EFFECT OF LIGHT EMITTING DIODE (LED) VERSUS HALOGEN PHOTO-POLYMERIZATION ON SHEAR BOND STRENGTH OF THREE TYPES OF RESIN COMPOSITES

Mona Abd Eltawab*, Amira Al Zogby**, Faten Kamel** and Dalia Abu El Magd**

ABSTRACT

Objective: This study investigated the effect of light emitting diode (LED) and halogen (QTH) photopolymerization on shear bond strength of three types of resin composites.

Materials and methods: Sixty molars were selected and randomly assigned into 6 groups. The materials used were: Hybrid resin composite, nano-filled resin composite and silorane based resin composite. The analyzed resin composites were polymerized either by LED or halogen curing systems. After 24 hours storage in distilled water the specimen was submitted to push-out shear bond strength testing using a universal testing machine at cross head speed of 0.5mm/min. one debonded representative specimen of each tested group was examined using an environmental scanning electron microscope to determine the mode of failure.

Results: All the specimens cured by LED demonstrated higher shear bond strength than those cured by QTH. There was no statistically significant difference between the two light curing units (LCUs) except for nano-filled resin composite that showed a significant difference. Silorane based resin composite groups were statistically significant higher than nano-filled and hybrid resin composites groups. While nano-filled resin composites was statistically non-significant higher than hybrid resin composite groups.

Conclusions: (1) The light emitting diode is effective as halogen curing light to obtain resin-composite with shear bond strength of no significant difference. (2) The silorane-based resin-composite restorative material is promising material regarding bonding efficiency to dentin.

Recommendation: It is advised to cure nano-filled resin composite with light emitting diode (LED) to obtain higher shear bond strength to dentin.

INTRODUCTION

For reducing polymerization shrinkage and improving mechanical properties of resin composite, nano-filler particles have been introduced in the last years, which allow for a significant increase in filler volume. For further reduction of polymerization shrinkage, a special group of dental composite...
materials has been developed under the name siloranes, which derives from their major chemical building blocks siloxanes and oxiranes. These materials polymerize by cationic ring-opening polymerization, which partially compensates volume shrinkage during polymerization (Hahnel et al, 2010).

The majority of light-activated resin-composites and dentin bonding agents (DBAs) contain camphorquinone as the main photo-initiator (Kim et al, 2005). So light-curing units (LCUs) must be able to bring enough energy to achieve the wavelength of the resin’s photo-initiator to photoactivate (Nicoló et al, 2010).

Polymerization of resin composite is initiated when photoinitiators are activated by light. The available curing units, Halogen based (QTH), light emitting diode (LED), plasma arc or laser technology have different light intensities & light sources with energy levels range from 300 to more than 1,000 mW/cm² (Journal of ADA, 2002).

Testing the bond strength of a given system is of a vital importance to evaluate the ability of this system to withstand the stresses generated by composite materials during polymerization and also during functioning in the oral environment with its thermal and mechanical fluctuations (Fahmy, 2008). Therefore, it would be beneficial to conduct a study to evaluate the effect of light emitting diode (LED) versus halogen photopolymerization on shear (push-out) bond strength of three types of resin-composites.

MATERIALS AND METHODS

Selection of teeth and Grouping of specimens:

A total of sixty freshly extracted for periodontal reasons human caries free permanent molars were selected for this study. The molars were collected from patients between 40-60 years old. Teeth were then stored in distilled water* at room temperature till use. The selected teeth were randomly divided into two main groups 30 teeth each according to the used light-curing unit either light-emitting diode-curing unit (LED) (PM-LED02; China) or quartz tungsten halogen (QTH) (Cromalux-E; Germany) curing unit. Each main group of teeth was further subdivided into three subgroups 10 teeth each, according to the type of resin composite: either hybrid resin-composite (Filtek Z250), nano-filled resin-composite (Filtek Supreme XT), or silorane based resin-composite (Filtek P90).

Preparation of push-out test specimens:

Acrylic resin blocks were formed by embedding teeth in cylindrical plastic molds containing acrylic resin (Acrostone dental factory, Egypt) till the crown level, with the occlusal surfaces facing outside in the center of the mold. A grinding-drilling machine (BV20B-L, Automatic Feed Bench Lathe, Bengbu, China) was used for abrading occlusal enamel under water coolant using a metal bar till flat dentin surfaces were exposed. A driller 3mm in diameter was used to drill a standardized hole in the center of each tooth. A dentin disc 2mm in thickness was cut from each tooth using a metal disc.

