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Impact of Resin Composite Viscosity and Fill-technique on Internal Gap in Class I Restorations: An OCT Evaluation

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Clinical Relevance

Although bulk-fill, resin-based composites are attractive for direct posterior Class I restorations, conventional resin-based composites with incremental-fill technique resulted in better internal adaptation, even after being exposed to thermal fatigue.

SUMMARY

The aim of this *in vitro* study was to quantitatively evaluate the internal gap of resin composites of high- and low-viscosity used in single- and incremental-fill techniques in Class I cavities exposed to thermal cycling (TC) using optical coherence tomography (OCT). Cavities of 4-mm depth and 3-mm diameter were prepared in 36 third molars randomly distributed into four groups, according to viscosity of restorative resin-based composite (high or low viscosity, all from 3M Oral Care) and technique application (bulk or incremental fill)

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used (n=9): RC, high-viscosity, incremental-fill, resin-based composite (Filtek Z350 XT Universal Restorative); BF, high-viscosity, bulk-fill, resin-based composite (Filtek One Bulk Fill); LRC, low-viscosity, incremental-fill, resin-based composite (Filtek Z350 XT Flowable Universal Restorative); and LBF, low-viscosity, bulk-fill, resin-based composite (Filtek Flowable Restorative). Single Bond Universal Adhesive system (3M Oral Care) was used in all the experimental groups. The incremental-fill technique was used for RC and LRC groups (2-mm increments), and a single-layer technique was used for BF and LBF groups, as recommended by the manufacturer. The internal adaptation of the resin at all dentin walls was evaluated before and after TC (5000 cycles between 5°C and 55°C) using OCT images. Five images of each restored tooth were obtained. Images were analyzed using ImageJ software that measured the entire length of the gaps at the dentin–restoration interface. The length of gaps (μm) was analyzed using two-way repeated measures ANOVA and the Tukey tests (α=0.05). There was a significant interaction between material types and TC (*p*=0.006), and a significant difference among all material types (*p*<0.0001), before and after TC (*p*<0.0001). Increased internal gaps at the dentin–restoration interface were noticed after TC for all groups. RC presented the lowest value of internal gap before and after TC, while LBF showed the highest values of internal gap after TC. In conclusion, TC negatively affected the integrity of internal gap, whereas high-viscosity, incremental-fill, resin-based composite presented better performance in terms of internal adaptation than low-viscosity, bulk-fill materials in Class I cavities.

INTRODUCTION

Resin-based composites are the primary choice for direct restorations on posterior and anterior teeth, as their technological development led to improved physical properties and greater restoration longevity.[1] Although significant progress has been made towards the use of resin-based composite restorations, limitations have been reported leading to clinically relevant problems as recurrent caries and restoration fractures.[2] Furthermore, resin-based composite polymerization shrinkage stress may cause cusp deflection, postoperative sensitivity, and marginal and internal gaps at the dentin–resin-based composite bonding interface that lead to potential development of caries lesions around the restoration.[3-6] Several factors, including cavity preparation, operative technique, and material properties have been described to be associated with internal adaptation of resin-based composite restorations,[3,7,8] and their impact has been suggested to be strongly dependent on cavity size and configuration (C-factor), filler content in resin-based composite, formulation of organic matrix, elastic modulus, viscosity, and bond strength of resin-based composite materials to the walls of the cavity preparation.[3,7,9-12] Clinical strategies have been proposed to reduce polymerization stress, including the use of incremental-fill techniques, or modifications of the light-activation protocol. However, they are time consuming and technically demanding.[13,14]

