Research Article

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Shear Bond Strength Comparison of Brackets Using Varying Parameters of Three LED Curing Lights: An *In-Vitro* Cross-Sectional Study

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ABSTRACT

Background: Purpose of this study was to evaluate the shear bond strength of brackets cured using a halogen light-curing unit and three light-emitting diodes with different light intensities.

Material and method: This study was conducted on 180 metal brackets bonded to extracted maxillary first premolars. The sample was divided into six groups of 30 each according to light-curing units and exposure times. Brackets were cured with halogen light (CU-100 A) for 40 seconds and three LEDs (Bluephase Ivoclar, WL-090 Orthosystem, iLed Woodpecker) for 20, 6, 5 seconds. SBS was measured using Instron.

Results: The highest mean shear bond strength was found in group II (Bluephase Ivoclar Curing Light) 20 seconds followed by group VI (iLed Woodpecker) 6 seconds, group V (WL-090 Orthosystem light) 5 seconds, group III (WL-090 (Orthosystem light) 20 seconds, group I (Halogen light) 40 seconds, minimum with group IV (iLed Woodpecker) 20 seconds. There was a significant difference found in SBS of brackets using varying parameters of three LEDs**. (p=0.006)**

Conclusion: Reducing the curing time to 5 - 6 seconds with a high intensity curing lights produced clinically acceptable SBS.

Keywords: LED curing devices, Bond strength, Bracket bonding, Shear bond strength.

INTRODUCTION

The world of dentistry underwent an extensive transformation in the 1950's after Buonocore's introductions of acid etch bonding technique, facilitating the attachment of orthodontic brackets directly onto the enamel surface.[1] In 1970's the visible light-curable composite for bonding was first described and widely accepted by orthodontic fraternity.[2] The halogen light-curing units (LCU) with an intensity of 300-400 mW has been used most commonly but the disadvantages such as reduced light intensity, prolonged curing time with only 1% of overall energy being converted into light, with remaining energy being expressed as heat.[1, 4] Other disadvantages are degradation of a lamp, filter, reflector, noisy cooling fan, a lifetime of approximately 100 hours and reduction in the amount of light produced over time resulting in decreased curing efficiency.[5-7] In 1995 the Light-

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emitting diode (LED) technology was introduced in order to overcome the drawbacks of Quartz-Tungsten- Halogen visible LCUs.[8] They have less degradation with a lifetime of 10,000 hours and require no filter to produce blue light.[7] The LEDs emit the energy level up to 1600 mW. Recently there has been an influx of several high-intensity LEDs in the market having a light intensity of 3200 mW with curing time of as less as 3-5 seconds to save the chairside time.[9] New generation high-intensity LED units to have all the qualities of their predecessors with a considerable reduction in the curing time. However, very few studies have evaluated the bond strength of brackets cured with different LEDs curing lights to as less as 3-5 seconds. [5-10] Therefore, the objective of this study is to assess and compare the shear bond strength of orthodontic brackets with the 3 LED curing lights having different intensities and different curing time (6sec-20sec). This can help the orthodontist to choose an appropriate curing light with superior properties of efficiency and intensity to ensure the best possible results for their patients and with reduced chairside time.

