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ORIGINAL ARTICLE

Analysis of microleakage and marginal gap presented by new polymeric systems in class V restorations: An *in vitro* study

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Abstract *Objective:* Evaluating the contraction of polymerization effect of silorane-based composite on dental interface in enamel.

Materials and Methods: Eighty class V cavities were confectioned in forty extracted molar teeth and restored with different combinations of resinous-based and bond system. They were divided into the following groups: (G1) three-step etch-and-rinse adhesive system and methacrylate-based resin, (G2) two-step etch-and-rinse adhesive system and methacrylate-based resin, (G3) Filtek P-90 self-conditioning adhesive system and methacrylate-based resin, (G4) Adper SE Plus self-conditioning adhesive system and methacrylate-based resin, (G5) three-step etch-and-rinse adhesive system and silorane-based resin, (G6) two-step etch-and-rinse adhesive system and silorane-based resin, (G7) Filtek P-90 self-conditioning adhesive system and silorane-based resin, (G8) Adper SE Plus self-conditioning adhesive system and silorane-based resin.

Results: Group 7 showed lower marginal leakage when compared with all other groups ($p = 0.001$).

Conclusions: The results allows suggesting that silorane-based resinous system is adequate to promote more satisfactory marginal sealing than any other combination, since the system is combined with its own bond system.

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1. Introduction

Introduction of photo activated composites as restorative material in the middle of last century by Bowen was a revolution in restorative dentistry (Padovani et al., 2015). High esthetical potential, stability in oral environment, facility in the use when compared to other restorative materials and their constant improvement in mechanical properties made these composites the most used materials in current restorative dentistry (Angeletaki et al., 2016; Khoroushi and Ehteshami, 2016).

Dentistry composites are basically constituted by a multifunctional long chain monomer, and when they are polymerized, result in three-dimensional network of cross-links: this process is called monomer degree of conversion (Khoroushi and Ehteshami, 2016). Initially the composites were chemically polymerized, which did not allow control on the work time. The search for more control on the work time to obtain greater monomer conversion and a possible guarantee of best restoration, which could be more durable, encouraged new photo activated composites development. However, this process does not minimize an inherent problem to composites: polymerization contraction (Angeletaki et al., 2016).

This contraction generates a clinical inconvenient: gaps in the interface tooth/restoration. These gaps occur because the forces generated on the material body which are transmitted to the interface tooth/restoration, compromising the bond strength and marginal integrity. Consequently, the restoration becomes more susceptible to leakage, secondary caries and postoperative sensitivity (Wang and Chiang, 2016; Ferracane and Hilton, 2016).

Microleakage is a result of polymerization contraction and from the difference between the coefficient of thermal expansion of dental structure and restorative material, which might cause bond failure (Wang and Chiang, 2016; Chandrasekhar et al., 2017). Besides, marginal microleakage has been the cause of several failures in restorative dentistry, because it accelerates the material deterioration, what makes restorative procedure life shorter and leading to irreversible damage to the dental structure integrity, marginal discoloration, secondary caries, postoperative sensitivity, pulp pathologies and break restorations (Irie et al., 2014).

Lately, a new monomer system has been used as substitute to current methacrylate, the silorane. It was characterized by low polymerization contraction, and it is obtained by oxirane and silorane molecules reaction (Porto et al., 2013). This restorative system is formed by combination of conventional methacrylate, which activates the initial polymerization, and the silorane, which opens itself in a cationic ring insensitive to oxygen. Thereunto, the photo-activation initiates the molecules opening, overcoming the maximum clinical inconvenient generated by polymerization contraction of current systems. Photo-initiator used in this system is still camphor Quinone, and the current methods of dry may be used for this composite (Irie et al., 2014; Porto et al., 2013; Santos et al., 2017).

Silorane is stable and insoluble to biological fluids used to simulate clinical conditions, presenting mechanical properties similar to conventional methacrylate applied, encouraging its clinical use (Porto et al., 2013). Besides, silorane has shown good characteristics of biocompatibility and hydrophobicity. These characteristics indicate it as excellent alternative to well established methacrylate-based materials (Karaman et al., 2017).

