British Biotechnology Journal
3(2): 205-212, 2013

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Effect of Argon Laser Curing on the Shear Bond Strength of Composite Resin Restorative Material

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Authors' contributions

This work was carried out in collaboration between both authors. Author IMH designed the study, performed the laboratory testing, statistical analysis, wrote the protocol, wrote the first draft of the manuscript, managed the analyses of the study, and managed the literature searches. Author MMB contributed for all work steps. Both authors read and approved the final manuscript.

Research Article

Received 24th December 2012
Accepted 16th March 2013
Published 3rd April 2013

ABSTRACT

Aim: The aim of this *in vitro* study was to analyze the shear bond strength of composite resin using two different curing light sources: halogen light (control group) for 20 or 40s, and Argon laser (test group) for 10 or 15s.
Study Design: This study was carried in the Department of Dental Biomaterials, Faculty of Dentistry and Ophalmolgy Hospital, Mansura University between January 2011 and August 2012.
Methodology: Sixty freshly extracted human molars were prepared to receive composite resin samples in four groups "n=15". The teeth were centrally horizontally mounted in plastic molds with cold cure acrylic resin. Flat occlusal surfaces were prepared and smoothed. One-step self-etching dental adhesive (Xeno®111) was applied to the dentine surface and cured. Composite resin (Spectrum universal composite) was inserted into standardized Perspex mold and polymerized with a halogen light and an argon laser

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curing units. Specimens were stored in deionized water at 37°C for 48 hours. The specimens were stressed under shear force at a crosshead speed of 0.5 mm/min using Lloyd testing machine. The shear bond strength was calculated to the four groups and statistical analysis performed (One-way ANOVA and LSD tests) at the level of significance at $p<0.05$.
Results: LSD tests indicated that there was significantly higher shear bond strength for the composite cured with argon laser compared with the halogen light curing method. There was no statistical significant difference between curing times of the same light source.
Conclusions: The argon laser is a promising source for optimal initiation of polymerization of composite resins. The use of argon laser has been suggested as a new alternative for polymerization of restorative materials. The shear bond strength of composite resin cured with argon laser was superior to that was cured with halogen light even with short curing times.

Keywords: Argon laser; polymerization; composite resin; shear bond strength.

1. INTRODUCTION

Theodore H. Maiman developed the first laser, a pulsed ruby laser in 1960 [1]. Since that time, dental interest in lasers has been high and research has been continuing into ways to improve dental treatment through laser application [2]. Since the early 1980s, one research has been focused on the use of the argon laser for photo polymerization of composite resin restorative materials [3]. This interest has arisen because the wavelength (488 nm) of light emitted by the argon laser is optimal for the initiation of polymerization of composite resins [4]. Photo- activation of composite resin could be achieved by using halogen light or light emitting diode curing units. The initiator (camphoroquinone) in the resin is activated by light for polymerization [5].

Camphoroquinone activation is initiated by a hue of blue light that has a wavelength within the range of 400 to 500 nm, with broad peak activity in the 480-nm range [5,6]. Halogen visible light curing (VLC) units consist of white light with unwanted wavelengths filtered out thereby producing a polychromatic spectrum of blue light. The resulting hue and brightness of the color are of wide spectrum and low intensity respectively [3]. In research on composite-resin photo polymerization, VLC units can activate camphoroquinone, but optimum-curing power is not achieved, and the units often fail to meet the challenges presented by more complex resin restorations [7].

Additionally, the hue and brightness parameters of halogen light are not uniform over time. Unlike VLC units, the argon laser does not employ the use of filters. Instead, it generates one wavelength of blue light (i.e., the light is monochromatic) having a bandwidth of only 40 to 45 nm [4,8]. In addition, the brightness of the light can be set to the manufacturer's specifications for optimum efficiency, unique for each brand of composite resin. Laser photons travel ''in phase'' (i.e., are coherent), and are collimated such that they travel in the same direction [1,8].

The argon laser units put out less power than the halogen light, yet they can cure the resin more effectively because the wavelength of the light is specific to the job being performed. VLC units 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 [8]. Low photons of incoherent light that are180 degrees out of phase can cancel each other, resulting in decreased curing power and less polymerization of the composite resin. VLC units also produce a divergent beam of light, resulting in a loss of 40% of energy from the curing surface [5]. In contrast, the argon laser emits a collimated (narrow, focused, no divergent) beam focusing on specific target, resulting in a more consistent power density over distance [3,4,7,9].

The aim of this *in vitro* study was to analyze the shear bond strength of composite resin using two different curing light sources (laser and halogen light curing units).

