Influence of light - Curing Mechanism on Microshear Bond Strength of Different Adhesives

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Abstract: Objectives: To evaluate the microshear bond strength of two novel adhesives with their corresponding restoratives when cured with conventional halogen, plasma arc and argon laser curing units. **Methods:** Occlusal surfaces of 18 human molars were ground to obtain a flat dentin surface. The teeth were divided into 2 groups (n=9) according to the adhesive used [Adper Prompt L-Pop Self-Etch Adhesive (AP) with Filtek Supreme Ultra, 3M/ ESPE, and Ketak N100 nano-ionomer primer (KN) with Ketak N100 light-curing nano-ionomer restorative, 3M/ESPE]. Each group was further divided into 3 subgroups (n=3) according to the curing methods used to polymerize both the adhesive system and the resin composite: 1) Cured with a halogen light curing unit (PRO-DEN systems, USA); 2) Cured with a plasma arc unit (Apollo 95E, Calif., USA) and 3) Cured with argon laser. After curing each adhesive, the restorative material corresponding to each adhesive [AP with Filtek Supreme Ultra, 3M/ESPE, and KN with Ketak N100 light-curing nano-ionomer restorative, 3M/ESPE] was used for composite cylinder build-up (0.9 mm diameter x 0.5 mm height). Three composite cylinders were constructed on each treated surface (n=9). A Lloyd universal testing machine was used to test microshear bond strength at crosshead speed of 0.5 mm/minute. Data were analyzed using two-way ANOVA and Tukey's test ($P \leq 0.05$). **Results:** The mean microshear bond strength of KN (30.3 MPa) showed a statistically significantly higher value than AP (22.47 MPa). The argon laser curing subgroup (26.3 MPa) showed the highest mean microshear bond strength values. There was no statistically significant difference in the microshear bond strength values between the halogen light (23.77 MPa) and plasma arc (24.55 MPa) specimens. **Conclusion:** The novel nano-ionomer offered better microshear bond strength, whereas the argon laser provided better microshear bond strength.

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1. Introduction:

Polymerization lamps have become key instruments in dental practice, since the clinical failure of composite resins is largely due changes taking place during polymerization. These changes are partly governed by the type of curing unit and the technique employed. The clinician should fully understand the chemistry of the restorative materials being used, the nature of the polymerization process itself, and the operating characteristics of the curing unit, Katona et al., (1996); Blankenau et al., (1999). The technology and the techniques of restorative materials and their bonding are currently undergoing major changes, due in part to attempts to reduce operating time and in part to more thorough understanding of polymerization process. These changes have in turn prompted regular reviews covering the latest developments, Burke et al., (1996); Rueggeberg (1999); Davidson and de Gee (2000).

There are different curing lamps available for curing restorative materials, halogen, plasma arc, laser and light –emitting diode. Halogen lamps use an incandescent light –bulb consisting of tungsten filament surrounding by the halogen gases that give them their name and working at wavelength between 400-500 nm. Halogen lamps emit white light, so to produce the blue light required for curing, unwanted portions of the spectrum are filtered out. Because the light spectrum of the lamp is limited only by filter, all possible portion of the spectrum are available if required. Disadvantages of the halogen lamp including low energy performance, generation of high temperature, loss of the lamp power, and the need for filter and ventilation fan. All these mean that halogen lamps require considerable maintenance, Yap and Senteviratne (2001); Jimenez-Planas et al., (2008). Plasma arc lamps use fluorescent bulb containing plasma, which defined as a material generally gas, most of whose atoms are molecules ionized, Lapides (1981). When an electric current passes through plasma, generally in the form of xenon gas, ultraviolet radiation is produced; when this radiation collides with the bulb wall, it is converted to light. The main disadvantages of plasma arc curing lights are similar to halogen lamps: low energy performance, the need for filter and ventilation fan, and high cost. These high intensity lamps work at wavelength between 430-500 nm. The plasma curing light Apollo 95 E (DMDS, Marburg, Germany) emits light at frequencies between 440 nm and 500 nm, with peaks at 470 nm and 485 nm and an intensity of 1320 m W/cm^2. Due to the high intensity, the manufacturer claims that 1 s to 3 s of plasma irradiation cures many resin composites to hardness similar to that achieved after 40 s with conventional curing lights, Jimenez-Planas et al., (2008).

Laser lamps are based on the laser principles (light amplification by stimulated emission of radiation). The main property of laser light is that all electromagnetic wavelength has the same frequency and are all in phase, thus providing a narrow beam of coherent light. The wavelength will deepened on the type of material used. In this case argon produces blue light. Experimental studies using monochromatic lasers have shown that the 454.5 nm and 495.5 nm wavelengths are less effective than 476.5 nm but still contribute considerably to polymerization Jimenez-Planas et al.,(2008).

