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Abstract

The aim of this study is to evaluate the shear bond strengths of metal brackets using two different fluoridereleasing adhesives (Light bond and Enlight) activated by two photoactivation systems [a conventional halogen light-curing system (HLC), and a plasma arc light curing system (PALC)]. Methods: Forty extracted premolars were divided into four groups of ten. Stainless steel brackets were bonded to the teeth using either a halogen light with a 20-second curing time or a plasma arc light with a 4-second curing time. After being immersed in a 37°C distilled water bath for 24 hours, the brackets were debonded. The bond strengths were tested on a testing machine at a crosshead speed of 0.5 mm/minute. The bracket failure interface was observed by SEM and an adhesive remnant index (ARI) score was recorded for each tooth. Results: The bond strengths of the four groups ranged from 7.78 ± 2.01 MPa to 9.42 ± 3.12 MPa. There were no significant differences among the four groups in terms of bond strength or ARI score. Conclusions: The results indicate that plasma arc light with a 4-second curing time is able to produce a similar bond strength and bracket-failure type as a longer halogen light curing time when used with either types of fluoride-releasing orthodontic adhesive.

Keywords

shear bond strength, fluoride-releasing orthodontic adhesive, plasma arc curing machine

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INTRODUCTION

The potential risks of decalcification or caries around brackets following orthodontic treatment as a result of inadequate oral hygiene remains a problem in orthodontics.[1-3] Meticulous oral hygiene, fluoride mouth rinses, and topical fluoride application after etching have been recommended to alleviate this problem.[4] Fluoride-releasing material can provide local concentrations of fluoride ions at the specific sites that are most susceptible

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to demineralization and therefore there has been a growing interest in fluoride-releasing dental material.[5] Fluoride-releasing orthodontic adhesives have been reported to be effective at protecting the enamel from decalcification,[6,7] but these adhesives had significantly lower bond strengths than conventional composite cements.[8-11] After matrix-bound fluoride-releasing (MBF) adhesives for orthodontic use were introduced, their bond strengths were found to be similar to conventional composite cements.[12] As a result, fluoride-releasing adhesives have became popular.

Fluoride-releasing adhesives are light-activated and therefore a light curing machine is recommended. Visible light curing (VLC) was introduced about 1980[13] with polymerization of the VLC resins being based on the presence of a photo initiator, camphorquinone, which is sensitive to light at a wavelength in the region of 470-nm.[14] Plasma arc light was introduced in the mid-1990, and it has also been used for the rapid curing of resin materials.[15] This system has a filter that narrows the spectrum of visible light to a band centered on the 470 nm wavelength; this then activates the camphorquinone using high intensity light at 1200mW/cm^2. This significantly reduces the curing time for the bonding agent without affecting the shear bond strengths.[16]

Plasma arc curing thus can save chair-time, while at the same time allowing the use of fluoride-releasing adhesives that have sufficient bond strength and are able to prevent decalcification. There have been few previous reports that have explored the bond strength of fluoride-releasing adhesives after plasma arc curing, and these have no really compared the curing method across those adhesives.[17,18] Therefore the aims of this study were (1) to evaluate the shear bond strengths of metal brackets using two different fluoride-releasing adhesives that had been cured using either plasma arc light or halogen light, and (2) to explore the bracket-failure interfaces created from disrupting the bonds formed by the two curing-light systems.

MATERIALS AND METHODS

Forty fresh human premolars extracted for orthodontic reasons were collected. The criteria for tooth selection were that they were non-carious and had non-restored buccal surfaces with no visible cracks. The teeth were not exposed to any pretreatment chemical agent such as hydrogen peroxide or bleach. They were stored in distilled water. The teeth were kept moist in a humidor until bonding.

Two different light units for curing orthodontic bracket adhesive were used. There were a conventional halogen light-curing system (OrtholuxTMXT; 3M, Monrovia, Calif, USA) and a plasma arc light curing system (Apollo 95E; DMT, Orange, Calif, USA). The former produces a light intensity of approximately 400 mW/cm^2, while the later produces approximately 2000 mW/cm^2.

