**Introduction**

Shrinkage stress is the fundamental reason why composite polymerization shrinkage is a clinical concern [1-4]. Polymerization contraction, which induces stress when the shrinkage cannot be accommodated by viscous flow of the composite [5], is capable of causing initial gaps in the restorations margins [6], leading to tooth sensitivity, pulp damage [7], and secondary caries [8, 9]. This situation becomes more critical in class II restorations due to the difficulty of adapting the material at the gingival margin [10-12].

Viscous materials exhibit low wetting capacity that interferes in adaptation of the material in the cavity, therefore, flowable materials may be a good alternative to improving marginal integrity and internal adaptation of restorations [13]. Since flowable composite liners or glass ionomer liners act as a more resilient elastic layer, absorbing more energy from the shrinkage stress, they also act as a buffer causing better marginal fit, because their low elastic modulus promotes higher elastic deformation to compensate the shrinkage stress [14-16].

Thus, the objective of the study was to evaluate the marginal adaptation, in enamel (E) and dentin (D), of adhesive materials, such as composite resin (CR), flowable resin composite (flow), bulk fill flowable liner (bulk) and resin modified glass ionomer cement (RMGIC) in slot cavities. The hypothesis tested was that different materials did not influence the marginal adaptation in enamel and dentin.

**Material and Methods**

 This study was conducted after approval (Protocol No. 21148413.4.0000.5417) from Ethics Committee of the Bauru School of Dentistry. In total, 40 extracted human molar teeth without caries were used. The teeth were embedded in PVC tubes (diameter: 15mm, height: 25mm) with acrylic resin, leaving the cemento-enamel junction (CEJ) exposed. The occlusal surface was planed in a water-cooled mechanical grinder and polisher (ER-27000; Erios) at a speed of 300 rpm 120-grit abrasive paper was used for three minutes, teeth were shaped with vinyl polysiloxane prior to cavity preparation, and the mold was used as matrix for cavity restorations (Figure 1).

 The forty teeth were randomly assigned into eight experimental groups (5 teeth per group) according to table 1. For each tooth, two vertical slot preparations with standard sizes (depth: 2.0 mm, height: 2.5 mm, width: 2.0 mm) were created, in mesial and distal of the same tooth, with burs #245 (KG Sorensen, São Paulo, SP, Brazil) on a machine for making cavities (ELQUIP, São Carlos, SP, Brazil). This device has three digital micrometers coupled to the table, a coordinate system supporting a high-speed turbine that determines the depth of wear and the inclination of the rotating device. The burs were replaced after five preparations.

 Cervical margins were defined in enamel and dentin in relation to CEJ. Thus, for the cervical margins in enamel the preparation was carried out short of CEJ and for dentin, besides CEJ. Considering that for each tooth two cavities are made, forty cavities were made with enamel margin and forty cavities with margin in dentin.

 The restoration were made with Filtek Z350 composite resin (3M Espe, St. Paul, MN, USA) by the incremental technique, with or without liner; by using flowable resin Filtek Z350 (3M ESPE, St. Paul, MN, USA) and Surefil SDR (Dentsply, Konstanz, Germany) and RMGIC Vitremer (3M Espe, St. Paul, MN, USA). Flowable and bulk resin composites and RMGIC were placed in a single increment (2.0 mm) by “open sandwich” technique. Polymerization was performed with a DB 686 LED appliance (Dabi Atlante, Ribeirão Preto, SP, Brazil). The adhesive treatment of substrates was performed according to the manufacturers’ recommendations, and the excess material was removed with a scalpel blade. The materials, batch numbers, and manufacturers are listed in Table 2.

Table 1 – Experimental groups

|  |  |  |
| --- | --- | --- |
| Groups(n=10 restorations) | Cervical margin | Adhesive Material |
| E-CR | Enamel | Filtek Z350 composite resin |
| E-BULK | Enamel | Filtek Z350 composite resin + SDR flowable composite (2mm) |
| E-FLOW | Enamel | Filtek Z350 composite resin + Filtek Z350 flowable composite (2mm) |
| E-RMGIC | Enamel | Filtek Z350 composite resin + RMGIC Vitremer (2mm) |
| D-CR | Dentin | Filtek Z350 composite resin |
| D-BULK | Dentin | Filtek Z350 composite resin + SDR flowable composite (2mm) |
| D-FLOW | Dentin | Filtek Z350 composite resin + Filtek Z350 flowable composite (2mm) |
| D-RMGIC | Dentin | Filtek Z350 composite resin + RMGIC Vitremer (2mm) |

