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ORIGINAL ARTICLE

A Comparative Evaluation Of The Shear Bond Strength Of Five Different Orthodontic Bonding Agents Polymerized Using Halogen And LED Curing Lights - An *In Vitro* Investigation.

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ABSTRACT

Purpose: With the introduction of photosensitive (light activated) restorative materials in orthodontics, various methods were suggested to enhance the polymerization of the materials used, including use of more powerful light curing devices. Bond strength is an important property and determines the amount of force delivered and the treatment duration. Many light cured bonding materials have become popular but it is the need of the hour to determine the bonding agent that is the most efficient and has the desired bond strength.

Aim: To evaluate and compare the shear bond strength for five different orthodontic light cure bonding materials cured with traditional halogen light and low intensity Light Emitting Diode light curing unit.

Materials and Methods: 100 human maxillary premolar teeth, extracted for orthodontic purpose were used to prepare the samples. 100 maxillary stainless steel bicuspid brackets of 0.018 slot of Roth prescription manufactured by D-tech Company (USA) were bonded to the prepared tooth surfaces of the mounted samples using 5 different orthodontic bracket bonding light cured materials namely Enlight (Ormco Corporation), Fuji Ortho LC (GC Corporation)(Resin modified glass ionomer cement), Orthobond LC (D- tech Company), Relybond (Reliance Corporation), Transbond XT (3M Unitek). The bond strength was tested on an Instron Universal testing machine, (model no 5582, USA)

Results: In Group 1 (halogen group) Enlight showed the highest shear bond strength (16.4 MPa) and Fuji ortho LC showed the least bond strength (6.59 MPa) (p value 0.000). In Group 2 (LED group), Transbond showed the highest mean shear bond strength (14.6 MPa) and Orthobond LC showed the least mean shear bond strength (6.27 MPa) (p value 0.000). There was no statistically significant difference in the shear bond strength values of all samples cured using either halogen (mean MPa 11.49) or LED (mean MPa 11.20) as the p value is 0.713.

Conclusion: Polymerization with both halogen and LED resulted in shear bond strength values which were above the clinically acceptable range given by Reynolds[8]. The LED light curing units produced comparable shear bond strength when compared to the halogen curing units.

Key Words : shear bond strength, bonding agents, halogen curing light, LED curing light.

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Introduction

Bond strength is an important consideration for the bonding of brackets to teeth [1]. Shear bond strength depends on various factors including the adhesive properties of the bonding materials, the attachment at the different interphases like the tooth to composite interphase and the composite to bracket interphase, as well as the polymerization of the composite bonding material. Bond strength determines the amount of force delivered and also affects the treatment duration. There was therefore a constant quest to improve the bond strength of orthodontic bonding agents. This paved the way to improve the strength of the interphase between the composite to tooth and composite to the base of the bracket.

With the introduction of photosensitive (light activated) restorative materials in dentistry, various methods were suggested to enhance the polymerization of material used, including use of more powerful light curing devices [2]. Many light cured bonding materials have become popular but it is the need of the hour to determine the bonding agent that is the most efficient and has the desired bond strength. Light curing is another area which has become increasingly popular. The unlimited working time and the 'command set' allow the orthodontist to manipulate and adjust the position of the brackets as desired with ease and convenience. Halogen bulb based light curing units are most commonly used to cure dental composites. Though frequently used, this technology has inherent drawbacks. Halogen bulb has a limited effective lifetime of around 40 to 100 hours [3]. The bulb, reflector and filter degrade over time due to high operating temperatures produced, leading to reduction in light output. This reduces the effectiveness of polymerization of composite bonding materials. The clinical implication of this reduced polymerization for the orthodontist is frequent debonding of the brackets causing inconvenience to the patient as well as the orthodontist [4],[5].