Bulk-fill, resin-based composites were originally developed to reduce clinical time without affecting light-induced conversion rate and polymerization shrinkage stress on the adhesive interface.[15] In addition, bulk-fill, resin-based composites provide low elastic modulus.[16,17] Most of them have increased translucency to create deeper light penetration and also incorporate additional photoinitiators.[17] Compared to incremental-fill, single-fill (bulk) resin-based composites display up to 60% reduction of polymerization stress.[12] However, effective polymerization of resin-based composite materials in deeper layers remains controversial.[18] Inefficient polymerization associated with thermal and mechanical stresses may result in cracks, marginal leakage, and internal gaps ultimately causing decrease in restoration performance.[8] In this context, viscoelastic flow behavior and reaction kinetics have been shown to play a key role affecting polymerization shrinkage stress.[9,13,19-21] Contradictory studies have been reported on the potential benefit of using low-viscosity, resin-based composite as an intermediate layer to act as a stress-absorbing layer to relieve the polymerization shrinkage stress at the tooth–resin-based composite bonding interface, and reduce microleakage and internal gaps.[11,21-26]

To predict resin-based composite restoration performance inside a tooth cavity, *in vitro* studies including thermal cycling (TC) and optical coherence tomography (OCT) have been proposed. TC simulates oral environment stress promoting temperature changes that lead to deleterious impact to the tooth–resin-based composite restoration bonding interface,[27,28] whereas OCT is a well-established nondestructive method used to assess internal adaptation of a given restorative material without specimen cross-sectioning.[4,6,29,30] OCT is a method similar to ultrasound, in the sense that the backscattered light from the internal tissue structures contains the information to be analyzed. The OCT technique is based on interferometry using a broadband light source. This interferometer is composed by two arms—the reference and the sample arms; the broadband light source is split between the two arms. The light that comes back from the reference arm and the sample arm is combined, giving rise to an interference pattern that depends on the position of the reference arm; knowing the position of that arm, it is possible to determine which depth of the sample the light comes from in that incident point. Making a lateral scan in the sample, it is possible to generate two-dimensional or three-dimensional (2D or 3D) images.[6,24,29,30] Although a number of studies have evaluated the internal adaptation of bulk-fill, resin-based composite restorations, very few have assessed the effect of TC on the internal gaps of these materials in Class I and II cavities.[5,6,31,32] Therefore, the aim of this laboratory study was to quantitatively evaluate the internal gaps of high- and low-viscosity, bulk- and incremental-fill, resin-based composite materials exposed to TC in Class I cavities, using the OCT approach. The null hypothesis was that there is no difference in the presence of internal gaps in Class I direct restorations performed with different resin-based composite material viscosities combined with the application technique and submitted to restoration aging (TC fatigue).

METHODS & MATERIALS

Experimental Design

This was a simple, parallel, randomized study. The factors in the study were: 1) Types of resin-based composite materials combined with different techniques (high and low viscosity in single or incremental fills); and 2) Thermal cycling (before and after TC). Thirty-six sound human third molars were randomly divided into four experimental groups (n=9/group). Sample size was defined based on a pilot study to obtain statistical power of 0.8. Restoration internal gap was determined (μm) before and after TC by OCT, and the results were presented as the internal gap of restorations in resin-based composites before and after TC—the variation of the internal gap (Δ Gap) and the proportional difference between before and after TC (%). Figure 1 illustrates a schematic of workflow used for data collection.

Selection of teeth

All teeth were examined under 40× magnification (Eikonal Equip, model EK3ST, São Paulo, SP, Brazil) to exclude those with enamel defects or dental deformities. Their roots were removed 2 mm below the cementoenamel junction using a double-face diamond

