RESEARCH

Evaluation of curing distance of high intensity led curing units on microleakage of ceramic restorations

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ABSTRACT

Evaluation of curing distance of high intensity led curing units on microleakage of ceramic restorations

Background: To assess the microleakage in slot shaped cavities restored with IPS e.max Press inlays luted with a resin cement that cured with two types of high intensity LEDs units at 0 or 9 mm distances.

Methods: Forty-eight extracted human premolars were used in this study. The proximal surfaces of the teeth were prepared for the slot shaped cavities using an inlay preparation set (Komet, Germany). IPS e.max Press (Ivoclar Vivadent AG, Liechtenstein) ceramic restorations were fabricated. Two different LED units; high power intensity LED (HPIL; Demi Ultra, Kerr) and high intensity LED (HIL; Valo Cordless) were used to polymerize the dual cure resin cement (NX3 Nexus, Kerr). The curing tip distances to the restoration of 0 or 9 mm were used and controlled by using the plastic rings. The teeth were randomly divided into four groups. Group 1: No distance between the HPIL tip and the restoration, Group 2: No distance between the HIL tip and the restoration, Group 3: The distance between the HPIL tip and the restoration was 9 mm, Group 4: The distance between the HIL tip and the restoration was 9 mm. After curing, the specimens were thermocycled for 5000 cycles between 5 and 55 ˚C using a dwell time of 30 s. The specimens were sealed with nail varnish, coloured by 0.5 % basic-fuchsine for 24 hours, sectioned and examined under a stereomicroscope, and scored for microleakage gingival margins. Statistical analyses were performed using Kruskal-Wallis and Mann-Whitney U-tests.

Results: There were no significantly statistically differences among the groups 1, 2 and 3 ($p > .05$), however, the microleakage in the group 4 was greater than the other groups ($p < .05$).

Conclusions: Increase in the distance between the HIL light source and the restoration surface resulted in an increase in microleakage values.

KEYWORDS

Ceramics, dental materials, light sources

ÖZ

Seramik restorasyonların mikrosızıntısı üzerine yüksek yoğunluklu LED ışık kaynağı mesafesinin değerlendirilmesi

Amaç: Rezin simanla yapıştırılmış IPS e.max Press slot kavite restorasyonlarının; iki farklı yüksek yoğunluklu LED ışık kaynağı ile ve 0 ve 9 mm uzaklıktan mikrosızıntılarının değerlendirilmesidir.

Gereç ve Yöntemler: Bu çalışmada 48 adet çekilmiş insan premoları kullanılmıştır. Dişlerin aproksimal yüzeylerinde inley preparasyon seti (Komet, Germany) kullanılarak slot kaviteler oluşturulmuştur. IPS e.max Press (Ivoclar Vivadent AG, Liechtenstein) seramik inley restorasyonlar hazırlanmıştır. İki farklı LED ışık kaynağı yüksek güç yoğunluklu LED (HPIL; Demi Ultra) ve yüksek yoğunluklu LED (HIL; Valo Cordless) dual cure rezin simanı polimerize etmek için kullanılmıştır (NX3 Nexus, Kerr). Işık kaynağının ucu ile restorasyon arasındaki mesafe 0 ve 9 mm olarak ayarlanıp ve plastik halka kullanılarak kontrol edilmiştir. Dişler rastgele olarak 4 gruba ayrılmıştır. Grup 1: HPIL ışık kaynağı ile restorasyon arasında mesafe yok, Grup 2: HIL ışık kaynağı ile restorasyon arasında mesafe yok, Grup 3: HPIL şık kaynağı ile restorasyon arasında 9 mm mesafe bulunmakta, Grup 4: HIL ışık kaynağı ile restorasyon arasında 9 mm mesafe bulunmaktadır. Polimerizasyon işleminden sonra, örnekler 5 ve 55 ˚C arasında, her bir haznede 30 s kalacak şekilde 5000 termal siklusa tabi tutulmuştur. Örnekler tırnak cilasi ile kaplanmış, % 0.5'lik bazik fuksinde 24 saat bekletilmiş, dişler ikiye bölünmüş, stereomikroskop altında incelenmiş ve gingival marjindeki mikrosızıntı skorlanmıştır. Kruskal-Wallis ve Mann-Whitney U-tests kullanılarak istatistiksel analiz yapılmıştır.

