer (<1 mm) used and relatively small differences in distance may explain why no dissimilarity was observed in bond strength for the two distances in the present study (Figure 3).

Irradiance values for the LED group (≈800 mW/cm^2) were higher than the QTH group (≈400 mW/cm^2), but when controlling for time, the group cured with a halogen light presented with a higher bond strength; the differences may be attributed to the wavelength of the light produced. LED units emit light in a very tight wavelength around 470 nm, whereas QTH units emit a much broader spectrum of light. This does not make the QTH light as efficient as the LED at initiating CQ, the most common photoinitiator in composites. However, some composites contain other photoinitiators in addition to CQ, so called coinitiators, which absorb light at shorter wavelengths (<410 nm),[26] which only the QTH light may be emitting. In a previous study, an LED light did not perform as well as a QTH light with respect to Knoop hardness with certain composites.[27] If the LED unit was used, the Knoop hardness of the composite containing coinitiators was in most cases significantly lower when compared with that cured by the halogen unit. Lower hardness indicates a lower degree of monomer conversion.[28] Thus, clinicians need to be cognizant of the composition of the composite used and the wavelength required for optimum polymerization. In this study, Transbond XT composite was used to bond the brackets to enamel. The exact composition of this composite is proprietary information; however, it may have coinitiators in its three-part initiator system. Although this may have led to slightly higher bond strengths for the QTH group, it is important to note that bond strengths attained after curing with the LED light for more than a total of 5 seconds were all at acceptable levels.[22]

The variability of the data could be attributed to the use of bovine enamel. However, bovine enamel was shown to be a suitable substitute for human enamel.[29,30] Variability between specimens could also be attributed to surface enamel differences from that of the deeper layers.[31] In a search of three recent bonding studies, variability was compared with that of the present study. These studies ranged from 48% to 66%, 21% to 77%, and 23% to 39% variability in mean bond strength[16,32,33] compared with 39% to 65% for the present study. The comparative studies all used extracted molar teeth and still yielded high amounts of variability. Thus, bovine enamel is not the only possible explanation for variability. This emphasizes the overall technique sensitive nature of all such studies, despite the medium of specimens used and attempts to standardize processes. The clinician must be aware of the possibility for even higher variability in a clinical setting.

CONCLUSIONS Return to TOC

- The mean SBS increased curvilinearly to time of exposure (Figure 2; Table 5).
- Exposures at or above 10 seconds total per bracket were deemed to be at a clinically acceptable level.[24] Longer time exposures appear unnecessary.
- No statistically significant difference was noted between mean SBS at 1 or 10 mm of source to specimen distance.
- Specimens exhibiting the lowest bond strengths demonstrated higher frequencies of ARI score 3 (all the composite left on the tooth); a clinician should not assume that an acceptable bond strength was obtained if a bracket was undesirably debonded with all composite remaining on the tooth, blaming the occurrence on patient misuse.
- Inadequate polymerization in the bracket mesh itself may actually lead to lower than usual bond strengths.

REFERENCES Return to TOC

1. Mills RW. Blue light emitting diodes—another method of light curing?. *Br Dent J.* 1995; 178:169

2. Nakamura S, Mukai T, Senoh M. Candela-class high brightness in GaN/AlGaN double heterostructure blue light emitting diodes. *Appl Phys Lett.* 1994; 64:1687–1689.

3. Jandt KD, Mills RW, Blackwell GB, Ashworth SH. Depth of cure and compressive strength of dental composites cured with blue LEDs. *Dent Mater.* 2000; 16:41–47. [PubMed Citation]

4. Cook WD. Spectral distribution of dental photopolymerization sources. *J Dent Res.* 1982; 61:436–438.

5. Mills RW, Jandt KD, Ashworth SH. Dental composite depth of cure with halogen and blue light emitting diode technology. *Br Dent J.* 1999; 186:388–391. [PubMed Citation]

6. Johnston WM, Leung RL, Fan PL. A mathematical model of post-irradiation hardening of photo-activated composite resin. *Dent Mater.* 1985; 1:191–194. [PubMed Citation]

7. Rueggeberg FA, Caughman WF, Curtis JW. Effect of light intensity and exposure duration on cure of resin composite. *Oper Dent.* 1994; 19:26–31. [PubMed Citation]

8. Fujibayashi K, Ishimaru K, Kohno A. A study on light activation units using blue light emitting diodes. *J Jpn Dent Pres Acad.* 1996; 39:180–188.

9. Fujibayashi K, Ishimaru K, Takahashi N, Kohno A. Newly developed curing unit using blue light emitting diodes. *Dent Jpn.* 1998; 34:49–53.

