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In vitro microleakage of a fissure sealant polymerized by either a quartz tungsten halogen curing light or a plasma arc curing light

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Background. The benefits of using plasma arc curing lights with their shorter curing times in the management of children are potentially great, provided there are no adverse effects.
Objective. The aim of this study was to investigate whether the microleakage of a resin-based sealant is influenced by polymerization with either a conventional quartz tungsten halogen or a plasma arc curing light.
Design. This study took the form of an *in vitro* randomized control trial. Seventy extracted human first and second permanent premolars and molars were randomly allocated into two groups. Their occlusal surfaces were sealed with a light-cured fissure sealant using either a quartz tungsten halogen curing light or a plasma arc curing light. The teeth were then sectioned, resulting in four surfaces per tooth, which were examined for microleakage under × 15 magnification with a light microscope. The principal unit of analysis was the tooth (worst section score) and not the section microleakage score.
Results. No statistical significant difference in microleakage scoring between the two groups was demonstrated.
Conclusion. This study found no difference in the degree of microleakage of fissure sealants polymerized by either light source.

Introduction

A pit and fissure sealant (sealant) is a material that obliterates or seals any pits and fissures when applied to the surface of a tooth. A large number of studies have demonstrated that sealants are effective in caries prevention[1]. The polymerization of light-cured sealants can be achieved by a number of light sources (e.g. quartz tungsten halogen, plasma arc, light emitting diode and laser curing lights). Current sealants are most commonly cured with a quartz tungsten halogen curing unit because these light-curing units are inexpensive and well established. Quartz tungsten halogen curing lights have some limitations, namely a short working life span as a result of bulb and filter degradation, heat build-up of the unit and decreased light output over time[2–4]. Newer curing units, such as the plasma arc lights, offer the potential for much shorter curing times. The replacement of halogen curing lights with plasma arc curing light has some potential disadvantages; for example, significant heat generation with the potential to cause pulpal damage, and an increase in both polymerization shrinkage and the water solubility of the resin[2,5–7]. A study carried out by Stritikus and Owens[8] found that one of the main disadvantages of the plasma arc light compared to conventional quartz tungsten halogen light when used to polymerize resin-based composites was an increase in microleakage. They did not find this to be the case with sealants, however. These authors postulated that the short curing time used with plasma arc lights might not allow the composite resin to flow, thus resulting in shorter resin tags penetrating the tooth surface. Because of their reduced viscosity when compared to composite resins, this effect may not be seen with sealants, and therefore,

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the use of plasma arc lights to polymerize sealants may not have an adverse effect on microleakage.

Several studies have suggested that an increase in microleakage may have an adverse effect on the effectiveness of the sealants[9–11], and therefore, it is essential that microleakage is minimized. Currently, there is, with the exception Stritikus and Owens' study[8], no literature on the use of the plasma arc curing light and sealants.

The aim of this study was to compare the degree of microleakage seen at the enamel–resin interface when sealants were polymerized with either a conventional quartz tungsten halogen or a plasma arc curing light source. The null hypothesis proposed is that, when used to polymerize a resin-based occlusal pit and fissure sealant, there is no significant difference to be found between a quartz tungsten halogen and a plasma arc curing light for sealant microleakage.

Materials and methods

A power calculation was carried out based on the data for Manzo's trial[12] (complete dye penetration failure data), which indicated that a minimum of 28 teeth for each group were required at 80% power to detect a 30% difference in microleakage at a probability of $P < 0.05$. Seventy cavitation- and restoration-free extracted teeth were collected, of which 25 were molars (excluding third molars) and 45 premolars. The teeth were collected in the Edinburgh Dental Institute, Edinburgh, UK, after written consent was obtained from the patients and/or their parents. Each tooth was stored in 0.12% thymol solution immediately after extraction, and was not allowed to dry out thereafter. They were stored for the same amount of time in thymol solution.

The teeth were divided into the control and test groups following computer randomization: control group (35 teeth) – sealants cured with a quartz tungsten halogen curing light (XL 3000, 3M Dental Products, St Paul, MN, USA) for 40 s; test group (35 teeth) – sealants cured with a plasma arc curing light (Ortho Lite, 3M Unitek Orthodontic Dental Products, St Paul, MN, USA) for 5 s.

Both curing light units were checked with a light intensity radiometer for adequate light emission intensity according to the manufacturers guidelines. The light emission intensity was measured for the quartz tungsten halogen and plasma arc curing lights in the range of 500 and 1600 mW cm^{-2}, respectively.

