Do the type of light curing source and dental adhesive affect the bond strength to dentine?

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Abstract: Purpose: To assess microshear bond power of two adhesives methods with their matching restoratives exposed to diverse light curing units LCU (LED, laser and plasma arc). **Materials and Methods:** Occlusalfaces of 18molars of human beings were crushed gaining flat dentin faces. The eighteen molar tooth were classified into two experimental groups (n=9 each) owing to the adhesive material 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]. Every group was additional partitioned into 3 subgroups (n=3) owing to the light curing unit LCU applied for treating of both the paste system and the restorative material; 1) Treated with LED unit, 2) Treated with plasma arc unit and 3) treated with Argon laser. After treating of every adhesive, the restorative material consistent to every adhesive [AS with Filtek Supreme Ultra, 3M/ ESPE, and KN with Ketak N100 Light-curing Nano-ionomer restorative, 3M/ESPE] were applied for chambers build up (0.9mm diameter x 0.5mm height). Three chambers were made on each cured surface (n=12). Evaluating microshear bond strength at crosshead speed of 0.5 mm/minute was performed using Lloyd universal testing machine. The data were analyzed by applying two-way ANOVA and Tukey's test ($P \leq 0.05$) statistical method. **Results**: The average microshear bond strength of KN (30.3 MPa) recorded high significant value than AP (19.12 MPa) under the test conditions, Argon laser treating subgroup (26.3 MPa) demonstrated the maximum average microshear bond strength values, although, there was no significant variation in the microshear bond strength values among the specimens cured using plasma arc (24.55 MPa) and LED unit (23.77 MPa). **Conclusion:** Under the test conditions, laser LCU provided better microshear bond strength, whereas the nano-ionomer primer together with the nano-ionomer restorative material offered better bonding.

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1. Introduction

While light-treated repairs are brilliant for esthetic processes, together the chemical and physical characters of occupied mixtures are directly linked to the transformation of monomers to polymers. Slow in the rates of transformation can cause marginal breakdown, fracture, degradation and ingredient damage, consequently restrictive the lifetime of the resin complex. Sufficient polymerization of resin compound healing ingredients is necessary for gaining best chemical and physical characters, and for attaining perfect clinical presentation.[1]

The shear bond strength is an important and notable mechanical property in clinical durability of tooth-colored restorations. This property of resin composite restorations relates directly to polymerization shrinkage. Different methods have been suggested to increase the bond strength, such as the use of dentin bonding agents with higher bond strength and also the use of new lighting units which claim to create better mechanical properties because of the penetration of light to deeper layers.[2] The intensity of light is another important factor in polymerization and affects the mechanical property of composite resins.[3]

At present, the following major technologies for curing the different restorative materials used in dental practice are: quartz tungsten halogen (QTH) lamps, plasma arc (PAC) lamps, light-emitting diode (LED) lamps, and laser lamps. Several years ago, quartz-tungsten-halogen (QTH) bulbs have been applied as the chief dental light-curing unit (LCU) for photo-polymerization. These LCUs produce comparatively broad wavelengths spectra, generally ranged between 370 and 520 nm.[4]Though; some influences may conciliation the presentation of QTH units, such as long-term degeneration of the bulb and filter, fluctuation in the line voltage, damage to the fiber-optic bundle, bulb overheating within the unit in addition to pollution of the light guide.[5]

Plasma arc lamps were introduced as high strength light-curing units. Within the plasma arc (PAC) light unit, the light is produced by high voltage amongst two tungsten electrodes, disconnected by a small hole. The resultant flash ionizes the gaseous surroundings (Xenon) and generates a conductive gas which is called a plasma. The light liberating from curing unit was capable for producing a high of power exceeds 2000 mW/cm^2 and was promoted with suggested treating periods of 3s per rise of resin composite. Conversely advanced investigations revealed that the exposing time of the 3s was very short to get a best exchange. The high intensity lamps work at wavelength ranged from 430-500 nm. The disadvantages of treatment with plasma arc curative lights are comparable to halogen lamps.[5]

