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Effect of new light curing units on microleakage and microhardness of resin sealants

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To determine new developed light curing units with shorter curing times effects on microleakage and microhardness values for resin fissure sealants. Resin filled sealant (UltraSeal-XT), resin unfilled sealant (Delton Type-II) and ormocer-based sealant (Admira-Seal) were light cured with a quartz-tungsten-halogen (QTH), two LED light and a high power LED. Two hundred and forty extracted human molars were randomly allocated into four groups according to used light-curing unit and three subgroups were formed for three different fissure sealant materials. Specimens were immersed in 0.5% basic fuchsin for 24 h, sectioned and examined under a stereomicroscope, and scored for marginal microleakage. Knoop hardness number (KHN) readings were measured after 48 h. Statistical analyses of test were found in significant difference both microleakage and microhardness values between the various light curing units. The time saving approaches in the curing light were determined higher microhardness, although it was found in higher microleakage.

Keywords: Microleakage, Microhardness, Fissure sealant, Light curing unit

INTRODUCTION

Preventive measures, use of fluoride agents and improvement of oral hygiene, have verified effective in reducing caries prevalence. However, posterior teeth have not uniform tooth surfaces as pit and fissure surfaces. The morphology of the occlusal surface in posterior teeth obstructs the mechanical cleaning and reduces the effects of preventive measures. Studies have demonstrated that the use of pit and fissure sealants is an effective way for preventing caries1-6).

Light-cured resin sealants used the most common and conventionally. The polymerization of light-cured sealants can be achieved with many light sources (*e.g.* quartz tungsten halogen, plasma arc and light emitting diode (LED)). Current sealants are most commonly cured with a quartz tungsten halogen curing lights (QTHs), which has a peak absorption at a maximum of 465 nm. QTHs have some limitations, such as relatively short working life span, high operating temperatures and decreased light output over time3,7,8). LEDs can be operated for thousands of hours without a significant reduction in light output. The reduced temperature associated with LEDs also can prevent degradation of light guides and does not pose a threat to the pulpal tissue. Several studies, however, have shown that LEDs with relatively low irradiances may result in insufficiently cured composites and, therefore, adversely effects mechanical properties of the restorations. The light output of the first-generation LEDs required improvement to match with the cure produced by QTHs.

A number of second-generation LEDs with high power light sources are now available. The results of studies have shown that these are capable of curing CPQ-initiated composites in half the radiation time of their predecessor. The curing kinetics of photo polymerized dental sealants using LEDs showed that the second-generation LEDs reached conversion similar to control in only 10 s2,3,8). The third-generation of LED curing units contains multiple diodes (violet/blue diodes, polywave), and recently a third-generation LED curing unit was marketed (Valo, Ultradent, South Jordan, UT, USA), which is claimed to reach irradiances of up to 3,200 mW/cm^2 depending on the chosen mode.

These time saving approaches could have significant clinical implications, provided that there is no adverse effect on the fissure sealant's marginal integrity. The purpose of this *in vitro* study was to evaluate the effect of different generation light emitting diodes and quartz tungsten halogen curing units used for various sealants curing on the microleakage and microhardness values.

MATERIALS AND METHODS

Microleakage section

Sample size calculations were performed using PASS software (NCSS, LLC, Kaysville, UT, USA). It is estimated at about 180 teeth with a 90% confidence interval level and a standard error of 5%. Caries-free, extracted for orthodontic reasons human mandibular third molars were collected from healthy children ages 15–20. Participants signed the informed consent form. Each tooth was stored in 0.12% thymol solution immediately after extraction and for the same amount of time. Organic remnants were removed off of teeth,

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and the occlusal surfaces were cleaned with a slow speed bristle brush with a continuous irrigation of water coolant. The teeth were then examined under a dissecting microscope to discard those with caries, any visible hypoplasia, extraction damage, or microcracks. Teeth with irregular occlusal morphology were also excluded. The condition laboratory was under the daylight 63% relative humidity at room temperature. In the study, three various fissure sealant materials and four curing units were used (Tables 1 and 2).