The sealant selected was Delton Type II Opaque (Dentsply, Weybridge, Surrey, UK), which is a light-cured sealant. The methodology for this microleakage trial followed that of Srinivasan *et al.*[13]. All teeth were rinsed for 30 s with an air–water spray. Next, the occlusal surfaces of all teeth were cleaned for 10 s with a dry rotary prophylaxis brush (Stoddard, Henry Schein, Gillingham, UK) on a slow-speed hand-piece without pumice or prophylaxis paste. The occlusal surface was then subjected to 30 s of rinsing with water again, and air-dried with compressed air for 10 s. The surface was etched with 38% volume ortho phosphoric acid for 60 s, as recommended by the sealant manufacturer, and then washed and dried for 10 s, respectively. The occlusal surfaces of the teeth were coated with the sealant using a small spoon excavator, and a periodontal probe was run through the sealant to allow the fissure to be completely covered with the sealant and to minimize the risk of any air bubbles. The sealant was then cured for the requisite time, selecting them alternatively from the test and control group, over a one-day period. The apices of the teeth were sealed with sticky wax and the tooth surface was varnished with nail varnish (Max Factor Diamond Hard, Proctor and Gamble, Weybridge, UK) to within 1 mm of the sealant. The varnish was allowed to dry, and then the teeth were immediately immersed in 2% aqueous solution of methylene blue, buffered to pH 7.00 for 48 h at room temperature and subsequently carefully rinsed in tap water.

Following this, the roots of the teeth were removed using a high-speed hand-piece and a diamond bur, and the crowns were encased in chemically cured polymethylmethacrylate acrylic resin into acrylic blocks. They were mounted in a sectioning machine (Isomet 1000, Buehler, Lake Bluff, IL, USA) and sectioned with a water-cooled diamond disc in the buccal-lingual plane to achieve two cuts resulting in three

Table 1. Scoring system of dye penetration.

Score	Dye penetration
0	No dye penetration
1	Dye penetration restricted to the outer half of the sealant
2	Dye penetration to the inner half of the sealant
3	Dye penetration into the depth of the underlying fissure
1c, 2c, 3c	Dye penetration due to carious area

sections. Therefore, four surfaces per tooth were available for scoring.

Examiner 1 (S.S.) received training from examiner 2 (E.R.), who had previous experience with microleakage scoring[14,15]. Subsequently, all four surfaces of the tooth sections were examined under $\times 15$ magnification with a light microscope (Olympus SZ60, Olympus, Tokyo, Japan), and scored independently and blind for microleakage. The assessment of microleakage was based on a scoring system suggested by Overbo and Raadal[16], which was modified by Srinivasan *et al.*[13] (Table 1). Subsequently, any disagreements were re-scored with both clinicians present. Having scored the four sections, the worst score of each of the four sections was used to indicate the microleakage of the individual tooth (tooth score).

Intra-examiner reproducibility for examiner 1 was calculated by repeat examination of all sections.

The tooth section and tooth score were entered on a Microsoft Excel spreadsheet and the statistical analyses was carried out using the SPSS computer program. The tooth score was taken as the principle unit of analyses because the individual tooth sections are not independent of each other.

The results of the statistics are detailed in the results.

Results

During the sectioning process, one tooth in the test group was damaged, and therefore, lost from the study sample. Hence, 69 tooth scores were included in the results (control group $n = 35$ and test group $n = 34$), and in turn, 276 tooth sections were analysed.

Dye penetration, and therefore, microleakage, was evident in 69.6% ($n = 95$) and 65.7% ($n = 92$) of the tooth sections in the test and control groups, respectively. Table 2 presents the microleakage scores of the 276 tooth sections. Statistical analyses of these scores with a Mann–Whitney U-test ($P = 0.68$) resulted in no significant difference between the two groups.

When the worst score for each tooth was used for statistical analysis, again there was no significant difference between the two groups (Table 3). The scores were compared with a Mann–Whitney U-test ($P = 0.32$).

Table 4 compares the results of the tooth scores with no microleakage (score 0) with

Table 2. Microleakage of tooth sections.

	Score [n (%)]			
Curing light	0	1	2	3
Quartz-tungsten-halogen ($n = 140$)	48 (34.3)	28 (20.0)	16 (11.4)	48 (34.3)
Plasma arc ($n = 135$)	41 (30.4)	35 (25.9)	10 (6.7)	50 (37.0)
Total sections ($n = 276$)	89 (32.4)	63 (22.9)	26 (9.1)	98 (35.6)

Table 3. Microleakage of teeth (worst score per tooth).