2. MATERIALS AND METHODS

This *in vitro* study was performed upon 60 freshly extracted, non-carious human molar teeth, which had been stored in normal saline solution to prevent desiccation. All authors hereby declare that all experiments have been examined and approved by the appropriate ethics committee and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. The authors have obtained all necessary ethical approval from the Ethical Committee in the Faculty of Dentistry, Mansoura University. Just prior to the preparation, a tooth was thoroughly rinsed in running water, and any excess tissue was removed. The tooth was then mounted in Isomet low speed bone saw (no. 11-1180; Buehler Ltd., Evanston, IL, USA) with a 4 x 0.012 in^2 diamond-rim blade (no.11-4244; Buehler) and the crowns were cross-sectioned from the roots, pulpectomy was performed and pulp chambers were sealed with wax. Occlusal surfaces of the teeth were wet ground flat by using a model trimmer to expose flat superficial dentin. Water-cooling was essential to reduce temperature effects in all groups. After trimming, for better smoothing for the samples, silicon carbide paper grits 600 was mounted on a grinding wheel with copious amounts of water to obtain smooth dentin surfaces. The flat surface was 1.5 mm below the deepest occlusal pit. The flattened surface of each tooth were centered flush horizontally fixed in self-cured acrylic resin (Epoxicure TM Resin, made in USA) in a plastic ring and then stored in deionized water at 37ºC. Before the bonding procedure, the teeth were again ground slightly using 600-grit silicon carbide paper to assure clean and fresh surfaces for bonding and remove any acrylic flashes from the dentin surfaces. The teeth were classified into 4 groups, 15 teeth each as follow:

Group 1: Composite resin polymerized with halogen visible light for 20 s.
Group 2: Composite resin polymerized with halogen visible light for 40 s.
Group 3: Composite resin polymerized with argon-ion laser for 10 s in a continuous mode.
Group 4: Composite resin polymerized with argon-ion laser for 15 s in a continuous mode.

Just before application of composite resin, scanning electron micrograph of non-conditioned and conditioned dentin surfaces were examined. Dentin bonding agent (Xeno®111, one-step self - Etching Dental Adhesive, Dentsply Detrey Gmbh, 78467 Kanstang, Germany) was applied as recommended by the manufacturer’s instructions. Equal amounts of liquid A and liquid B were dispensed into a dampen dish. Both liquids were mixed thoroughly for 5 s with the applicator tip supplied. The mixed adhesive was applied to the dentin surface with the applicator and left undisturbed for at least 20 s. A gentle blow of air uniformly spread the adhesive until there is no more flow of the adhesive. The bonding agent was polymerized by halogen light (Spectrum curing light, Dentsply, 230 V, 50 HZ, model no 201 RE) for 10 s or argon-laser for 5 s. The argon laser (HGN, Salt Lake City, Utah, USA) was used with fiber diameter of 600 µm, wavelength of 488 nm, and an output power of 300 mW. The intensity of the curing light was verified before the polymerization using a radiometer (Curing

Radiometer Model 100, Demetron Research Corp., Danbury, USA). The irradiance of halogen LCU was 600 mW/cm^2 with a wavelength of 450 - 520 nm.

The curing procedure was performed with the hand piece perpendicularly placed on the top of the surface without any distance between the hand piece and the composite resin surface. Split Perspex mold of 2 mm height and 3 mm diameter was firmly attached to the tooth with a metal device over the bonding area. Composite resin (Spectrum universal composite, series 007782, Shade A2, DENTSPLY, Germany) was inserted inside the mold and cured according to the groups studied. The split mold was removed after curing of the restoration.

The specimens were stored in deionized water for 48 hours in a black container (protected from external light) at 37ºC. The Specimens were fixed in specified grips in Lloyd testing (Lloyd instruments LS 500 LTD; England) and loaded in a shear mode at a crosshead speed of 0.5 mm / min until fracture occurs. A knife-edge shear probe was attached to the crosshead. Shear forces were recorded when the fracture occurred directly from the chart of the testing machine. The load was recorded in Newton (N); shear bond strength (Mpa) was calculated by dividing the load over the area of bonding.

2.1 Statistical Analysis

The calculated mean shear bond strengths were analyzed using One-way analysis of variance (ANOVA) and the least-significant difference (LSD) multiple comparison test was conducted at the level of significance at $p \leq 0.05$.

3. RESULTS

The mean shear bond strengths and standard deviations for each curing method are given in Table 1. The results for one-way ANOVA showed very high significant difference among the studied groups ($p \leq 0.001$), (Table 2). LSD test showed statistical difference between groups 1 and 3 and 4. Also, there were a significant difference between 2 and 3 and 4. The highest mean shear bond strength was recorded for group 4. On the other hand, the lowest shear bond strength was recorded for group 1. There was no statistical difference between groups polymerized by the same curing method either halogen light (1 and 2) or polymerized by argon laser (3 and 4).