Accordingly, 240 teeth were selected and assigned randomly into 1 of 4 experimental groups:

In group 1 (Hilux), pits and fissures were etched with 37% phosphoric acid (Vococid, Voco, Cuxhaven, Germany) for 30 s, rinsed with air-water spray for 15 s, and air-dried for 10 s. A bonding resin (Clearfil SE Bond, Kuraray, Okayama, Japan) was applied on the fissures according to the manufacturer's instructions and light with a conventional QTH curing unit (Hilux, Benlioğlu Dental, Ankara, Turkey). A radiometer was utilized for detecting the curing unit's performance. Thereafter, three subgroup was formed by 20 teeth according to applied different fissure sealants mentioned in Table 2. Light curing was performed for 30 s with the same QTH curing unit, and kept distance standard 2 mm.

In group 2 (Elipar) acid-etch and bonding procedures were performed as in group 1, with the adhesive resin being light cured for 10 s with another LED curing unit (Elipar Free Light 2, 3M ESPE, St. Paul, MN, USA). Three subgroups were formed as with group 1 and light cured with the Elipar curing unit for 10 s, and kept distance standard 2 mm.

In group 3 (Valo SP), acid-etch and bonding procedures were performed as in groups 1 and 2, with

Table 1 Light curing used in the study

Light curing	Curing unit	Curing time	Manufacturer	Intensity (mW/cm^2)	Peak Wavelength (nm)
Hilux	QTH	20 s	Benlioğlu Dental, Ankara, Turkey	600	410–500
Elipar Free Light 2	LED	10 s	3M ESPE, St Paul, MN, USA	1,000	430–480
Valo Standart Power mode (SP)	LED	10 s	Ultradent, South Jordan, UT, USA	1,000	440–480
Valo Xtra Power mode (XP)	Plasma LED	3 s	Ultradent	3,200	440–480

Table 2 Fissure sealant used in the study

Fissure Sealant	Structure	Manufacturer	Composition	Function
UltraSeal XT	Resin Filled	Ultradent, South Jordan, UT, USA	Diurethane dimethacrylate Bisphenol A dimethacrylate Sodium monofluorophosphate Titanium dioxide Resin fillers (57%) Light activators	Monomer Monomer Fluoride Opaquer Fillers Photoinitator
Delton Type II	Resin Unfilled	Dentsply, York, PA, USA	Triethylene glycol dimetharcylate Bisphenol A dimethacrylate Barium alumino fluroboro silicate glass (55%) Titanium dioxide (opaque) Sodium Fluoride Ethyl p-dimethylaminobenzoate	Monomer Monomer Fillers Opaquer Fluoride Photoinitator
Admira Seal	Ormocer-based	Voco, Cuxhaven, Germany	Hydroxyethyl dimethacrylate Bisphenol A dimethacrylate Ormocers Silicate and glass ceramic Inorganic/organic co-polymers Light activators	Monomer Monomer Fillers Fillers Co-polymers Photoinitator

the adhesive resin being light cured for 10 s with another LED curing unit (Valo Standart Power, Ultradent). Three subgroups were formed as with groups 1 and 2 and light cured with the Valo SP curing unit for 10 s, and kept distance standard 2 mm.

In group 4 (Valo XP), acid-etch and bonding procedures were performed as in groups 1, 2 and 3, with the adhesive resin being light cured for 3 s with another LED curing unit (Valo Xtra Power, Ultradent). Three different fissure sealants were applied as with groups 1, 2 and 3 and light cured with the Valo XP curing unit for 3 s, and kept distance standard 2 mm.

Specimens were stored in deionized water at 37°C for 24 h, after which thermal cycling in deionized water was performed at 5±2 to 55±2°C for 500 cycles with a dwell time of 30 s and a transfer time of 10 s. Thereafter, the teeth were kept in distilled water at 37°C for 4 weeks before dye-penetration procedures. The water (pH:7) was changed every week.

