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Effect of Thermal Cycling on Microleakage of a Fissure Sealant Polymerized with Different Light Sources

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The purpose of this study was to examine the effect of thermal cycling on microleakage of a fissure sealant after it was bonded with different bonding agents and polymerized with different light curing units. To this end, two bonding agents (Xeno III, iBond), three light curing units (Astralis 3, Elipar free-light, Elipar free-light 2), and a fissure sealant (Fissurit FX) were used. Microleakage was then evaluated using a dye penetration method after thermal cycling. When the fissure sealant was polymerized with Elipar free-light and Elipar free-light 2, microleakage at 10,000 cycles was significantly increased compared with that at 5,000 cycles. In terms of comparison among the curing units, the best microleakage score was observed with Astralis 3 ($p<0.05$). In terms of comparison between the two bonding agents, no significant differences in microleakage score were observed ($p>0.05$). Further, it was concluded that in order to evaluate microleakage scores appropriately, it was necessary for specimens to be subjected to thermocycling of 10,000 times or more.

Key words: Fissure sealant, Thermal cycling, Microleakage

INTRODUCTION

Fissure sealants are materials applied to the tooth surface to obliterate fissures and remove the sheltered environment in which caries may thrive. This conservative technique of tackling pit and fissure caries is a minimal-intervention approach which even most children have no difficulty in accepting[1]. Therefore, pit and fissure sealants undoubtedly play a critical role in preventing occlusal caries in both primary and permanent teeth[2,3]. Against this background, the use of pit and fissure sealant materials has been promoted for a number of years to prevent the incidence of dental caries. Owing to the widespread adoption of pit and fissure sealants, their mechanical properties and clinical effectiveness are well documented in published literature[4].

It has been suggested − although with ongoing debate − that a bonding agent be placed before the sealant was applied[5−7]. In some studies, it was said that application of bonding agent before fissure sealant increased the latter's effectiveness[8−10]. On the other hand, a clinical evaluation indicated that the use of a bonding agent prior to the application of a pit and fissure sealant did not increase the retention rate[11].

Some problems long plaguing the clinical integrity of resin composite restorations arise from the curing efficiency of light-cured resin composites and the shrinkage stresses induced during polymerization. Apart from material characteristics, light curing units also significantly influence the polymerization efficiency of light-activated resin composites. Spectral output of the light source, emitted light intensity, and curing mode are some important factors associated with the effectiveness of light curing units[12]. Currently, a diverse range of photopolymerization techniques are available, and each technique has its own advantages and disadvantages with respect to the properties of the final restoration and the long-term status of the restored tooth[13].

In previous studies, the effect of thermal cycling up to 5,000 times on microleakage has been evaluated[8,10,14,15]. Therefore, the primary aim of the present study was to assess the performance of a fissure sealant after being subjected to long-term thermal cycling. The secondary aim of this study was to evaluate the microleakage of the fissure sealant after prior application with two different bonding agents and then polymerized with three different light curing units.

MATERIALS AND METHODS

Tooth specimens

A total of 54 freshly extracted, sound third molar teeth assigned as suitable for sealant application were chosen and stored in a saline solution with 0.1% sodium azide[16,17]. Having removed the soft tissue remnants, calculus, and fissures, the teeth were cleaned with fluoride-free pumice and a rubber cup. All teeth were subsequently washed under tap water to remove fluoride-free pumice from their surfaces prior to sealant application.

Teeth in both bonding agent groups were subjected to drying with an air syringe for 10 seconds. Each tooth was then etched with 35% phosphoric acid gel for 30 seconds (3M/ESPE, St. Paul, USA), washed for 15 seconds, and dried for 15 seconds. Following which, Xeno III (Dentsply DeTrey GmbH, Konstanz, Germany) and iBond (Heraeus Kulzer, Hanau, Germany) dentin bonding agents were applied to the etched and dried enamel surface according to the manufacturers' instructions. Fissurit FX (Voco, Cuxhaven, Germany) was used for sealing the fissures, and was polymerized with three different light curing units according to three subgroups (Table 1). The curing time of each light curing unit was determined according to the manufacturer's instruction. Sealant margins were then checked for any failure of sealant retention and application.