Table 2 – Batch number and manufacturer of materials used in this study

|  |  |  |
| --- | --- | --- |
| **Material** | **Batch** | **Manufacturer** |
| Phosporic Acid - Phosphoric acid 37%, colloidal silica, surfactant, and colorant | 140213 | Dentsply, Konstanz, Germany |
| Adper Scotchbond Primer - 2-hydroxyethyl-methacrylate and polyalkenoic acid | N481327 | 3M ESPE, St. Paul, MN, USA |
| Adper Scotchbond Adhesive - Bismethacrylate (1-methylethylidene) bis (4,1-phenylenoxy [2-hydroxy-3,1-propanediyl]) and 2-hydroxyethyl methacrylate | N465871 | 3M ESPE, St. Paul, MN, USA |
| Filtek Z350 composite resin - Ceramics treated with silane, BIS-GMA, BIS-EMA, silica and zirconia treated silane, dimethacrylate diurethane, polyethylene glycol dimethacrylate, TEG-DMA, 2,6-di-tert-butyl-p-cresol (BHT) | 726707 | 3M ESPE, St. Paul, MN, USA |
| Filtek Z350 flowable - Ceramics treated with silane, substituted dimethacrylate, bisphenol A diglycidyl ether dimethacrylate (BIS-GMA), silane treated silica, triethylene glycol dimethacrylate (TEG-DMA), ytterbium fluoride, functionalized dimethacrylate polymer and titanium dioxide. | N470064 | 3M ESPE, St. Paul, MN, USA |
| SureFil SDR flowable (Bulkfill)Modified UDMA, TEGDMA, EBPDMA, pigment, photoinitiator, barium and strontium alumino-fluoro-silicate glasses, Silicon Dioxide—Amorphous, Strontium. Aluminosilicate Glass. Filler load: 68 wt%; 45 vol%. | 02221 | Dentsply, Konstanz, Germany |
| Vitremer - **Powder**: silane treated glass, potassium persulfate, pigments.**Liquid**: copolymer of acrylic and itaconic acids, water, 2-hydroxyethyl methacrylate (HEMA), diphenyliodonium hexafluorophosphate **Primer**: 2-hydroxyethyl methacrylate (HEMA), ethyl alcohol, copolymer of itaconic and acrylic acids, diphenyliodonium hexafluorophosphate | N449108N394817N509198 | 3M ESPE, St. Paul, MN, USA |

Subsequently, the specimens were stored in deionized water for 24h. After this they were subjected to 2000 cyclic loading, 120N, 2Hz (Elquip, São Carlos, SP, Brazil) at 37°C, and then sectioned sagittal direction in relation to the tooth`s long axis by a cutting machine (Isomet low speed saw - Buehler, Lake Bluff, IL, USA) to analyze the marginal adaptation of the restored cavities. This analysis was performed by scanning electron microscopy (SEM) at 35x magnification (JSM-T220A, Jeol, Tokyo, Japan) that allowed full view of the cervical margin. The micrographs were analyzed with the Image J program to measure the size of the marginal gaps. This program provides the corresponding marginal extension of the microgap by converting pixels into square millimeters. The distance between the margins of restorations was used to calibrate the program.

The data were transformed into percentages using the formula %GAPS = LG ÷ LM × 100, where LG is the length of the gap and LM is the total length of the margin. Gap percentage values of restorative treatments, in enamel and dentin, ​​were analyzed by 2-way ANOVA followed by the post hoc Tukey test (α=0.05).

**Results**

 The percentages of marginal gap in each group are shown in Figure 2. The results of the 2-way ANOVA of marginal gap data are listed in Table 3.

Table 3 – Two-way ANOVA (P<0.05)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Source of Variation | df | Sum of Squares | Mean Squares | F | P |
| T | 3 | 41,380.60 | 13,793.53 | 21.58419 | 0.0000 |
| S | 1 | 1,796.59 | 1,796.59 | 2.81131 | 0.0979 |
| TxS | 3 | 1,603.87 | 534.62 | 0.83658 | 0.4781 |

T, treatments; S, substrate.

There was a significant difference between different experimental treatments in relation E-RMGIC and D-RMGIC and others groups (*p<0.01*) (TABLE 4). The combination of composite resin with modified glass ionomer resin by using the open sandwich technique had the highest percentage of marginal gap in enamel (E-RMGIC: 57.91 ± 35.56%) and dentin (D-RMGIC: 72.98 ± 29.05%). There was not difference between enamel and dentin (*p=0.0979*).

Table 4 – Experimental groups and standard deviation (SD).

|  |  |
| --- | --- |
| Groups | Median (SD) |
| E-CR | 17,22 (33,77)a |
| E-BULK | 5.15 (13.62)a |
| E-FLOW | 9.59 (17.08)a |
| E-RMGIC | 57.91 (35.56)b |
| D-CR | 27.53 (26.22)a |
| D-BULK | 23.00 (25.05)a |
| D-FLOW | 4.28 (8.43)a |
| D-RMGIC | 72.98 (29.05)b |

 The groups restored with composite resin (E-CR: 17.22 ± 33.77%, D-CR: 27.53 ± 26.22%) and with flowable composite resin liner (E-BULK: 5.15 ± 13.62%, E-FLOW: 9.59 ± 17.08%, D-BULK: 23 ± 25.05%, D-FLOW: 4.28 ± 8.43%) showed a similar percentage of marginal gap *(p>0.05)*. Photomicrographs are shown in Figure 3.

