SCIENTIFIC SECTION

Halogen versus high-intensity light-curing of uncoated and pre-coated brackets: a shear bond strength study

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Abstract

Aim To evaluate the shear bond strengths of adhesive pre-coated brackets (APC) and conventional uncoated brackets (Victory) cured with two different light-curing units: a conventional halogen light (Visilux 2) and a micro-xenon light (Aurys).

Setting *Ex vivo* study

Materials and methods Sixty freshly extracted bovine permanent mandibular incisors were randomly assigned to one of four groups, each group consisting of 15 specimens. Two groups (one for each type of bracket) were exposed to the halogen light for 20 seconds and used as controls. The remaining two groups were cured with the micro-xenon light for 2 seconds. After 24 hours, all samples were tested in a shear mode on an Instron Machine. Analysis was by two-way ANOVA with Scheffé's test for comparisons, Kaplan–Meier survival estimates, and Cox model. The Chi-square (χ^2) test was used to determine significant differences in the ARI scores.

Results The mean shear bond strength of the uncoated brackets cured with Visilux 2 was significantly higher than those of all the other groups tested. Both groups cured with Visilux 2 produced significantly higher mean shear bond strengths than those of the corresponding groups cured with Aurys. No statistically significant differences were found between the two groups cured with Aurys.

Conclusions Compared to halogen light-curing, the micro-xenon light enables the clinician to reduce significantly the curing time of both APC and uncoated brackets, and although significantly lower, their shear bond strengths may be clinically acceptable.

Index words:
Bond strength, light-curing, orthodontic bonding, orthodontic brackets, xenon arc light.

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Introduction

Composite resins are the most popular adhesive systems used for bonding orthodontic brackets directly to the tooth surface. The chemically-cured composites were the first systems developed for bracket bonding.[1] Ultraviolet (UV) light sensitive resins were developed as an alternative to the self-curing resins, the latter having a more rapid polymerization time. Due to safety problems, visible light-curing (VLC) was introduced around 1980. Both light-cured and chemically-cured composites have been shown to be clinically acceptable and effective.[2] However, several investigations comparing the bond strengths and clinical failure rates of brackets bonded with light-cured and chemically-cured composites have shown conflicting results both *in vitro* [3–5] and *in vivo*.[6–9]

Orthodontic composite resins involve a series of technique-sensitive steps and require a completely dry field of operation throughout the bonding procedure. In an attempt to save chairside time, and perform faster and easier bonding procedures, light-cured adhesive pre-coated brackets (APC, Unitek/3M, Monrovia, Ca) were introduced in 1992.

Cooper *et al.*[10] described the advantages of APC brackets over conventional light-cured systems: (a) consistent quality and quantity of adhesive; (b) reduced waste during bonding; (c) easier clean-up following bonding; and (d) improved asepsis. The ingredients in the adhesive applied to the pre-coated brackets are the same as those in the Transbond XT adhesive (Unitek/3M, Monrovia, Ca).

The greatest advantage of light-cured adhesives is that they provide the orthodontist with ample time to

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accurately position the bracket on the enamel surface before polymerization. A disadvantage of the light-cured approach is the time it takes to expose each bonded bracket to the light. According to manufacturer's guidelines, halogen light-curing (HLC) units can cure orthodontic composite resins (Transbond XT) and APC brackets in 20 seconds per bracket. This prolonged curing-time is inconvenient for the patient and uncomfortable for the clinician. Therefore, various methods have been employed to enhance the polymerization of bonding agents, including the use of argon lasers[11, 12] and xenon arc lights. [13, 14]

Recently, a new micro-xenon light-curing unit, which permits a high-intensity polymerization of light-curing adhesives, has been introduced on the market (Aurys, Degrè K, Schiltigheim, France). Its light intensity is 1650 mW/cm^2, which is about three times greater than that of a conventional HLC unit. It has filters that narrow the spectrum of visible light to a band centred on the 470-nm wavelength for activation of the photo-initiator. A high energy, high pressure ionized gas in the presence of an electrical current is used to create a light source strong enough to increase the curing rate of light-cured adhesives.

