New Trends and Issues Proceedings on Advances in Pure and Applied Sciences

Issue 9, (2017) 58-65

www.propaas.eu
ISSN: 2547-880X

Selected Paper of Selected Paper of 3rd Global Conference on Material Sciences (GC-MAS-2017), 28-30 August 2017 Bahcesehir University Besiktas Campus, Istanbul, Turkey

Silorane versus methacrylate composites: A comparative study of the micro-leakage

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Suggested Citation:

Fejjeri-Mezghanni, M., Jaafoura, S., Kikly, A. & Sahtout, S. (2017). Silorane versus methacrylate composites: a comparative study of the micro-leakage. *New Trends and Issues Proceedings on Advances in Pure and Applied Sciences*. 9, 58–65. [Online]. Available from: www.propaas.eu

Selection and peer review under responsibility of Assist. Prof. Dr. Engin Baysen, Near East University, Nicosia, Cpyrus.

Abstract

This *in vitro* study aimed to evaluate the micro-leakage at the occlusal and cervical margins in class II cavities in permanent molars restored with a low shrink silorane resin composite (Filtek P90) applied with or without etching and two methacrylate-based composite resins (valux plus and Amelogen® plus). Two standardised class II box cavities were prepared in proximal surfaces of 60 sound non-fluorotic permanent molars which were divided into three groups of 20 each according to the type of composite. Group I: silorane-based composite (Filtek P90) in the mesial cavity and methacrylate-based micro-hybrid composite (Adper single bond 2/valux plus) in the distal cavity, Group II: silorane-based composite in the mesial cavity and silorane-based composite with previous etching in the distal cavity, and Group III: silorane-based composite in the mesial cavity and methacrylate-based micro-hybrid composite (PQ1 /Amelogen plus) in the distal cavity. The samples underwent an artificial aging with thermocycling. Root apices were sealed with transparent orthodontic resin and coated with transparent

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varnish except 1 mm around the restoration. The specimens were immersed in 1% methylene blue solution at room temperature for 48 hour. The samples were sectioned longitudinally in the mesiodistal direction and evaluated under a stereomicroscope at 20X. Scoring was done according to the depth of methylene blue penetration into the cavities. Statistical analysis of the data was performed using SPSS 17.0 software. Silorane-based composite resin showed less micro-leakage than the methacrylate-based composites. Etching improved the sealing ability of silorane restorations. Silorane-based composite preceded by etching had less micro-leakage among the other materials used in this *in vitro* study.

Keywords: Silorane, methacrylate based composite, sealing, micro-leakage, class II cavity.

1. Introduction

Posterior restorations have to restore the form and the function of the tooth but also to ensure the marginal sealing. The transition between the restorative material and the dental hard tissue must be continuous in order to increase the survival probability of the restoration. Composite materials have greatly improved since their introduction to the dental profession. However, a number of problems are associated with the use of dental composites. The polymerisation shrinkage still remains the major problem [1]. Polymerisation shrinkage creates contraction stresses in the resin composite restoration and internal stress and deformation in the surrounding tooth structure [2]. Consequently, post-operative sensitivity, micro-leakage, marginal discoloration and gap formation may be encountered.

Numerous attempts to reduce the shrinkage by changing the nature of the resin were achieved by the development of silorane resin. The low-shrinking Filtek P90 LS restorative is based on the new ring-opening silorane chemistry. Siloranes are a totally new class of compounds for the use in dentistry. The name 'silorane' derives from its chemical building blocks siloxanes and oxiranes [3]. The combination of these two chemical building blocks provides the biocompatible, hydrophobic and low-shrinking silorane-base of Filtek P90 LS Low Shrink posterior restorative.

The marginal adaptation was significantly influenced by composite type, adhesive system and thermo-mechanical loading. When evaluating enamel and dentin margins separately, a distinct behaviour was observed between the silorane and methacrylate composite with respect to both tooth substrates. Marginal adaptation on enamel was not affected by the composites tested on contrary dentinal margins, where highly affected by the type of composite [4]. Therefore, we proposed to add a step of etching prior to the application of the silorane adhesive system.