Thermocycling test

Sealant-treated teeth were allocated into three thermocycling groups: two test groups (5,000 and 10,000 times) and one control group. Specimens were thermocycled 5,000 and 10,000 times, by using an electronic thermal cycling machine (Nova Tic., Konya, Turkey) (Fig. 1), in water baths at 5±2℃, room temperature (22±2℃), and 55±2℃ with a dwell time of 30 seconds in each bath.

Microleakage assessment

Apices of teeth were covered with sticky wax, and the surface of each specimen was covered with two layers of nail varnish leaving a 1-mm window around the sealant. All specimens were then immersed in a 5% basic fuchsin dye solution for 24 hours. Following immersion in the dye solution, the teeth were washed under running tap water for 30 seconds to remove excess solution.

The mesial and distal sides of each tooth were ground using a disk mounted on a slow-speed handpiece. Each tooth was subsequently sectioned longitudinally in a buccolingual direction through the line connecting the buccal and palatal cusp tips to provide four sections from each tooth for microleakage evaluation (two lateral sections and two central ones).

One trained (and blinded) examiner was asked to score the dye penetration depth in each section using a stereomicroscope (×60 magnification) (SZ-TP, Olympus, Tokyo, Japan). The scoring system used in this study was the same as that adopted by Grande et al.[18], which was as follows: 0 - No dye penetration; 1 - Dye penetration into the occlusal third of the enamel-sealant interface; 2 - Dye penetration into the middle third of the interface; and 3 - Dye penetration into the apical third of the interface. Highest score was established as the final score obtained after examining both the buccal- and palatal-inclined cuspal planes in each section.

Statistical analysis

Combination groups were formed between the light curing units and bonding systems for statistical evaluation. Statistical analysis was performed with Kruskal-Wallis and Mann-Whitney U tests. Level of statistical significance was set at 0.05.



Fig. 1 Electronic thermal cycling machine used in this study.

RESULTS

Table 2 shows the microleakage scores. When the three light curing units were used with both adhesive systems, the lowest average microleakage scores were obtained only when QTH was used. With LED and LED 2 light curing units, the average microleakage scores increased as the number of thermocycles increased. However, with QTH, increase in number of thermocycles did not lead to statistically significant differences between the two bonding systems ($p>0.05$). Further, at 10,000 cycles, QTH enabled both bonding systems to yield the lowest average microleakage scores (Fig. 2).

When polymerized with LED, the average microleakage scores of both bonding systems increased with the number of thermocycles. However, the leakage scores of Xeno III and LED were lower than those of iBond and LED ($p<0.05$) (Fig. 2).

Table 1 Characteristics of light curing units used in this study

Light curing unit		Light density (mW/cm^2)	Curing time (s)	Manufacturer
Astralis 3	(QTH)	530	40	Ivoclar Vivadent, Schaan, Liechtenstein
Elipar Freelight	(LED)	400	40	3M ESPE, St. Paul, MN, USA
Elipar Freelight 2	(LED 2)	1000	20	3M ESPE, St. Paul, MN, USA

Table 2 Microleakage scores according to number of cycles

		0 cycles					5,000 cycles					10,000 cycles				
		Mean±SD	0	1	2	3	Mean±SD	0	1	2	3	Mean±SD	0	1	2	3
XENO III	QTH	0	22	0	0	0	0.79±1.15	19	0	7	3	0.79±0.94	16	12	3	3
	LED	0	28	0	0	0	0.29±0.46	15	6	0	0	2.04±1.27	7	1	5	16
	LED 2	0.80±0.28	23	2	0	0	0.58±1.06	18	0	4	2	2.54±0.83	1	2	4	17
iBond	QTH	0	25	0	0	0	0.48±0.95	22	2	3	2	0.71±1.05	17	5	3	3
	LED	0.15±0.37	17	3	0	0	1.00±1.28	14	1	4	5	2.83±0.39	0	0	4	19
	LED 2	0	26	0	0	0	0.60±0.96	17	2	5	1	2.83±0.64	1	0	1	22