Prior to dye penetration, the apices were sealed with sticky wax and the samples were coated with 2 consecutive layers of nail varnish up to 1 mm from the sealant margins. Samples were then immersed in 0.5% basic fuchsine solution (Wako Pure Chemical Industry, Osaka, Japan) for 24 h. After thoroughly rinsing with distilled water, the samples were air-dried and embedded in epoxy resin (Struers, Copenhagen, Denmark). Five parallel longitudinal sections were made through the occlusal surfaces using a low-speed diamond saw (Isomet, Buehler, Lake Bluff, IL, USA) in the bucco-lingual direction. One calibrated researcher examined all sections under a stereomicroscope at ×16 magnification (Wild Type 308700, Heerbrugg, Switzerland). He was blind to the groups.

For each section, the following criteria was used to rate dye penetration scores: score 0=no dye penetration; 1=dye penetration restricted to the outer half of the sealant; 2=dye penetration into the inner half of the sealant; and 3=dye penetration into the underlying fissure. The microleakage score of each tooth was obtained by calculating the mean score of 5 slices each. Statistical evaluation of microleakage scores between the test groups was performed using the Kruskal-Wallis test with significance set at p=0.05.

Microhardness section

Three various sealant materials and above-described of the four curing units were investigated by using for each of LCU and material (Tables 1 and 2). All specimen were prepared by a single operator, with care taken to avoid bubble formation.

The sealant material was placed into a 2-mm-thick silicone mold with a 4-mm internal diameter. The mold was placed between 2 glass slides. Sample size calculations were performed using PASS software (NCSS, LLC). It is estimated at about 180 specimens with a 90% confidence interval level and a standard error of 5%. One hundred eighty specimens were prepared and assigned randomly into1 of 4 experimental groups. Each specimen was cured for the appropriate amount of time from the top surface only. The specimens were stored in the dark under 100% relative humidity at 37°C for 48 h. Five Knoop Hardness Number (KHN) readings were made at least 1 mm from the edge of each top and bottom surface after an indenter dwell time of 15 s and a load of 50 g (Microhardness Tester FM-700, Mitutoyo G3, Mitutoyo, Tokyo, Japan). A Bottom/Top (B/T) KHN ratio was calculated for each specimen. Top and bottom surface hardness and B/T KHN means were determined for each group. Microhardness scores between the test groups were performed using the Kruskal-Wallis test. The level of significance was set at p=0.05.

Table 3 Dye penetration score, percentage of microleakage and standard deviation for the various curing lights and sealant materials

	Dye penetration score *n*:20				Microlekage % (SD)	
	0	1	2	3	0	1–3
Hilux-UltraSeal XT	15	2	1	2	75	25±18.2^{b}
Hilux-Delton Type II	15	2	2	1	75	25±18.7^{b}
Hilux-Admira Seal	15	1	2	2	75	25±18.3^{b}
Elipar LED-UltraSealXT	18	1	0	1	90	10±14.4^{a}
Elipar LED-Delton Type II	18	1	1	0	90	10±12.5^{a}
Elipar LED-Admira Seal	17	1	1	1	85	15±15.5^{a,b}
Valo SP-UltraSealXT	19	0	1	0	95	5±11.3^{a}
Valo SP-Delton Type II	19	0	0	1	95	5±9.5^{a}
Valo SP-Admira Seal	18	1	0	1	90	10±14.2^{a}
Valo XP-UltraSealXT	12	3	2	3	60	40±30.2^{c}
Valo XP-Delton Type II	12	2	3	3	60	40±28.6^{c}
Valo XP-Admira Seal	11	2	3	4	55	45±32.1^{c}

a,b,c: Statistically significant differences among groups are expressed (p>0.05).

RESULTS

Microleakage section

Total 240 teeth scores were analyzed in the results, it were included to each light curing units and fissure sealant subgroups 20 samples. The means and standard deviations of microleakage for the various light curing units and sealant materials are shown in Table 3. Also, Table 3 compares the results of the tooth scores with no microleakage (score 0) with those where microleakage