Bulgular: Çalışmanın sonucunda grup 1, 2 ve 3 arasında istatiksel bir fark gözlenmezken ($p>0.05$), grup 4'ün mikrosızıntı değeri diğer tüm gruplardan daha yüksek bir değer göstermiştir ($p<0.05$).

Sonuçlar: Restorasyon yüzeyinden, HIL ışık kaynağının mesafesinin artması diş ve restorasyon arasında mikrosızıntının artmasıyla sonuçlanmıştır.

ANAHTAR KELİMELER

Dental materyaller, ışık kaynakları, seramikler

The superior mechanical properties, high bondage strength, and low solubility, which increase reinforcement of ceramic restorations, have led to the wide use of resin cements in cementation of all-ceramic restorations (Fraga and Pimenta 2000, Al-Assaf *et al.* 2007, Holderegger *et al*. 2008, Hill and Lott 2011). Resin cements should be adequately cured during ceramic restoration in order to ensure

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good biological and physical properties (Alpöz *et al*. 2008, Ilie and Simon 2012).

Many researchers and dental practitioners consider polymerization shrinkage to be an important problem (Lambrechts *et al.* 1987). A series of chemical reactions create polymerization, which the macromolecule, or the polymer, is formed by linkage of a large number of small molecules, known as monomers (Stephen *et al.* 2009). Various researchers (Cobb *et al*. 1996, Bouschlicher *et al.* 1997, Hashimoto *et al.* 2004) have shown that physical properties of the filling are affected by variations in the procedure steps. For example, inadequate resin polymerization results in increased microleakage of resin composite, and thus decreased integrity of the adhesion surrounding the margins. This causes marginal microleakage and penetration of oral fluids and bacteria, and the resultant percolation will lead to a recurrence of caries.

Despite the quality of present day light curing materials and the simplicity of the procedures, the risk of microleakage persists. The reduction in bond strength is associated with changes in the adhesive properties of the resin and in the resin quality. Poor adhesion between the tooth and restorative material predisposes the interface to gap formation, which then leads to microleakage. Consequently, microleakage occurs to a large number of clinical problems such as secondary caries, marginal discoloration, pulpal inflammation, and hypersensitivity (Triadan 1987, Bullard *et al*. 1988, Retief 1994). Dual-cured resin cements have been developed in an attempt to combine the properties of chemical-cured and light-cured materials, by that providing adequate polymerization in deeper regions and a shorter setting time (Hill and Lott 2011).

Dental curing light technology has changed from using a quartz–tungsten halogen light sources to using powerful light emitting diode (LED) light sources. Some currently available curing lights are more powerful than curing lights on the market 15 years ago, prompting some manufacturers to advertise curing times of less than 3 s (Develop guidelines for effective light curing 2003). The LEDs offer various curing regimes, including “soft start curing,” which allows better viscoelastic flow of the dental composite during polymerization, thereby decreasing the overall polymerization shrinkage and microleakage (Abbas *et al.* 2003). LED lights offer a much narrower emission spectrum (a bandwidth of about 20 nm centered on 470 nm), and the spectrum falls closely within the absorption range of camphorquinone (CQ), the most frequently used photoinitiator in resin composites. In general, LED lights have the following advantages: extended lifetimes of more than 10,000 hours, little light output degradation over time, and resistance to shock and vibration (Rencz *et al.* 2012). High-intensity LED curing units are claimed to reach irradiances of 2.000- 3.200 mW/cm^2, depending on the selected mode of use (Rueggeberg 2011). Third generation LED curing units that have multiple diodes (violet/blue diodes, polywave), which therefore affect curing of CQ containing cements and those containing its other alternatives, have been introduced to the market recently (Rueggeberg 2011). Shorter irradiation periods are reportedly adequate in most of the recently introduced high-power LED units (Rueggeberg 2011, Rencz *et al*. 2012).

Aguiar and others (Aguiar *et al*. 2007) showed that, with a distance of 8 mm from the tip of the light-curing unit, the top surface of a resin receives adequate irradiant energy. Therefore, on the top surface, high-intensity photoactivation initiated a multitude of growth centers of polymers with higher cross-linking density (Meng *et al*. 2008, Schneider *et al*. 2008), however there is a little information in the literature about the microleakage of resins cured using high intensity LEDs with the distance from the resin surface more than 8 mm.