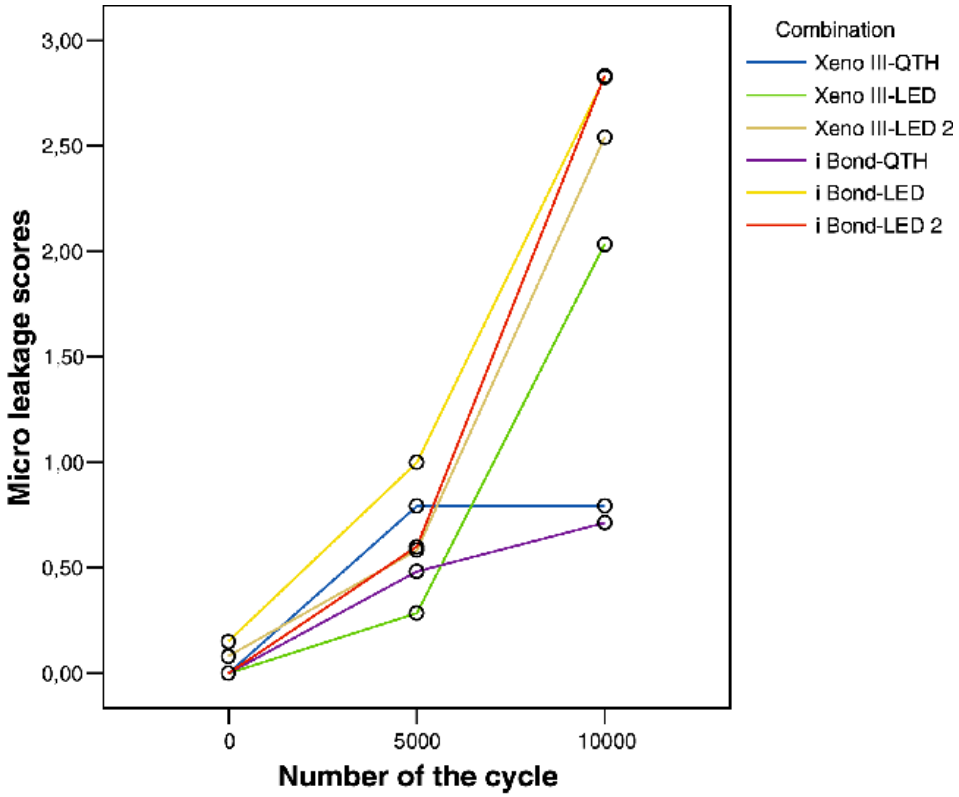


Fig. 2 Microleakage scores after thermal cycling.

When polymerized which LED 2, both bonding systems did not show statistically significant differences in average microleakage score ($p>0.05$) (Fig. 2), despite a statistically significant difference in average microleakage score ($p<0.05$) for each bonding system as the number of thermocycles increased.

DISCUSSION

The purpose of this in vitro study was to examine how thermal cycling would affect the effectiveness of a fissure sealant which was bonded with two different bonding agents and polymerized with three different light curing units. It has been widely accepted that current adhesive resins and dental materials, as opposed to the earlier versions, have good biocompatibility with the dental tissue[19]. These materials were developed to reduce voids and porosity in the adhesive layer, enhance fissure obturation at the enamel-resin interface, and thereby improve sealant retention rates-thus reducing the possibility of fissure caries, especially for deep fissures which are more sensitive to caries attack. However, for the enamel surface in deep fissures, its proper conditioning may be compromised by the inability to remove debris, dry adequately, and ensure total penetration of the resin. Therefore, bonding agents are used to enhance the adhesion and penetration of fissure sealants due to the former's ability to displace water and tolerate some degree of water contamination on the tooth surface[8,19]. For this reason, two different self-etching bonding agents were used in this study with the aim of increasing fissure sealant penetration and decreasing microleakage. However, these two

self-etching bonding systems were not statistically different from each other, in that they demonstrated the same microleakage performance when examined under the same conditions of light curing unit and number of thermocycles.

Light curing units have a narrow spectral range with a peak around 470 nm, which matches the optimum absorption wavelength for the activation of the camphorquinone photoinitiator. Moreover, LED units generate minimal heat so that there is no need for a cooling fan, and they are also associated with low noise level and low power consumption[20-22]. It should be mentioned that the curing efficiency of light-cured resin materials and the shrinkage stresses induced during polymerization affect the clinical integrity of resins. Then, apart from material characteristics, light curing units also significantly influence the polymerization efficiency of light-activated resin materials. Spectral output of the light source, emitted light intensity, and curing mode are some important factors associated with the effectiveness of light curing units[12]. Currently, a diverse range of photopolymerization techniques are available, and each technique has its own advantages and disadvantages with respect to the properties of the final restoration and the long-term status of the restored tooth. In this study, three different types of polymerization source were used: halogen lamp, light-emitting diode, and light-emitting diode 2.