In contrast, laser sources emit light at a few distinct frequencies within the desired region, thus completely eliminating the need for filtering undesired wavelengths as compared to conventional light sources. Resin composites cured with continuous or pulsed argon lasers showed equivalent or superior Knoop hardness, Vargas (1998), flexural strength, Cobb et al., (1996), conversion of double bonds, Meniga et al., (1997), degree of polymerization, Blankenau et al., (1991) and bond strength to enamel and dentine. Laser curing required shorter irradiation time and reduced the increase of pulpal temperature, Powell et al., (1999). Today, a variety of dental materials available under different brand names in the market is based on nanotechnology as nanofilled composite and light cure nano-ionomer restorative materials and their novel adhesives. Nano-technology consists of controlling or reducing component of a material to the nanometric scale (e.g. filler sizes from 0,005-0.01mm) to improve the final mechanical properties and bond strength. These newer type of restorative material were developed because of the increasing demand for universal aesthetic dental material suitable for all types of direct restoration, Taher (2011).

The aim of this study is to evaluate the microshear bond strength of two novel adhesives with their corresponding restoratives when cured with different curing system Conventional halogen light, Plasma arc light and argon laser.

2. Materials and Methods:

2.1. Materials:

2.1.1. Samples:

A total of eighteen freshly extracted sound human molars were collected.

The teeth were divided into 2 groups (n=9) according to the adhesive used [Adper Prompt L-Pop Self-Etch Adhesive (AP) with Filtek Supreme Ultra, 3M/ ESPE, and Ketak N100 nano-ionomer primer (KN) with Ketak N100 light-curing nano-ionomer restorative, 3M/ESPE].

Each group was further divided into 3 subgroups (n=3) according to the curing methods used to polymerize both the adhesive system and the resin composite:

1) Cured with a halogen light curing unit (PRO-DEN systems, Inc-north Lombard Street-portland, USA) at 10 s bonding agent, 20 s for restorative materials.
2) Cured with a plasma arc unit (Apollo 95E, Calif., and USA)at 3 s bonding agent, 6 s restorative materials.
3) Cured with argon laser (Flexilas Argonlaser, A.R.C. laser GmbH, Eckental, Germany), 5 s for bonding and 10 s for restorative materials.

2.1.2. Adhesives and their corresponding restorative materials:

Illustrated in table (1)

2.2. Methods:

2.2.1.Scheme of the work:

Teeth were cleaned by removing the remaining soft tissues and stored in physiologic saline solution until testing. Each tooth was embedded in an acrylic resin up to cement-enamel junction (CEJ) using a special designed mould. . Dimension of the mould was 20mm width x 20 mm length x 15mm height. The occlusal third of the crown of each tooth was removed by sectioning the crown perpendicular to its long axis using a low speed diamond saw (Buehler- Isomat, LakeBulff, IL, USA) under copious amount of water. The exposed dentin were finished using 600 Grit Wet Silicone Carbide abrasive papers in circular motion under water coolant to create a uniform, clinically relevant smear layer. The teeth were then rinsed and dried and the exposed dentin surfaces were inspected under a stereomicroscope to ensure removal of all enamel remnants.The performance of the curing light was monitored daily using handle dradiometer (Curing Radiometer, Demetron,Danbury, CT, USA).

The light intensity of plasma arc curing is reported by the manufacturer 1320Mn/cm^2 and would have exceeded the scale of radiometer. To reduce its output to a level that could be handled by the radiometer, an aperture 3mm in diameter was inserted between the light tip and the measuring window of the radiometer. These results do not allow a ranking of plasma arc in comparison to the halogen light and argon laser, but instead served as to monitor consistency of performance, Hofman et al., (2000). Table (2).

After curing each adhesive according to the manufacturer instructions, the restorative material corresponding to each adhesive [AP with Filtek Supreme Ultra, 3M/ESPE, and KN with Ketak N100 light-curing nano-ionomer restorative, 3M/ESPE] was used for composite cylinder build-up (0.9 mm diameter x 0.5 mm height). Three restorative cylinders were constructed on each treated surface (n=9).

A Lloyd universal testing machine (Model LRX-plus; Lloyd Instruments Ltd., Fareham, UK) was used to test microshear bond strength at crosshead speed of 0.5 mm/minute.

2.2.2. Statistical analysis:

Data were analysed using two-way ANOVA and Tukey's test at (P≤0.05).