The thermo-mechanical loading allows the weakening of the adhesive resin interface. Studies suggest that thermocycling could accelerate deterioration of the dentin/restoration interface [5].

The aim of this study is to compare the micro-leakage of silorane-based composite resin applied with or without etching and two methacrylate-based composite resins in Class II cavities at the occlusal and cervical margins by means of dye penetration after thermocycling. The research hypothesis was that no difference in micro-leakage of class II cavities restored would be observed with different resin systems.

2. Materials and Methods

Sixty human maxilary and mandibular permanent molars freshly extracted, were stored in water up to the operating procedures. The teeth were scaled for surface debridement and cleaned with water, polished with rotative brush and pumice in order to get rid of tartar, soft tissues and other debris.

All teeth were examined under a stereomicroscope in order to verify that they are free from caries, fluorosis or any structural alteration. Each tooth was numbered.

2.1. Materials

Three micro-hybrid composite resins were used in this study.

- Silorane-based composite Filtek P90 in combination with a two-step self-etch adhesive system (3M EPSE)
- Valux Plus (a methacrylate-based composite) with Adper Single bond 2 (3M EPSE)
- Amelogen® plus (a methacrylate-based composite) with PQ1 (Ultradent)

2.2. Methods

2.2.1. Cavity preparation

Two amelo-dentinal cavities (box): one at the mesial surface and the other at the distal surface, were prepared on each tooth. The cervical margin was located 1 mm coronaly to the cementoenamel junction, so that all the margins were located within enamel. Each cavity presented the following dimensions: mesio-distal width (2 mm), opening of the occlusal side (2mm) and cervical width (3mm). Cavities were prepared using a tungsten carbide cylindrical burr (010 Dentsply) under irrigation. The measurements were verified with a periodontal probe and the cervical angles were rounded. Each cavity was examined under a stereo microscope (Zeiss).

2.2.2. Cavities obturation

The teeth were randomly divided into three groups of 20 teeth for each group:

- Group I: The mesial cavities were restored by the silorane according to the manufacturer's instructions, and the distal cavities were restored by the Adper single bond 2 (3M) / valux plus.
- Group II: The mesial cavities were restored by the silorane according to the manufacturer's instructions, and the distal cavities were restored by the silorane with previous etching.
- Group III: The mesial cavities were restored by the silorane according to the manufacturer's instructions, and the distal cavities were restored by the PQ1/ Amelogen plus.

The cavities were sealed with the corresponding materials strictly following the protocols recommended by the manufacturer for each product.

2.2.3. Preparation of teeth for thermocycling

The root apices were sealed with a transparent orthodontic resin. Two layers of transparent nail varnish were applied on each crown leaving 1 mm around the restorations. The teeth were placed in a 0.9% KCl solution.

2.2.4. Thermocycling

The thermocycling technique proposed by Teplitsky et al. was selected for this study.

Two cycles of temperature simulated the thermal variations observed in the oral cavity: a daily cycle included 45 minutes at 6°C, followed by 45 minutes at 60°C and repeated four times. Thereafter, the teeth were kept for 16 hours at room temperature.

This daily cycle was repeated for five consecutive days allowing a total of 15 hours of exposure at each extreme temperature.

2.2.5. Methylene blue infiltration

A second application of the two layers of varnish on each crown was made. The crowns of the teeth were subsequently immersed in 1% methylene blue solution for 48 hours at room temperature. After removing the solution, the teeth were dried in the open air and cleaned with abrasive discs to remove any trace of dye.

The roots of the teeth were immersed into blocks of orthodontic resin and then labelled.

Each tooth was cut longitudinally at the centre of the two restorations, in the mesio-distal direction, using a water-cooled low-speed precision saw Isomet® chainsaw (Buehler).

The cutting speed was set at 7 rpm and the diamonded blade (disc) had a thickness of 0.4 mm. After separating the roots of each tooth from the crown, two sections were obtained, a vestibular and a lingual one.

2.2.6. Stereomicroscope observation

The level, intensity and importance of the infiltration of methylene blue at the tooth-material interface were assessed in each cavity and for each product.

The degrees of penetration of methylene blue in each restoration were noted separately for the cervical wall (cervical enamel) and the occlusal wall (occlusal enamel), according to the following scores (Table1).

