

EVALUATION OF THE EFFECT OF DIFFERENT LIGHT CURING AND ADHESIVE SYSTEMS ON THE POLYMERISATION SHRINKAGE OF DENTAL COMPOSITE: AN *IN VITRO* STUDY

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Abstract

This study evaluated the effect of three types of light curing systems (quartz tungsten halogen, light emitting diode and soft-start curing light) on three types of dental adhesives (Xeno® III, Prime and bond® NT™ and Unibond II).

Sixty freshly extracted sound bicuspid teeth were used; two standardized cavities were created on the middle third of the buccal and lingual surfaces of each tooth. After storage for one day in normal physiological saline at 37°C, teeth were divided into four groups of fifteen teeth each. The three selected bonding and filling agents, as well as curing systems were applied according to the manufacturers' instructions. The first group was considered as a control (without bonding agent) and cured by three different curing systems. The second, third and fourth groups were treated with one of the adhesive agents. Then all groups were coated with nail varnish and immersed in 2% aqueous solution of methylene blue dye for 24 hours, then washed, sectioned and scored under light microscope. The microleakage at the resin-based composite (Filtek™ Z250, 3M, ESPE) – tooth interface was assessed.

Soft-start light-curing mode showed the lowest microleakage values among the curing modes, while the quartz tungsten halogen light curing revealed the highest values of microleakage in all types of bonding systems.

Concerning the dental adhesives, the lowest microleakage values were observed when the Unibond II was used whereas Xeno III® exhibited the highest degree of microleakage.

Keywords: Light curing unit – adhesive resin – microleakage – resin-based composite.

IAJD 2014;5(3):102-107.

ÉVALUATION DE L'EFFET DE DIFFÉRENTS SYSTÈMES DE LUMIÈRE BLEUE ET D'ADHÉSIFS SUR LE RETRAIT DE POLYMERISATION DU COMPOSITE DENTAIRE : UNE ÉTUDE *IN VITRO*

Résumé

Cette étude a évalué le degré de micro-infiltration à l'interface dent-composite lorsque trois systèmes de lumière bleue (« quartz tungsten halogen », « light emitting diode » et « soft-start ») et trois types d'adhésifs dentaires (« Xeno® III », « Prime and bond® NT™ » et « Unibond II ») ont été utilisés.

Soixante prémolaires saines fraîchement extraites ont été utilisées; deux cavités ont été créées au niveau du tiers médian des faces vestibulaire et linguale / palatine de chaque dent. Les trois agents adhésifs choisis ont été appliqués selon les instructions du fabricant. Ensuite, les dents ont été immergées pendant 24 heures dans du sérum physiologique à 37 °C puis réparties en quatre groupes de quinze dents chacun. Le premier groupe a été considéré comme un groupe-témoin (sans adhésif); dans les second, troisième et quatrième groupes, un des trois types d'adhésifs a été appliqué. Ensuite, toutes les dents ont été recouvertes d'une couche de vernis et immergées pendant 24 heures dans une solution aqueuse à 2% de bleu de méthylène, puis rincées, sectionnées et observées au microscope optique.

Le degré de microinfiltration à l'interface dent-composite (Filtek™ Z250, 3M, ESPE) a été évalué.

La photopolymérisation utilisant le mode « soft-start » a montré la valeur la plus faible de micro-infiltration, tandis que la lumière au tungstène de quartz a révélé les valeurs les plus élevées de micro-infiltration quel que soit le type d'adhésif.

En ce qui concerne les adhésifs dentaires utilisés, le degré de micro-infiltration était le plus faible avec « Unibond II » alors que le Xeno® III a présenté le plus haut degré de micro-infiltration.

Mots-clés: système de photopolymérisation - résine adhésive - microinfiltration - composite à base de résine.

IAJD 2014;5(3):102-107.