Before bonding, the teeth were randomly divided into 4 groups, each containing 10 teeth. Group I consisted of brackets bonded with the adhesive Light bond (Reliance Co., Itasca, IL, USA) and cured by a halogen light (Ortholux™XT) for 20 seconds (10 seconds each for the mesial and distal sides).[19] Group II consisted of brackets bonded with the adhesive Enlight (Ormco Co., Orange, Calif, USA) and cured by a halogen light for 20 seconds. Group III consisted of brackets bonded with the adhesive Light bond and cured by a plasma arc light (Apollo 95E); according to manufacture's instruction, the curing time was 4 seconds (2 seconds each for mesial and distal side). Group IV consisted of brackets bonded with the adhesive Enlight and cured by a plasma arc light for 4 seconds.

A premolar metal standard edgewise bracket with a micro-loc base (Tomy, Tokyo, Japan) was chosen. The average bracket base area was 9.73mm^2. The bonding surface of each tooth was pumiced for 10 seconds with pumice powder (Pumice Fine, Miltex Inc., York, PA, USA) and rinsed for 10 seconds with distilled water. The enamel surface was conditioned with 37% phosphoric acid gel (Ultra-Etch, Ultradent, South Jordan, UT, USA) for 15 seconds and then rinsed with distilled water[20]. The surface was thoroughly dried and a bonding agents, either Sealant resin (Reliance Co.) or Ortho Solo (Ormco Co.), was applied on the dry enamel surface. Then, the composite adhesive, Light bond or Enlight, was placed on bracket base. Each bracket was placed on the tooth, and an explorer was used to seat the brackets with a constant force. Excess adhesive was removed, and the bracket adhesive was light-cured using the designated curing unit.

After bonding, the teeth are embedded in chemically cured epoxy resin in plastic cylinders and a dental surveyor was used to align the facial surface of each tooth so that it was perpendicular with the bottom of mounting ring. This oriented the bonding surface to be parallel to the force applied during the shear strength test, allowing standardized and secure placement during testing. The specimens were then stored at 37℃ in a distilled water bath for 24 hours.

The debonding force in Newtons for each tooth was determined using a testing machine, the AG-1 universal testing machine (Shimadzu, Kyoto, Japan), at a crosshead speed of 0.5mm/min. The shear-peel force was applied using a custom-made chisel-shaped rod from the occlusal side parallel to the bracket surface between the bracket base and the tie wings (Fig.1).

The bond strengths in MPa were calculated based on the bracket base area. After debonding, the adhesive left on the bracket base was examined by SEM (JSM-6390LV; JEOL Ltd. Tokyo, Japan) at 35X magnification to explore the bracket-failure interface. Adhesive remnant index (ARI) scores[21] (Fig.2) were used to evaluate the amount of adhesive remaining on the brackets after debonding. The scores were classified as: 0, no adhesive remained on the tooth; 1, <1/2 adhesive remained on the tooth; 2, >1/2 adhesive remained on the tooth; 3, all adhesive remained on the tooth.

For this in-vitro study, significant differences in shear bond strength (MPa) and ARI scores between test groups were determined using ANOVA and the Tukey-Kramer multiple comparison test.[22] Significant differences were assumed if $p < 0.05$.

RESULTS

In vitro bond strength study

The shear bond strengths for brackets bonded with the two types of curing lights and two bonding adhesives are shown in Fig.3. The bond strengths of the four groups were 9.42±3.12 MPa (Light bond-HLC), 9.18±2.1 MPa (Light bond-PALC), 8.9±3.61 MPa (Enlight-HLC) and 7.78±2.01 MPa (Enlight-PALC). There were no statistically significant differences in the shear bond strength among the four test groups.

In-vitro bracket-failure interface

The ARI scores for adhesive remaining on the bracket after debonding across the four groups are shown in Table 1 and no significant differences were found among these four groups. An ARI score of 2 or 3 was predominant in all four test groups, and this suggests that bracket–resin interface failure was the most common form of failure.