Table 1. The scores of methylene blue penetration

Scores	Infiltration
Score 0	Absence of infiltration
Score 1	Infiltration less than half of the enamel thickness
Score 2	Infiltration more than half of the enamel thickness
Score 3	Infiltration of the enamel and the dentin
Score 4	Infiltration beyond the cavity

The observation was carried out separately by two observers.
The penetration of the dye was noted separately for each face of the section: buccal face and lingual face.

2.2.7. Statistical analysis

Statistical analysis was carried out using data processing software: SPSS statistics 17.0.

Microsoft Office Excel 2007 software was also used to establish some numeric functions and descriptive graphics.

One-factor variance analysis (ANOVA) was used to determine the statistically significant differences in the sealing of the four composite resin systems tested. The *T*-test for independent samples was used for comparison of the means between the different systems two to two, in order to check the influence of the tooth factor. The mean difference is considered significant at the 0.05 level.

3. Results

For each product, we evaluated the level of the infiltration at the various cavities. The results obtained were counted according to the different scores (Table 2).

Table 2. The level of the infiltration at the various groups

	Score 0	Score 1	Score2	Score3	Score4	Total
Silorane according to manufacturer's instructions	45	14	6	2	9	76
Group 1	20	30	8	3	7	68
Group 2	21	3	0	1	7	32
Group 3	86	47	14	6	23	176
Total						
Silorane with previous etching	58	7	1	1	8	75
PQ1/Amelogen plus	27	5	1	2	1	36
Single bond2/Valux plus	60	9	0	7	4	80

The one-way ANOVA showed that the scores varied significantly (p = 0.004) between the four composite resin systems: Silorane according to the manufacturer's instructions, silorane with previous etching, PQ1 / Amelogen plus and Single Bond2 / Valux plus. The Silorane used according to manufacturer's instructions showed the average of the lowest sealing scores compared to the others systems.

A descending ranking can be attributed as follows: Silorane with etching, PQ1 / Amelogen plus, Single Bond2 / Valux plus and then Silorane according to the manufacturer's instructions.

The silorane as well as the Silorane with etching exhibited a better distribution of the scores over the average.

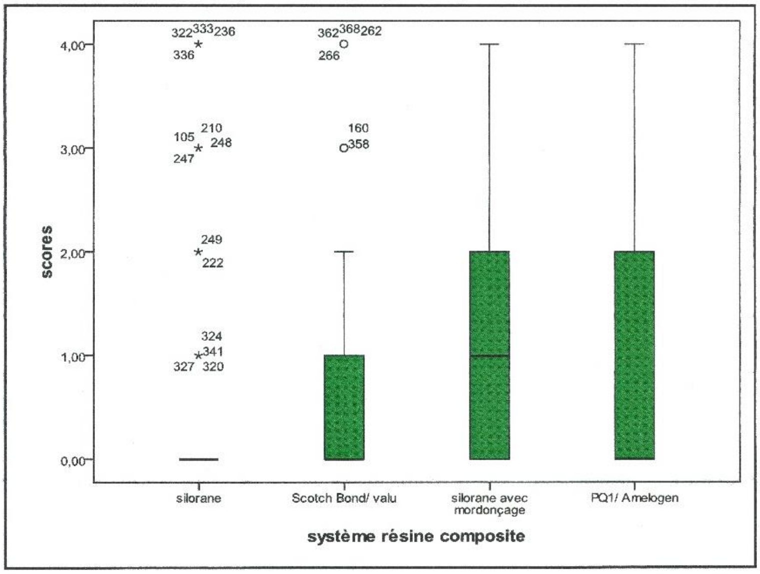

Figure 1. Box plot showing the variation of the sealing scores between the different materials and the distribution around the mean

3.1. T-test for paired samples

The difference in the sealing ability between silorane and single bond2 / Valux plus (3M) was not statistically significant (p = 0.105). The difference in the sealing ability between silorane and silorane with previous etching was statistically significant (p = 0.011). The difference in the sealing ability between silorane and PQ1 / Amelogen plus (ultradent) was not statistically significant (p = 0.136).