It is established that solid-state LED treating lights denote advanced technology in polymerizing composites. Also, the blue light and the high efficiency of LEDs are returned to the semiconductor (gallium nitride) which used during dental restorations.[6]LEDs is adjusted at a wavelength of about 470 nm and a bandwidth of approximately 20 nm, and then have the spectral transparency needed for dental resins of highly proficient treating effect. In addition, the second benefit of LEDs is that the dike tone camphor quinine has maximal absorption at 470 nm which are used in widespread as initiator of the polymerization reaction.[7]The characteristics of the advanced generation of LED curing lights are portable, and highly efficient, lightweight, and durable. In this apparatus a thin band of light is released, there is no necessity for fitting of filter systems. Also, on the advantages new generation of LED is the no emission of infrared released from the treating lights which means that a low quantities of wasted energy, and a less amounts of generated heat can emitted, accordingly no requirement for cooling fans fitted in the apparatus. Moreover, another benefit of using LED curing light's is the low amounts of power consumed, thus the batteries can persist for long time. The emitted light is stable, and the durability of bulb is long and no need for changeable with long half live.[8]

Nevertheless, some adhesive systems required multiple peaks of LEDs to give the desired a single peak of LEDs not sufficient to cure well due to changes in photo-initiators content; therefore a new generation of LEDs characterized by poly waves are presented to the market nowadays.[9, 10] The new generation of LEDs apparatus produce light wavelengths similar to the absorption peak of camphorquinone. Though, they distribute supplementary light yield at the UV-Vis region of the electromagnetic spectrum (400–415 nm). The 2ndpeak in the UV-VIS region may stimulate a reasonable treat of these adhesives materials, comprising another photo-initiators methods, such as trimethylbenzoyl-diphenylphosphineoxide (TPO), phenyl propanedione (PPD), and bis-alquylphosphinic oxide (BAPO).[11] This argument is critical due to some of the selection of an acceptable LCU is primitive to giving a satisfactory adhesive polymerization and resin/dentin bond strength.[10]

Laser is abbreviation for light magnification by augmented production of radiation. One of the advantages of laser light is related to the electromagnetic wavelengths that possess the same regularity and are all in phase, therefore releasing a fine beam of comprehensible light. In compare with the traditional light sources, laser sources release light at a few separate incidences within the chosen area, accordingly to tally eradicating the necessity for filtering unwanted wavelengths and requisite smaller irradiation period. Many researches applying monochromatic lasers have demonstrated that the 454.5 nm and 495.5 nm wavelengths are fewer influence than 476.5 nm but still donate extensively to polymerization.[5]

Generally nanotechnology means using of materials with diameters ranged from 1–100 nm and are used in many systems, or modification of the functions of materials which are used in recent applications in many fields.[12, 13] It has been postulated that integration of nano-sized materials or "nanoclusters" can enhance the mechanical characters of dental restorative substance like resin composites.[14]Relatedmethodologies have been tried to develop the mechanical and physical properties of glass ionomer cements GIC applying recent nano-technique methods. There are two methods for the manufacture of nano-size particles: bottom-up and top-down[13]. The first method which known as top-down nanofabrication includes the construction of nano-size particles via eradicating the majorityof substance. Whereas, the second method for preparation of nanoparticles is called bottom-up nanofabrication includes construction of nano-sized particles atom by atom. Manufacture of nano-sized particles for integration to GICs, is mostly performed by top-down nanofabrication of bulk substances like silicate glasses, some metal oxides and apatite.[13,15]

Thus, the aim of the current work was to estimate, in vitro, the performance of two adhesive systems with their corresponding restoratives irradiated with different light curing units LCU by means of microshear bond strength test.

2. Materials and Methods

Specimen preparation:

Eighteen freshly extracted caries-free human third molars were collected, washed under running water and stored at 4°C in phosphate-buffered saline containing 0.002% sodium azide to prevent microbial growth. The teeth were used within 1 week after extraction. Flat surfaces in the mid-coronal dentin were obtained by the removal of the superficial enamel and dentin from the occlusal surface with an Isomat saw (Buehler Ltd., Lake Bluff, IL, USA) under water-cooling. The dentin surfaces were then finished using 600 and 1000 grit silicon carbide papers (Soft Flex, Germany) under running water to create a standard homogenous smear layer.