MATERIAL AND METHODS

This cross-sectional *in vitro* study was conducted in Central Institute of Plastics Engineering and Technology (CIPET), Bhopal (M.P India). A total of 180 healthy human maxillary first premolars were included in this study. Teeth had been extracted for the therapeutic purpose in the patients undergoing orthodontic treatment. The inclusion criteria included freshly extracted maxillary first premolars with intact enamel surface without any restoration and surface cracks from extraction forceps. Teeth were not subjected to any pre-treatment clinical agents. The extracted teeth were cleaned to remove blood, soft tissues and debris and were immersed in the distilled water initially followed by normal saline. After that, the teeth were stored in 10% formalin solution (9 parts of water was added to one part of 40% aqueous formaldehyde to make 10% formalin). The premolars were mounted on a self-cure acrylic block in such a way that the roots were completely embedded into the acrylic blocks up to the cementoenamel junction leaving the crown exposed. All the specimens were immersed in distilled water except at the time of bonding and debonding procedures. The total sample of 180 teeth was divided into 6 experimental groups with 30 teeth in each group (N=30). Polymerization sources used were one halogen light-curing unit (CU-100 A, Unicorn Warranty) and three LED curing units namely, Bluephase (Ivoclar), WL-090 curing light (Orthosystem) and iLed curing light (Woodpecker). For all the experimental groups, the buccal enamel surface was polished with a rubber cup and polishing paste for 30 seconds and rinsed thoroughly with water and dried with the air stream. The area where the bracket was to be placed was etched with 37% phosphoric acid gel (3M ESPE) for 30 seconds, rinsed for 15 seconds, and dried with oil-free and moisture-free air for 20 seconds until the enamel surface became faintly white. After acid etching, a thin layer of Transbond XT primer (3M UNITEK) was applied on teeth and light-cured. Orthodontic metal brackets (Gemini series, 3M Unitek) were bonded on the teeth using Transbond XT composite (3M Unitek) and light-cured according to manufacturer's instructions. The brackets were positioned along the long axis of teeth and pressed firmly with an explorer to expel the excess adhesive. The samples were colour-coded and divided into 6 random groups (Fig 1).

Table A:- Six groups divided and cured with halogen and LED units.

Group I (Clear Acrylic)	Group II (Pink & white)	Group III (Pink)	Group IV (White)	Group V (White-Pink-White)	Group VI (Blue)
N=30 Teeth	N=30 Teeth	N=30 Teeth	N=30 Teeth	N=30 Teeth	N=30 Teeth
Cured with Halogen light for 40 seconds.	Cured with Bluephase (Ivoclar curing unit) for 20 seconds.	Cured with WL-090 (Orthosystem light) for 20 seconds.	Cured with iLed curing light (Woodpecker) for 20 seconds.	Cured with WL-090 (Orthosystem light) for 5seconds	Cured with iLed curing light (Woodpecker) for 6 seconds

Fig 1: Colour-coded samples divided into six groups.

A radiometer device (LM-1 Woodpecker meter) was used to check the light intensity of all three LED's and a halogen light-curing unit before each photo-activation cycle.

Table B: Light intensities of LCUs.

Light curing units	Intensity by Manufacturer	Intensity with Radiometer
Halogen light curing unit	300 mW/cm²	200 mW/cm²
Bluephase (Ivoclar)	1,200-1450 mW/cm²	958 mW/cm²
Orthosystem light (WL-090) at 20 seconds	1000 mW/cm²	925 mW/cm²
Orthosystem light (WL-090) at 5 seconds	1800 mW/cm2	950 mW/cm²
Woodpecker iLED at 20 seconds	1000 -1200 mW/cm2	950 mW/cm²
Woodpecker iLED at 6 seconds	2300 mW/cm2	1925 mW/cm2

The cordless LED lights curing units were returned to the battery charger after each specimen was polymerized. The samples were stored in the distilled water at 37°C for 24 hours before the testing and submitted to the SBS testing in a universal testing machine Instron (Model no. 3382 with Bluehill software) (Fig 2).

All the tests were performed by a single operator to avoid interexaminer bias. All specimens were submitted to the SBS testing in a universal testing machine Instron. Before debonding, the specimen mounted in the acrylic block was secured to the lower grip of the Instron machine such that the buccal surface of the tooth with the bonded brackets was parallel to the chisel-edge-shaped plunger that was attached in the movable crosshead of the universal testing machine. The leading edge of the plunger was aimed at the enamel–adhesive interface and moved at a speed of 1 mm/min. (Fig 3) **the** load was applied occlusogingivally to the bracket, which produced a shear force at the bracket–tooth interface. A computer connected with the testing machine showed the results of each test that were recorded. The force required to dislodge the brackets was measured in Newton, subsequently calculated in Mega Pascals (MPa or N/mm²).

Fig 2: Universal testing machine Instron.

Fig 3: Sample at Instron machine.