Hence, the aim of this study was at evaluating microleakage and the formation of marginal gap presented by restorative composites methacrylate-based and silorane, and evaluate the interaction between bond systems in both formulations. A null hypothesis set is the use of silorane-based composite and different adhesive systems have no effect on microleakage and marginal gap in class V restorations.

2. Materials and methods

Forty freshly human permanent molars extracted for orthodontic reasons, caries-free and with similar dimensions and anatomic structure were selected and stored in 0.9% physiologic saline with 1% thymol at room temperature (Galil, 1975). The teeth were examined under x4 magnification to remove remnants of periodontal tissue, and periapical radiographs were obtained to verify fractures absence and internal root resorption. Approval was obtained from the local ethical committee at the University of Southern Santa Catarina, number 609.507.

Class V standardized cavities were performed in buccal and lingual faces of teeth. These cavities were carried out in quadrangular shape in 3.0 mm width, 3.0 mm length and 2.0 mm depth using a Diamond bur (#2143, KG Sorensen, Brazil) in high rotation and under abundant air/water cooling. Cavities were concluded with diamond bur in the same diameter, but in lower granulation (#2143F, KG Sorensen, Brazil), also under cooling. Cavities were verified in their dimensions using a precision caliper rule (Digimatic, Mitutoyo Corp, Japan). All the 40 teeth were divided into eight experimental groups. Four of them were restored using methacrylate-based resin (Filtek Z250, 3M ESPE, USA), and in four using silorane-based restorative material (Filtek P-90, 3M ESPE, USA).

To perform restorative procedures, four bond systems were used: (1) Adper Scotchbond Multipurpose (three-step etch-and-rinse adhesive system, 3M ESPE), (2) Adper Single Bond (two-step etch-and-rinse adhesive system, 3M ESPE), (3) Filtek P-90 (self-conditioning adhesive system developed for silorane-based restorative system, 3M ESPE), (4) Adper SE Plus (self-conditioning adhesive system developed for methacrylate-based composites, 3M ESPE); and two restorative systems: (1) Filtek Z250 (methacrylate-based restorative system, Bis GMA, 3M ESPE), (2) Filtek P-90 (silorane-based restorative system, 3M ESPE). Total-etch conditioning was performed using 37% phosphoric acid according to manufacturer instructions when self-conditioning adhesive was not used.

The teeth were divided into 8 groups with 5 specimens with 2 restorations per tooth: (G1) three-step etch-and-rinse adhesive system and methacrylate-based resin, (G2) two-step etch-and-rinse adhesive system and methacrylate-based resin, (G3) Filtek P-90 self-conditioning adhesive system and methacrylate-based resin, (G4) Adper SE Plus self-conditioning adhesive system and methacrylate-based resin, (G5) three-step etch-and-rinse adhesive system and silorane-based resin, (G6) two-step etch-and-rinse adhesive system and silorane-based resin, (G7) Filtek P-90 self-conditioning adhesive system and silorane-based resin, (G8) Adper SE Plus self-conditioning adhesive system and silorane-based resin.

After preparing cavities, enamel acid conditioning was performed for 30 s, and next dentine acid conditioning for 15 s, except self-conditioning group, and washed using air spray and water about 10 s. Humidity excess was dried using cotton without air drying. Bond agents were applied in a single layer and they were photo-activated during 10 s with curing light in 9 mm diameter (Valo, Ultradent, USA). The activation energy was controlled in regular intervals in order to ensure a minimum value of 1400 mW/cm^2. The distance between the light source and specimens was maintained from 1 to 2 mm. Resins were applied in different groups using the incremental technique with insertion of three oblique increments, and the third increment filled the cavity. Then, they were polymerized for 20 s with the same device and same polymerization way used in adhesive. Restorations were concluded with finishing bur (KG Sorensen, Brazil) in order to remove excesses, followed by sof-lex discs (3M ESPE, USA).

