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ORIGINAL RESEARCH

Evaluation of a New and Advance Curing Light on the Shear Bond Strength of Orthodontic Brackets

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ABSTRACT

Introduction: With the introduction of photosensitive (light-cured) restorative materials in dentistry, various methods were suggested to enhance their polymerization and curing time including layering and the use of more powerful light curing devices. The purpose of this study was to comparatively evaluate shear bond strength of stainless steel bracket using conventional halogen light and light-emitting diode (LED) curing units.

Materials and methods: This *in vitro* study was carried out in the Department of Orthodontics, Pacific Dental College, Debari, Udaipur, India. Sample included 120 freshly extracted human premolars collected and etched by 37% phosphoric acid, washed and dried, and sealent applied. Then preadjusted edgewise upper premolar stainless steel brackets were applied on the teeth. The teeth were divided into groups of six, each group having 20 teeth. Group I was cured by halogen light curing unit by 10 seconds, group II is cured by LED curing unit by 10 seconds, group III is cured by halogen light curing unit by 20 seconds, group IV is cured by LED curing unit by 20 seconds, group V is cured by halogen light curing unit by 40 seconds, group VI is cured by LED curing unit by 40 seconds.

Result: One-way analysis of variance (ANOVA) showed that p score was significant at <0.001, which indicated that all the six groups differ significantly. This was further investigated using multiple range test by Tukey's honest significant difference (HSD) procedure in Table 4. And it was observed that mean shear bond strength in group I was significantly lower than the mean shear bond strength in groups II to VI ($p < 0.05$). Also, the mean shear bond strength in group II was significantly lower than the mean shear bond strength in groups III to VI ($p < 0.05$).

Conclusion: It is concluded that 10 seconds of curing time is not adequate for both halogen and LED light. Twenty seconds of curing time is adequate for both LED and halogen light, since increasing the curing time to 40 seconds showed no significant difference.

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INTRODUCTION

Bonding of brackets to enamel has been a critical issue in orthodontic research, since the significance of achieving a stable bond between the tooth and its bracket is very important. Biomechanical principles required a relatively inelastic interface that would transfer a load applied to the bracket, due to engagement of an activated arch wire to the tooth without exceeding its bond strength.[1,2] Clinicians soon became aware of problems related to low bond strength and the resulting necessity of repeating the bonding procedure as treatment progressed. Early bonding systems consisted of brackets welded into bands bonded to enamel with zinc phosphate cement. Apart from esthetic considerations, this approach presented other serious disadvantages:

- The requirement of extensive chair time.
- The necessity of frequent screening for development of caries or decalcification of underlying tooth structure.
- The pronounced effect on periodontal health due to chemical and mechanical irritation of the gingiva caused by cements and the accumulated plaque.
- The requirement of additional arch space to accommodate band placement, thus affecting consideration of extraction in borderline cases.

Therefore, the need of finding an alternative procedure was felt after understanding the aforementioned drawbacks of banding which would provide retention of the brackets to tooth enamel. One of the most dramatic changes in the orthodontic specialty in the 1970s was the use of composite resin as a bonding material. The use of self-cured composite resin for direct bonding of orthodontic brackets to the tooth surface was then well documented. For years, the use of self-cured orthodontic resin was the only choice for direct bonding. The polymerization of self-cured resin with the two-paste system or the one-paste system starts immediately on mixing; thus, the operator is unable to manipulate the setting time, which affects bonding accuracy and positioning on the tooth surface. The air bubbles that arise during mixing or the uneven consistencies in resins that are mixed by hand result in the weakening of the bond strength in the two-paste system.[3-6]

Then ultraviolet light-cured materials were introduced and quickly replaced those products that were self-cured. These ultraviolet light-cured materials have the disadvantages of radiation hazards and limited depth of cure. These problems have been largely overcome by the introduction of a blue, visible light-cured composite resin. Compared with ultraviolet light, visible light has deeper curing capabilities, is more effective through enamel, and does not diminish with time or with the intensity of the light source.[7,8]