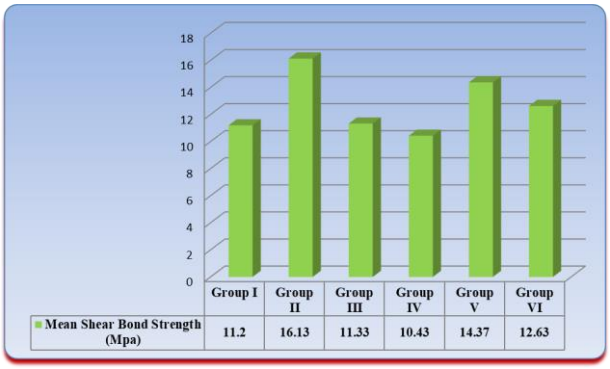
RESULT

ANOVA test showed statistically significant differences among the groups (P=0.006). Highest shear bond strength was found in group II samples, i.e. samples cured with Bluephase (Ivoclar Curing Light) for 20 seconds followed by group VI Cured with iLed (Woodpecker) for 6 seconds, group V samples cured by WL-090 (Orthosystem light) for 5seconds , group III samples WL-090 (Orthosystem light) for 20 seconds, group I samples (Halogen light for 40 seconds). Mean shear bond strength was found minimum in group IV samples which were cured by iLed (Woodpecker) for 20 sec. (Table I) (Graph I). Tukeys post hoc analysis test was applied for inter group comparison of different pairs.

Overall significant difference was found in shear bond strength between all six groups. It showed significant difference found only between group I vs. II, Group II vs. III, IV. ($p<0.05$). For rest of intergroup comparison statistically not significant difference found. ($p>0.05$). (Table II).

Table 1: Comparative evaluation of shear bond strength of brackets using varying parameters of three LED curing lights.

Groups	Shear Bond Strength (MPa)		
	MEAN	SD	RANGE
Group I	11.20	4.055	3.57-20.41
Group II	16.13	6.776	6.37-28.74
Group III	11.33	7.131	3.46-25.36
Group IV	10.43	5.876	3.39-25.02
Group V	12.63	7.351	3.39-28.42
Group VI	14.37	7.252	5.50-28.47
ANOVA 'F' Value	3.372		
Significance 'p' Value	0.006(S)		



Graph 1: Mean Shear Bond Strength of all 6 groups.

Table 2: Tukey's Post Hoc Analysis for inter group comparison.

Groups	Mean Difference in SBS	Significance 'p' Value
Group I vs. II	-4.933*	0.043(S)
Group I vs. III	-.133	1.000(NS)
Group I vs. IV	.767	0.997(NS)
Group I vs. V	-1.433	0.957 (NS)
Group I vs. VI	-3.167	0.416 (NS)
Group II vs. III	4.800	0.05 (S)
Group II vs. IV	5.700*	0.011(S)
Group II vs. V	3.500	0.302(NS)
Group II vs. VI	1.767	0.900(NS)
Group III vs. IV	.900	0.995(NS)
Group III vs. V	-1.300	0.972(NS)
Group III vs. VI	-3.033	0.466(NS)
Group IV vs. V	-2.200	0.780(NS)
Group IV vs. VI	-3.933	0.184(NS)
Group V vs. VI	1.733	0.907(NS)

Table 3: Comparative evaluation of shear bond strength of brackets between group I & IV.

Groups	Shear Bond Strength (MPa)		
	MEAN	SD	RANGE
Group I	11.20	4.055	3.57-20.41
Group IV	10.43	5.876	3.39-25.02
Student 't' Test Value	0.588		
Significance 'p' Value	0.559(NS)		

Graph 2: Mean shear bond strength of group I and Group IV.

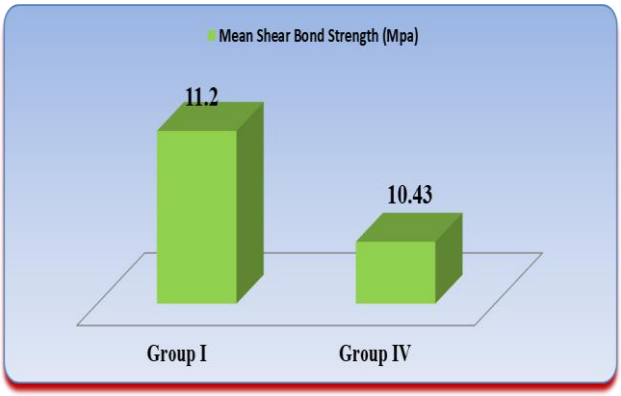
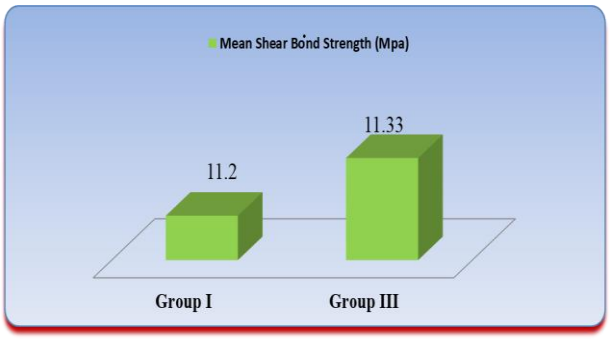