To each resin-composite used as in table (1), dentin surfaces were treated in accordance with manufacturer’s instructions. After conditioning and adhesive systems application, each type of resin-composite was bulk inserted into the dentin disc specimen. LED or QTH was used for curing each type of resin-composite (hybrid, nano-filled or silorane-based) for 40 seconds. Then the specimens were stored in distilled water at room temperature for 24 hours prior to push-out testing.

Each specimen was fitted in a specially constructed metal jig and then was tested for

* CID solvent chemical industries development; Giza ARE.
shear bond strength using the universal testing machine (Nexygen-MT; Lloyd Instruments) at a crosshead speed of 0.5 mm/min. the fracture loads were obtained in Newton (N). To express the shear strength in MPa the following formula was used:

\[ \tau = \frac{P}{\pi dh} \]

Where; \( \tau \) =shear strength

\( P \) =load at failure

\( \pi =3.14, d = \text{diameter of punch} \)

\( h = \text{height of sample} \)

Fracture mode of one representative specimen of each subgroup was examined using environmental scanning electron microscope at 800 X magnification (Philips, model XL30, Neither land). Statistical analysis was performed using ANOVA and Newman-Keuls (NK) multiple comparison tests.

RESULTS

Table (2) and figure (1) show punch-out shear bond strength results (Mean±SD) of the tested resin based restorative materials with both curing systems.

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**TABLE (1)** The materials used in the current study.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Composition</th>
<th>Lot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filtek Z250</td>
<td>Hybrid methacrylates-based resin-composite</td>
<td>1370</td>
</tr>
<tr>
<td>Filtek Supreme XT</td>
<td>Nano-filled methacrylates-based resin-composite</td>
<td>3910</td>
</tr>
<tr>
<td>Filtek P90</td>
<td>Silorane-based resin-composite</td>
<td>4762</td>
</tr>
<tr>
<td></td>
<td><strong>Resin matrix:</strong> Silorane (3,4 Epoxycyclohexylethyl cyclo- methylsiloxane, bis-3,4-epoxycyclohexylethyl-phenethylsilane )</td>
<td></td>
</tr>
<tr>
<td>Adper single bond 2 adhesive</td>
<td>Etch &amp; rinse (2-step procedure) Bond matrix: Bis-GMA, HEMA,Water, dimethacrylates, Ethanol methacrylates, Functional copolymer of polyacrylic &amp; polyitaconic acid and silica photoinitiator</td>
<td>7523</td>
</tr>
<tr>
<td></td>
<td>Bond matrix: Hydrophobic dimeth-acrylate, phosphorylated methacrylate, silane-treated silica filler, TEGDMA, initiators and stabilizers</td>
<td>51202</td>
</tr>
</tbody>
</table>

**Abbreviations:** Bis-GMA, bisphenyl Glycidylmethacrylate; HEMA, hydroxethyl methacrylate; TEGDMA, triethylene glycol dimethacrylate.

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**TABLE (2)** Punch-out shear bond strength results (Mean±SD) of the tested resin based composites with both curing systems

<table>
<thead>
<tr>
<th>Curing system</th>
<th>With halogen</th>
<th>With light emitting diode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composite</td>
<td>Mean ±SD</td>
<td>Mean ±SD</td>
</tr>
<tr>
<td>Silorane composite</td>
<td>22.47 ± 0.6883</td>
<td>25.50 ± 1.364</td>
</tr>
<tr>
<td>Nano-composite</td>
<td>17.35 ± 1.208</td>
<td>19.20 ± 0.8593</td>
</tr>
<tr>
<td>Hybrid composite</td>
<td>15.74 ± 1.041</td>
<td>17.53 ± 0.8838</td>
</tr>
</tbody>
</table>

**HAL:** Halogen curing system **LED:** Light emitting diode curing system

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**Fig. (1)** A bar chart of punch-out shear bond strength mean values of the tested resin based composites with both curing systems.
Silorane composite cured with light emitting diode curing unit recorded the highest mean shear bond strength value while Hybrid composite cured with halogen curing unit recorded the lowest mean shear bond strength value. All the specimens cured by light emitting diode demonstrated higher shear bond strength than those cured by halogen. Although, there were no statistically significant differences between the two LCUs except for Nano-composite that showed a significant difference. With both curing units Silorane composite group was statistically significant higher than Nano-composite and Hybrid composite groups. Nano-composite was statistically non-significant higher than Hybrid composite group.