With time, desire to cure on demand is driving an increasing number of orthodontic practices to utilize light cure adhesives instead of the more traditional two-paste adhesives requiring in-office mixing. Now light-cured adhesives are routinely used for bonding in orthodontics. The greatest advantage of a light-cured adhesive system is that it gives the clinician ample time to accurately position the bracket on the enamel surface before using the light to polymerize the adhesive.[9]

Light-cured orthodontic adhesives have been used almost exclusively with light emitted from a halogen source. However, tungsten–quartz halogen curing units have several shortcomings. They have a harmful effect on teeth pulp, especially when used in orthodontic practice where most of patients are from younger age group with large pulp chambers. Only 1% of the total energy input is converted into light and the remaining is generated as heat. The short life of halogen bulbs, noisy cooling fan, and the time it takes to expose each bonded bracket to the light (10–40 seconds) are other disadvantages.

However, up to 40 seconds of curing time per bracket has been recommended to allow for adequate polymerization with a conventional halogen light source, resulting in a considerable amount of chair time if one or both arches are bonded to overcome these problems. Light curing units with gallium nitride *blue LEDs* have been proposed for curing resin-based dental adhesives. The spectral output of LEDs falls within the absorption spectrum of camphorquinone, so the LEDs require no filters to produce blue light. Mills et al were among the first to suggest the use of solid-state LEDs for the polymerization of light-sensitive dental materials. The use of LED technology has two major advantages, namely, avoiding the use of the heat-generating halogen bulbs and the fact that they have 10,000 hours lifetime with little degradation of output.

The LEDs showed about 83% of the irradiance produced by the halogen curing units, and the depth of cure produced by the halogen curing unit sources was larger than that obtained with the LEDs. Furthermore, advancements in the power output of LEDs have allowed them to achieve a higher irradiance than halogen curing units.[10]

These high-intensity LEDs may decrease total light curing time.

The aim of this study was

- To evaluate shear bond strength of stainless steel bracket cured with two different lights, i.e., halogen and commercially available LED curing units.
- To establish the optimum curing time while using LED curing light.

MATERIALS AND METHODS

Teeth

One hundred and twenty freshly extracted human upper premolars were collected and stored in a solution of 1% (wt/vol) thymol. The criteria for tooth selection included intact buccal enamel, not subjected to any pretreatment chemical agents like hydrogen peroxide, with no cracks, due to the pressure of the extraction forceps, and no caries. The teeth were cleansed and polished with pumice and rubber prophylactic cups for 10 seconds.

Etching

The buccal surface of enamel of each tooth was conditioned for 20 seconds with 37% phosphoric acid gel. Each tooth was then rinsed with a water spray for 20 seconds and dried with oil-free air for 10 seconds. The buccal enamel surfaces of the etched teeth appear chalky white.

Brackets

Preadjusted edgewise upper premolar stainless steel brackets (0.22 Roth prescription, 3M Unitek Gemini series) were used. The average surface area of the bracket base was 11.8 mm^2.

Curing Lights

One hundred and twenty teeth were randomly divided into six equal groups that were bonded according to time and different type of curing lights (Table 1). The curing lights were halogen light curing unit (Elipar 2500, 3M-ESPE, Seefeld, Germany) and LED curing unit (Woodpecker).

Before starting the procedure, both light sources were tested using a Curing Radiometer Modal 100 (Demetron Research Corp., Danbury, Conn). Both light sources were of 400+ mW/cm^2.