To overcome the several drawbacks of halogen curing light units, light emitting diode technology was introduced by Mills [2] et al in 1995. It generates appropriate wavelength and curing cycles. The LED has distinct advantages when compared with halogen bulbs. Previous studies [2],[3],[4],[5] have shown that blue Light Emitting Diodes have the potential to polymerize dental composites without having the drawbacks of halogen Light Curing Units. It has been reported[3] that dental resins cured with blue Light Emitting Diodes have a higher degree of polymerization and a more stable 3-dimensional structure than those cured with halogen lamps. It is therefore important to evaluate the shear bond strength of bonding materials polymerized using the LED curing units.

Therefore, at such a time when various light curing units and bonding agents claiming to possess the best of properties have flooded the markets, a need was felt to evaluate and compare the shear bond strengths of orthodontic brackets attached with four light activated composite resins and a resin modified glass ionomer cement polymerized using two different types of low intensity halogen lights and Light emitting diode curing units.

Materials & Methods

Materials Used

Light Curing Units

Halogen Light Curing Unit: 'QHL 75 Lite', model no 502, Dentsply Corporation, Milford, USA, with a light intensity of 450mW/cm².

Light Emitting Diode Unit
Light Emitting Diode curing unit 'Hilux LEDMAX 450' with intensity of 450mW/cm²

Bonding Materials
Following 5 different orthodontic bracket bonding light cured materials were used:
1. Enlight - Ormco Corporation
2. Fuji Ortho LC - GC Corporation
(Resin modified glass ionomer cement)
3. Orthobond LC- D- tech Company
4. Relybond - Reliance Corporation
5. Transbond XT- 3M Unitek

Orthodontic Brackets
100 maxillary stainless steel orthodontic bicuspid brackets of 0.018 slot of Roth prescription manufactured by D-tech Company (USA) were used. All bracket bases had mesio-distal and oocluso-cervical contour and 80 gauge foil mesh grid with single layer mesh

configuration. The total surface area of each bracket base was 11.56mm.

Method

The sample consisted of 100 human maxillary premolar teeth which were extracted for orthodontic purpose and stored in 10% formalin solution at room temperature to prevent dehydration till experiment. Before bonding the teeth were removed from the formalin solution and washed thoroughly in distilled water to eliminate any formalin sticking to the tooth surface which could interfere with the bonding. The cleaned teeth were then mounted separately in a circular block of 3 cm diameter & 3 cm height in a die stone (Ultrabase, Kalabhai) so that it could properly be seated on the testing machine. All the mountings were made in such a way that the teeth mounted upright and only the root portion embedded in stone while the crown portion fully exposed above the stone to facilitate proper positioning of the bracket on labial surface.

The 100 mounted specimens were randomly divided into 2 groups (Group 1 and Group 2) with 50 specimens in each group. Group 1 was further divided into 5 subgroups (Subgroup A to Subgroup E). Following 5 different bonding materials were used to bond the brackets for specimens in subgroup A to E.

SUBGROUP A - Enlight used as bonding material
SUBGROUP B - Fuji Ortho LC used as bonding material
SUBGROUP C - Orthobond LC used as bonding material
SUBGROUP D - Relybond used as bonding material
SUBGROUP E - Transbond XT used as bonding material

Group 2 was also divided into 5 subgroups (Subgroup F to Subgroup J). Following 5 different bonding materials were used to bond the brackets for specimens in subgroup F to J.
SUBGROUP F - Enlight used as bonding material
SUBGROUP G - Fuji Ortho LC used as bonding material
SUBGROUP H - Orthobond LC used as bonding material
SUBGROUP I - Relybond used as bonding material
SUBGROUP J - Transbond XT used as bonding material

Bonding Procedure

All specimens were kept in distilled water except during the bonding and testing procedure. Before bonding, the buccal surfaces of the teeth were cleaned with non-oily pumice powder in water using a rotary rubber cup at slow speed (25000 rpm) to ensure removal of any dirt \ calculus \ deposits or stains [7],[8],[9]. All teeth were dried with oil & moisture-free compressed air. The exact position of the bracket on the tooth was marked with a Boon's gauge having 0.5 mm HB lead pencil point. On all the specimen teeth the centre of the labial surface of the crown was marked vertically with the lead pencil. The horizontal markings were made at 4 mm from the tip of the labial cusp by using Boon's gauge.