**Discussion**

Gaps can compromise the restoration due to infiltration of fluids and bacteria that can lead to the development of secondary caries [8, 9]. This study investigated the percentage marginal gap by means of SEM analysis of different treatments with composite resin, and flowable, bulkfill, and RMGIC by open sandwich technique in enamel and dentin cervical margins. The hypothesis tested was rejected because different materials influenced the marginal adaptation in enamel and dentin.

Two flowable resin composites were tested: Filtek Z350 Flow (3M ESPE, St. Paul, MN, USA) and Surefil SDR Flow - bulk fill flowable base - (Dentsply, Dentsply, Konstanz, Germany).

The flowable composite Filtek Z350 has 65% of filler particles by weight that reduces its stiffness; and it must be used in up to 2mm increments. Among the components of the composition, UDMA and Bis-EMA are resins with higher molecular weight that have fewer double bonds resulting in less shrinkage, and PEGDMA, in moderating shrinkage. The Surefil SDR Flow has 68% filler by weight; has fluoride in its formulation and offers the possibility of up to 4mm increments since it presents a differential urethane dimethacrylate monomer associated with a modulator of polymerization that results in a low polymerization shrinkage stress.

It was observed that the combination of these flowable resins (2 mm) with composite resin did not influence the marginal adaptation after 2000 mechanical loading cycles, of cavities filled with the hydrophibic 3-step adhesive system Adper Scotchbond Multipurpose (3M ESPE, St. Paul, MN, USA). Scotchbond primer consists of an aqueous solution of 2-HEMA and a copolymer of polyalkenoic acid that increases the resistance of the adhesive system when used in the oral environment with a high level of humidity. Pecie et al. (2013) [17] also observed no improvement in marginal adaptation, before and after the thermal cycling, when they used a flowable resin liner and a 3-step adhesive system Optbond FL (Kerr Corporation). Several authors have demonstrated the superiority of conventional adhesives in maintaining marginal integrity at the dentin/resin interface [18, 19]. Aggarwal et al. (2014) [8] observed improvement when they used a flowable liner and 2-step resin adhesive system, but when the 1-step self-adhesive system was used, the flowable resin liner did not influence the marginal adaptation in comparison with the composite resin used alone.

Flowable resins are heterogeneous materials, since they have different modulus of elasticity and shrinkage [20, 21]. The performance of these resins is unpredictable with respect to the absorption of stress at the interface [17]. Thus, they should be used with caution, avoiding thick layers, since the low filler content may contribute to the increased polymerization shrinkage [8]. Some studies have found conflicting results with regard to the effect of flowable resin liner on marginal integrity [10, 22, 23].

Another type of liner used in this study was the RMGIC Vitremer (3M ESPE, St. Paul, MN, USA). The primer of Vitremer, which was used previously to applying the RMGIC, is a tooth structure conditioner composed of copolymer modified polyalkenoic acid, methacrylate groups, ethanol and camphorquinone, and its function is to moisten the tooth surface to increase the bond of RMGIC.

When the RMGIC was used, the percentage of marginal gap increased in enamel and dentin. On the one hand, the RMGIC has an anticariogenic effect due to fluoride release [24] and chemically bonds to dental substrate through bonding of the carboxylic groups of polyalkenoic acid to hydroxyapatite [25]; on the other, RMGIC has technique sensitivity from manipulation though to final setting, and a very viscous consistency that makes it difficult to insert and accommodate in the cavity [26], so that it use requires a well-trained and experience operator. Furthermore, when RMGIC is exposed to the oral environment, its surface may deteriorate due to its solubility [27, 28].

The literature reports studies that had failures with the use of GIC in the "open sandwich" technique [26, 29-31]. Whereas, many authors have observed that the GIC improved marginal integrity [8, 15, 26, 32]. Other authors have suggested dentin hybridization with an adhesive system before RMGIC application to guarantee dentinal tubule sealing in case of failure at the interface [33]. In the present study, RMGIC was used without an adhesive system, in accordance with the manufacturer’s indications for the material used.

Although many materials are being developed to facilitate the implementation of clinical procedures, the main factor that seems to influence the possibility of success is the ability and technical expertise of the operator.

**Conclusion**

It was concluded that the different restorative treatments had the same behavior in enamel and dentin cervical margins. Restorations with flowable composite resin liner and bulk fill did not influence marginal adaptation, however the association RMGIC with composite resin increased the percentage of marginal gap in the slot cavities.

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**Figures**