Table 1: Number of teeth, color, time and light used to cure among different study groups

Number of teeth	*Color*	*Time (seconds)*	*Light used to cure*
Group I, 20	White	10	Halogen
Group II, 20	Yellow	10	LED
Group III, 20	Green	20	Halogen
Group IV, 20	Red	20	LED
Group V, 20	Blue	40	Halogen
Group VI, 20	Black	40	LED

Table 3: Analysis of variance

Bond strength	*Sum of squares*	*df*	*Mean square*	*F*	*Significance*
Between groups	825.333	5	165.067	33.851	0.000
Within groups	555.897	114	4.876		
Total	1381.230	119			

Table 2: Mean, SD, and test of significance of mean values between different study groups

Groups	*Mean ± SD (MPa)*	*Light curing unit*	*p-value**	*Significant# groups at 5% level*
Group I	1.712 ± 0.869	Halogen		VI, V, IV, III, II *vs* I, VI, V, IV, III *vs* II
Group II	4.719 ± 1.766	LED		
Group III	7.824 ± 2.617	Halogen		
Group IV	7.534 ± 2.682	LED		
Group V	8.261 ± 2.390	Halogen		
Group VI	8.489 ± 2.373	LED	<0.0001 (significant)	

*One-way ANOVA was used to calculate the p-value; #Multiple range test by Tukey's HSD procedure was employed to identify significant groups at 5% level

Shear Bond Strength

Debonding was carried out with Universal Testing Machine (Instron), load cell = 1 KN. The machine has two vertically placed jaws. The acrylic block with the tooth embedded was placed in the lower jigs.

The embedded teeth and brackets were aligned in the testing apparatus to ensure consistency for the point of force application and direction of the debonding force for all specimens. The shear-peel force was applied with a custom-made chisel-shaped rod from the occlusal side parallel to the bracket surface between the bracket base and the tie wings.

An occlusogingival load was applied to the bracket producing a shear force at the bracket–tooth interface. A computer electronically connected with the Instron Universal Testing Machine recorded the results of each test. Shear bond strengths were measured at a crosshead speed of 1 mm/min.

The Instron Universal Testing Machine unit was attached to an electronic console that displayed the debonding forces acting between the jaws. Thus, the exact force at which the bracket debonded was noted from the console. This force was expressed in Newtons.

Statistical Analysis

The results obtained from the shear bond strength testing of metal brackets cured by two different light curing units were tabulated. Their mean and standard deviation (SD) were calculated and then subjected to following statistical evaluation to determine the statistical significance of the present study. The following statistical evaluation was done:

- one-way ANOVA test
- multiple range test by Tukey's HSD procedure
- Kaplan–Meier survival analysis

RESULTS

The mean and SD value of shear bond strength of stainless steel bracket cured with halogen for 10 seconds (group I) shown in Table 2 is 1.172 ± 0.869 MPa. The mean and SD value of shear bond strength of stainless steel bracket cured with LED for 10 seconds (group II) is 4.719 ± 1.766 MPa. The mean and SD value of shear bond strength of stainless steel bracket cured with halogen for 20 seconds (group III) is 7.824 ± 2.617 MPa. The mean and SD value of shear bond strength of stainless steel bracket cured with LED for 20 seconds (group IV) is 7.534 ± 2.682 MPa. The mean and SD value of shear bond strength of stainless steel bracket cured with halogen for 40 seconds (group V) is 8.261 ± 2.390 MPa. The mean and SD value of shear bond strength of stainless steel bracket cured with LED for 40 seconds (group VI) is 8.489 ± 2.373 MPa.

One-way ANOVA analysis in Table 3 shows that p-value was found significant at <0.001, which indicated that all the six groups differ significantly.

This was further investigated using multiple range test by Tukey's HSD procedure in Table 4. And it was observed that mean shear bond strength in group I was significantly lower than the mean shear bond strength in groups II to VI ($p < 0.05$). Also, the mean shear bond strength in group II was significantly lower than the mean shear bond strength in groups III to VI ($p < 0.05$).

Hence, this study shows that shear bond strength in group I was significantly lower than the shear bond strength in groups II to VI. Also, the shear bond strength in group II was significantly lower than the mean shear bond strength in groups III to VI. However, there was no significant difference between any other contrasts.

- Therefore, it is concluded that 10 seconds of curing time is not adequate for both halogen and LED light.
- Twenty seconds of curing time is adequate for both LED and halogen light, since increasing the curing time to 40 seconds showed no significant difference.