Table 1: Adhesives with their corresponding restorative materials tested

Material	Manufacturer	Type	Composition
Filtek Supreme Ultra	3M ESPE Products, St Paul, MN, USA	Dental Universal nano-filled composite	**Filler:** combination of aggregated zirconia/ cluster filler with particle size primarily of 5-20 nm and non-aggregated of 20 nm, 78.5 wt% or 59.5vol% **Matrix:** Bis-GMA,UDMA,TEGDMA,Bis-EMA resins
Adper Prompt L-Pop	3M ESPE Products,,St Paul, MN, USA	Adhesive system	**A**: Phosphate mono and di-hema, dimethacrylate, camphorquinone, substituted aromatical amine and substituted phenol **B**: water, hydroxyethyl methacrylate, methacrylate polycarbonic acid and substituted phenol
Ketac N100	3M ESPE, Products, St Paul, MN, USA	Dental Modified ionomer , Restorative	**Filler:** fluoroaluminosilicate glass, nanomer and nanoclusters average particle size 1 mm, 69 wt%.Nanofillers are discrete non-agglomerated and aggregated fillers of 5-25 nm **Matrix;** Vitrebond copolymer, methacrylatemodified polyalkenoic acid, HEMA

Table 2: Curing unit used in the study

	Unit type	Spectrum	Intensity
PRO-DEN systems, USA	Halogen lamp	400-500 nm	450 Mw/cm^2
Apollo95E, Calif., USA	Plasma arc	430-500 nm	1320 Mw/cm^2
FlexilasArgonlaser, A.R.C. laser GmbH	Argon laser	400-515 nm	450 Mw/cm^2

3. Results:

3.1. Microshear bond strength values of different adhesive systems:

Table (3): Mean and standard deviation for microshear bond strength of the tested materials

Adper Prompt L		Ketac N		*P*-value
Mean	**SD**	**Mean**	**SD**	
19.12	1.6	30.3	2.4	**<0.001***

* The mean microshear bond strength of Ketak N100 nano-ionomer primer (KN) with Ketak N100 light-curing nano-ionomer restorative showed a statistically significant higher value (30.3 MPa) than Adper Prompt L-Pop Self-Etch Adhesive (AP) with Filtek Supreme Ultra restorative material (22.47 MPa). Table (3) and Fig (1).

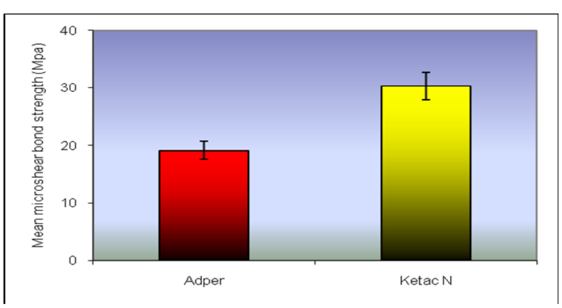

Figure (1): Bar chart representing means and SD values for comparison between microshear bond strength values of the two materials

*The highest mean microshear bond strength values with KN (32.24 MPa) and AP (20.36 MPa) adhesive systems when cured with argon laser system followed by plasma arc KN(30.1 MPa), AP (19 MPa) and Halogen KN (29.54 MPa), AP (18 MPa) showed the lowest value. Table (4) and Fig (2).

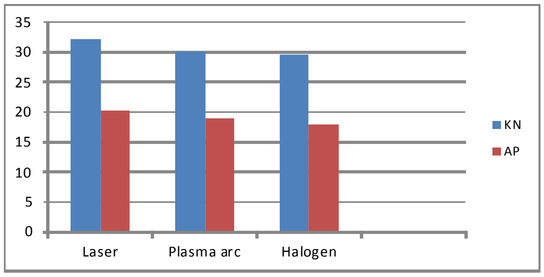

Figure (2): Bar chart representing means and SD values for comparison between microshear bond strength (MPa) with the three curing modes.

Table (4): Descriptive statistics for microshear bond strength values

Material	Curing	Mean	SD
Adper Prompt L	Argon Laser	20.36	1.8
	Plasma arc	19	1.1
	Halogen	18	1.1
Ketac N	Argon Laser	32.24	1.9
	Plasma arc	30.1	1
	Halogen	29.54	1

3.2.Results of microshear bond strength the two adhesives with the three curing modes

Table (5) showed the mean microshear bond strength values of the two adhesives with three curing system. Laser curing system showed the statistically significantly highest mean microshear bond strength (26.3MPa). While, there was no statistical significant difference between Plasma arc (24.55MPa) and Halogen (23.77MPa) which showed the lowest means microshear bond strength.