37 % buffered orthophosphoric acid gel from DPI Company (Dental Products of India) was applied with a sponge microtip applicator on 4 sq mm area marked for bracket positioning. After 30 seconds the etching solution was washed out with distilled water/spray combination for 20 seconds and then dried with oil free compressed air until a characteristic frosty white etched area was observed [9]. Latex gloves were worn throughout the procedure to prevent contamination during procedure.

Application Of The Primer And Bonding Material

A thin, uniform coat of primer was painted gently with a nylon brush to the etched area of each tooth. Then using a syringe tip, the bonding material was dispensed on to the base of the bracket. The material was firmly spread over the entire base. (For the resin modified GIC (Fuji Ortho LC), which is supplied in the form of a powder and liquid separately, was dispensed on the mixing pad with 1:1 proportion and mixed with a plastic agate spatula for 45-60 seconds, then the mixed cement was placed onto the bracket base. The bracket was placed directly on the tooth surface and then pressed firmly to the desired position. Excess adhesive from edge of the bracket was removed with a sharp scalar.

Group 1: Total 50 specimens (Subgroup A to Subgroup E) were cured with halogen light curing unit (Dentsply Corporation) for 40 seconds (20 seconds on the mesial and 20 seconds on the distal surface of each bracket). They contain quartz and tungsten filaments in an incandescent lamp that produces a broad spectral emission of 400-500 nm.

Group 2: Total 50 specimens (Subgroup F to Subgroup J) were cured with Hilux light emitting diode (LED) for 20 seconds (10 seconds on the mesial and 10 seconds on distal surface of each bracket). Hilux LEDMAX 450, Light emitting diodes (LED) is electrically operated semiconductors for the production of light in a narrow spectrum of 450-490 nm.

The light-tip distance[10] from the mesial or distal surface of the bracket was kept 3 mm and standardized using a graph paper marked at 3mm. It was fixed to the tip of the curing unit with the help of a 21 gauge orthodontic wire. During polymerization, the wire with the graph paper was kept touching a line marked on the tooth coinciding with the edge of the bracket.

After the light polymerization all 100 specimens were kept in artificial saliva (Wetmouth, MP Sai Biomed, Mumbai)prepared by dissolving the supplied powder in 500 ml of distilled water, at 37ºC for 24 hours to simulate intraoral conditions. After 24 hours the specimens were subjected to testing for the shear bond strength on an Instron universal testing machine (model no 5582, USA) with the long axis of the specimen parallel to the direction of the applied force [11]. The specimen was held tightly on the fixed lower part to restrict any movement while force is applied. The standard knife edge was positioned to make contact with the bonded specimen. Bond strength was determined in the shear mode at a crosshead speed of 5mm/min until bracket detaches. Values of breaking load (N) were recorded and converted into megapascals by dividing the breaking load (N) by the surface area of the bracket base ($11.56mm^2$) [12].

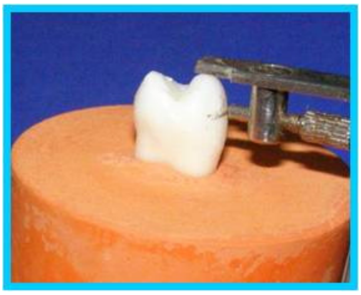
The bond strength in MPa was then calculated using the following formula:-

$$\text{Bond Strength (MPa) ss} = \frac{\text{Breaking Load (in Newton)}}{\text{Area of bracket base (mm}^2\text{)}}$$