To date, however, the effect of high-intensity curing lights on the shear bond strength of adhesive pre-coated brackets has not been investigated. Accordingly, the purpose of this study was to compare the effects of a conventional and a micro-xenon light on the shear bond strength of adhesive pre-coated brackets and conventional uncoated brackets. In addition, the amount of residual adhesive remaining on the tooth after debonding was measured.

Materials and methods

Preparation of specimens

Sixty freshly extracted bovine permanent mandibular incisors were collected from a local slaughterhouse and stored in a solution of 0.1 per cent (weight/vol) thymol for 1 week.

The criteria for tooth selection included intact buccal and lingual enamel with no cracks caused by the pressure of the extraction forceps, and no caries. The teeth were randomly assigned to one of four groups. Each group consisted of 15 specimens. The teeth were cleansed of soft tissue and then embedded in cold curing, fast setting acrylic (Leocryl, Leone, Sesto Fiorentino, Italy) and placed in metal rings. Each tooth was orientated so that its labial surface would be parallel to the force during the shear bond test. Before bonding, in order to standardize the enamel surface characteristics, the facial surface of each incisor was wet-ground for 30 seconds on 600-grit silicone carbide paper using a rotating disc (DPU4, Struers, Copenhagen, Denmark), in a similar way to previous studies.[15, 16] Then, the enamel surface was cleaned with a mixture of water and fluoride-free pumice using a rubber polishing cup for 10 seconds, rinsed thoroughly with water to remove any pumice or debris and dried with an oil-free air stream. After initial prophylaxis, the bonding procedure followed the manufacturers' guidelines. The enamel surfaces were etched with 37 per cent orthophosphoric acid gel for 30 seconds, followed by thorough washing and drying. After application of the primer on the tooth, the brackets were bonded near the centre of the facial surface of the tooth with sufficient pressure to express excess adhesive, which was removed from the margins of the bracket base with a scaler before polymerization. Thirty uncoated and 30 pre-coated Victory Series stainless steel maxillary right central incisor brackets with 0.018-inch slot (3M/Unitek, Monrovia, Ca) were bonded by the same operator. Measurement of base surface area for each bracket type was performed using a digital caliper. The area of 15 brackets of each type was recorded on three different occasions to derive a mean surface area per bracket, which was determined to be 11.78 mm^2 for the uncoated brackets and 11.84 mm^2 for the pre-coated brackets. The adhesive used for bonding the uncoated brackets was Transbond XT (3M/Unitek, Monrovia, Ca).

Two groups (one for each type of bracket system) were exposed to a conventional halogen light-curing unit (Visilux 2, 3M Dental Products, St Paul, Minn; light intensity: 530 mW/cm^2) and used as controls. The remaining two groups were cured with Aurys (Degrè K, Schiltigheim, France; light intensity: 1650 mW/cm^2).

- *Group A*: Conventional uncoated Victory brackets (3M/Unitek, Monrovia, Ca) cured for 20 seconds with the Visilux 2, 10 seconds each from the mesial and the distal.
- *Group B*: Adhesive Pre-coated Victory brackets (3M/Unitek, Monrovia, Ca) cured for 20 seconds with the Visilux 2, 10 seconds each from the mesial and the distal.
- *Group C*: Conventional uncoated Victory brackets (3M/Unitek, Monrovia, Ca) cured for 2 seconds with the Aurys, 1 second each from the mesial and the distal.

- *Group D*: Adhesive pre-coated Victory brackets (3M/Unitek, Monrovia, Ca) cured for 2 seconds with the Aurys, 1 second each from the mesial and the distal.