After finishing, all the specimens were embedded in 1% methylene blue (Prolabo, France) during 48 h. The evaluation of coloring penetration in the interfaces was carried out after washing the specimens in distilled water and longitudinally sectioned in lingual direction using double face diamond disc (Microdont, Brazil) linked to a low rotation motor. Microleakage analysis was performed using stereo microscope (model S2H, Olympus Corp, Japan) by only one examiner to avoid bias. Evaluation criterion was the distribution of scores from 0 to 4: (0) microleakage absence, (1) leakage until half surrounding wall, (2) leakage in the whole surrounding wall, (3) leakage in surrounding wall and axial one, (4) leakage in surrounding wall and axial towards the pulp. For analysis and measurement of marginal gap, scanning electron microscopy (JSM 5600 LV, JEOL, Japan) was used after metalize surfaces with thin gold layer.

Obtained results were statistically analyzed by Two-way Analysis of Variance test (ANOVA) ($P < 0.05$), and as there was statistically significant difference, the Tukey Test was used for multiple comparisons ($P < 0.05$).

3. Results

The data were submitted to statistical analysis by Kruskall-Wallis Test in order to find differences among the groups. As there were differences, Tukey Test was used for multiple comparisons. Kruskall-Wallis Test results and the differences among groups are presented in Table 1.

Differences in average values among treated groups are greater than expected (Fig. 1), and there is a statistically significant difference ($P < 0.001$). Lower marginal microleakage scores were found with Filtek P-90 self-conditioning adhesive system combined with silorane-based resin (G7), with average 0.5 of microleakage and statistically significant difference when compared with all other groups, excepted group 6 ($P < 0.05$). G6 group did not present statistical difference ($P < 0.05$) when compared with any group. Other combinations among adhesives and materials did not present statistically significant difference ($P > 0.05$).

4. Discussion

Null hypothesis states the use of silorane-based composite and different adhesive systems have no effect on microleakage and marginal gap in class V restorations was rejected.

The results from this study reveal silorane-based resin, when combined with bond system (Filtek P-90 self-conditioning adhesive), provides a good marginal sealing, as proved by lower marginal microleakage values found in group G7. The polymerization with opening ring in Filtek silorane occurs through cleavage and structure opening, which provides a gain in space and may neutralize or minimize the volume loss during the polymerization, explaining the result found for G7 (Bacchi et al., 2015). Besides, loading levels for Filtek Silorane (53% vol.) are lower than Z250 composite resin (60% vol.). Providing a better material flow, developing low stress in curing. Ferracane et al. (2017) reports the stress accumulation depends on kinetics reaction in the polymerization, and an insufficient conversion degree from monomers in polymers was described for Filtek silorane related to Filtek Z250 (Hussain et al., 2017). These factors may lead to a low stress in silorane-based composite. Besides, this composite shows a slower polymerization time, allowing enough time to relax the stress through the material flow (Dickson et al., 2014; Bicalho et al., 2015).

This study obtained significant results, better when a particular adhesive system for silorane-based resin was used, observed by statistically significant differences found in the groups G3, G5, G7 and G8, differently from previous study that found similar results with silorane adhesive system combined with silorane and methacrylate-based restorative material (Ende et al., 2010). The result is due to the chemical characteristics of material, which contains a bi-functional

Table 1 Microleakage scores obtained in each group and median score.

Group	n	Microleakage score					Median	SD
		0	1	2	3	4		
1^{AC}	10	5	0	4	11	0	3	1.24
2^{AC}	10	9	4	5	2	0	1	1.04
3^{AC}	10	3	2	9	6	0	2	0.99
4^{AC}	10	5	4	9	2	0	2	0.96
5^{AC}	10	3	2	6	9	0	2	1.07
6^{BC}	10	9	6	5	0	0	1	0.81
7^{B}	10	10	8	2	0	0	0.5	0.66
8^{AC}	10	2	3	7	8	0	3	0.86

Groups followed by the same letter are not significantly different ($p > 0.05$).