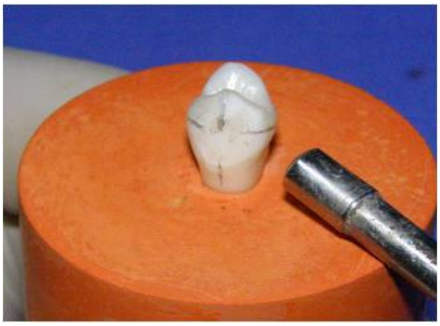
Observations & Results

The recorded values were then tabulated systematically and subjected to statistical analysis by using mean, median, standard deviation, Student't' test, and ANOVA (Analysis of Variance) to determine statistical significance in difference in bond strength. Within the Halogen group (Group 1) the shear bond strength values of samples using different bonding adhesives when compared statistically (p value 0.000) showed significant difference, Enlight showing the highest shear bond strength (16.4 MPa) and Fuji ortho LC showing the least bond strength (6.59 MPa). When the shear bond strength values of samples using different bonding adhesives were compared statistically within the LED group (Group 2), the observation showed statistical significance (p value 0.000). Transbond showed the highest mean shear bond strength (14.6 MPa) and Orthobond LC showed the least mean shear bond strength (6.27 MPa). Shear bond strength of two bonding materials Enlight and Fuji Ortho LC cured with halogen and LED curing units, when statistically compared, did not show any significant difference (p value 0.071and 0.052 respectively). It means both materials showed same shear bond strength with halogen curing and LED curing units. There was statistically significant difference in the shear bond strength values of samples using Relybond and Transbond XT when cured with halogen (11.31 MPa and 12.47 MPa respectively) or LED (14.12 MPa and 14.62 MPa respectively). Curing with LED gave better shear bond strength, p values being 0.001 and 0.002 respectively. There was statistically significant difference in the shear bond strength values of samples using Orthobond LC when bonded with halogen or LED. Curing with halogen showed better shear bond strength (10.63 MPa) than curing with LED (6.27 MPa), p value being 0.000. Shear bond strength of resin modified glass ionomer cement (Fuji Ortho LC) when cured with halogen curing light and also with LED showed very low shear bond strength (6.59 MPa and 7.49 MPa respectively). This is within the range of the desired shear bond strength but on a lower side. There was no statistically significant difference in the shear bond strength values of all samples cured using either halogen (mean MPa 11.49) or LED (mean MPa 11.20) as the p value is 0.713 [Table/Fig 1], [Table/Fig 2], [Table/Fig 3], [Table/Fig 4], [Table/Fig 5], [Table/Fig 6], [Table/Fig 7].

Table/Fig 1. Prepared sample.



Table/Fig 2. Location of bracket marked with Boon "s" gauge.



Table/Fig 3: Drying of itched tooth surface.

Table/Fig 4: Bracket placed with the bonding agent applied to bracket base.

Table/Fig 5: Light curling being done.

Table/Fig 6: Sample mounted on the instron testing machine.

Table/Fig 7: The instron testing machine used for the study.

Discussion

Halogen bulb based light curing units, though most widely used have some drawbacks such as reduction in light output due to degradation of the bulb, reflector and filter and a limited lifetime of 40-100 hours due to the high operating temperatures [2],[3],[4],[5]. This reduces the degree of polymerization and leads to a decrease in the shear bond strength of the cured materials.Light emitting diode technology introduced by Mills [2] et al in 1995 provided distinct advantages of a longer lifetime of about 10,000 hours and less reduction in output during this period when compared with halogen bulbs. Light emitting diodes use junctions of doped semiconductors (p-n) to generate narrow spectrum of blue light of 465nm and hence require no filters. Their relatively low power consumption and resistance to shock and vibration makes them suitable for portable use. These better qualities of light emitting diodes compared to halogen bulb technology show promise for clinical orthodontics.

The study was designed to comparatively evaluate the shear bond strength values of 5 different bonding materials used to bond orthodontic brackets to teeth after being cured with LED and halogen lights, out of which four were composite resin materials and one was light polymerized glass ionomer cement. Demineralization and loss of fluoride from the tooth results from loss of surface enamel during bonding composite resins [13]. A bonding material that could make the tooth structure more resistant to caries yet retain bonding strength and properties of composite resins without the loss of enamel would be the material of choice for bonding and one such potential dental adhesive is the glass ionomer cement. It serves as a reservoir of fluoride ions that protect against decalcification [14]. It claims to provide good shear bond strength and is also easier to remove than the traditionally used composite resins. Therefore in the present study a GIC, Fuji Ortho LC was also selected along with the other composite resin bonding materials.