Table 4: Comparative evaluation of shear bond strength of brackets between group I & III.

Groups	Shear Bond Strength (MPa)		
	MEAN	SD	RANGE
Group I	11.20	4.055	3.57-20.41
Group III	11.33	7.131	3.46-25.36
Student 't' Test Value	0.089		
Significance 'p' Value	0.929(NS)		



Graph 3: Mean shear bond strength among the group I and group III.

DISCUSSION

Attaining adequate bond strength is an essential factor in clinical orthodontic practice as the brackets are subjected to stresses applied by orthodontic appliances, masticatory forces, iatrogenic forces or a combination of all these factors[6]. Low efficient light cure unit results in incomplete polymerization which has been associated with frequent bond failures. The bond strength values ranging from 5.9 MPa to 7.8 MPa has been recommended for a clinically efficient orthodontic bonding and to resist conventional orthodontic forces.[11, 12] LEDs are aggressively marketed and the manufactures claim that the recent high-intensity LCUs incorporates all the superiorities of their precursors enhancing bond strength with a significantly reduced exposure time of as less as 5 to 6 seconds to help the orthodontists save valuable chairside time.[13, 14] However, whether optimal bond strength can be achieved after curing the material for 5- 6 seconds has to be determined. Taking into consideration the advantages and differences among halogen and LED curing units, the present in vitro study compared the SBS of brackets bonded with different light-curing groups at a different time interval.

Discussion of Validity and Reliability of Study

Ansari S Gupta [8] evaluated the effect of different light-curing devices i.e. Light Emitting Diodes (LED) for bonding orthodontic brackets, using the shear bond strength. Brackets were bonded on seventy-five premolars. The samples were divided into 5 groups consisting of 15 brackets in each group according to light curing procedures: HL Halogen DENTSPLY (Control), I – Ivoclar (Bluephase), M - 3M (Elipar), W - (Woodpecker) and A - (Allure). Light curing was performed for 40 sec. It showed the maximum shear bond strength mean value. In conclusion, Ivoclar L edition and 3M Elipar LED's showed the highest values of bracket adhesive strength.

Abdullah Alper Oz[9] compared the clinical failure rates and the in-vitro bond strengths of metal brackets polymerized with different LED devices and curing times. Forty extracted premolars were included in the clinical study. Brackets were bonded with the adhesive in Group 1 cured for 10 seconds with an LED unit (Elipar S10; 3M Unitek), and the adhesive in Group 2 cured for 3 seconds with another LED unit (VALO Ortho). No statistically significant difference was found between the groups. In-Vitro bond strengths indicated that both protocols were adequate for clinical usage and high intensity LED units with reduced curing time can save the clinical chair time.

Assessment of SBS values by using Halogen LCU:

In the present study, the mean SBS value of the group cured by Halogen LCU (11.20±4.055 MPa) was lower than the mean SBS values of groups cured by LEDs except the group cured with iLED for 20 seconds (10.43±5.876 MPa) (Table III) (Graph II). However, the mean SBS values were acceptable for the orthodontic bonding. However, the mean SBS of Group III samples (Orthosystem LED for 20 seconds) was 11.33±7.131 MPa while it was 11.20±4.055 MPa for Group I samples (Halogen for 40 seconds) (Table IV) (Graph III). There was statistically no significant difference found in SBS of brackets between Group I and III (p=0.929). In this context, **Üşümez et al.** [15] suggested that the 20 seconds (13.9 ± 4.8 MPa) of LED exposure may yield SBS values comparable with those obtained by halogen-based units in 40 seconds (13.1± 3.1 MPa). **Palomares et al** [16] and **Abdullah MK et al.** [17] also agreed with this result.