Table 4: Multiple comparisons by Tukey's HSD procedure

(I) Group	(J) Group	Mean difference (I–J)	Standard error	Significance	95% Confidence interval Lower bound	95% Confidence interval Upper bound
1.00	2.00	–3.54700*	0.69830	0.000	–5.5712	–1.5228
	3.00	–6.65200*	0.69830	0.000	–8.6762	–4.6278
	4.00	–6.36150*	0.69830	0.000	–8.3857	–4.3373
	5.00	–7.08850*	0.69830	0.000	–9.1127	–5.0643
	6.00	–7.31650*	0.69830	0.000	–9.3407	–5.2923
2.00	3.00	–3.10500*	0.69830	0.000	–5.1292	–1.0808
	4.00	–2.81450*	0.69830	0.001	–4.8387	–0.7903
	5.00	–3.54150*	0.69830	0.000	–5.5657	–1.5173
	6.00	–3.76950*	0.69830	0.000	–5.7937	–1.7453
3.00	4.00	0.29050	0.69830	0.998	–1.7337	2.3147
	5.00	–0.43650	0.69830	0.989	–2.4607	1.5877
	6.00	–0.66450	0.69830	0.932	–2.6887	1.3597
4.00	5.00	–0.72700	0.69830	0.903	–2.7512	1.2972
	6.00	–0.95500	0.69830	0.746	–2.9792	1.0692
5.00	6.00	–0.22800	0.69830	0.999	–2.2522	1.7962

*The mean difference is significant at the 0.05 level

The results of this study are promising for the orthodontic application of LED curing units, but further compatibility and physical characteristic studies of various orthodontic adhesives and clinical trials should be performed before validation.

DISSCUSSION AND CONCLUSION

To achieve more effective photoactive and cure dental adhesives, various types of lights have been used including the newly introduced Turbo tips.[11-13] These turbo tips were not too effective for orthodontic purposes.[13] Ideally, the early, i.e., more effective, cure should result in less stress at the enamel–adhesive interface during the initial ligation of arch wires. Therefore, any enhancement to the initial curing by a more effective method of photoactivation is intended to help bond the adhesive to the tooth faster.[12]

Mills et al[14] studied the difference in depth of cure and compressive strength of dental composites cured with either a LED-based light curing unit or a conventional halogen-based light curing unit.

The irradiance and emitted light spectra were also measured for both light curing units. No statistically significant difference in compressive strength was found between samples cured with halogen or the LED light curing units. Depth of cure for the halogen light curing unit was about 20% higher than that obtained for LED light curing unit. The difference in irradiance of the two types of light curing units is large but only a small difference in depth of cure was found. A good correlation was found between the absorption spectrum of camphoroquinone and the spectrum of the LED light curing unit. The advantage of the LED light curing device is that the clinician is able to light cure two orthodontic brackets with the same light exposure without significantly influencing the shear bond strength. This approach reduces the total curing time by half when bonding orthodontic brackets with photosensitive. Our study showed that LED is a viable alternative to halogen light curing unit in spite of its reduced irradiance. Although the LED does not cure faster than the halogen light curing units, it is a much less expensive alternative to xenon light and argon laser. While the cost is comparable to conventional halogen light, they have additional advantages of low maintenance cost, half the heat production of halogen lights, and are lighter and portable.[15-17]

Therefore, it is concluded that 10 seconds of curing time is not adequate for both halogen and LED lights. Twenty seconds of curing time is adequate for both LED and halogen light, since increasing the curing time to 40 seconds showed no significant difference.

The LED can be considered as useful tool for orthodontist to save bonding time. The LED light units are cordless, smaller, and lighter with estimated lifetimes of over 10,000 hours, and they do not require a noisy cooling fan. Therefore, it seems that they are a better choice as compared with halogen sources. Further investigation under clinical conditions is suggested to compare the results to previous *in vitro* studies.

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