Shear bond strength also depends on the duration of light exposure. An exposure time of 40 and 20 seconds was chosen for halogen and LED curing respectively as Usumez [15] et al suggested 20 seconds of LED exposure might yield shear bond strength comparable with those obtained with halogen unit in 40 seconds. It was also chosen to use lower intensity light curing units of 450 mW/ cm^2 as, though the high intensity curing units provide the advantage of faster polymerization, according to Ilie N, Felton K, Trixner K et al (2005) [16] curing with high intensity units induces high polymerization stresses which weakens the bond to tooth structure. With low intensity curing, reduced number of free radicals are released and this increases the viscosity by extending the pre-gel state allowing time for the material to undergo some flow before the polymer network reaches the gel stage, and thereby reducing the stress build up at the tooth-bonding agent interface. Higher intensity curing units have also been studied to cause pulpal injury [17] which was found to be less with LED curing units as compared to the halogen curing units.

The light tip was held at a distance of 3mm from the bracket and was standardized using an orthodontic wire holder with a graph paper with 3mm marking kept extending from the light tip as previous studies by Oyama N, Komori A and Nakahara R (2004) [18], Lindberg A, Peutzfeldt A, Dijken JW [19] and Cacciafesta V, Sfondrini MF, Brinkmann PG et al (2004) [10], suggested that 0 mm distance of the light tip from the bonding surface produced highest light intensity which produced maximum rise in pulpal temperature and at a 0-3 mm distance there was insignificant rise in pulpal temperature.

In the present study, in halogen light curing group the shear bond strength values of samples using different bonding adhesives were compared statistically using Analysis of Variance (ANOVA).There was significant difference (p value 0.000) within the Halogen group, Enlight showing the highest shear bond strength (16.4 MPa), Orthobond (10.63 MPa), Relybond (11.31 MPa), Transbond (12.47 MPa) and Fuji Ortho LC showed the least bond strength (6.59 MPa). The reduced shear bond strength of Fuji Ortho LC may be due to faster disintegration of the cement due to microleakage and increased polymerization shrinkage as compared to the composite resins. The result of the present study is in accordance to the results obtained in the previous studies comparing Fuji Ortho LC to other bonding materials [20],[21],[22].There was statistically significant difference (p = 0.000) in the shear bond strength amongst the samples using different bonding adhesives within the LED group too. Transbond XT showed the highest bond strength (14.6 MPa), Enlight (13.50 MPa), Fuji Ortho LC (7.49 MPa), Relybond (14.12 MPa) and Orthobond showed the lowest bond strength (6.27 MPa). The probable reason for the lowest shear bond strength for the Orthobond LC would have been the chemical composition of the composite resin material which may have been less compatible to the wavelength [22] of the LED curing unit and therefore resulted in a lower degree of conversion and thereby a lower shear bond strength.

A Student't' test was used in this study to compare the bond strength of materials in the two groups cured with the halogen and LED curing units. Enlight and Fuji Ortho LC did not show any statistically significant difference (p values being 0.071 and 0.052 respectively) in the shear bond strength with either curing with Halogen (16.44 MPa and 6.59 MPa respectively) or LED light (13.50 MPa and 7.49 MPa respectively). Relybond and Transbond XT bonding materials when cured with LED, gave better shear bond strength values (14.12 MPa and 14.62 MPa respectively) than when cured with halogen light curing unit (11.31 MPa and 12.47 MPa respectively), the p value was 0.001 and 0.002 respectively. Orthobond bonding material, when cured with halogen and LED, and compared statistically, showed highly statistically significant results. Shear bond strength achieved with halogen light was better (10.63 MPa) where as the same was low with LED (6.27 MPa), (p value 0.000). This indicates that halogen light gives better shear bond strength than LED light. The probable reason for this result would have been the chemical composition of the composite resin material which would have been more compatible to the wavelength of the 'QHL-75 Lite' halogen light curing unit. All materials used in the study produced mean shear bond strength above the minimum value suggested by Reynolds [7] for a clinically effective orthodontic bond of 5.9 -7.8 MPa, which suggests that all the materials tested can be clinically acceptable for bonding brackets to teeth. However Fuji Ortho LC and Orthobond have shown shear bond strength very much on lower side.