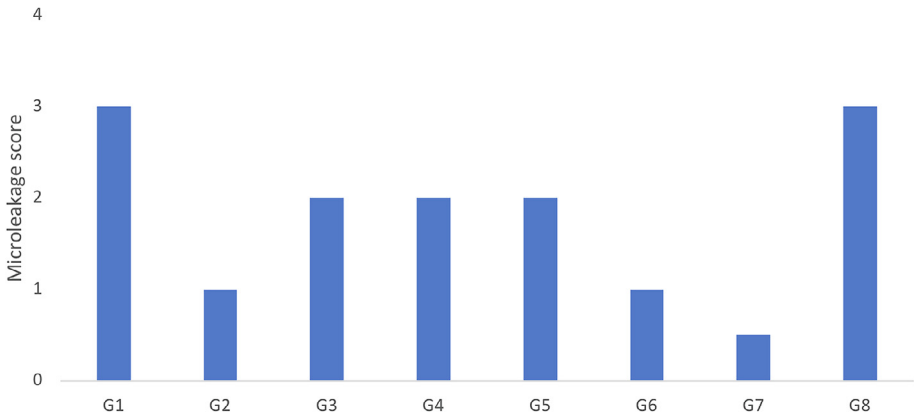

Fig. 1 Microleakage scores (median) obtained in each group.

monomers chain and hydrophobic monomers able to match in a better way with silorane resin, whose hydrophobicity is higher than conventional methacrylate because of the silorane in its structure. Furthermore, a higher formation capacity of hybrid layer of silorane adhesive system, especially when it is compared to self-conditioning adhesives used with conventional methacrylate-based resins, might have influence in better results in P-90 adhesive use (Van Meerbeek and Frankenberger, 2016; Masarwa et al., 2016).

Nowadays, several generation of dentin adhesives have been developed, and a new concept of adhesion is introduced in order to eliminate the stage of acid conditioning of the surface to be treated (Campos et al., 2018). This study compared different adhesive systems: three-, two-step and self-conditioning. Better results were found in Filtek P-90 self-conditioning and the two-step adhesive system. The self-conditioning adhesive probably obtained good results due to the elimination of acid conditioning rinsing step, and there was not complete elimination of smear layer, consequently incorporated to the hybrid layer, called integration layer. Therefore, there is a smear plug formation (Bedran-Russo et al., 2017), which might have contributed to the marginal sealing. Beyond technical simplification, eliminating step of acid conditioning followed by rinsing, what is difficult to be clinically standardized, may avoid the water excess during the preparation or in curing, avoiding a collapse of collagen fibers, what is a negative influence in adhesion (Collares et al, 2016). It also may explain the reason for more sensitive adhesive technique, such as the three-step adhesive system, has presented worst results.

Previous studies have demonstrated better results in microleakage with self-conditioning adhesives because these agents increase dentin permeability by their intrinsic acidity, facilitating the monomers pervasion in the cavities produced in dentin (Pradelle-Plasse et al., 2004). The fail between hybrid layer and dentin increases the risk of bacterial invasion, sensitivity and pulpal irritation, and these risks are higher when the monomer pervasion is lower than the demineralization depth, generally common in total conditioning adhesive systems, also explaining worst results for three-step adhesive system flasks in this study (Hirata et al., 2016).

Due to the lower polymerization contraction of silorane composite when compared to the methacrylate composite, the interface is exposed in a significant way in a lower stress level, and silorane also presented lower adhesion to Strepococcus than conventional methacrylate (Buergers et al., 2009). The evolution of adhesive systems should also be highlighted, aiming at smaller postoperative sensitivities and technical simplification, especially in the use of self-conditioning adhesives (Sundfeld et al., 2016; Baracco et al., 2016). However, more studies about this new and promising silorane polymeric system are necessary, as well as on different adhesive systems currently in use, in order to allow a good guidance to the surgeon dentist regarding the resinous material and more appropriate bond system for each case.

The limitation of this study was to be an "*in vitro*" study. The authors did not find enough patients to conduct a "*in vivo*" study. Further, thermo and mechanical cycles were not carried out to simulated aging, and microleakage not nanoleakage was performed to evaluate the specimens.

5. Conclusion

From the results obtained in this study, we conclude that silorane-based resinous system, when combined to its particular adhesive system presents statistically significant difference when compared with the other groups, excepted with group 6 ($P < 0.001$). Other combinations among adhesives and materials did not present statistically significant difference ($P > 0.05$).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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