	Score [n (%)]			
Curing light	0	1	2	3
Quartz-tungsten-halogen ($n = 35$)	6 (17.1)	7 (20.0)	2 (5.7)	20 (57.1)
Plasma arc ($n = 34$)	1 (2.9)	9 (26.5)	2 (5.9)	22 (64.7)
Total teeth ($n = 69$)	7 (10.1)	16 (23.2)	4 (5.8)	42 (60.9)

Table 4. Distribution of tooth level scores with and without microleakage.

Curing light	Score [n (%)] 0 (no microleakage)	1–3 (microleakage)
Quartz-tungsten-halogen ($n = 35$)	6 (17.14)	29 (82.86)
Plasma arc ($n = 34$)	1 (2.94)	33 (97.06)
Total ($n = 69$)	7 (10.1)	62 (89.9)

those where microleakage was present (scores 1, 2 and 3). Out of the 69 teeth, one tooth in the test group presented with no microleakage in contrast to six teeth in the control group. Statistical analysis of these results with a Fisher's exact test showed no significant difference between the control and test groups ($P = 0.106$).

Inter- and intra-examiner reproducibility was analysed with the kappa statistic and interpreted according to the Landis and Koch's six-point scale[17]. The intra-examiner kappa values for examiner 1 were 0.86 and 0.91 for the tooth sections and the tooth score, respectively. The interexaminer agreement between the two examiners was 0.55 for the readings of the tooth sections. A Wilcoxon signed-ranks test demonstrated a significant difference in readings between the two examiners in the scoring of the 276 sections, with examiner 2 scoring higher than examiner 1 ($P = 0.010$). The overall agreement on the tooth score, however, presented as a kappa value 0.56 for this analyses.

During microleakage assessment, it became evident that 15 teeth had occlusal dentinal caries. These teeth were evenly distributed across the groups, with seven belonging to the test group and eight to the control group. On reviewing the degree of dye penetration of all teeth, however, the presence of dentinal caries did not appear to have affected the microleakage scores.

Discussion

The benefits of using plasma arc curing lights, with their shorter curing times, in the management of children are potentially great provided there are no adverse effects. A reduction in operating time is of obvious benefit to patient and operator alike, but is especially beneficial to anxious, uncooperative patients. Uncooperative patients tend to exhibit a reduced attention span, which limits the available operating time in turn[18].

This *in vitro* study demonstrated that microleakage was evident in the test group as well as the control group. Hence, it can be assumed that polymerization shrinkage took place in both groups. These findings are comparable to previous microleakage studies with composite resins and sealants[8,16]. Furthermore, this study demonstrated no significant difference in the degree of microleakage of sealants polymerized by a conventional quartz tungsten halogen curing light compared to a plasma arc curing light. Therefore, it would appear that the rapid cure by the plasma arc light did not have an adverse affect on the microleakage of the sealant. The majority of studies investigating the effectiveness of plasma arc curing lights have dealt mainly with composite resins, compomers or resin-modified glass-ionomers, and not sealants. In addition to composite resin, however, Stritikus and Owens[8] included sealants in their dye penetration microleakage study. While polymerization of composite resin with a plasma arc unit resulted in an increase in dye penetration along the resin–tooth surface interface, when compared to the results obtained with a quartz tungsten halogen curing light, neither light source appeared to have a significant effect on the microleakage scores of the sealant groups. The incidence of dye penetration reported by Stritikus and Owens[8], however, was much lower than that found in this study, with no leakage and eight of 22 sections demonstrating dye penetration in the test and control groups, respectively. One reason for this could be that the teeth examined by Stritikus and Owens[8] were only immersed in the dye for 4 h compared to the 48 h of this study. In addition, the teeth were only sectioned once, which may have led to an underestimation of dye penetration. While the incidence of dye penetration varies between the two studies, however, both found no significant difference in the microleakage between the two curing lights when used with sealants. Possible reasons why the sealants may have less microleakage than composite resins are that the latter have a higher filler load compared to an unfilled sealant, and hence, will generate a higher stress build-up at the tooth–restorative material interface. These differences in stress generation between both materials could contribute to the reason why fissure sealants show more favourable results regarding microleakage scores. Consideration was given to thermocycling the samples. The clinical significance of thermocycling has been challenged, particularly when specimens are subjected to temperature variations for periods longer than several seconds. Wendt *et al.*[19] evaluated thermocycling on dye penetration analysis of microleakage associated with composites using differing cycles and no thermocycling, and concluded that thermocycling had no significant effect. These findings were confirmed in a study on sealants by Xalabarde *et al.*[20] Therefore, it was decided that there was no benefit to be gained by adding thermocycling to the study design.