Regarding fracture mode analysis as shown in figure (2), an adhesive mode of failure was observed in hybrid resin composite group cured with halogen curing system, nano-filled resin composite group cured with light emitting diode curing system and both groups of silorane based resin composite. While cohesive mode of failure was observed in both hybrid resin composite group cured with light emitting diode curing system and nano-filled resin composite group cured with halogen curing system as shown in figure (3).

**DISCUSSION**

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 (Banerjee & Sable, 2010). It is therefore important to evaluate and compare the shear bond strength of resin composites polymerized using the LED and QTH curing units.

The results of the present study in table (2) and figure (1) showed that all the specimens cured by LED demonstrated higher shear bond strength than those cured by QTH. Although, there were no statistically significant differences between the two light curing units (LCUs) except for nano-filled resin-composite that showed a significant difference. Nano-filled resin composite has the smallest filler particles. Since smaller filler particles scatter the light more than large filler particles. The higher the proportion of filler, the more difficult it is for the light to penetrate the composite (Mills et al, 1999).

This was in agreement with findings observed by (Caughman et al, 1995), (Lopes et al, 2008) and (Ghullman & El-Gazawi, 2009) who found greater attenuation and scattering of light by the submicron filler particles than other light cured resins, requiring more energy for adequate polymerization.
Higher shear bond strength obtained with LED light curing unit can be attributed to that the emission peak of the LED LCU used in this study was ranged from 460 nm to 470 nm, which is relatively close to the maximum absorption peak of CQ (468) while the emission peak of QTH LCU was ranged from 400 nm to 500 nm. This means that the photons emitted from LED LCU have higher probability of being absorbed by CQ than that those emitted by halogen LCU as reported by Kim et al., 2005. In other words, in halogen light, because of the selective absorption characteristics of photo-initiator camphorquinone, 98% of the radiation does not contribute to polymerization (Klocke et al., 2002). Therefore, LED produces an almost ideal bandwidth of the light that is required (Krishnaswamy & Sunitha, 2007). Besides, that LED source producing the same irradiance as halogen source produces a significantly greater depth of cure than the halogen source.

This finding was in agreement with the findings of Dunn and Taloumis, 2002, Bishara, 2003, Loretto et al, 2004, Banerjee and Sable, 2010, Nicoló et al, 2010 and Retamoso et al, 2010. While it was in disagreement with findings observed by D’Alpino et al, 2006 who found that significantly lower values were observed when the LED light was used to polymerize DBA compared to QTH and plasma arc (PAC) lights. Their reasonable explanation for the poorer results for the LED light is related to its narrow radiation spectrum. It is possible that the DBA contains photoinitiators other than camphorquinone which absorb light at lower wavelengths. Some initiators can be activated with the broad range QTH and PAC light sources but not with narrow range LED lights.

The present study showed that with both QTH and LED curing systems, silorane based resin-composite recorded the lowest punch-out shear bond strength mean value, while nano-filled resin composites were statistically non-significant higher than hybrid resin-composite groups.

Silorane System Adhesive Bond is based on methacrylate chemistry. It contains a unique hydrophobic bifunctional monomer in order to match the hydrophobic silorane resin. Other components include acidic monomers that initiate the ring-opening cationic cure of Filtek Silorane restorative, thus providing chemical bonding to Filtek Silorane (Fahmy, 2008). The Silorane Adhesive showed a very high degree of conversion (DC) within the hybrid layer (HL) that could significantly contribute to the formation of a stable adhesive interface (Navarra et al, 2009). In addition to the acid-base resistant zone in dentin is located adjacent to the hybrid layer in self-etch adhesive systems and may also influence the bond durability as it is more chemically and mechanically stable than normal dentin (Roeder et al, 2011).

The result of the present study was in agreement with Tagami et al, 2010 who reported that, regarding the adhesive with self-etch primer, comparatively more stable bond durability was confirmed than that with the adhesive system using the more aggressive acid etching. It is also in agreement with Van Meerbeek et al, 2010 and Roeder et al, 2011 who suggested that, when bonding to dentin, a mild self-etch approach is superior, as it involves (like with glass-ionomers) additional ionic bonding with residual hydroxyapatite (Hap). This additional primary chemical bonding definitely contributes to bond durability.

Available difference between methacrylates and oxiranes is that methacrylates are cured by radical intermediates and oxiranes polymerize via cationic intermediates (Weinmann et al, 2005). Whereas methacrylate photo-polymerizations involve the conversion of a carbon-carbon double bond into single bonds, the ring-opening reaction relies on
the opening of a cyclic structure to facilitate inter-
monomer bonding and crosslinking (Bowman et
al., 2010). The differences in composition and the
conversion mechanism of silorane monomer and
the tested MBCs may contribute to the findings of
this study.