The effectiveness of blue light in the light-curing of dental composites has been known since the 1970s. The most frequently used source of blue light for this purpose is the halogen lamp. This is because the maximum absorption of the sensitizer component of most photoinitiator systems in dental materials (i.e., camphorquinone) occurs at 465 nm, and blue light is of the wavelength range between 410 and 500 nm. When camphorquinone is exposed to light in the presence of an amine-based co-initiator, radicals are formed, initiating polymerization[21].

It has been suggested that apart from factors such as light intensity, curing mode, and irradiation time, the total energy output of light curing units also remarkably influences the degree of conversion in resin materials[23]. In this study, the light densities of the light curing units were: QTH at 530 mW/cm^2, LED at 400 mW/cm^2, and LED 2 at 1000 mW/cm^2. In terms of curing time, that of QTH, LED, and LED 2 were 40, 40, and 20 seconds respectively. In this study, it was shown that the light intensity of light curing units was not important until thermal cycling of 5,000 cycles was applied. In other words, effective bonding of the adhesive systems to be the enamel — arising from bonding agent application prior to fissure sealant application — was an effective solution to reducing microleakage such that microleakage was barely detected at 0 cycles. It should be mentioned that the average microleakage scores of fissure sealant polymerized with QTH were smaller than LED and LED 2 after 10,000 times of thermal cycling. The curing time of QTH was higher than that of LED 2, and the light density of QTH was higher than that of LED. This finding thus showed that when the effects of light curing units, fissure sealants, and bonding agents were combined together and their performance assessed simultaneously in a microleakage study, it was necessary and expedient to apply a higher number of thermal cycles.

Dental materials in the oral cavity are constantly exposed to heat and pH changes[24-26]. Formation of marginal gaps caused by thermal stress and microleakage stems from the different thermal expansion coefficient of tooth tissue[27]. The coefficients of thermal expansion of composite resins (25-60 ppm/℃) are greater than that of enamel (11.4 ppm/℃) and dentin (8 ppm/℃)28). As such, to assess the in vitro performance of resin materials, thermal cycling and mechanical loading are the common methods used to simulate the long-term stresses to which the resin restorations are exposed[29]. Thus, on the subjects about the number of cycles and immersion time used in thermal cycling, abundant and wide-ranging data exist in published literature[30,31]. In this study, the specimens were kept in each bath for 30 seconds. For constant temperature ageing, many thermal ageing regimes have cited 37℃ as an appropriate temperature; while for extreme temperature ageing effects, a limited temperature range of 0-67℃ has been adopted[32-36]. In this study, the temperature range was between 5 and 55℃, which was claimed by various studies to be the most clinically relevant[24,37,38].

As for the effect of thermal cycling on microleakage of resin restorations, some studies claimed that microleakage was increased significantly as a result, while other studies indicated otherwise[16,39]. In this study, the number of thermal cycles applied to the specimens was higher than in a previous study, as it has been shown that low thermal cycling application did not affect microleakage[16]. Indeed, results of the previous study[16] and the present investigation were in agreement, where there were no significant differences in microleakage at 5,000 cycles. Average microleakage scores after 5,000 cycles in this study showed that specimens in microleakage studies should be exposed to a higher number of thermal cycles.

CONCLUSIONS

Within the limitations of the present study, the following conclusions were drawn:

- Both bonding agents used in this study showed a similar, favorable performance. It could thus be said that application of bonding agent prior to

application of fissure sealant gave beneficial results in terms of microleakage.

- After polymerizing with the three light curing units in this study, the average microleakage measurements of both bonding agents — used in conjunction with the fissure sealant — increased after 5,000 thermocycles. But after 10,000 thermocycles, the average microleakage measurements obtained with LED and LED 2 were significantly greater than those obtained with QTH. In light of these peculiar findings at 5,000 and 10,000 cycles, light curing performance at higher number of thermal cycles should be further evaluated.
- Electronic thermal cycling machines, which offer thermal cycling in different forms in terms of number of thermocycles and immersion temperature, are foreseen to be of great assistance in future studies.
- For microleakage studies that involve bonding agents, fissure sealants, and light curing units, it was found to be advisable and necessary to conduct the experiments at a higher number of thermal cycles.

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