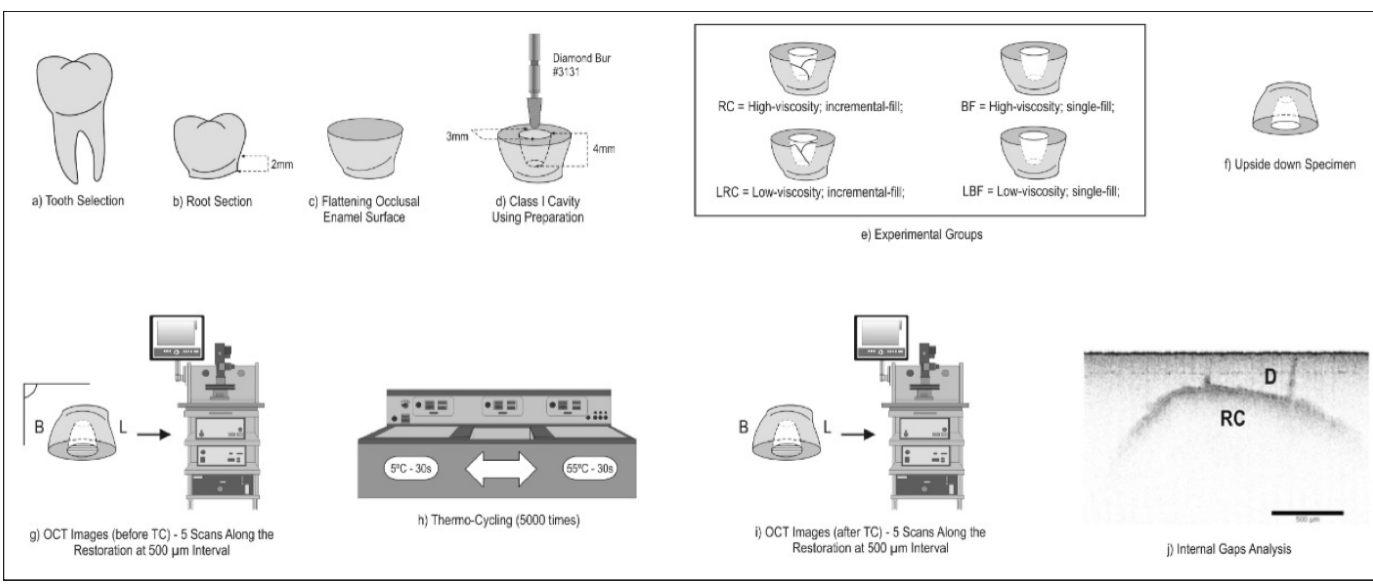

Figure 1. *Representative schematic illustration of the methodological approach for measuring percentage (%) internal adaptation of resin composites: (a) Tooth selection; (b) root section; (c) flattening occlusal enamel surface; (d) Class I cavity preparation (3-mm deep × 4-mm deep); (e) application of resin composites (RC—high viscosity, incremental fill; BF—high viscosity, incremental fill; LRC—low viscosity, incremental fill; LBF—low viscosity, single fill); (f) given the imaging depth limitation of OCT (Model OCS930RS), the images were taken with specimens placed upside down in order to evaluate the interface of the cavity floor; (g) OCT image before TC (thermal-cycling) at 500-µm interval; (h) thermal cycling (5000 times of 30 seconds in each bath of 5oC and 55oC water, with an interval of 30 seconds in a 37oC bath); (i) OCT image after TC (thermal cycling) at 500-µm interval; (j) analysis of interval gap percentage (%) using ImageJ program. The variations of internal dentin gap percentage were calculated as follows: D%Gap = [(%G2−%G1) × 100]/ %G2. G1, dentin gap percentage before TC (Baseline) and G2, dentin gap percentage after TC.*

saw disk and discarded (KG Sorensen; São Paulo, SP, Brazil) (Figure 1a,b).

Class I Cavity Preparation

Each tooth was fixed in polyvinyl tubes (Amanco–Mexichem Brazil, Suape, PE, Brazil) using silicone (Express XT, 3M Oral Care, Sumaré, SP, Brazil). Occlusal enamel surfaces (cusps) were flattened on a water-cooled mechanical grinding machine (Aropol 2V, Arotec Indústria e Comércio, São Paulo, SP, Brazil) using 80-grit sandpaper (Buehler, Lake Bluff, IL, USA). Standardized Class I cavities were prepared at the center of the occlusal surface (4-mm depth and 3-mm diameter) in dentin. Care was taken not to expose the pulp chamber. The cavity preparation machine (Federal University of Uberlândia, MG, Brazil) was used with a high-rotation turbine (Kavo Dental Excellence, Joinville, SC, Brazil) using diamond bur #3131 (Microdont, São Paulo, SP, Brazil) under water cooling (Figure 1).[33] Each bur was replaced after the preparation of five cavities. To prepare teeth for OCT analysis, the root portion of each tooth was flattened to within 0.1-mm of the pulp chamber with 320-grit sandpaper (3M Oral Care) (Figure 1c,d). A millimeter caliper (Golgran, São Caetano do Sul, SP, Brazil) was used to measure the depth and thickness of the cavities. Subsequently, they were randomly distributed into four groups according to resin-based composite material (high and low viscosity) and technique application (Figure 1).