Table 1. *The ARI scores for the different combinations of bonding adhesive and light source*

Group	Light source	Adhesive resin	ARI scores 0	1	2	3	
I	HCL	Light bond	0	3	5	2	NS
II	HCL	Enlight	0	0	7	3	
III	PACL	Light bond	0	1	7	2	
IV	PACL	Enlight	0	1	7	2	

NS: not significant

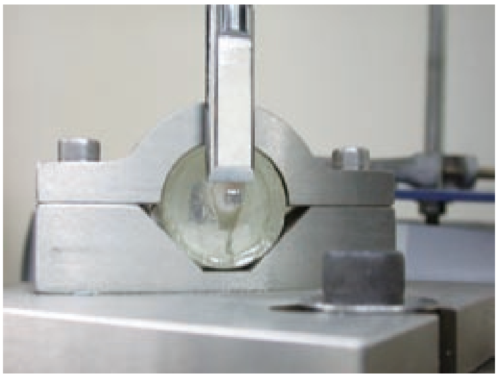

Fig 1. *The shear-peel force was applied by a custom-made chisel-shaped rod from the occlusal side of bracket using an AG-1 universal testing machine.*

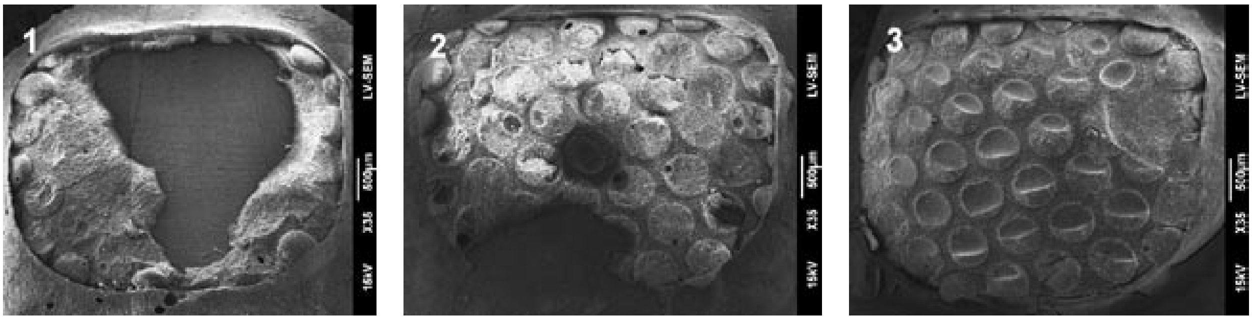

Fig 2. *The various adhesive remnant index (ARI) scores (1, 2 & 3) are shown as found under SEM. 1: <1/2 adhesive remained on the tooth, 2: >1/2 adhesive remained on the tooth, and 3: all adhesive remained on the tooth.*

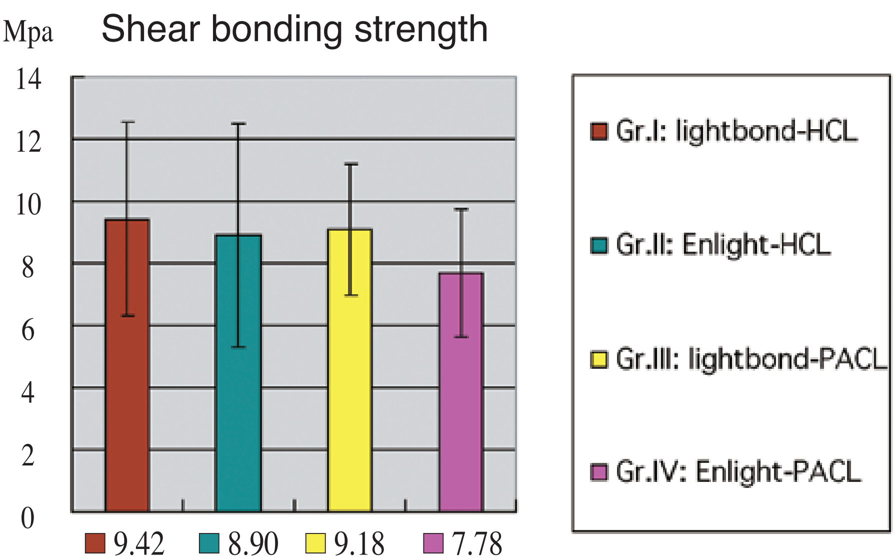

Fig 3. *The shear bond strengths for the different combination of bonding adhesive and light source.*