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Introduction

Visible light curing units are an integral part of modern adhesive dentistry. They are used to cure resin-based composites, resin-modified glass ionomers, preventive pit and fissure sealant and to bond orthodontic brackets to teeth. Light-activated resin composite, introduced in the 1970s, revolutionized clinical dentistry by maximizing working time and minimizing setting time [1].

An inherent disadvantage of visible light-activated resin composites is that they shrink during light polymerization; this shrinkage creates stresses between the composite and the tooth cavity leading to adhesive failure [2].

Polymerization of resin-based composites has received considerable attention owing to the introduction of many curing systems. The relevant properties of light for activating photoinitiators are wavelength and number of photons.

The spectral absorbance of camphoroquinone indicates that this compound has absorption peaks in the UV region as well as in the visible light range. Within the visible light range, camphoroquinone has a sharp absorption peak of approximately 470 nm, with peak ranging from 400 to 520 nm. When the light energy becomes intense, more photons will hit the composites, and greater will be the number of camphoroquinone molecules that will be raised to the excited state, react with the amine and form free radicals [3].

Changes in light intensity and irradiation time may affect the degree of conversion. Units with higher power density may cause more rapid development of polymerization contraction force [4]. The greater incidence of leakage at gingival margins was observed in restorations cured by the plasma arc method in comparison to the restorations cured with conventional quartz tungsten halogen method [5].

One way of minimizing polymerization shrinkage is to allow flow through

controlled polymerization during setting. This may be achieved by applying short pulses of light energy, prepolymerization at low light intensity followed by final cure at high intensity; that results in smaller gap formation and improved material properties [6].

Leakage is the passage of fluids, bacteria, molecules, ions or even air along the restoration-tooth interface [7]. The gap between the restoration and the tooth is considered a major factor influencing the longevity of dental restorations [8].

A bonding agent or adhesive system may be defined as an intermediate substance that, when applied to surfaces of the substances, can join them together and makes them resist the separation [9].

Bonding of restorative dental materials to tooth tissue has been a highly desirable property in restorative dentistry for many years. This revolutionary concept of adhesive dentistry offers several advantages over the conventional mechanical restorative techniques, that include the use of a more conservative approach during cavity preparation, better marginal sealing potential, improved stress distribution across the tooth restoration interface, reinforcement of decay-weakened tooth structure and, finally, superior esthetic possibilities [10].

The aims of this study were to evaluate the influence of different types of light curing units (light emitting diode, soft-start and conventional light curing) on the microleakage of resin-based composite restorations, and to determine the impact of different adhesive systems on the microleakage of dental composite restorations cured with the three above-mentioned light curing units.

Materials and methods

Sample preparation

Sixty extracted human upper premolars free of caries, restorations, cracks or obvious defects were cleaned and stored in 50% ethanol at 8°C for a maximum of 1 month following

extraction in order to avoid microbial contamination. This storage medium was chosen because it produces little change in dentin permeability. Prior to the experiments, the teeth were placed in water for 24 hours at 20°C [11].

Cavity preparation

Standardized cavities with butt-joint marginal configuration were prepared in the middle third of the buccal and the lingual / palatal surfaces of the tooth (2mm high, 3mm wide and 2mm depth) using a high-speed hand piece adapted to the horizontal arm of a surveyor in such a way that the long axis of the bur is perpendicular to that of the tooth, using a medium grain diamond bur, under water coolant. For standardization and accurate positioning of the two cavities, two vertical lines were drawn from the tips of the buccal and lingual cusps to the lowest points of the cervical lines. The mid-distance of these lines represent the center of each cavity. This guidance helped in the perfect sectioning through the two opposite cavities. The outline of the cavity was drawn on the tooth surface with a 0.5 mechanical pencil using a matrix band with a pre-cut hole of 2 x 3 mm fixed on the tooth with a retainer.

The cavities per tooth were not interrelated and the data was analyzed as if they were independent replica cavities for each of the treatments.

Sample grouping

The sample of 60 teeth was randomly divided into four groups of 15 teeth each.