Restorative Procedure

Enamel was etched with 37% phosphoric acid for 30 seconds (Condac 37, FGM Dental Products, Joinville, SC, Brazil) and then rinsed with water for 30 seconds. A moist dentin surface was maintained by using an absorbent paper pellet. Next, cavities were bonded using a universal adhesive system (Single Bond Universal, 3M Oral Care) to improve marginal sealing.[34] The adhesive system was applied by rubbing the internal area of the cavity for 20 s with a fully saturated microbrush (FGM Dental Products). Subsequently, a gentle air spray was applied for 5 seconds to evaporate the solvent, and light cure was done for 10 seconds. Both, the adhesive system and resin-based composites were photoactivated using a light-emitting diode curing light at 1000 mW/cm^2 intensity, set up in a standard power, with 9.6 mm lens diameter, wavelength of 395-480 nm, and kept plugged to an electrical outlet (VALO, Ultradent Products, South Jordan, UT, USA). For all restorations, the curing light tip was fixed perpendicularly to the occlusal cavity at the cavosurface margins to ensure that all layers of the restoration were reached by the curing light in a standard way for all experimental groups. Light-curing times were adjusted according to the manufacturer's instructions, as described in Table 1, and restorations were performed by the same operator to control for technical bias.

Filtek Z350 XT Universal Restorative high-viscosity and Filtek Z350 XT Universal Restorative flowable low-viscosity, resin-based composites (3M Oral Care) were inserted with a 2 mm oblique incremental technique. While, Filtek One Bulk Fill (high-viscosity) and Filtek Bulk Fill low-viscosity, resin-based composites (3M Oral Care) were inserted into the cavity in a 4-mm single-layer increment. Careful deposition of increments was taken to avoid interfacial gaps and porosity between layers. Resin-based composites were light cured using a previously describe methodology that is described in Table 1. Finishing and polishing were performed using a sequence of medium, fine, and superfine aluminum-oxide abrasive disks (Sof-Lex Pop-on, *3M Oral Care*) for 15 seconds each., and teeth were stored for 24 hours at 37°C in a humid environment (Figure 1e).

Optical Coherence Tomography (OCT)

The analysis of internal dentin/restoration gap in the cavity floor was performed by OCT (Thorlabs, Inc., Model OCS930RS, Newton, NJ, USA), operating in a 930 nm with 6.0 μm resolution in air. A silicone specimen holder (Speedex, Vigodent, Rio de Janeiro, RJ, Brazil) was fabricated for each tooth to individually fix it to the OCT worktable, and allow identical assessment of each tooth before and after TC. Next, transverse 2D images were obtained by scanning the occlusal surface in the mesiodistal direction over the restoration, and five images were obtained every 500 μm (Figure 1f,g,i), as previously described.[4]

Thermal Cycling (TC)

After baseline OCT analysis of internal gap, all teeth were subjected to TC for 5000 cycles (30 seconds in each bath of 5ºC and 55ºC water, with an interval of 30 seconds in a 37ºC bath) in a TC simulator machine (TCMD-3, ElQuip, São Carlos, SP, Brazil) (Figure 1h), which corresponded to approximately 6 months of *in vivo* clinical service.[27,28] Then, internal gap analysis was carried out again, using the same parameters and locations as the baseline, to obtain gap percentage.[4]

Internal Gap Percentage Calculation

Images were quantitatively analyzed using ImageJ software (ImageJ 1.45, NIH, Bethesda, Maryland, MD, USA) (Figure 1j). The dentin internal gap was linearly measured along the interface of the dentin–resin-based composite restoration. The internal gap was defined as any space between the dentin and restoration. First, the total length of the interface between the tooth structure

Table 1: *Material Type and Classification, Composition, Protocol, Manufacturer, and Batch Number Used in this Study*