Grouping of teeth:

The teeth were divided into two groups (n=9) according to the adhesive system applied **Table (1):**

1. Adper Prompt L-Pop Self-Etch Adhesive (AP), and
2. Ketak N100 nano-ionomer primer (KN)

Each group was further subdivided into 3 subgroups (n=3) according to the light curing unit LCU used to polymerize both the adhesive system and the restorative material:

- Cured with LED (Bluephaseunit, Ivoclar, Vivadent) for 20 seconds,
- Cured with plasma arc unit (Apollo95E, Calif., USA) for 3+3+3 seconds, and
- Cured with Argon laser Cured with argon laser of 488 nm (Accu Cure 3000, Laser Med, West Jordan, UT, USA) with 5 mm beam size and 10 seconds exposure.

The tested adhesives were applied to the flat dentin surfaces according to manufacturers' instructions and were cured using the curing unit assigned for each subgroup. Polyethylene tubes 0.9 mm height and 0.5 mm internal diameter were placed on a glass slide and filled with the restorative material, Filtek Supreme Ultra (3M/ ESPE) for the AP group and Ketak N100 (3M/ESPE) for the KN group. The tubes of each restorative material were then transferred to its corresponding adhesive- treated dentin surfaces. Each specimen received three cylinders (for each subgroup n=9). The tubes of each subgroup were irradiated for 40 seconds using the assigned curing unit. All polyethylene tubes were carefully removed and the specimens were stored in distilled water for 24 h. at 37°C.

Microshear bond strength test:

Microshear testing was used to measure the bond strength of the tested adhesives to tooth structure[1,2]. Each specimen was mounted in an acrylic resin block and then attached to the universal testing machine (Model LRX-plus, Lloyd Instrument Ltd., Fareham, UK). Each acrylic-embedded tooth with its bonded microcylinders was secured with tightening screws to the lower fixed compartment of the universal testing machine. Around each microcylinder, a loop of orthodontic stainless steel wire (0.014" in diameter) was wrapped as close as possible to the base of the microcylinder, touching the tooth surface and aligned with the loading axis of the upper movable compartment of the testing machine. The specimens were stressed in shear at a crosshead speed of 0.5 mm/min until failure occurred. The maximum shear force required to detach the microcylinder was recorded and converted to shear stress in MPa units using computer software (Nexygen-MT Lloyd Instruments).

Table (1): Manufacturers and compositions of the adhesive systems with their corresponding restorative materials tested

Material	Principal components	Manufacturer
Adper Prompt L-Pop Self-Etch Adhesive	**Liquid 1 (red blister):** Methacrylated phosphoric esters, Bis-GMA, initiators based on camphorquinone and stabilizers. **Liquid 2 (yellow blister):** Water, 2-Hydroxyethyl methacrylate (HEMA), polyalkenoic acid and stabilizers.	3M/ESPE, St. Paul, U.S.A
Filtek Supreme Ultra (Nanofilled Resin Composite)	**The resin:** Bis-GMA, UDMA, TEGDMA, and bis-EMA (6) resins. **The filler:** A combination of non-agglomerated/non-aggregated 20 nm silica filler, non-agglomerated/non n aggregated 4 to 11 nm zirconia filler, and aggregated zirconia/silica cluster filler (comprised of 20 nm silica and 4 to 11 nm zirconia particles). Average cluster particle size of 0.6 to 10 microns	3M/ESPE, St. Paul, U.S.A
Ketak N100 nano-ionomer Primer	Vitrebond™ copolymer, HEMA, water, and photoinitiators. The primer is acidic in nature.	3M/ESPE, St. Paul, U.S.A
KetakN100 Nano-ionomer (Light-curing Nano-ionomer restorative)	De-ionized water, Blend including HEMA, methacrylate-modified polyalkenoic acid (Vitrebond Copolymer—VBCP) and acid-reactive fluoroaluminosilicate glass, Nanoparticles and Nano-clusters (69% byWt).	3M/ESPE, St. Paul, U.S.A

Statistical analysis

Data were presented as mean and standard deviation (SD) values. Regression model using Two-way Analysis of Variance (ANOVA) was used in testing significance for the effect of material, curing units and their interactions on microshear bond strength. Tukey's post-hoc test was used for pair-wise comparison between the means when ANOVA test is significant. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with SPSS 16.0® (SPSS, Inc., Chicago, IL, USA) (Statistical Package for Scientific Studies) for Windows.