A number of studies have demonstrated the efficient use of plasma arc curing lights for the cementation of orthodontic brackets and lingual retainers[12,21]. Additionally, surface hardness of orthodontic adhesives for lingual retainers appears to be unaffected when cured with either a conventional or plasma curing light.

The results of this study illustrate that dye penetration presented in 69.9% and 65.7% of the tooth samples in the test and control groups, respectively. These findings are in agreement to other work[10]. The clinical significance of microleakage is still uncertain, although it is believed that a certain degree of microleakage occurs *in vivo*. The penetration of dye suggests that the sealant is lacking a perfect seal at the tooth–sealant interface. This in turn is believed to be a flaw in the quality of the sealant[9–11]. If microleakage does occur in most sealed teeth but the sealants exhibit long retention rates, is the measurement of microleakage an appropriate method to assess the effectiveness of a material?

The interexaminer kappa values for the scoring of the tooth sections showed a reproducibility of moderate agreement (0.55), with examiner 2 scoring systematically higher for the examination of tooth sections than examiner 1. This could be a result of several causes, including difficulty determining the deepest point of penetration since dye penetration was not uniformly present along the sealant/tooth surface. This difficulty was noted by Raskin *et al.*[22] in their literature review on the reliability of microleakage scoring. This level of interexaminer reproducibility is unlikely to have affected the validity of the results, however, since differences in scorings were reviewed by both examiners and agreement was reached.

Whilst the inclusion criteria included cavitation- and restoration-free teeth, it became evident on sectioning that 15 teeth had evidence of occlusal dentinal caries. These findings were not dissimilar to those of Srinivasan *et al.*[13], who investigated the microleakage of repaired sealants. In this study, eight of the 15 carious teeth belonged to the control group and the remaining seven were in the test group. Therefore, the incidence of carious teeth affected both groups similarly. Furthermore, investigation of the microleakage scoring of these samples showed that the degree of microleakage was not affected by the presence of caries since the distribution of the scores was comparable to the results of the teeth with no caries. Therefore, it would appear that the presence of noncavitated dentinal caries did not influence the microleakage scores in this study.

Whilst the author found no adverse effect on the microleakage scoring of the sealants polymerized with the plasma arc unit, other studies looking at the polymerization of composite resin with these units have identified other concerns, such as temperature generation and incomplete polymerization. These have reported problems with temperature generation resulting in the potential risk of pulpal injury when using such a high-intensity light in a cavity[2,5]. Ozturk *et al.*[23] concluded that plasma arc units should not be utilized in deep cavities where dentine thickness is less than 1 mm. It is unlikely that thermal damage to the pulp will occur when placing sealants, however, since the thickness of the enamel and dentine will protect the pulp. In addition, incomplete polymerization of composite resins with plasma arc curing lights has been demonstrated in some studies[6,7,24,25]. Incomplete polymerization can be associated with an insufficient irradiation time causing a reduction in monomer conversion and polymerization of the material, and insufficient energy output of the curing light. A high-intensity output plasma arc curing light allows for a reduction in curing time. Because of their short, high-intensity irradiation time, however, insufficient irradiation time may lead to incomplete monomer conversion and polymerization of composite resins, which subsequently might exhibit a shorter durability of the material. This has been demonstrated in an *in vitro* study by Millar and Nicholson[25], where composite resins cured with plasma arc curing lights showed greater water solubility in contrast to materials cured with conventional light units. This problem may not be an issue when polymerizing sealants with a plasma arc light source, since the thickness of the sealant is substantially reduced when compared to composite resin restorations, and therefore, the required depth of cure is much lower. Further areas of research with plasma arc lights and sealant placement should involve the effects of temperature generation on pulp, a surface hardness test, solubility tests and long-term retention studies *in vivo*.

What this paper adds

- This paper adds to the literature results of an *in vitro* study investigating whether the microleakage of a resin-based sealant is influenced by the polymerisation with either a conventional quartz tungsten halogen or a plasma arc curing light.

Why this paper is important to paediatric dentists

- This study demonstrated no significant difference in the degree of microleakage of sealants polymerised by either curing lights.
- The benefits of using a plasma arc curing light in fissure sealant application and the management of children could be potentially great due to their shorter irradiation time.

Conclusion

This *in vitro* study demonstrated no difference in the degree of microleakage of sealants polymerized by a conventional quartz tungsten halogen curing light when compared to a plasma arc curing light. Therefore, the null hypothesis was accepted.

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