Classification	Material/ Abbreviation	Composition and (Shade)[a]	Filler Composition Filler Amount (wt/vol.%)[a]	Protocol[b]	Manufacturer/ Batch #
Phosphoric acid	Condac 37	37% phosphoric acid, thickener, dye and deionized water	—	a,b	FGM Dental Products, Joinville, SC, Brazil/ 20418
Adhesive system	Single Bond Universal	Bis-GMA, Ethanol, Water, Camphorquinone, Dimethylbenzocaine, Polyalkenoic acid copolymer, Photoinitiators	Silica	a,b,c	3M Oral Care, Sumaré, SP, Brazil/ 645026
Incremental oblique layered, resin-based composite: High viscosity	Filtek Z350 XT/RC	Silanized Ceramic, Bis-GMA, Bis-EMA, UDMA, TEGDMA, Zirconium, Polyethylene Glycol (A2 body)	Silica (66.3 vol%)	a,b,c,d	3M Oral Care, Sumaré, SP, Brazil/ 646748
Incremental oblique layered, resin-based composite: Low viscosity	Filtek Z350 XT Flow/LRC	Silanized Ceramic, BisGMA, Bis-EMA, TEGDMA, EDMAB, YbF, Polymer, Benzotriazole, Diphenyliodonium (A2)	Silica (46 vol%)	a,b,c,d	3M Oral Care, Sumaré, SP, Brazil/ 838190
Bulk-fill, single-layer, resin-based composite: High viscosity	Filtek One Bulk Fill/BF	Silanized Ceramic, AUDMA, UDMA, DDDMA, YbF3, Zirconium, Water (A2)	Silica (58.4 vol%)	a,b,c,d	3M Oral Care, Sumaré, SP, Brazil/ 685666
Bulk-fill, single-layer, resin-based composite: Low viscosity	Filtek Bulk Fill Flow/LBF	Silanized Ceramic, Bis-GMA, Bis-EMA-6, UDMA, YbF, Benzotriazole, TEGDMA (A2)	Silica (42.5 vol%)	a,b,c,d	3M Oral Care, Sumaré, SP, Brazil/ 913202

[a] *Information provided by the manufacturer; Bis-GMA, bisphenol A-glycidyl dimethacrylate; Bis-EMA, ethoxylated bisphenol-A dimethacrylate; UDMA, Urethane dimethacrylate; TEGDMA, triethylene glycol dimethacrylate; EDMAB, Amine compound ethyl-4-(dimethylamino) benzoate; AUDMA, aromatic urethane dimethacrylate; DDDMA, dodecanediol dimethacrylate;*

[b] *Application Protocol: (a) Selective acid etching only to the enamel surface for 30 seconds; (b) washing for 30 seconds and drying the cavity with an absorbent paper pellet; (c) applying the self-etch function of the Single Bond Universal Adhesive system to the prepared tooth and rubbing it in for 20 seconds, gentle air spray for 5 seconds to evaporate the solvent, and light cure for 10 seconds. (d) Insertion of the restorative composite according to the manufacturer's guidelines (incremental oblique layer or single layer).*

(dentin) and the restoration was measured. Then, the percentage of dentin internal gap was calculated as follows: 1. Dentin gap percentage before TC (Baseline): $\%G_1 = (ld/Ld) \times 100$, where Ld=Total Dentin Internal Length and ld=Dentin Internal Gap Length; 2. Dentin gap percentage after TC: $\%G_2=(ld/Ld) \times 100$; 3. Dentin internal gap percentage: $\%Gap=\%G_2 - \%G_1$; 4. The variation of internal dentin gap percentage (D%Gap): $D\%Gap=(\%Gap \times 100)/\%G_2$.[4] Out of the total five measurements obtained every 500 µm per specimen, the least adapted region was used for statistical analysis, as previously reported.[4] The images obtained were always analyzed by a blind and calibrated operator.