Testing procedure

After bonding, all samples were stored in distilled water at room temperature for 24 hours and subsequently tested in a shear mode on an Instron Universal Testing Machine (Instron Corp., Canton, Mass.). For shear testing, the specimens were secured in the lower jaw of the machine, so that the bracket base of the sample paralleled the direction of the shear force. The specimens were stressed in an occlusogingival direction with a crosshead speed of 1 mm/min. The maximum force necessary to debond or initiate bracket fracture was recorded in Newtons and then converted into MegaPascals (MPa) as a ratio of Newtons to surface area of the bracket.

After bond failure, the bracket bases and the enamel surfaces were examined by the same operator under a light stereomicroscope at ×10 magnification and the amount of adhesive left on the enamel surface was scored for each tooth using the Adhesive Remnant Index (ARI).[17]

Statistical analysis

nQuery 4 (Statistical Solutions, Cork, Ireland) was used to estimate the power of the study. Statistical analysis was performed with the software Stata 7.0 (Stata Corp., College Station, TX). Descriptive statistics including the mean, standard deviation, median, minimum and maximum values were calculated for each of the four groups tested. A two-way analysis of variance was used to determine whether significant differences existed among the various groups. If a significant difference was found, then the Scheffé's test was used to identify which of the groups were different.

Cumulative probability of failure at given levels of applied stress was calculated for each group by Kaplan–Meier estimates together with their 95 per cent confidence intervals. A Cox model was fitted to compare groups.

The Chi-square (χ^2) test was used to determine significant differences in the ARI scores among the different groups.

The level of significance for all the tests was set to $P \leqslant 0.05$.

Results

The descriptive statistics of the shear bond strength for each group are shown in Table 1. The results of the analysis of variance comparing the experimental groups are shown in Table 2. This revealed the presence of significant differences among the groups ($P = 0.000$). The mean shear bond strength of group A bonded with Transbond XT and cured with Visilux 2 (15.2 ± 2.2 MPa) was significantly higher ($P = 0.000$) than those of all the other groups tested. No statistically significant differences were found either between group B (13.2 ± 0.9 MPa) and group C (12.1 ± 1.6 MPa; $P = 0.31$), or between group C and D (11.2 ± 1.5 MPa) ($P = 0.54$). The shear bond strength of group B was significantly higher ($P = 0.01$) than that of group D.

Kaplan–Meier estimates were applied to calculate the cumulative probability of bond failure at given levels of stress. The data from the Kaplan–Meier survival analysis is presented graphically in Figure 1. The graph plots the cumulative probability of bond failure of the four different groups against applied stress. The Kaplan–Meier curve for group A is clearly distinct from those of all the other groups. The cumulative probability of failure for each group together with their 95 per cent confidence intervals at pre-determinate levels of stress is presented in Table 3. The results of Cox model comparing the probability of failure of the different groups revealed the presence of significant differences ($P = 0.000$). Group A showed a significantly lower ($P < 0.005$) probability of failure at given levels of stress than that of the remaining groups. No statistically significant differences were found between group B and C ($P = 0.14$). Group D presented a significantly higher probability of failure

Table 1 Descriptive statistics (in MPa) of shear bond strengths of the four groups tested

	Mean ± SD (MPa)	Median (MPa)	Range (MPa)	Sample size (n)
Group A	15.2 ± 2.2	14.4	12.5–19.9	15
Group B	13.2 ± 0.9	13.3	11.8–14.9	15
Group C	12.1 ± 1.6	12.2	8.7–14.5	15
Group D	11.2 ± 1.5	11.5	8.1–13.0	15