DISCUSSION

The mean shear bond strengths of the four groups after bonding showed no statistically significant differences between the groups when the bonds were cured with either a halogen light or a plasma arc light. These results agree with the findings by other researchers.[17,22-24] It has been suggested that the plasma arc light can be used to bond orthodontic brackets to the enamel surface using a shorter curing time without any significant decrease in shear bond strength. The faster curing time saves chair time and may also decrease the risk of bond failure due to moisture contamination. When compared with the bond strengths produced by halogen light with an exposure of 20 seconds, a plasma arc light exposure of 4 seconds having lower bond strengths than those produced by the halogen light was noted in the present study. Although the differences of bond strengths between plasma arc and halogen light groups did not reach statistical significance, a plasma arc light exposure of 4 seconds might not provide enough bond strength. In other previous studies have suggested that a plasma arc light exposure of 6 seconds is required to create an equal bond strength to halogen light with an exposure of 20 seconds.[22,24] In another study, it was found that only a 3-second exposure time by plasma arc light was needed to create a similar bond strengths to that formed by halogen light.[17] The differences in bond strength would seem to be due largely to the use of different adhesives, variations in the tooth surface or differences in immersion time after bonding.

Bond strengths of different fluoride-releasing orthodontic adhesives when light-cured have been investigated previously.[17,18,23,25-27] Fluoride-releasing resin adhesives have similar bond strengths to non-fluoride-releasing light-cure resin adhesives,[23,27] but are lower than non-fluoride-releasing conventional resin adhesives.[17] The glass ionomer adhesive Fuji ortho LC was found to have a lower bond strength than resin adhesive.[17,25] Light bond was found to have a similar bond strength to Enlight when using HLC.[26] The present study shows that the measured shear bond strength values for Light bond and Enlight showed no statistically significant difference when either HLC or PALC was used for curing.

The ARI scores enable the clinician to determine the bracket-failure interface. A low score is interpretable as a failure between the adhesive and enamel interface, and a high score indicates a failure between the adhesive and bracket interface. All groups were shown more than 50% adhesive remained on the tooth, which suggests a lower risk of enamel fracture when the bracket debonded.

CONCLUSIONS

1. Both test adhesives (Light bond or Enlight) when cured using either of the light sources (HCL or PACL) showed no statistically significant difference in shear bond strength.
2. The brackets bonded with the plasma arc light for 4 seconds were found to produce a similar bond strength and bracket-failure mode as those bonded with halogen light using a 20-second curing time.

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氟釋放矯正樹脂以電漿或鹵素光聚合的黏著強度

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本研究的目的是評估以電漿或鹵素光聚合兩種氟釋放矯正樹脂（Light bond 及Enlight）的黏著強度。首先將40顆因矯正拔除的小臼齒分為4組，將金屬支架分別用鹵素光20秒聚合或電漿4秒聚合，再將試片浸在37ºC水浴中24小時，然後以每分0.5 毫米的速度用拉力測試機測試其黏著強度，用電子顯微鏡觀測其破壞表面並紀錄其黏著劑剩餘指數（adhesive remnant index, ARI）。結果顯示4組的黏著強度由7.78±2.01 MPa 至 9.42±3.12 MPa，4組的黏著強度及黏著劑剩餘指數在統計上沒有明顯的差異。結論為以電漿4秒聚合兩種氟釋放矯正樹脂，能提供類似鹵素光20秒聚合的黏著強度及破壞表面。***(J. Taiwan Assoc. Orthod. 23(2): 14-20, 2011)***

關鍵詞：黏著強度、釋放矯正樹脂、電漿聚合

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