With methacrylate based composites (MBCs),
polymerization shrinkage and diffusion of moisture
through the resin component lead to the initiation
and propagation of microcracks in the resin matrix.
In contrast the polymerization shrinkage of Filtek
Silorane was lower (<1%) than the MBCS (1.9-
3.5%). In other words, the MBCs could be more
affected than Filtek Silorane with respect to the
immersion in the storage solutions (Yesilyurt et
al., 2009). Besides, some authors reported that
zirconia/silica fillers were more susceptible to
aqueous attack. While composites containing quartz
fillers were shown to be less susceptible to aqueous

These findings were in agreement with that the
silorane technology provides restorative composites
with the lowest polymerization shrinkage and stress
as reported by Weinmann et al 2005. They were
also in agreement with Allen et al, 2006 who found
that the total volumetric polymerization shrinkage
was reported as 0.99% for the siloranes, which was
half as great as commercially available composites.

Although, the analyzed hybrid and nano-filled
resin composites were used with the same adhesive
system and had the same chemical composition
but the bond strength values revealed that
nanocomposite had higher mean shear bond strength
than that of hybrid resin composite although it was
not significant. This could be due to the use of
nanotechnology in nanocomposite.

Increased filler content has been associated with
lower volumetric shrinkage, as it reduces the volume
of organic matrix present in the material. However,
a negative effect on composite degree of conversion
attributed to the filler have been reported, caused
by the mobility restrictions imposed on the reactive
species and by light scattering (Gonçalves et al,
2010). Since, increased filler content has a negative
effect on composite degree of conversion this may
be explained as a contributing factor for why
nanocomposite showed higher shear bond strength
than hybrid resin-composite as the higher degree of
conversion, lead to higher final shrinkage, which
contributes to producing higher stresses (Braga and
Ferracane, 2004).

This finding of higher shear bond strength of
nanocomposite than hybrid composite was in
agreement with the findings that were observed by
EL-Gazawi, 2009 and Bowman et al, 2010.

Based on that concluded by Hara et al, 2001
who reported that in the SBS test, the variation of
cross-head speed may influence the bond strength
values and the fracture pattern obtained. Cross-head
speeds of 0.50 and 0.75 mm / min result in more
adhesive failures. In this study the cross-head speed
was 0.5 mm / min.

In the current study, the fracture modes were
shown in figures (2&3). An adhesive mode of
failure was observed in hybrid resin composite
group cured with halogen curing system, nano-filled
resin composite group cured with light emitting
diode curing system and both groups of silorane
based resin composite. While cohesive mode of
failure was observed in both hybrid resin composite
group cured with light emitting diode curing system
and nano-filled resin composite group cured with
halogen curing system. These findings of mode
of failure examination could be due to shrinkage
forces which develop when composite is bonded to
cavity walls. This resulting in stresses on the bond
between composite and tooth structure. These forces
are not uniformly distributed along the cavity walls,
the bond strength between tooth and composite
also varies along the bonded surface (Braga &
Ferracane, 2004).

With MBCs, polymerization shrinkage and
diffusion of moisture through the resin component
lead to the initiation and propagation of microcracks in the resin matrix. In contrast the polymerization shrinkage of Filtek Silorane was lower (<1%) than the MBCS (1.9-3.5%). This mean that, Filtek Silorane could be less affected than the MBCs with respect to the immersion in the storage solutions (Yesilyurt et al, 2009). Besides, in the current study only a representative area of a representative specimen of each group was selected for the purpose of mode of failure examination.

The findings of this study were in agreement with Braga et al, 2010 and Roeder et al, 2011 who reported that cohesive failure is explained by the mechanics of the test and brittleness of the materials involved. While this was in disagreement with that found by Van Meerbeck et al, 2010, who reported that the higher the bond strength, the higher the rate of cohesive failure.

CONCLUSION

Within the limitations of this in-vitro study and based on the obtained results, the following Conclusions could be drawn:

(1) The light emitting diode is effective as halogen curing light to obtain resin-composite with shear bond strength of no significant difference.

(2) The silorane-based resin-composite restorative material is promising material regarding bonding efficiency to dentin.

RECOMMENDATION

It is advised to cure nano-filled resin composite with light emitting diode (LED) to obtain higher shear bond strength to dentin.

REFERENCES

- Fahmy OMI: Bonding efficiency of a novel low shrinkage composite (silorane) to dentin; microshear and nanoleakage study. Egyptian Dental Journal 2008; 54:1417-34.