A Student't' test done to statistically compare the shear bond strengths of samples cured using halogen light and the shear bond strengths of samples cured using LED showed that there was no statistically significant difference in the shear bond strength values of samples cured using either Halogen or LED, p value being 0.713, which is not significant. This result is in accordance with the result of many previous studies such as by Dunn WJ, Taloumis LJ (2002) [24], Cacciafesta V, Sfondrini MF, Brinkmann PG etal (2002) [23], Usumez S, Buyukyilmaz T and Karaman AI (2004) [15], Layman W and Koyama T (2004) [25] where in halogen and LED curing units were compared for the shear bond strength and it was found that LED curing units produced comparable bond strengths in a lesser exposure time.

The insignificant difference in the shear bond strength values between the halogen and LED light considering the difference in the exposure time can be explained as a difference in the spectral distribution of the two [25]. Halogen curing units contain quartz and tungsten filaments in an incandescent lamp that produces a broad spectral emission of 400-500 nm. Much of this is infrared energy that generates heat, and therefore the lamp becomes extremely hot. Because of this heat generation, there is a power loss of 70% and less than 1% of the electrical energy is used for light emission. In addition, the light intensity decreases to 10% when a filter is used to reduce infrared energy and to obtain the optical wavelength range required for curing composite resin. Due to a wider spectrum of the light waves produced a small amount of the light emitted is actually absorbed by the camphoroquinone which is the photoinitiator in most of the composite resins. The bulb, reflector and filter degrade over time due to high operating temperatures produced, leading to reduction in light output [26]. This reduces the effectiveness of polymerization of composite restorative materials.

The solid state light emitting diode technology was proposed for the polymerization of light activated dental materials to overcome the shortcomings of halogen visible light curing units. Light emitting diodes use doped semiconductors for the production of light in a narrow spectrum of 450-490 nm unlike the halogen curing units and therefore do not get heated up. About 95% of the light beams from an LED are absorbed by the photoiniator – camphoroquinones as the wavelength of the blue light spectrum emitted from an LED is about 465 nm which is very close to the maximum absorptive range of camphoroquinone which is 470 nm [24]. Therefore the polymerization requires less exposure time, as well as the depth of cure obtained is comparable to that obtained with a greater exposure time of the halogen curing [24],[25].

The laboratory assessment cannot predict clinical performance fully. Also it has been seen that there is significant difference in the output for various manufactured lights including the range of the wavelength of the light produced [26],[27]. Light sources also generate different light intensities over time depending on the quality and age of the lamp [28]. These differences can create a lot of variation in the results obtained in various studies. Clinically, intraoral contamination, moisture, temperature and other factors such as masticatory forces and orthodontic loading can influence bond strength [29]. As oral conditions are difficult to simulate in the laboratory, the results obtained should be interpreted with caution in the clinical practice and further clinical studies are necessary for validation. Evaluating bond strength is a sensitive experimental procedure and the same bonding materials can yield different results due to variations in experimental conditions.

Conclusion

Newer technologies like the Light emitting diode are slowly replacing the traditional halogen bulbs. The LED provides similar bond strength, depth of cure etc when compared to the halogen curing units in a shorter period of time while providing other benefits like a longer lifetime and being user-friendly. Statistical analysis of the shear bond strength of samples cured using halogen light and cured with LED light showed that there was no statistically significant difference in the shear bond strength as proved in previous studies too [30],[31]. Polymerization of the five different orthodontic bonding agents with both halogen and LED resulted in shear bond strength values which were above the clinically acceptable range given by Reynolds [4]. The LED light curing units can therefore be called a viable alternative to the halogen curing units.

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