10. Dunn WJ, Taloumis LJ. Polymerization of orthodontic resin cement with light-emitting diode curing units. *Am J Orthod Dentofacial Orthop.* 2002; 122:236–241. [PubMed Citation]

11. Rueggeberg FA, Caughman WF, Curtis JW. Effect of light intensity and exposure duration on cure of resin composite. *Oper Dent.* 1994; 19:26–31. [PubMed Citation]

12. Kauppi MR, Combe EC. Polymerization of orthodontic adhesives using modern high-intensity visible curing lights. *Am J Orthod Dentofacial Orthop.* 2003; 124:316–322. [PubMed Citation]

13. Bennett AW, Watts DC. Performance of two light-emitting diode dental light curing units with distance and irradiation-time. *Dent Mater.* 2004; 20:72–79. [PubMed Citation]

14. Wang ME, Meng CL. A study of bond strength between light and self-cured orthodontic resin. *Am J Orthod Dentofacial Orthop.* 1992; 101:350–354. [PubMed Citation]

15. Oesterle LJ, Messersmith ML, Devine SM, Ness CF. Light and setting times of visible-light cured orthodontic adhesives. *J Clin Orthod.* 1995; 29:31–38. [PubMed Citation]

16. Swanson T, Dunn W, Childers D, Taloumis L. Shear bond strength of orthodontic brackets bonded with light-emitting diode curing units at various polymerization times. *Am J Orthod Dentofacial Orthop.* 2004; 125:337–341. [PubMed Citation]

17. Meyer GR, Ernst CP, Willerhausen B. Decrease in power output of new light emitting diode curing devices with increasing distance to filling surface. *J Adhes Dent.* 2002; 4:197–204. [PubMed Citation]

18. Price RB, Felix CA, Andreou PA. Evaluation of a second generation LED curing light. *J Can Dent Assoc.* 2003; 69:666a–666i. [PubMed Citation]

19. Hansen EK, Asmussen E. Visible-light curing units: correlation between depth of cure and distance between exit window and resin surface. *Acta Odontol Scand.* 1997; 55:162–166. [PubMed Citation]

20. MacColl GA, Rossouw PE, Titley KC, Yamin C. The relationship between bond strength and orthodontic bracket base surface area with conventional and microetched foil-mesh bases. *Am J Orthod Dentofacial Orthop.* 1998; 113:276–281. [PubMed Citation]

21. Artun J, Bergland S. Clinical trials with crystal growth conditioning as an alternative to acid-etch enamel pretreatment. *Am J Orthod.* 1984; 85:333–340. [PubMed Citation]

22. Reynolds I. A review of direct orthodontic bonding. *Br J Orthod.* 1975; 2:171–178.

23. Oesterle LJ, Shellhart WC, Belanger GK. Effect of tack in time on bond strength of light cured adhesives. *J Clin Orthod.* 1997; 31:449–453. [PubMed Citation]

24. Ruyter IA, Oysaed H. Conversion in different depths of ultraviolet and visible light activated composite materials. *Acta Odontol Scand.* 1982; 40:179–192. [PubMed Citation]

25. Tirtha R, Fan PL, Dennison JB, Powers JM. In vitro depth of cure photo-activated composites. *J Dent Res.* 1982; 61:187

26. Park YA, Chae KH, Rawls HR. Development of a new photoinitation system for dental light-cure composite resins. *Dent Mater.* 1999; 15:120–127. [PubMed Citation]

27. Uhl A, Sigusch BW, Jandt K. Second generation LEDs for the polymerization of oral biomaterials. *Dent Mater.* 2004; 20:80–87. [PubMed Citation]

28. Rueggeberg FA, Craig RG. Correlation of parameters used to estimate monomer conversion in a light-cured composite. *J Dent Res.* 1988; 67:932–937. [PubMed Citation]

29. Nakamichi I, Iwaku M, Fusayama T. Bovine teeth as possible substitutes in the adhesion test. *J Dent Res.* 1983; 62:1076–1081. [PubMed Citation]

30. Oesterle LJ, Shellhart WC, Belanger GK. The use of bovine enamel in bonding studies. *Am J Orthod Dentofacial Orthop.* 1998; 114:514–519. [PubMed Citation]

31. Jenkins GN. *The Physiology and Biochemistry of the Mouth*. Oxford, UK: Blackwell Scientific Publications. 1978;54–112.

32. Bishara SE, Oonsombat C, Ajlouni R, Laffoon JF. Comparison of the shear bond strength of 2 self-etch primer/adhesive systems. *Am J Orthod Dentofacial Orthop.* 2004; 125:348–350. [PubMed Citation]

33. Theodorakopoulou LP, Sadowsky PL, Jacobson A, Lacefield W. Evaluation of the debonding characteristics of 2 ceramic brackets: an in vitro study. *Am J Orthod Dentofacial Orthop.* 2004; 125:329–336. [PubMed Citation]

TABLES Return to TOC

TABLE 1. Distribution of Successfully Tested Specimens in Each Group

Distance (mm)	Irradiation Time (s) 5	10	20	40	Total
1	15	15	15	15	60
10	15	14[a]	15	15	59
Total	30	29	30	30	119

[a] Specimen came out of mold, discarded.