Group I (n=15): control group: Teeth were filled with composites without any adhesive.

Group II (n=15): Xeno® III (Dentsply) adhesive (alcohol-based solvent) was applied.

Group III (n=15): Prime & bond® NT™ (Dentsply) adhesive (acetone-based solvent) was applied.

Group IV (n=15): Unibond II (Cavex Holland BV, Netherlands) adhesive (solvent-free bonding agent) was applied.

Then each group was polymerized using three different types of light curing systems technology according to the manufacturers' instructions for 2 mm depth composite, as follows:

1-Quartz tungsten halogen light curing system (for 20 seconds).

2-Light emitting diode curing system (for 40 seconds).

3-Soft-start light-curing system (150 mw for 10 seconds then 400 mw for 30 seconds).

Conditioning of enamel and dentin

The teeth were etched using the total etch technique. A 37% phosphoric acid etchant was applied to the enamel and dentin beginning with the enamel margins for 15 seconds.

The cavities were thoroughly rinsed from phosphoric acid gel with water. The dentin surface was dried with an air syringe for two seconds to achieve a slightly moist surface (the surface is slightly glossy); however, no visible excess water should remain on the tooth surface.

Application of bonding agents

The bonding agent (Xeno® III, Prime and bond® NT™ and Unibond II) was applied onto the conditioned tooth structure with a bonding applicator. In a light motion, the material was brushed gently into the dentin for 10 seconds, was left for 10 seconds and then the excess was removed with air stream free of water and oil. Light curing devices were used and the light intensity of each device was checked using a radiometer.

Filling procedure

The resin-based composite (Filtek™ Z250, 3M, ESPE) was applied in bulk technique and hand-condensed with a small plastic instrument especially at margins. The excess was removed from the peripheries. Mylar celluloid strip was applied and the material cured with nozzle of light cure device in contact with the strip. The restoration was light-cured for 20 seconds for quartz tungsten halogen, 40 seconds for soft-start and light emitting diode.

Then the samples were stored in normal physiological saline at 37°C in an incubator for 24 hours.

Thermal cycling

Thermal cycling was performed by preparing two water baths. One bath was maintained at 15°C ± 2°C and the other was maintained at 45°C ± 2°C; the temperature differential was 30°C. The immersion time was 30 seconds in each bath. The number of temperature cycles was 100 cycles. The teeth were then removed, dried superficially and placed in methylene blue dye solution.

Dye preparation technique

A methylene blue dye method was used to study the microleakage in all tested groups. In this technique, the apical portions of the teeth were sealed by coating with sticky wax while all other surfaces were coated with two nail varnish coats avoiding the restoration and their margins that will be subjected to dye solution by about 1-1.5 mm. When the varnish was dry, the teeth were immersed in 2% aqueous methylene blue solution and stored for 24 hours at 37 °C in the incubator.

Sectioning and assessment techniques

In order to have equal and uniform sections, the tooth with the two restorations (on the buccal and lingual / palatal surfaces) was sectioned through the bucco- palatal cusp tips downwards toward the restorations. Sectioning was done using a diamond disc operated by a heavy duty head-piece of a laboratory engine under continuous drops of water to avoid overheating and chipping. This process provided two surfaces with four cavity walls / restoration interface for both buccal and lingual restorations. The degree of dye penetration was evaluated using standardized scoring system as following:

Score 0: No dye penetration detected.

Score 1: Dye penetration involved enamel / restoration interface only.

Score 2: Dye penetration involved whole enamel thickness and dentin/restoration interface.

Score 3: Dye penetration involved enamel, dentin including axial wall/restoration interface.

Results

Two readings of dye penetration, representing the microleakage of tooth restoration interfaces occlusally and gingivally were done by two examiners for all specimens, using a light microscope (x40).

Table 1 shows the means and standard deviations obtained in the four groups.