The aim of this study was to evaluate the microleakage following use of two type of LEDs; high power intensity LED (HPIL) and high intensity LED (HIL) at different distances (0 mm and 9 mm) for induction of polymerization in dual-cured resin cement through occlusal surface of ceramic restorations. The null hypothesis in the present study was that different type of LEDs and differences in distance between curing tip and the restoration would not affect the microleakage that occurs at the ceramic/dentin surfaces.

MATERIAL AND METHODS

Preparation of the samples

Forty-eight caries-free extracted human maxillary premolars were collected. The teeth were stored in distilled water, at 37°C, immediately after extraction. The calculus was removed using a scaler and the teeth were following polished using a rotating brush and pumice. The prepared teeth were embedded up to 2 mm apical to the cemento-enamel junction ın autopolymerizing resin (Meliodent; Bayer Dental Ltd, Newbury, UK). Teeth were prepared for slot shaped cavities. Teeth were prepared according to the the following criteria using inlay diamond rotary cutting instruments (Komet, Herbst GmbH& Co., Germany): 10

degrees of axial wall convergence; flat floor; 5 mm depth and 3 mm width of the isthmus; and proximal box limited to enamel 1 mm apical to the cemento-enamel junction. Impressions were then made of all specimens with polyvinylsiloxane impression material (Virtual, Ivoclar Vivadent AG, Schaan, Lichtenstein) and refractory dies were prepared (Alpha Die MF; Schültz-Dental GmbH, Rosbach, Germany). IPS e.max Press (Ivoclar Vivadent AG) hot-pressed lithium disilicate based ceramics were prepared in accordance with the manufacturer's instructions. A dual cured resin cement (NX3 Nexus third generation, Kerr) was used in this study. Curing units are shown in Table 1. The teeth were randomly divided into four groups of 12 slot shaped cavities each.

Table 1.

Curing units and their outputs used in this study

Curing unit	Manufacturer	Serial no	Light Intensity mW/cm^2
High intensity LED	Valo Cordless Ultradent	C26011	1000
High power intensity LED	Demi Ultra Kerr	35664	1100

The bonding agent OptiBond All-In-One (Kerr, Orange, CA, USA) was applied for 10 s to the dentin surface and then gently dried with oil-free compressed air. IPS e.max Press ceramic restorations were etched with 9 % HF acid (Ultradent, South Jordan, Utah, USA) for 20 s. The gel was rinsed off with water for 20 s, and then dried with oil-free compressed air.

This was followed by application of dual-cured resin cement (Yellow, NX3 Nexus third generation, Kerr) to the cavity.

Group 1: Light curing was done for 10 s with the HPIL (Demi Ultra, Kerr) from the top of the restoration.

Group 2: Light curing was done for 10 s by the HIL (Valo Cordless, Ultradent) from the top of the restoration.

Group 3: Light curing was done for 10 s by the HPIL at a distance of 9 mm.

Group 4: Light curing was done for 10 s by the HIL at a distance of 9 mm.

A curing radiometer (Bluephase meter, Ivoclar-Vivadent), apart from the inbuilt meters in the curing units, was used to measure the intensity of the light before every application. To standardize these distances, plastic rings corresponding in height to the distances were used. Specimens were stored in light-proof boxes after the polymerization procedure to avoid further exposure to light. After curing, the teeth were thermocycled 5000 times at 5± 2 °C to 55± 2 °C using a dwell time of 30 s.

Microleakage evaluation

The surfaces of the specimens were coated with two layers of nail polish except for 1 mm around the sealant. The specimens were immersed in 0.5 % solution of basic fuchsin for 24 hours at room temperature. After removal from the solution, the teeth were rinsed in tap water, the superficial dye was removed, and the teeth were dried. The teeth were rinsed after removal from the solution and sectioned with slow-speed diamond saw sectioning machine (Buehler Ltd., USA) bucco-lingually in mesial and distal surfaces of each tooth to assess dye penetration under X15 magnification of a stereomicroscope (Sten SV 11, Zeiss, Germany).