Assessment of SBS values by using LEDs

The mean SBS values of all the groups cured by light emitting devices in this study were above the SBS values recommended by **Reynolds** [11] i.e. 5.9 – 7.8 MPa. However, at 20 seconds Ivoclar LED showed higher mean SBS values (16.13±6.77 MPa) than

Orthosystem (11.33±7.131 MPa), iLED (10.43±5.876 MPa) and Halogen at 40 seconds (11.20±4.055 MPa) (Table I). There was a statistically significant difference found in shear bond strength of brackets among these groups **(p=0.006)** as concluded in the study conducted by **Teshima[18], Tsai[19], Rêgo[20], Maruo[21], Silta[22], Artun[23],** which suggested that light-curing devices such as LED at 20 seconds display equivalent or even better performance equated to halogen light devices for 40 seconds photo-activation time. **Rueggeberg et al[24]** suggested that with the higher light power, more no. of photons reaches the orthodontic adhesive which results in the emission of more top no. of free radicals obtained for the polymerization of monomer into polymer. In this study, higher SBS value for Group II can be interpreted by the high mean power of Bluephase (Ivoclar) LED (1200- 1450 mW/cm^2) as compared to other LEDs and halogen LCU.

This study showed that the mean SBS of Group V samples (Orthosystem LED for 5 seconds) was 12.63±7.351 MPa which was higher than the mean SBS value of Group III (Orthosystem for 20 seconds), i.e. 11.33±7.131 MPa (Table I). Similarly, mean SBS of Group VI (iLED for 5 seconds) was higher (14.37±7.252 MPa) than Group IV (iLED for 20 seconds) i.e. 10.43±5.876 MPa. But statistically, no significant difference was found in SBS of brackets between Group III and V and Group IV and VI.

Hence the results of the present study were consistent with the results of **Mavropoulos et al. [7]** and **Gronberg et al[25]** and **Gupta et al[26]** who suggested that a minimum of 5 seconds exposure time and according to **Verma et al. [6]** reductions of exposure time to 6 seconds appeared to be clinically acceptable. However, the study by **Silta et al[22]** showed varying results by studying different polymerization time (20 seconds, 10 seconds, 6 seconds) for halogen and LED units and found significant differences. Higher SBS found with 20 seconds (5.44MPa) followed by with 10 seconds (4.22 MPa) and with 6 seconds (2.67MPa). The shorter the curing time resulted in lower SBS.

CONCLUSIONS

The shear bond strength values were affected by light intensity, exposure time and total energy intensity. The LED light provided higher mean SBS in relation to the halogen LCU. At 20 seconds maximum SBS were shown by IVOclar (Bluephase) (LED followed by iLED and Orthosystem LCU). Mean SBS values at 5 and 6 seconds were higher than the mean SBS values at 20 seconds. However, it was statistically insignificant. Therefore, it can be suggested that the reduction of curing time to 5 - 6 seconds with high-intensity curing lights are clinically acceptable and should be recommended for orthodontic bonding to reduce clinical chair time.

CONFLICTS OF INTEREST

The authors declare they have no potential conflict of interests regarding this article.

REFERENCES

1. Buonocore MG. A simple method of increasing the adhesion of acrylic filling materials to enamel surfaces. J Dent Res 1955;34:849-53.

2. Newman GV. Epoxy adhesives for orthodontic attachments: progress report. Am J Orthod 1965;51:901-3.

3. Dall'Igna CM, Marchioro EM, Spohr AM, Mota EG. Effect of curing time on the bond strength of a bracket bonding system cured with a light- emitting diode or plasma arc light. Eur J Orthod 2011;33:55-9.

4. Fleming PS, Eliades T, Katsaros C, Pandis N. Curing lights for orthodontic bonding: a systematic review and meta-analysis. Am J Orthod Dentofacial Orthop 2013;143:92-103.

5. Türkkahraman H, Küçükesmen HC. Orthodontic bracket shear bond strengths produced by two high-power light emitting diode modes and halogen light. Angle Orthod 2005;75:854-57.