TABLE 2. Mean Shear Bond Strength (MPa) in Relation to Exposure Time and Distance From Light Source to Composite

		Irradiance Time (s)							
		5		10		20		40	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Distance (mm)	1	9.8	5.6	11.7	5.4	13.7	5.8	17.1	7.0
	10	5.2	2.8	11.8	5.9	15.9	6.5	17.9	7.1
Group mean		7.5	4.9	11.76	5.6	14.8	6.1	17.5	6.9

TABLE 3. Scheffe Multiple Comparisons of the Mean Shear Bond Strength Differences Between Exposure Times[a]

Comparisons of Mean Differences					
5–10 s	5–20 s	5–40 s	10–20 s	10–40 s	20–40 s
NS	***	***	NS	*	NS

[a] NS indicates not significant.
* $P < .05$.
*** $P < .001$.

TABLE 4. Absolute (Abs) and Relative (Rel) Frequency (%) of ARI Scores in Relation to Distance From Light Source to Composite[a,b]

Distance (mm)	ARI Scores 0		1		2		3		
	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Total
1	10	16.7	16	26.7	28	46.7	6	10	60
10	11	18.6	11	18.6	26	44.1	11	19	59
Total	21		27		54		17		119

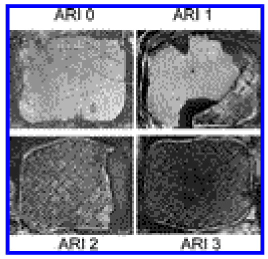
[a] Abs, absolute number of scores; Rel, % of total.
[b] $X^2 = 2.5$, df = 3, $P = .473$.

TABLE 5. Absolute (Abs) and Relative (Rel) Frequency (%) of ARI Scores in Relation to Exposure Time[a,b]

	ARI Scores								
	0		1		2		3		
Time (s)	Abs	Rel	Abs	Rel	Abs	Rel	Abs	Rel	Total
5[b]	2	6.7	3	10	14	46.7	11	36.7	30
10	8	27.6	7	24.1	11	37.9	3	10.3	29
20	5	16.7	7	23.3	16	53.3	2	6.7	30
40	6	20	10	33.3	13	43.3	1	3.3	30
Total	21		27		54		17		119

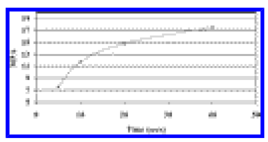
[a] Abs, absolute number of scores; Rel, % of total.
[b] $X^2 = 22.8$, df = 9, $P = .007$.

FIGURES Return to TOC



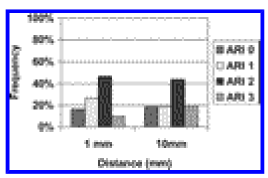
Click on thumbnail for full-sized image.

FIGURE 1. Sample of ARI scores 0, 1, 2, 3; scanning electron microscope photographs, 25×. ARI indicates adhesive remnant index



Click on thumbnail for full-sized image.

FIGURE 2. Mean shear bond strength (MPa) in relation to exposure time



Click on thumbnail for full-sized image.

FIGURE 3. ARI Frequency in relation to distance from source to specimen. ARI indicates adhesive remnant index

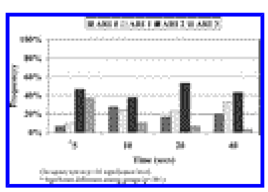


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FIGURE 4. ARI frequency in relation to exposure time. ARI indicates adhesive remnant index

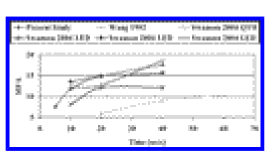

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FIGURE 5. Shear bond strength (MPa) in relation to exposure time; comparison of the literature

[a]Orthodontic Resident, Department of Orthodontics, Baylor College of Dentistry, Dallas, Tex

[b]Professor and Department Chair, Department of Orthodontics, Baylor College of Dentistry, Dallas, Tex

[c]Associate Professor, Department of Biomaterials Sciences, Baylor College of Dentistry, Dallas, Tex

[d]Professor, Department of Orthodontics, Baylor College of Dentistry, Dallas, Tex

Corresponding author: Dr. P. Emile Rossouw, Department of Orthodontics, Baylor College of Dentistry, 3302 Gaston Avenue, Dallas, TX 75246 (E-mail: ERossouw@bcd.tamhsc.edu)