3. Results

The highest mean micro shear bond strength values with KN and AP were averaged (32.24 MPa) and (20.36 MPa), respectively. Whereas, adhesive systems when treated with laser system followed by plasma arc and LED, the average KN was (30.1 & 29.54 MPa, respectively) and AP was (19 MPa & 18 MPa, respectively), LED showed the least values as compared with laser system (Table 2).

Treatment with laser demonstrated significant elevation in the average microshear bond strength (26.3MPa) than both LED and plasma arc treatment which recorded a non-significant increase (23.77 and 24.55MPa, respectively) (Table 3).

With regard to the average microshear bond strength of Ketak N100 nano-ionomer primer (KN) with Ketak N100 light-treatingnano-ionomer restorative exhibited a significant increase (30.3 MPa) than Adper Prompt L-Pop Self- Etch Adhesive (AP) with Filtek Supreme Ultra restorative material (19.12 MPa) as seen in table 4.

The results revealed that the regression model is appropriate to define the association among the considered variables. The data indicated that the adhesive systems with their corresponding restorative materials and light curing units had a statistically significant effect on microshear bond strength. The relations among the two parameters had non significant variation concerning the impact on average microshear bond strength (Table 5).

Table (2): Descriptive statistics for microshear bond strength values:

Material	Light Curing Unit	Mean	SD
Adper Prompt L-Pop Self-Etch Adhesive	Laser	20.36	1.8
	LED	18	1.1
	Plasma arc	19	1.1
Ketak N100 nano-ionomer Primer	Laser	32.24	1.9
	LED	29.54	1
	Plasma arc	30.1	1

Table (3): Microshear bond strength the two adhesives with the three light curing units:

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

*: Significant at $P \leq 0.05$, Means with different letters are statistically significantly different according to Tukey's test.

Table (4): Comparison between microshear bond strength of the two materials:

Adper Prompt L-Pop Self-Etch Adhesive		Ketak N100 nano-ionomer Primer		P-value
Mean	SD	Mean	SD	
19.12	1.6	30.3	2.4	<0.001*

*: Significant at $P \leq 0.05$.

Table (5): Regression model results for the effect of different variables on microshear bond strength:

Source	Type III Sum of Squares	df	Mean Square	F-value	P-value
Corrected Model	83.1	5	16.6	8.9	<0.001*
Material	14.2	1	14.2	7.6	0.011*
Curing	62.0	2	31.0	16.7	<0.001*
Material x curing	6.9	2	3.5	1.9	0.177

R Squared = 0.651 (Adjusted R Squared = 0.635), df: degrees of freedom.*: Significant at $P \leq 0.05$.

4. Discussion

Recently, due to the attractiveness of tooth colored restorative constituents has led to a fastproliferation in the practice of resins. Different types of resins are used commonly such as polyacid modified resin-based composites (compomer), and resin-modified glass ionomers (RMGIC) are mainly applied light polymerizablerestorative materials. Due to advantages of light polymerizable restorative ingredients are used in large scale, these advantages represented in improved physical properties, operator's governoralong the working timeandesthetics.[16] from the time when the light polymerizable restorative materials was introduced in the field of therapy, there has been a anxiety about the suitable deepness of treatment during the restoration. Furthermore, the important function of successful polymerization in long-term clinical good results of resin restorations has been well-recorded.[17] Several researches indicated that insufficient polymerization were responsible for different kinds of clinical circumstances like pulpal inflammation, post-operative sensitivity, discoloration and ended with collapse of the restoration.[18] There are several factors which influencing the polymerization of the resins comprise those directly concerned with restorative ingredient such as composition of the material, shade, and thickness during polymerization. in addition, other factors are related to the light curing units (LCU) such as wavelength, light intensity, time of exposure, location and orientation of the tip of the source and size of exposed area.[19] For that reason, the recommendation for application of LCU is necessary for the reason of release enough and adequate energy to enhance composite polymerization. There are 4 kinds of polymerization sources have been developed which known as argon-ion lasers, quartz tungsten halogen (QTH) lamps,, plasma-arc lamps and light emitting diodes (LED) units.[20]