Table 2 Analysis of variance for shear bond strengths

	SS	df	MS	*F*	*P*
Effect	132.53	3	44.18	16.40	0.000
Error	150.84	56	2.69		

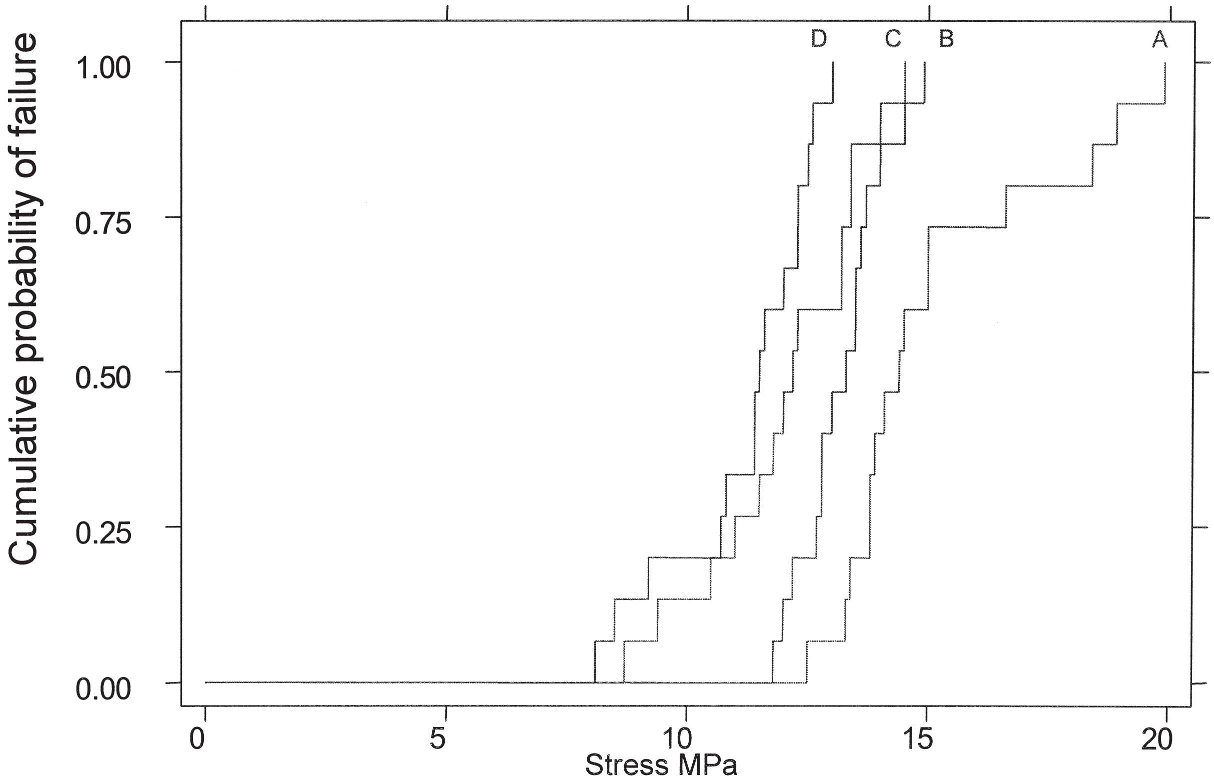

Fig. 1 Kaplan–Meier survival estimates.

Table 3 Cumulative probability of bond failure (%) at given levels of applied stress

	Stress (MPa)	Probability of failure (%)	95% CI lower limit	95% CI upper limit
Group A	10	0		
	12	0		
	14	40	20.3	68.2
	16	73.3	50.4	91.7
Group B	10	0		
	12	13.3	3.5	43.6
	14	86.7	65.4	97.8
	16	100		
Group C	10	13.3	3.5	43.6
	12	46.7	25.6	73.7
	14	93.3	74	99.6
	16	100		
Group D	10	20	6.9	50
	12	66.7	43.6	87.8
	14	100		
	16	100		

than that of group B (P = 0.000) and group C (P = 0.005).

The ARI scores for the four groups tested are listed in Table 4. The χ^2 test results ($\chi^2 = 11.2$; df = 9) indicated that there were no significant differences between the groups ($P = 0.2$).