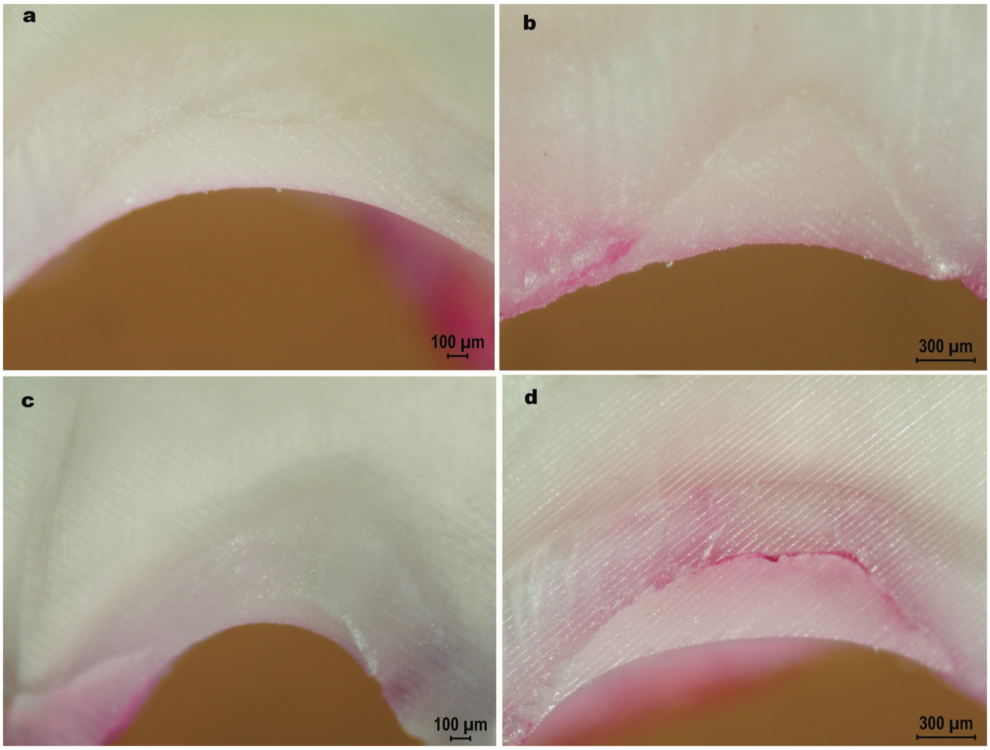

Fig. 1 View of the dye penetration scores 0, 1, 2 and 3.
a; score 0=no dye penetration, b; score 1=dye penetration restricted to the outer half of the sealant, c; score 2=dye penetration into the inner half of the sealant, d; score 3=dye penetration into the underlying fissure.

Table 4 Means and standard deviations of top (T) and bottom (B) hardness and hardness ratio (B/T) for the various curing lights and sealant materials

	Hilux	Elipar LED	Valo SP	Valo XP
UltraSeal XT				
T	23.6±1.12	14.5±0.76	14.1±0.65	9.4±0.45
B	6.5±0.54	1.3±0.43	0.4±0.1	NA*
B/T	0.27±0.07^{a}	0.08±0.02^{b,c}	0.02±0.01^{c}	NA*
Delton Type II				
T	16.5±0.87	12.8±0.96	9.7±0.78	3.8±0.34
B	4.5±0.39	NA*	NA*	NA*
B/T	0.27±0.03^{a}	NA*	NA*	NA*
Admira Seal				
T	16.4±0.77	13.1±0.97	10.3±0.83	5.6±0.46
B	4.8±0.31	1.7±0.23	0.3±0.12	NA*
B/T	0.29±0.06^{a}	0.12±0.03^{b}	0.02±0.01^{c}	NA*

* NA=not applicable.
a,b,c: Statistically significant differences among groups are expressed ($p>0.05$).

was present (scores 1, 2 and 3) (Fig. 1). The results showed that the various sealing material had not a statistically significant influence on the microleakage (p>0.05). Statistical analyses of these scores with a Kruskal-Wallis test resulted in significant difference between the various light curing units. Microleakage values demonstrated respectively the highest Valo XP, Hilux, Elipar and Valo SP groups. Valo XP exhibited statistically significantly higher microleakage, although Valo SP and Elipar were found in lowest microleakage. Valo SP had demonstrated a significantly lower leakage according to Hilux in all the sealant, however Elipar was excluding Admira Seal (p>0.05).