Table (5) Comparison between microshear bond strength with the three curing modes

Laser		**Plasma arc**		**Halogen**		***P*-value**
Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	
26.3 [a]	2.3	24.55 [b]	1	23.77 [b]	1.1	**0.011***

4. Discussion:

Photo-activated restorative materials have been developed in an attempt to surpass the limitations of chemically cured systems. Dentists have a choice of various types of curing lights for the photopolymerization of composites: conventional quartz tungsten- halogen (QTH), plasma arc (PAC) or argon laser (LAS) curing lights. These lights have different characteristics and advantages, but the optimal light-curing unit for the photopolymerization of composites has not yet been determined, Blankenau et al., (1991). Curing–time indications for newly marketed high power lamps tend to be very short, between 2 to 10 seconds. High intensity over a shorter irradiation time produces the same conversion factor as midrange intensity and leads the same degree of polymerization shrinkage and the same mechanical properties, Halvorson et al.,(2002). However, it prompts greater shrinkage stress and there for poorer interface, Ferracane and Mitchem (2003). High intensity is also associated with the development of high temperatures. More ever, since not all materials respond in the same way at different intensities, high intensity does not always yield the best results, Harris et al.,(1999).

The result of the present study revealed that the mean microshear bond strength of Ketac N100 nano-ionomer primer (KN) with Ketak N100 light-curing nano-ionomer restorative showed a statistically significantly higher value than Adper prompt with Feltik supreme ultra-restorative. This finding might be related to the Ketac N primer and Ketac N restorative material has the same material and also the ionomer form a chemical bond after conditioning the dentin surface. This is in agreement with other study which reported that, the incorporation of both nano-sized fillers and nano clusters, along with flouroaluminosilicate glass, is claimed to result in excellent mechanical properties, bond strength, high fluoride release, great aesthetics and relatively low wear.

The role of the conditioner probably involves effective removal of the smear layer and provides for good wetting of the surface by the glass ionomer. However, as acidic materials, the conditioners may also produce micro-porosity in the enamel surface that could contribute to either increased surface area for chemical bonding or micromechanical bonding through polymer penetration. When phosphoric acid was used, the expected enamel etch pattern and resultant micro-porosity was produced Glasspoole et al. (2002).

This result was disagreed with the other studies, Ozel et al.,(2009); Korkmaz et al., (2010) who concluded that Nano glass ionomer exhibited significantly lower shear bond strength compared to nano-composites. The self-etch adhesive showed higher shear bond strength than etch& rinse adhesive for both nanofill and flowable nanofill composites. In a study by Leuven BIOMAT Research Cluster it has been concluded that Ketac N100 "bonded as effectively to enamel and dentin as a conventional glass-ionomer, but bonded less effectively than a conventional resin-modified glass-ionomer. Its bonding mechanism should be attributed to micro-mechanical interlocking provided by the surface roughness, most likely combined with chemical interaction through its acrylic/itaconic acid copolymers, Coutinho et al.,(2009).

The results obtained revealed that, there was no statistically significant difference between plasma arc curing and halogen lamp curing unit. Some authors considered that plasma arc curing is less effective than halogen lamps, particularly for resin-modified glass ionomer, Millar and Nicholson (2001), others, Fano et al.,(2002) report less final shrinkage than with conventional halogen lamps ,which may be due to incomplete curing, although other article report the same conversion factor for both of uni, Knezevic et al., (2002). It is generally agreed that plasma arc units provide good results and significant time saving when used for cementing brackets and orthodontic bands, Ishikawa et al.,(2001); Dunn and Taloumis (2002).

Regard to the result, the mean microshear bond strength values of the two adhesives with three curing system. Laser curing system showed the statistically significantly highest mean microshear bond strength, while there was no statistically significant difference between Plasma arc and Halogen curing system. The argon laser has many advantages when polymerize restorative materials, Laser photons travel "in phase" (i.e., are coherent), and are collimated such that they travel in the same direction. Less power is put out by the argon laser units than the conventional halogen lamps, yet they can cure the resin more effectively because the wavelength of the light is specific to the job being performed. Halogen lamps emit wide bandwidths of 120 nm, resulting in a broad spectrum of wavelengths that overlap and are said to be "out of phase," or incoherent, Harris and Pick (1995). Two photons of incoherent light that are 180 degrees out of phase can cancel each other, resulting in decreased curing power and less polymerization of the composite resin. Halogen lamps also produce a divergent beam of light, resulting in a loss of 40% of energy 6 mm from the curing surface. In contrast, the argon laser emits a collimated (narrow, focused, non-divergent) beam focusing on a specific target, resulting in a more consistent power density over distance, Kelsey et al., (1989); Dederich (1993); Vargas et al.,(1998). Because of the properties of the argon laser described above, the thoroughness and depth of composite resin polymerization are greater with this laser than they are when halogen lamp or plasma arc are used. Less unpolymerized monomer is found in resins cured by argon laser compared to those cured with VLC units Blankenau et al.,(1991); Dederich (1993); Vargas et al.,(1998). This thoroughness results in the enhancement of certain physical properties of the laser-cured composite resin, including compressive strength, diametral tensile strength, transverse flexural strength and flexural modulus, Kelsey et al., (1989); Dederich (1993); Vargas et al.,(1998).

Conclusions:

The novel nano-ionomer offered better microshear bond strength, whereas the diode laser provided better microshear bond strength.

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