Statistical Analysis

After exploratory data analysis of internal gap percentages by Shapiro–Wilk test and Levene tests (p>0.05), two-way repeated measures ANOVA

(4x2) and Tukey tests were used to compare the internal gap for study factors—the types of resin-based composite materials combined with different techniques and the time (before and after TC). The data of variation of internal gap (in μm) were subjected to Kruskal–Wallis and Dunn tests. All tests employed a 0.05 level of statistical significance, and all statistical analyses were carried out with the statistical package SPSS 21 (Chicago, IL, USA).

RESULTS

There was a significant interaction between the factors: material types/techniques and TC (p=0.006) (Table 2). All material types/techniques showed an increase in internal gap compared to before TC (p<0.0001). The lowest values of internal gaps were observed for RC, while LBF presented the highest internal gap values. There were no statistically significant differences between BF and LRC internal gap values before and after TC (p<0.0001). Considering the variation of internal gap, LBF group showed the lowest variation of internal gap (10.5%) (p<0.05). While, the highest variation of internal gap was seen for the BF group (31.4%) (Table 2). There were no significant differences of internal gaps variation values between RC and LRC groups. Figure 2 represents the OCT images of the internal gap of experimental groups before and after thermal cycling.

DISCUSSION

The internal adaptation of Class I resin-based composite restorations was assessed instead of its marginal microleakage, as it is more challenging for the material to adapt to the deepest cavity's areas compared to other interface locations.[5,8,9,11,31] In this study, the methodology used to simulate restoration aging included 5000 cycles of TC to challenge thermal fatigue in the bonding dentin–restoration integration, as it has been reported to represent approximately 6 months of clinical service.[27,28] Others' laboratory studies have used long-term water storage to determine restoration bonding durability.[28,35,36] In this context, the null hypothesis, that thermal stress would not affect internal gaps amplitude of resin-based composite in Class I cavities, was rejected. The specimens submitted to TC had internal adaptation loss up to 31.4% (Table 2). These findings are in accordance with previous studies, which also found that TC significantly reduced material's bonding or internal adaptation.[28,31] Taken together, these findings strongly suggest that the thermal stress and the potential action of water on the restoration interface may be caused by temperature changes on the bonded materials. This is because there is a different between the expansion coefficients and thermal conductivity rates of the resin material and of the tooth.[37] Additionally, TC may produce interface degradation and debonding, and may change the stress or strain levels transferred to the interface, therefore, decreasing bond strength by hydrolytic degradation of interface components.[11,27,28]

Higher variation of internal gap in percentage was seen by high-viscosity, resin-based composite RC (25.6%) and BF (31.4%) groups, which suggests that TC jeopardized the dentin–restoration interface when cavities were filled with these material and technique application combinations, while low-viscosity resin composites—LRC (11.6%) and LBF (10.5%) groups—showed lower internal gap variation percentage (Table

Table 2: *Mean (Standard Deviation) of the Internal Gap of Restorations in Resin-based Composites/Techniques Before and After Thermal Cycling (TC), the Median (Minimum–Maximum) of Internal Gap Variation (D Gap), and the Percentage of Internal Gap Variation of the Resins/Techniques After TC*[a]

Experimental Groups	Internal Gap (μm)		Variation of Internal Gap (D Gap in μm)	Variation of Internal Gap in Percentage (D% Gap)
	Before TC	After TC		
RC	591.6 (98.9) Aa	795.4 (108.3) Ab	200.8 (80.2-347.3) AB	25.6
BF	859.4 (150.1) Ba	1252.2 (204.2) Bb	424.6 (14.6-687.3) A	31.4
LRC	1083.3 (154.1) BCa	1226.2 (139.0) Bb	142.9 (33.2-335.8) AB	11.6
LBF	1186.9 (244.2) Ca	1326.7 (135.9) Cb	139.7 (0.61-335.8) B	10.5

[a] *Different letters (uppercase letters vertically and lowercase horizontally) indicate significant differences by ANOVA two-way repeated measures and Tukey tests (internal gap data before and after TC). There was an interaction between material types and TC (p=0.006). Different uppercase letters vertically indicate significant diferences by Kruskal–Wallis and Dunn tests (variation of internal gap) (p<0.05). BF, Filtek One Bulk Fill; D%Gap = [(%G2 − %G1)×100)]/%G2; G1, Dentin Gap% before TC; G2, Dentin Gap% after TC; LBF, Filtek Bulk Fill Flow; LRC, Filtek Z350 XT; RC, Filtek Z350 XT Universal Restorative.*