Two observers assessed the microleakage, and the results after their agreement were recorded. The degrees of leakage on both the enamel and dentin margins were evaluated as shown below.

Scoring method used for the microleakage determinations:

0 = no dye penetration

1 = penetration of dye to less than a third from the margin

2 = penetration of dye to up to two thirds from the margin

3 = penetration of dye up to the floor

4 = dye along the floor of the cavity.

Statistical analysis

For each ceramic interface (ceramic/dentin), the microleakage score was obtained by calculating the mesial and distal microleakage scores. After statistical evaluation of the mesial and distal leakage, the scores for each interface were obtained by calculating the mean of the mesial and distal microleakage scores. The statistical of microleakage values between test groups was evaluated with Kruskal-Wallis and Mann Whitney U-tests. The level of significance was set at p=0.05.

RESULTS

The means and standard deviations of the microleakage for the different distance of two LEDs are summarized in Table 1. Kruskal-Wallis test indicated that microleakage scores were significantly affected by curing the different LEDs from the different distances to the slot shaped restorations ($p < .05$). The Mann-Whitney U test indicated a significant difference between Group 4 and the other groups. No significant differences were indicated among Group 1, Group 2, and Group 3 ($p < .05$).

The mean dye leakage scores are presented in Table 2. The results indicated that the least leakage was observed in Group 1, followed by Group 2, Group 3, and Group 4. The images of dye leakage are shown in Figure 1.

Table 2.

Comparison of microleakage scores among the groups

	N	Mean+SD
Group 1 (HPIL 0mm)	24	1.2 ± 0.97^{a}
Group 2 (HIL 0mm)	24	1.5 ± 0.97^{a}
Group 3 (HPIL 9mm)	24	1.9 ± 1.2^{ab}
Group 4 (HIL 9mm)	24	2.5 ± 1.15^{b}
Total	96	1.7 ± 1.1

Values with different superscript letters (a-b) are significantly different.

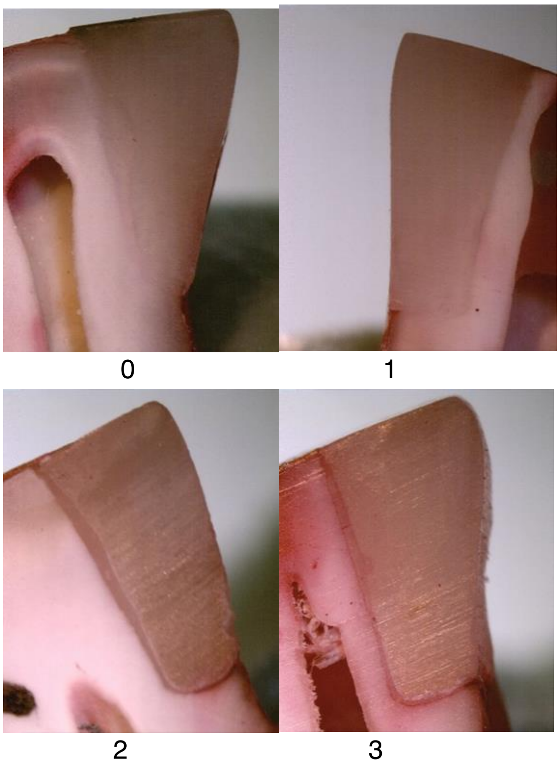

Figure 1.

Degrees of leakage on both the enamel and dentin margins (0, 1, 2, 3 degrees)

DISCUSSION

In the current study, two variables that may significantly affect the photo-polymerization efficacy of the resin-based composite cement were evaluated: the type of LED light source and the distance between the light source and the restoration. The result suggest that microleakage from IPS e.max Press restoration/dual cure resin cement/dentin is definitely affected by distance of the two different LEDs. The null hypothesis that the different type of LEDs would not affect the microleakage that occurs at the ceramic/dentin was rejected. The distance of 9 mm between the restorations and HIL significantly influenced the microleakage of the restoration and the tooth. The microleakage test revealed a trend for reduced dye penetration in the HIL group irradiated at 9 mm when compared to groups irradiated at 0 mm, and HPIL irradiated at 9 mm, regardless of the curing protocol.