4. Discussion

Micro-leakage has been determined by numerous quantitative and qualitative methods which include the use of dyes, scanning electron microscopy, electrochemical technique, nanotechnology and reversible radioactive adsorption [6]–[11].

The dye penetration test was used in our study to evaluate micro-leakage. It is a widely used and generally preferred method because it is readily available, inexpensive, simple to use and non-toxic [12].

The use of the *in vitro* dye penetration technique is considered as the gold standard for micro-leakage assessment rather than the techniques used in the oral cavity [13]. Saliva proteins can seal the marginal space of a resin restoration in the oral cavity. In addition, dye penetration appears to be better than that of bacteria and its products. This may be the main reason, dye penetration is considered as a better way to test micro-filtration. The penetration of the dye depends on several factors such as the size of the molecules, the concentration of the dye and the available surface area. In our study, a low molecular-weighted methylene blue was used.

Thermocycling of specimens in hot–cold water baths simulates the thermal stresses of the oral environment. The thermocycling process was used to determine whether artificial aging results in significant micro-leakage with either material.

According to Veronezi *et al*., the difference in thermal expansion between the material and the dental structure causes an alternating increase and decrease in the space between the material and the dental structure, which may provide an increase in marginal micro-leakage in the restoration of the composite resin [15]. Although every effort is made to reproduce the *in vivo* conditions, studies such as Eakle's [16] and Pereira *et al*. [24] showed that there is no difference in the micro-leakage between the groups with or without thermocycling, whatever the material used (silorane or composite methacrylate).

The comparison of the results of different studies is critical, since there are no standard norms for experimental parameters, such as the concentration of the storage solution, the type and duration of thermocycling, the criteria for observation. In addition, there is a lack of correlation between *in vivo* and *in vitro* studies since *in vivo* studies have some conditions that could hardly be replicated *in vitro*. Nevertheless, the results of *in vivo* studies are often less negative than *in vivo* studies. *In vivo* testing is essential for developmental purposes. Thus, *in vitro* results should be considered as the theoretical level of maximum micro-leakage that can be expected in *in vivo*.

Conventional methacrylate-based composite resins do not provide a completely hermetic seal, and numerous studies have demonstrated that liquid infiltration occurs between the restoration and the prepared dental surface [17].

All the tested groups showed dye penetration at the restoration-tooth interfaces, which can be attributed to the dimensional changes resulting from the polymerisation shrinkage of the resins and the differences in coefficients of thermal expansion between the teeth and the restorative materials. These changes result in internal forces in the composite resin materials, causing hiatus formation in the tooth restoration interface; therefore, micro-leakage occurs [18]. Clinically, the amount of marginal micro-leakage was important because it could lead to post-operative sensitivity, secondary caries, pain and even inflammation of the dental pulp [19], [20].

The silorane with etching gave a better seal than that observed with the silorane according to the operating protocol of the manufacturer.

The greater micro-leakage of P90 at the margin may be explained by the characteristics of the adhesive system in silorane-based composites. P90 primer has a pH of 2.7 that causes mild etching and slight demineralisation of tooth structure [21].

3-Step rinse etch adhesives are known as conventional adhesives in terms of durability of adhesions. Seeking to simplify the adhesive application steps, durability of the adhesion decreased and the two-step rinse-etching adhesives remained close to the conventional adhesives.

Self-etching adhesives offer higher and more predictable bond strength to dentin and are therefore recommended for direct composite resins, especially when they are mainly supported by dentin [22]. In this study, two step self-etching adhesives were evaluated.

The Filtek Silorane's low-polymerisation shrinkage exhibited a better marginal adaptation in class I restorations in comparison with methacrylate composite [23].

In the present study, although the silorane exhibits low micro-leakage scores relative to the tested methacrylate resins, according to the results of the studies in [24] and [25]. It was not able to completely prevent micro-leakage. However, a study in [26] showed that the large class II cavities restored with a silorane composite resin did not show micro-leakage and the margins were completely sealed.

5. Conclusion

Within limitations of this *in vitro* study, Silorane-based composite resin preceded by etching had less micro-leakage among the other materials used in this *in vitro* study.

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