Microhardness section

Total 180 specimens scores were analyzed in the results, it was included to each light curing units and fissure sealant subgroups 15 samples. The means and standard deviations of microhardnes for the various light curing units and sealant materials are shown in Table 4. There was a significant difference among the groups in terms of the microhardness ratio (p<0.005). Microhardness values showed respectively the highest Valo XP, Valo SP, Elipar and Hilux group.

The results showed that the Delton Type II presented a significantly higher hardness ratio than the other fissure sealants.

DISCUSSION

The pit and fissure sealants' effectiveness for reducing caries risk have been demonstrated by many studies[9)]. Despite a lot of advantages for light cured resin sealants, gap formation between tooth and material interfaces due to polymerization shrinkage is considered one of the most important disadvantage[10)]. Various attempts have been made for reducing operating time for anxious, uncooperative patients by newly developed light curing units[11,12)]. Although studies stated that decreasing the curing time had no effect on the microleakage of the sealants[2,13)], there is a scarcity of published data regarding their effects on the marginal integrity and degree of conversion.

Today, a majority of light curing units is based on the light-emitting diode (LED) technology with a single high-powered diode. Second-generation LED curing units typically reach irradiances of 1,200 to 1,500 mW/cm^2. The third-generation of LED curing units contains multiple diodes, and recently a third-generation LED curing unit was marketed (VALO, Ultradent), which is claimed to reach irradiances of up to 3,200 mW/cm^2 depending on the chosen mode[14)]. Dental visible light curing materials generally contain a diketone-type photoinitiator that absorbs light in the 400- to 500-nm range covered by the blue light from the visible spectrum. The studies showed that the emission peak of blue LED at 465 nm coincided with the absorption peak of camphoroquinone (CQ) at 467 nm[8,15)], but when the resin material contains new photointiators that absorb light energy in lower regions of visible spectrum early generation LED lights failed when compared with QTH[16)].

Interestingly, rapid cure did not have an adverse effect on Valo XP group's microleakage values. It is possible that, when upper part of the sealant polymerized adequately, it gained retention from the good adaptation. Short curing time might not allow the composite resin flow to form resin tags but this may not be valid for resin sealants. Nevertheless a higher stress level between the layers of resin material due to inadequately curing may increase the flexure under masticatory forces should not be forgotten.

For clinical success of light cured resin sealants adequate polymerization is always necessary. The higher degree of conversion for resin material provides increased mechanical properties. Knoop Hardness Number shows relative degree of conversion for resin materials[17)]. Unfilled resin sealant (Delton) showed a significant higher hardness ratio as previous studies[2,18)] can be explained by light's more easier passage from unfilled resin material.

In the present study, the lowest micro hardness values found for Hilux group. This was an unexpected result but light units spectrum is not the only factor that effect polymerization quality of the resin fissure sealants. Different (filler/matrix) compositions of light curing dental materials may have a more pronounced influence on material properties than radiant exposure[19)].

Higher amount of filler particles provides less porosity[20)], better wear resistance[21)], good shear-bond strength[22)] and similar retention scores as conventional ones[20)]. For the ormocer-based sealant tested, relatively high viscosity that cause greater thickness may explain the not statically significant but higher microleakage values. It is important for the clinician to understand that the polymerization process varies from different types of curing units and different resin materials. Further studies are needed to understand the nature of complex relationship between resin sealant's polymerization and different light curing technology.

CONCLUSION

Sealant microleakage and microhardness were effected by the type of light curing device technology. Valo XP exhibited statistically significantly higher microhardness, although it was found in statistically significantly higher microleakage. Valo SP showed lowest microleakage and higher microhardness values. UltraSeal XT and Delton Type II were showed similar microleakage, but Delton Type II presented a significantly higher hardness ratio than the other fissure sealants. This paper adds to the literature results of an *in vitro* study investigating whether the microleakage and microhardness of a different sealant is influenced either a quartz-tungsten halogen (QTH), two LED light and a high power LED. This study demonstrated that sealant microleakage and microhardness were effected by the type of light curing device technology.

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