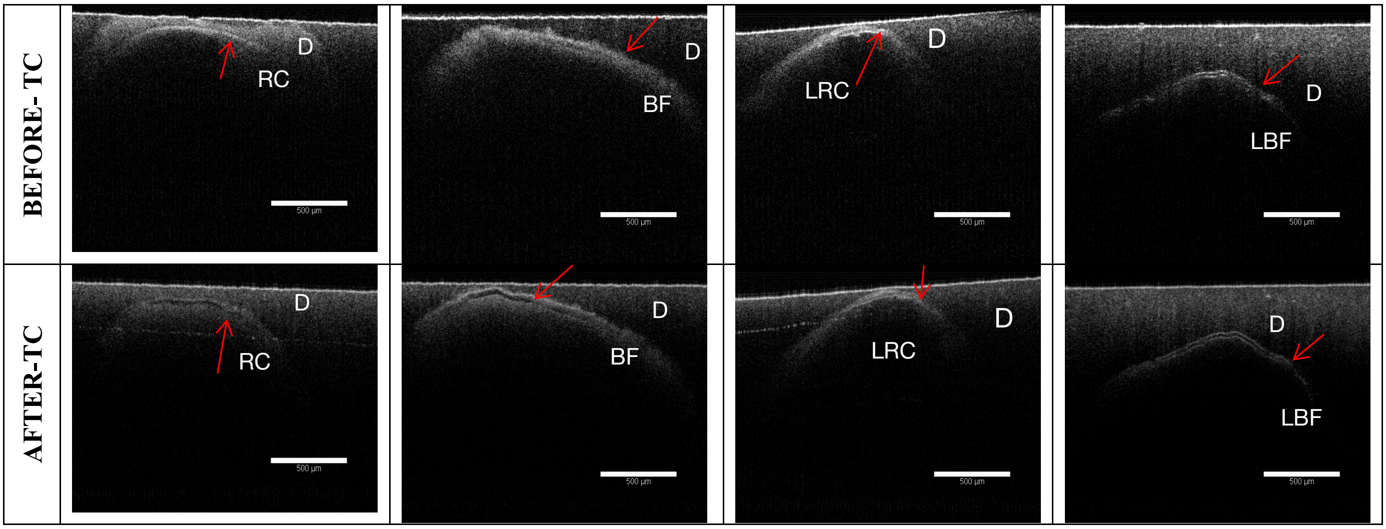

Figure 2. *OCT images of the internal gap (µm) of experimental groups before and after thermal cycling (TC). RC, Filtek Z350 XT Universal Restorative; BF, Filtek One Bulk Fill; LRC, Filtek Z350 XT Flow; LBF, Filtek Bulk Fill Flow; D, dentin. Red arrows indicate the internal gap in the resin-based composite–dentin interface observed by OCT.*

2). This might be attributed to the modified polymer chains of the low-viscosity resin composites, which are very flexible in the pregelation phase. This highly stress-relieving internal monomer might delay the gel point, which could allow more time to compensate for the shrinkage; consequently, polymerization shrinkage and internal gaps would be reduced.[16,38]

Considering the type of resin-based composite materials used in this study, the lowest values of internal gap were observed for RC (Table 2). The volume of material (2 mm increments)[39] applied to a high C-factor cavity (Class I), reducing the shrinkage generated by each increment, may explain the results obtained.[5,13,39] Thus, polymerization shrinkage stress is reduced, and the C-factor is minimized, reducing the incidence of internal gaps.[13] It is also reported that the use of incremental layers is one of the main methods to reduce polymerization stress, and that there is a statistically significant correlation between the percentage of internal interfacial gaps formed and the polymerization contraction.[13,14,31,40] However, finite element analyses demonstrated that increasing the number of increments and high postgel shrinkage and/or elastic modulus values caused higher stress in the remaining tooth structure and tooth–restoration interface.[41] Considering the viscosity of the resin-based composites that were used with the same application technique (incremental fill), the present study showed the LRC group had a greater content of triethylene glycol dimethacrylate (TEGDMA—a low-molecular-weight diluent monomer) than RC, which may have contributed to an increase in volume shrinkage and polymerization stress, jeopardizing the integrity of the resin-based composite–dentin interface.[13,40] The present result is supported by other studies reporting that an incremental-layer technique improved the adaptation of a composite to the cavity floor, as compared to a single-fill technique.[11,31,40]