Reliable adhesion of resin cements to all-ceramic restoration improves marginal adaptation, prevents microleakage, and increases retention in situations where mechanical retention does not exist (Edelhoff and Özcan 2007). Polymerization of the resin luting agent is an important factor to assure optimal bond strength at the ceramic/dentin interface, as well as optimal physical characteristics (Hofmann *et al.* 2001). When compared to previously used curing units for light-cured resin composites, the current ones have certain advantages. Several types of light curing units have been suggested in the literature to improve properties of light-cured resin composites, to shorten activation time, and to reduce working time (Wiggins *et al.* 2004).

Two different types of light sources were used in this study. Although LEDs are strongly promoted in commercial terms, there is still no verification by independent research as to whether LED units can fill in halogen light sources in dental practice (Dunn and Taloumis 2002). A number of studies have accepted the capacity of LED technology for the light activation of dental materials (Marais 1997, Nomoto 1997), indicating that high-intensity lights are compatible with the wavelength of the light essential to trigger polymerization in the composite resin (Berthold 2000).

A large body of research exists on the techniques that can be used to evaluate microleakage around dental restorations. Exposing the samples to a dye solution prior to the viewing of cross sections under a light microscope is the most convenient and most frequently used method (Ozturk *et al*. 2004). If the relevance of a leakage test is to be evaluated, the effective size of oral bacteria must be considered. Because of the range of bacteria sizes, dyes such as methylene blue and fuchsin are realistic agents to use for identifying the presence of a clinically relevant gap (Ferrari and Garcia-Godoy 2002). In the curent study dye penetration was used as it is simple, almost cheap quantitative and comparable method for assessing the performance of the different restoration techniques (Yap *et al.* 1996).

Increased distance between the light guide and restoration (Corciolani *et al*. 2008) results in excessive light attenuation and thus might imperil the extent of polymerization (Rueggeberg and Jordan 1993). Meyer et al. showed that with LEDs, an increase in distance from the curing tip diminishes the polymerization depth and light intensity (Meyer *et al*. 2004). The light intensity from the curing light affects the extent and rate of the polymerization reaction (Rueggeberg 1999). According to Rissi and Cabral (Rissi and Cabral 2002), an increased reduction in light intensity occurs as a result of an increase in the distance from the light source. This effect of the distance from the tip of light curing units is still a controversial issue in the literature. Price et al. (Price *et al*. 2003) reported that, compared to halogen lights, the light delivered from LED lights is directly dispersed from the light guide, and the power density on the target decreases with distance. The present study revealed no significant difference for a curing distance of 0 mm for the groups and the HPIL used at 9 mm, but significant differences were observed with the HIL used at 9 mm. This can be explained by the beam divergence angle of the HPIL and HIL (Table 3). The beam divergence angle of the HPIL was less and, therefore, more collimated than the majority of the (Yapp *et al.* 2014). HPIL has a high quality of beam providing even and efficient depth of cure (Demi Ultra, Kerr 2015). Furthermore in the current study different light curing units with different energy outputs (HPIL, 1100 mW/cm^2; HIL, 1000 mW/cm^2) were tested and the same irradiation duration were used according to the manufacturer's instructions. That means HPIL shows higher penetration depth than HIL in the restoration.

Table 3.

Beam divergence angle (deg) and tip diameter (mm)

Light	Tip (diameter)	Angle (deg)
HPIL (Demi Ultra)	8	18
HIL (Valo Cordless)	9,5	15

The microleakage test revealed a trend for reduced dye penetration at the group HIL irradiated at 9 mm when compared to groups irradiated at 0 mm, regardless of the photoactivation protocol. At the irradiated surface, this can be explained by the reduction in irradiance achieved at this level might have caused the reaction rate to be slower, providing extended opportunity for chain rearrangement by flow, which relaxed some of the stress developed within the bonded interface (Feilzer and Dauvillier 2003).

In the current study only one type of adhesive was tested. Future studies should be conducted in order to determine the best polymerization conditions and enhance material performance of HPIL and HIL LEDs on different types of adhesive systems.

CONCLUSIONS

Within the limitations of this in vitro study, it was concluded that HPIL and HIL LEDs at 0 mm effectively polymerize the resin composite with the lowest percentage of microleakage, HIL LEDs at 9 mm. Increase in the distance between the high intensity LED light source and the restoration surface resulted in an increase in microleakage.

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