In the group 1 (control), the highest microleakage value (2.9) was observed when using the quartz tungsten halogen while the soft-start light curing system represented the lowest value (2.7).

In group 2 using Xeno® III bonding, the highest microleakage value (2) was observed when using the quartz tungsten halogen. The lowest value (1.6) was obtained with the soft-start light-curing system.

In group 3 using Prime and bond® NT™ bonding agent, the highest microleakage value (1.7) was also observed when using the quartz tungsten halogen.

In group 4 using Unibond II, the quartz tungsten halogen led to the highest microleakage value (1.5); the lowest value (0.7) was observed when using the soft-start light curing system.

When comparing the four groups, the lowest mean score for dye penetration was found in group 4 (Unibond II) and the highest in the control group.

Using the ANOVA test, a statistically significant difference was found among the curing systems ($p < 0.05$).

In the control group, no statistically significant difference in microleakage values was found between quartz tungsten halogen and light emitting diode (t-test). No statistically significant difference in microleakage values was found between light emitting diode and soft-start light curing sys-

Light curing technique	Group 1: control	Group 2: Xeno® III	Group 3: Prime and bond® NT™	Group 4: Unibond II
QTH	2.9±0.30 *	2±0.30 *	1.7±0.24 *g	1.5±0.00* †
LED	2.8±0.4	1.8±0.33 †	1.4±0.29 *‡	1.2±0.24*‡
Soft-start	2.7±0.46 *	1.6±0.20 *‡	1.2±0.24 †g	0.7±0.45† †

*: $p < 0.05$; †: $p < 0.05$; g: $p < 0.05$; †: $p < 0.01$.

Table 1: Scoring of microleakage for the four groups (mean and standard deviation).

tem. However, a statistically significant difference was observed between quartz tungsten halogen and soft-start light curing system.

In group 2 (Xeno® III bonding agent), no statistically significant difference in microleakage values was observed when comparing quartz tungsten halogen and light emitting diode. However, a statistically significant difference was observed between quartz tungsten halogen and soft-start light curing in one hand and between light emitting diode and soft-start light curing on the other hand.

In group 3 (Prime and bond® NT™ bonding agent), a statistically significant difference in microleakage values was observed between quartz tungsten halogen and light emitting diode, quartz tungsten halogen and soft-start light curing and finally between light emitting diode and soft-start light curing.

In group 4, a highly statistically significant difference ($p < 0.01$) in microleakage values was observed between quartz tungsten halogen and soft-start light curing. There was also a statistically significant difference between quartz tungsten halogen and light emitting diode as well as between light emitting diode and soft-start light curing system.

When comparing the microleakage values among the different curing systems and the bonding agents, highly significant differences were observed between the control group and the other experimental groups.

Discussion

The application of light curing systems and bonding agents must be standardized. Factors such as the time of light cure application, the distance between the light tip to the bonding surface or dental composite and the thickness of the bonding and dental composite material influence the quality and the success of composite resin restorations.

The present study evaluated the effect of three light curing regimen and three bonding agents on microleakage. One type of resin composite was used in this study; any reduction in polymerization shrinkage and subsequent microleakage may be attributed to the light curing regimen and / or the type of the bonding agent [12].

In the control group, no bonding agent was used. The microleakage associated with the quartz tungsten halogen (conventional light cure unit with constant intensity) was higher than that observed when using light emitting diode even though the difference was not statistically significant.

While the result of microleakage of soft-start light curing device (which starts with low energy and then uses higher energy) revealed the lowest value among the groups.

The same results were reported by Mehl et al. [13] who found that soft-start polymerization improved the marginal adaptation of composite resin restoration in class V cavities, when they used low initial curing intensity and Yoshikawa et al. [14] who

found that most of the polymerization contraction was completed during the initial flowable stage of the resin composite.

Also, Obici [15] and Aguiar et al. [8] declared that the stepped-light techniques showed an effective reduction in polymerization shrinkage.

