Bulk-Fill Resin Composites: Polymerization Contraction, Depth of Cure, and Gap Formation

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Clinical Relevance

The filling of deep, wide cavities with bulk-fill resin composites is appealing. However, in Class II cavities some bulk-fill resin composites result in larger gaps on dentin walls than observed for a conventional resin composite.

SUMMARY

The bulk-filling of deep, wide dental cavities is faster and easier than traditional incremental restoration. However, the extent of cure at the bottom of the restoration should be carefully examined in combination with the polymerization contraction and gap formation that occur during the restorative procedure. The

aim of this study, therefore, was to compare the depth of cure, polymerization contraction, and gap formation in bulk-fill resin composites with those of a conventional resin composite. To achieve this, the depth of cure was assessed in accordance with the International Organization for Standardization 4049 standard, and the polymerization contraction was determined using the bonded-disc method. The gap formation was measured at the dentin margin of Class II cavities. Five bulk-fill resin composites were investigated: two high-viscosity (Tetric EvoCeram Bulk Fill, SonicFill) and three low-viscosity (x-tra base, Venus Bulk Fill, SDR) materials. Compared with the conventional resin composite, the high-viscosity bulk-fill materials exhibited only a small increase (but significant for Tetric EvoCeram Bulk Fill) in depth of cure and polymerization contraction, whereas the low-viscosity bulk-fill materials produced a significantly larger depth of cure and polymerization contraction. Although most of the bulk-fill materials exhibited a gap formation similar to that of the conventional resin composite, two of the low-viscosity bulk-fill resin composites, x-tra base and Venus Bulk Fill, produced larger gaps.

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INTRODUCTION

Bulk-filling techniques have become more widely used following the development of materials with improved curing,[1,2] controlled polymerization contraction stresses,[3,4] and reduced cuspal deflection.[5] Using this approach, the number of increments required to fill a cavity is reduced in comparison with traditional incremental filling techniques. In contrast to the maximum 2-mm increments recommended for conventional resin composites, manufacturers recommend 4- or 5-mm increments of the bulk-fill resin composites. The use of the bulk-fill technique undoubtedly simplifies the restorative procedure and saves clinical time in cases of deep, wide cavities. However, the data available for these materials are currently limited,[6] and therefore further laboratory studies are required in order to provide insight into likely clinical outcomes.

The use of thicker increments in bulk-fill resin composites is due to both developments in photo-initiator dynamics and their increased translucency,[7] which allows additional light penetration and a deeper cure.[8,9] Other than the improved depth of cure, recently developed bulk-fill resin composites exhibit lower polymerization contraction stress and contraction rates than hybrid and flowable resin composites.[3] However, a higher modulus of elasticity and increased plastic deformation suggest that the interfacial stress accumulation generated when using these bulk-fill materials, as well as the resulting consequences such as cuspal deflection and marginal gaps, may be difficult to predict.[3]

Gap formation may result from excessive contraction stresses at the interface between the restoration and the tooth,[5,10,11] which can be a consequence of the polymerization rate of the material[12] and the magnitude of polymerization contraction.[11,13] Additionally, contraction stresses are influenced by the composition and filler content of the resin composite,[1,13,14] its elastic modulus,[12,15] and its ability to flow, and thus compensate for the stresses generated during polymerization.[11-13,16] The degree of conversion[12,13,17] as well as depth of cure[18] of the material are also likely to influence the development of stresses, which may affect the quality of the bond at the interface of restorations. In materials with increased polymerization contraction, the interfacial stresses are more likely to be higher than can be compensated for by relaxation of the material [16] and cuspal deflection.[5,19,20] If these interfacial stresses exceed those that can be supported by the adhesive layer, gap formation will occur,[21-23] thus compromising the adhesive reinforcement of the tooth struc-

ture. Additionally, if the resin composite has limited depth of cure, it is likely to generate less contraction stress around the cavity walls and margins, thus possibly disguising an improved marginal adaptation due to poor polymerization. The complexity of interaction between some of these factors[1,13,15] may be further aggravated in cavities with an increased C-factor[24,25] or in the deeper and wider cavities, which are often encountered in the occlusal and approximal surfaces of posterior teeth.