Discussion

The present study indicated that the mean shear bond strengths of both uncoated and pre-coated brackets cured with the conventional HLC unit were significantly higher than those of the same brackets cured with a

Table 4 Frequency distribution of the Adhesive Remnant Index (ARI) scores of the four groups tested

	ARI scores				
Groups tested	0	1	2	3	Sample size (n)
Group A	2 (13.3%)	1 (6.7%)	1 (6.7%)	11 (73.3%)	15
Group B	3 (20.0%)	0 (0.0%)	0 (0.0%)	12 (80.0%)	15
Group C	6 (40.0%)	2 (13.3%)	2 (13.3%)	5 (33.3%)	15
Group D	5 (33.3%)	2 (13.3%)	2 (13.3%)	6 (40.0%)	15
		$\chi^2 = 11.2$; df = 9	$P = 0.2$		

micro-xenon light. Moreover, when cured with the conventional HLC unit, uncoated brackets produced significantly higher shear bond strengths than those of the pre-coated brackets. Importantly, the Kaplan–Meier estimates confirmed that group A had a significantly lower probability of failure at given levels of stress than that of all the other groups. When both types of brackets were cured with the micro-xenon light, the difference in mean bond strength was not statistically significant, however the Kaplan–Meier estimates and Cox model showed that group D had a significantly higher probability of bond failure.

Previous investigations comparing the bond strength of pre-coated brackets with that of conventional uncoated brackets cured with HLC units have shown conflicting results. For example, when Bishara *et al.* compared the mean shear bond strength of the same uncoated and pre-coated metal brackets tested in this study, using a conventional HLC unit for curing the composite on each bracket type,[18] they found that the pre-coated brackets had a significantly lower shear bond strength than the uncoated brackets bonded with Transbond XT. Similar results were reported by Sunna and Rock.[19] These findings are confirmed by the present investigation. A possible explanation suggested by Bishara *et al.* is that the increased viscosity of the adhesive used on the APC brackets, when combined with the mesh retention mechanism incorporated in the metal bracket base, seems to significantly lower the shear bond strength.[18]

However, other investigators have not supported this finding, for example, Bearn *et al.* reported no significant differences in bond strength between APC brackets and uncoated brackets bonded with Transbond.[20] However, they used a longer light-curing time (30 seconds) than that suggested by the manufacturer. In another investigation it was found that APC brackets cured for 40 seconds with a HLC unit had similar bond strengths to uncoated brackets bonded with Transbond XT.[19] This is in agreement with the findings of Wang and Meng,[5] who reported higher bond strengths with Transbond XT when light-curing was increased from 20 to 40 seconds. Therefore, it appears that the duration of light-exposure represents a critical factor, which can significantly affect the bond strength of APC brackets.

Clinicians are interested in determining the level at which a bond would become too weak to withstand the forces that are usually applied during an orthodontic treatment. It has been suggested that a minimum bond strength of 6–8 MPa was adequate for most clinical orthodontic needs.[21] In the current study, the mean shear bond strengths of the various combinations tested were above these limits, regardless of the type of light source. Even light-curing for only 2 seconds with the micro-xenon light produced clinically acceptable bond strengths of both uncoated and pre-coated brackets. The reduced curing time achieved by means of the micro-xenon light represents a great advantage when bonding orthodontic brackets for both the patient and the clinician.

Conclusions

1 Light-curing for only 2 seconds with the micro-xenon light does not preclude clinically acceptable bond strengths of both uncoated and pre-coated metal brackets.
2 The shear bond strengths of both uncoated and pre-coated brackets cured with the micro-xenon light unit are significantly lower than those of the same brackets cured with a conventional HLC unit.
3 When cured with the conventional HLC unit, uncoated brackets produce significantly higher shear bond strengths than those of the pre-coated brackets. However, the difference in mean shear bond strength between the two types of brackets is not significant when they are cured with the micro-xenon light.

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