6. Verma P. Curing efficiency of three light emitting diode units at different curing profiles. Indian J Dent Res 2016;27:168-73.

7. Mavropoulos A, Staudt CB, Kiliaridis S, Krejci I. Light curing time reduction: In vitro evaluation of new intensive a diode curing units. Eur J Orthod 2005;27:408-12.

8. Ansari S, Gupta G, Gautam R, Kalia A. Evaluation of different brands of LED curing devices for bonding metallic orthodontic brackets. Dentistry 2014;4:252-54.

9. Oz AA, Oz AZ, Arici S. In-vitro bond strengths and clinical failure rates of metal brackets bonded with different light-emitting diode units and curing times. Am J Orthod Dentofacial Orthop 2016;149:212-16.

10. Surmont P, Dermaut L, Martens L, Moors M. Comparison in shear bond strength of orthodontic brackets between five bonding systems related to different etching times: an in vitro study. Am J Orthod Dentofacial Orthop 1992;101:414-19.

11. Reynolds JR. A review of direct orthodontic bonding. Br J Orthod 1975;2:171-8.

12. Lopez JI. Retentive shear strengths of various bonding attachment bases. Am J Orthod 1980;77:669-78.

13. Mills RW, Jandt KD, Ashworth SH. Dental composite depth of cure with halogen and blue light emitting diode technology. British Dental Journal 1999;186:388–91.

14. Palomares NB, Sampaio-Filho H, de Oliveira Almeida MA, Miguel JA. Effect of high-intensity LED units at reduced curing time on in vitro bond strength of orthodontic brackets. World J Orthod 2008;9:203-8.

15. Üşümez S, Buyukyilmaz T, Karaman AI. Effect of light-emitting diode on bond strength of orthodontic brackets. Angle Orthod 2004;74:259-63.

16. Palomares NB, Sampaio-Filho H, de Oliveira Almeida MA, Miguel JA. Effect of high-intensity LED units at reduced curing time on in vitro bond strength of orthodontic brackets. World J Orthod 2008;9:203-8.

17. Abdullah MK, Rafique T, Biswas AK, Ghosh R, Gafur MA, Hassan GS. Comparison of shear bond strength of orthodontic bracket bonding to teeth using light-curing units between halogen and LED: an in vitro study. Bangladesh Med Res Counc Bull 2019;45:17-22.

18. Teshima W, Nomura Y, Tanaka N, Urabe H, Okazaki M, Nahara Y. ESR study of camphorquinone/amine photoinitiator systems using blue light-emitting diodes. Biomaterials 2003;24:2097-103.

19. Tsai PC, Meyers IA, Walsh LJ. Depth of cure and surface microhardness of composite resin cured with blue LED curing lights. Dent Mater 2004;20:364-69.

20. Rêgo EB, Romano FL. Shear bond strength of metallic brackets photo-activated with light-emitting diode (LED) at different exposure times. J Appl Oral Sci 2007;15:412-15.

21. Maruo IT, Godoy-Bezerra J, Saga AY, Tanaka OM, Maruo H, Camargo ES. Effect of etching and light-curing time on the shear bond strength of resin-modified glass ionomer cement. Braz Dent J 2010;21:533-37.

22. Silta YT, Dunn WJ, Peters CB. Effect of shorter polymerization times when using the latest generation of light-emitting diodes. Am J Orthod Dentofacial Orthop 2005;128:744-48.

23. Artun J, Bergland S. Clinical trials with crystal growth conditioning as an alternative to acid-etch enamel pretreatment. Am J Orthod 1984;85:333-40.

24. Rueggeberg F. Contemporary issues in photocuring. Compend Contin Educ Dent Suppl 1999;25:S4-15.

25. Gronberg K, Rossouw PE, Miller BH, Buschang P. Distance and time effect on shear bond strength of brackets cured with a second-generation light-emitting diode unit. Angle Orthod 2006;76:682-88.

26. Gupta SP, Shrestha BK. Shear bond strength of a bracket-bonding system cured with a light-emitting diode or halogen-based light-curing unit at various polymerization times. Clinical, cosmetic and investigational dentistry 2018;10:61-67.