In recent times, the micro-shear bond test was applied as a substitute to the micro-tensile bond test and as an alternate for the predictable shear test.[21] The micro-shear bond test comprises the using of a loading energy throughout a blade from a universal testing apparatus to a resin composite cylinder bonded to a substrate disc.[22]

One of the main benefits from this test are the simplicity in the control of the bond test region by using microbore (tygon) tubes and less difficult during specimen collection.[22,23] Some investigators (Shimida et al.[24]) used looped orthodontic wire. This method can offer precise and consistent shear bond force results. The smaller diameters of the specimens must be small as possible to enable the investigators to check many bonded samples on one enamel surface or flat dentin, therefore it permitting for the conservation of extracted teeth required to offer the needed substrates and the local mapping of the mineralized surface.

The micro-shear test propose the recompense of simplistic bond testing for quick selection of adhesive systems, local and deepness profiling of a different substrates for their comparative adhesiveness, and conservation of teeth. Also, some authors reported that the micro-shear test loans itself to in vitro stability tests and may help in explaining the mode of adhesion.[21], in addition the micro-shear bond power permits for instantly onward specimen preparation charitable accurate outcome preserving the consistency of the testing region.[25] Depending on the abovementioned causes that was tested and used in the present work.

In the current work, the mean microshear bond force values of the two utilized adhesive systems with three applied light curing methods, the results revealed that laser curing system demonstrated that the mean microshear bond strength was increased significantly, whereas, a non-significant differences between plasma arc and LED was recorded in the current study.

In spite of the laser units consumed a low of power in contrast to the usual halogen light, but they can treat the resin supplementary efficiently due to specificity of the wavelength of the light. Generally, VLC units discharge extensive bandwidths of 120 nm, which leads to releasing of a broad spectrum of wavelengths that go beyond and are confused. Disjointed light which is emit low photons, that reached 180 degree out of phase can terminate each other, leading finally to a decrease in curing power and diminish the force of polymerization of the resin composite. For the reason that laser light is collimated, monochromatic and consistent it was consideration that it might be a superior supply of light for treating.[26]

Moreover, argon laser discharges a fine, focused and non-divergent beam concentrated on a specific object ensuing in a extra reliable energy density over space. The more suitable is increase in the composite resin polymerization (carefulness, strength) and the percentage of un-polymerized monomer is low. This carefulness leads to an enhancement of some physical characters of the compressive strength of the argon polymerized resin, transverse flexural strength, flexural modulus and diametral tensile strength.[27] It was found that the bond strength for argon laser curing is equivalent to general light curing and is adequate for clinical usage.

Furthermore, in terms of shear bond strength consequence of those properties, the literature shows some contradictions. There were conflicting results about the efficacy of argon laser polymerization. Some investigators stated that, argon laser polymerization enhance shear bond strength in both enamel and dentine.[28]However, significant difference was reported in bond strengths according to distance between the resin surface and the light source. The laser-cured bond strengths did not decrease with increasing distance, whereas there was a significant decrease in halogen-cured bond strengths at distances greater than 0.5 mm.[28] It was reported that argon laser lights and plasma arc, significantly reducing the curing time of orthodontic brackets without affecting bond strength, and they have the potential to be considered as advantageous alternatives to conventional halogen light.[29]

On the other hand, a light-emitting diode (LED) uses diode technology which utilizes chips containing "doped cells".[30] Blue light is generated by a well-defined relaxation of excited electrons, and not by a thermal action.[31]However, they generate a blue light of specific wavelength between 400 and 500 nm without the requirement of filters by using a semiconductor material system.[32]