Table 1. Mean shear bond strength (Mpa) of composite resin cured with argon laser and halogen lamp

Curing techniques	Mean ± SD	*p* -value
20 s halogen light	20 .3$^{(B)}$ ± 2.5	$p \leq 0.001$
40 s halogen light	21.9 $^{(B)}$ ± 3.1	
10 s laser curing	24.3 $^{(A)}$ ± 2.6	
15 s laser curing	24.7 $^{(A)}$ ± 3.0	

Means with different superscripts are significantly different $p \leq 0.05$.

Table 2. One- way ANOVA and LSD test results

	Degree of freedom	Sum of squares	F-value	P-value
Between groups**	3	42.19	14.48	0.0000
Within groups	56	54.39		

*Highly significant = p≤0.001***

4. DISCUSSION

Because laser light is coherent, collimated and monochromatic, it was thought that it might be a better source of light for curing .VLC unit consists of white light with unwanted wavelengths filtered out [3] and produce a polychromatic spectrum of blue light. Those units emit wide bandwidths of 120 nm, resulting in a broad spectrum of wavelengths that overlap and are said to be incoherent [8]. Two photons of incoherent light can cancel each other (when those two photons are 180 degrees out of phase) so that the curing powers decrease as well as the polymerization of the composite resin. Another problem encountered with VLC units is that they produce a divergent beam of light resulting in a loss of energy (40% if 6 mm far from the curing surface).

In contrast, argon laser emits a narrow, focused and non-divergent beam focusing on a specific target resulting in a more consistent power density over distance [4,7,9,10]. Consequences should be greater composite resin polymerization (thoroughness, depth) with less unpolymerized monomer. This thoroughness results in the enhancement of certain physical properties of the argon polymerized resin compressive strength, diametral tensile strength, transverse flexural strength, and flexural modulus [11]. 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 [4,12]. On the other hand, there were no statistical significance differences were found [13]. 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 [12]. Furthermore, the laser required less time to achieve equivalent or greater polymerization of the restorative material [7,11]. No significant change was shown in linear polymerization shrinkage in one *in vitro* study [14] and another study showed that laser cured pit and fissure sealants demonstrated a superior seal to those cured with visible light [15]. Also, the bond strength for argon laser curing is comparable to conventional light curing and is sufficient for clinical applications. Although the argon laser left more adhesive on the tooth surfaces on debonding, there was no increase in enamel surface fractures [16].

Some researchers reported that, argon laser polymerization for 10 and 20 seconds in a single increment resulted in a lower tensile bond strength compared to the 40-second polymerization with halogen light and there was no statistical difference between halogen light (40 s) and argon laser-curing for the 30-seconds interval. There was no statistical difference between the curing sources for the incremental technique. Incremental technique showed the highest tensile bond strength values, except for the polymerizations with halogen light or argon laser for 30 s, which did not show statistical difference [17]. A 5-second cure using an argon laser produced bond failure loads comparable to those obtained after 40 s of halogen light cure, with less than half the frequency of enamel fracture at debonding [18].

It was reported that plasma arc and argon laser lights, 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 [19]. The tensile bond strength promoted by the polymerization with visible light presented greater tensile bond strength than the polymerization with argon laser with 200 mW and 250 mW, but there was no significant difference between halogen visible light and argon laser with 150 mW. There was no significant difference between argon laser with 150 mW and argon laser with 200 mW or 250 mW [20]. Microshear bond strength values of two adhesives with three curing systems were studied. The results showed that the 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 [21].

The purpose of the present work was to compare the shear bond strength of composite resin using two different curing light sources (laser and halogen light curing units). The practical application of this comparison is the potential increase in the curing depth and maintains optimum mechanical properties of the composite resin. This is a good way to decrease the working time and facilitate the restoration techniques leading to an improvement both in the working conditions and in the final result of the restoration procedure [22]. Curing depth is affected by the distance between the resin composite and the light source, but is crucial when exceeding 6 mm [23]. It has been reported that the hardness of a hybrid composite resin 1 mm thick, did not vary between when an argon ion laser at 250 mW for 30 s or a halogen lamp for 20 s was used for curing. A significant difference between the two light sources was observed using 2-mm thick resin. Using increments up to 1 mm thick, the laser may substitute satisfactorily the halogen lamp at power setting of 250 mW, exposure time of 30 s, but it would be interesting to investigate what would happen at higher power settings [24].

Within the limits of this study, the null hypothesis that there would be no difference in mean shear bond strength between composite and tooth surfaces cured with laser or with the conventional curing method, must be rejected. In fact the results of the present work indicate higher shear bond strength of composite resin when polymerized with argon laser. The shear bond strength varied between the halogen and laser cured resin and was not affected by the duration of curing tested in the present work.

5. CONCLUSION

Under the experimental conditions of the present work, the shear bond strength of argon laser polymerized composite resin was superior to the conventional light source treated resin.

ETHICAL APPROVAL

The authors have obtained all necessary ethical approval from the ethical committee in the faculty of dentistry, Mansoura University. This confirms either that this study is not against the public interest, or that the release of information is allowed by legislation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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