The low-viscosity, single-layer, resin-based composite (LBF group) exhibited the highest values of internal gap, corroborating previous studies using Class I[3,21,42] or Class II cavities.[5] Typically, low-viscosity, resin-based composites have higher content of organic matrix, lower filler content, and consequently higher polymerization shrinkage than the conventional resin-based composites,[7,8,10,19,24] and, consequently, a higher percentage of interfacial gap formation.[21,40] The types and ratios of matrix monomers present in the composition can strongly influence the polymerization shrinkage.[10] The increase of *Bis*-GMA:TEGDMA ratios in composition of resin-based composite were shown to significantly decrease elastic modulus, most specifically for the filler contents above 50% that negatively compromised restoration internal adaptation.[10]

Besides the present study's affirmation that viscosity and technique application are factors that play a role in internal adaptation of resin-based composite in high C-factor (Class I) cavities, changes in monomer structure or chemistry and modification of polymerization dynamics have been regarded as contributing factors to influence the elastic modulus and polymerization and, consequently, to impact internal gaps.[13,16] In the current study, we aimed at assessing whether interfacial gaps, most likely formed due to polymerization shrinkage and stress during and soon after polymerization, were impacted by TC. Data analysis revealed that LRC exhibited similar internal gaps to BF, while BF (58.4 vol%) had a higher filler content by volume percentage than LRC (46 vol%). More highly filled resins have less matrix monomer available to contribute to the polymerization process, and need the inclusion of low-molecular-weight monomers (UDMA with 470 g/mol) to ensure a proper handling viscosity, thus increasing the shrinkage and internal gaps. On the other hand, the composition of resin composite also affects its elastic modulus. The elastic modulus of dimethacrylate polymers can be ranked as follows: TEGDMA<*Bis*-EMA<UDMA<*Bis*-GMA.[43] Therefore, low molecular-weight TEGDMA decreases the viscosity and contributes to higher polymerization shrinkage than BF, which contains high-molecular-weight monomers, such as UDMA and *Bis*-EMA.[43] It suggests that LRC and BF resin composites are comparable due to a balance of their flexural modulus and filler loading.[7] Another concern raised with the use of the single-layer technique is that the material may suffer from reduced polymerization at the deeper layer of the increment due to light attenuation.

OCT images differentiate the tissue optical properties, which include the effects of optical absorption and scattering.[4,6] It can successfully measure internal gaps between cavity floor (pulpal wall) and resin composite in Class I , II, and V cavities and provide nondestructive information on the dental performance.[4,6,30,44] Although OCT is a promising technology for clinical and laboratory applications, some limitations should be considered, including the depth limit for the acquisition of images to be analyzed, which depends on the specificity of the equipment.[29] Furthermore, when analyzing images, the internal adaptation was determined by a critical grayscale threshold of OCT images and the definition of the threshold level is somewhat subjective; therefore, the measurements of the imperfections do not represent absolute values. Future laboratory and clinical studies should be considered to further define the impact of aging on the internal adaptation and long-term success rate of resin-based composite restorations.

CONCLUSIONS

It can be concluded that:

- TC negatively influenced the internal gap of resins at the tooth–restoration interface in Class I restorations, regardless of the material used;
- The high-viscosity, incremental-fill, resin-based composite showed better performance in terms of internal adaptation than the low-viscosity, single-fill material with similar monomer composition in Class I restorations.

Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subjects' oversight as per Ethics and Research Committee of Faculdade São Leopoldo Mandic. The approval code for this study is # 97266217.0.1001.5374.

Conflict of Interest

The authors of this manuscript certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this manuscript.

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