The satisfactory results of the LED group were attributed to the closeness of the output wavelength of the LED unit that was being tested (450-470 nm) to the maximum absorption peak of camphorquinone (470 nm) that is the main light initiator in composite resins. In fact, the light output of this unit will make a more complete and more effective polymerization possible. Advances in LED technology led to the development of high power units comparable to plasma arc curing sources.[33]

Generally it is known that plasma arc lights are characterized by high intensity light curing system which possessing high strength of light sources emitted from the fluorescent bulb filled with plasma or xenon) which enhancing for a shorter exposure period. The light spectrum released plasma is restricted. The wavelength of high intensity light released is calculated by the bulb covering substance and filtered to prevent libration of infrared and ultraviolet energy and discharge of blue light (400nm to 500 nm). By this way the amount of heat librated from the system is decreased.[5] These units have a high energy output and short curing time. These units have shown higher conversion rates and depth of cure of resin based composites compared with the conventional curing lamps. [34]

Furthermore, the result of the present study revealed a noteworthy finding that the average microshear bond strength of Ketac N100 nano-ionomer primer (KN) plus Ketak N100 light-curing nano-ionomer restorative demonstrated a high significant value than Adper Prompt L-Pop Self-Etch Adhesive (AP) plus Feltik supreme ultra-restorative.

The micromechanical bond of RMGICs to dentine via infiltration of the collagen network pre-exposed to 10% polyacrylic acid, in union with chemical bonding resulting from ionic interaction of COOH groups from the acid with Ca ions of residual HAP crystals between the partially demineralized dentin and enamel.[35] Nano-filled RMGIC (Ketac N100/Ketac Nano;3M ESPE, St. Paul, MN, USA) display a comparable bonding system but there is negligible infiltration of resin attached into dentin which is pinpointing of high ionic bonding with tooth somewhat micromechanical retention, much akin to conventional GICs.[36]

Nano-filled RMGIC contains nano-clusters of silica fillers and is provided with a primer (Ketac N100 nano-ionomer primer (KN). After etching procedures due to over-drying of dentine may ended with fall down of collagen fibers. The water-wet bonding system permits the dentinal area to stay wet with water that stops the fall down of the demineralized dentinal matrix that happens post sever air aeration. Unhappily, it is impracticable to permeate distorted collagen with RMGICs or resin adhesives; therefore, debonding and restoration breakdown are forever ordinary in such status.[36] Though, the application of specific dentin previously treated with efficient primers may stop the fall down of dentinal collagen fibers and recover the bonding presentation.[37]

On the other hand, the smear layer corresponds to a additional impediment that can hinder good bonding of restorative substances to dental elements. It is a type of debris in the form of film formed around the teeth and still attached with the tooth surface even after preparation of tooth. It has been recorded that etching with acid (37% phosphoric acid) can enhance the shear bond force of nano-filled RMGIC by eradicating the formed film layer and elevating the surface power.[38]

On the other hand, the composition of both GICs and RMGICs include in their ingredients a polycarboxylic acid-based polymers with a moderately high-molecular-weight (Mw: 8000-to-15,000) that are expelled during from the phosphoric acid decalcified dentine during infiltration.[39] During dental etching by using phosphoric acid, the collagen complex can stay unguarded and be subjected for degeneration or decay due to hydrolytic dreadful conditions. Such violent pre-therapies of dentine should not be used in case of applying GIC-based ingredients, since their polyalkeonic polymers are expelled from permeating into dentine collagen.[40] However, the decrease in pH value play an important role in removing of the debris formed around the tooth surface (the smear layer) and augment the chemical bond to tooth area.[41] On the contrary, such results was contradicts with the other authors, Ozel et al.2009;[42]Korkmaz et al., 2010[41] who reported that Nano glass ionomer exhibited significantly lower shear bond force contrasted to nano-composites.

Conclusion

The novel nano-ionomer offered better microshear bond strength along with the laser curing. Consequently, the laser based units are promising as curing lights for optimal initiation of polymerization of composite resins; their usage is still not a widely accepted idea in the clinical practice.

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