However, different results were observed with Hasegawa et al. [16] who used a very low initial curing intensity (180 mw/cm², 166 mw/cm²), with Friedl et al. [17] who used light intensity of 150 mw/cm² and finally with Yap et al. [1] when they used a light intensity of 289 mw/cm².

These intensities may not have activated sufficient number of molecules initiators to start an adequate polymerization; therefore a final cure at high intensity of a nearly unpolymersized material may have corresponded to an immediate full intensity curing.

A linear relationship between light intensity and polymerization contraction has been demonstrated by Park et al. [4] and a relation between the rate of polymerization and the cavity adaptation of the light-cured resin composite has been suggested.

Hasegawa et al. [16] reported that a faster polymerization causes poor marginal integrity of the resin composite restoration. In this situation, the excessive polymerization stress on the adhesive bonds leads to greater incidence of leakage [18].

This is in agreement with the results obtained in our study when using the quartz tungsten halogen curing device for 20 seconds and explains the highest values of microleakage.

The three groups showed relatively greater leakage at the gingival than at the occlusal margin. The most likely cause for this phenomenon is the polymerization contraction of the resin composite, which is manifested towards the stronger enamel-composite interface. This is due to the fact that the adhesion to dentin is more complicated because of the composition and the histological structure of the resin substrate [19, 20].

Significant differences in microleakage scores were observed in the control group compared to the other experimental groups. This result is in agreement with the results of Pioch et al. [21] who proved that the ability of the adhesive system to penetrate through demineralized dentin substrate was related to the ability of the solvent within this dentin bonding to penetrate the dentin surface and help reduce its hydrophilic character, improving the chemical integrity between hydrophilic dentin and hydrophobic resin.

The Prime and bond® NT™, an acetone-based bonding agent, has the ability to penetrate through the filigree of the dentin substrate more than the Xeno® III, an alcohol-based system. These results agree with those of Gwinnett [11] who found an increase in bond strength when using acetone-containing primers. Due to their relatively high volatility, solvents such as acetone and, to a lesser degree, ethanol, may displace the surface moisture and carry better the primer monomers into the micro- or nanoporosities of the dentin substrate.

In the Unibond II group, the water remnant in the dentin substrate bends with HEMA within Unibond II and composes a new mixture of solvent. HEMA alone is not capable of re-expanding dry dentin matrix [22].

It was expected that the HEMA/water primer would induce the highest degree of expansion and would therefore result in the highest bond

strength, assuming that the wide interfibrillar spaces are preserved during bonding procedures. Although it has been demonstrated that solvents with higher bond strength values induce higher degrees of expansion when applied to dry, demineralized dentin matrix and this would lead to decrease the microleakage value, the current results indicate that the maintenance of matrix expansion during bonding procedures is more important than the pre-bonding expansion of the matrix.

Higher bond strengths were obtained when the interfibrillar spaces are maximally preserved. However, our attempts to correlate the expansion values of the HEMA mixtures with the resultant of microleakage were statistically insignificant.

Although the HEMA/water primer may have induced the highest expansion of the dried matrix, the transmission electron microscope images showed that the interfibrillar spaces of HEMA/water primer-infiltrated matrices were significantly smaller than those resulting from the application of the HEMA/methanol or HEMA/ethanol primers or HEMA/acetone. Residual water located within the fibrils not only helps maintain their normal diameter but also preserves their compliance.

Although results with the use of more complex mixtures such as HEMA/solvent/water cannot be predicted, it may be speculated that the degree of expansion will be proportional to the amount of HEMA present in the mixture.

Conclusion

Within the limitations of the present study, we can conclude that the lowest microleakage values were obtained when the Unibond II bonding agent was applied and the soft-start light-curing system was used.

The obtained results added information on the mechanism(s) of den-

tin bonding; manufacturers should be challenged to devise new products that include solvents capable of maintaining the structure of the demineralized dentin matrix in an expanded configuration during and after resin infiltration.

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