Earlier research has demonstrated lower cuspal deflection after restoration of mesio-occlusodistal (MOD) cavities with two bulk-fill materials when compared with a nanohybrid resin composite.[5] This corroborates the previously reported findings of lower polymerization contraction stresses for a bulk-fill resin composite.[3] Finally, under fatigue testing, similar marginal integrity was observed in MOD cavities restored with one type of bulk-fill material and conventional resin composites.[26] Despite the positive results reported from previous studies, bulk-fill resin composites are somewhat recent materials with varied composition and handling characteristics, and thus have different physical properties.[2,3,6,27-30] Additionally, the availability of newer bulk-fill materials justifies further investigations because the overall properties of resin composite materials are usually composition-dependent.[6,27] Therefore, the aim of this study was to investigate the polymerization contraction, depth of cure, and gap formation of bulk-fill resin composites. The null hypotheses investigated were that 1) the polymerization contraction, 2) the depth of cure, and 3) the gap formation of bulk-fill resin composites are similar to those observed for a conventional resin composite.

METHODS AND MATERIALS

The polymerization contraction and depth of cure of high-viscosity (Tetric EvoCeram Bulk Fill, Ivoclar Vivadent, Schaan, Liechtenstein; SonicFill, Kerr Corporation, Orange, CA, USA) and low-viscosity (x-tra base, Voco GmbH, Cuxhaven, Germany; Venus Bulk Fill, Heraeus Kulzer GmbH, Hanau, Germany; SDR, Dentsply Caulk, Milford, DE, USA) bulk-fill resin composites were compared with a conventional resin composite (Tetric EvoCeram, Ivoclar Vivadent). The investigated materials were extruded from their respective capsules with the help of a manual applicator, with the exception of SonicFill, which due to its higher viscosity was extruded using its respective sonic handpiece (Kavo SonicFill, Kavo Dental GmbH, Biberach, Germany) attached to pressurized air.

Table 1:	*Investigated Restorative Materials and Their Composition According to Information Provided by the Respective Manufacturers*		
Composite	**Monomers**		**Fillers**
Venus Bulk Fill, Heraeus, Lot: 010031	Urethane dimethacrylate Ethoxylated bisphenol A dimethacrylate		Barium glass Ytterbium trifluoride Silicon dioxide (65 wt%, 38 vol%)
SDR, Dentsply Caulk, Lot: 1106281	Modified urethane dimethacrylate Ethoxylated bisphenol A dimethacrylate Triethyleneglycol dimethacrylate		Barium glass Strontium glass (68 wt%, 45 vol%)
x-tra base, Voco, Lot: 1137400	Dimethacrylates		Inorganic fillers (75 wt%)
Tetric EvoCeram Bulk Fill, Ivoclar Vivadent, Lot: P48869	Urethane dimethacrylate Bisphenol A dimethacrylate		Barium glass Ytterbium trifluoride Mixed oxide Prepolymer (79-81 wt%, 60-61 vol%)
SonicFill, Kerr, Lot: 3739797	Ethoxylated bisphenol A dimethacrylate Bisphenol A dimethacrylate Triethyleneglycol dimethacrylate		Barium glass Silicon dioxide (83.5 wt%)
Tetric EvoCeram, Ivoclar Vivadent, Lot: P40104	Urethane dimethacrylate, Bisphenol A dimethacrylate		Barium glass Ytterbium trifluoride Mixed oxide Prepolymer (82-83 wt%)

Polymerization Contraction

Polymerization contraction of the investigated materials (Table 1) was assessed with the bonded-disc method.[31] Triplicates were conducted for each investigated material. Standard amounts of the different materials (0.22 ± 0.02 g), which corresponded approximately to one application capsule, were inserted on top of a glass plate attached to a metallic ring. On top of the ring, a thin glass lamina was positioned. A linear variable differential transformer (LVDT; 7DCDT-100, Hewlett-Packard, Waltham, MA, USA) connected to a power output of 5 V rested on the surface of the thin glass lamina. A light-emitting-diode device (950 ± 50 mW/cm^2, bluephase, Ivoclar Vivadent) placed underneath the glass lamina was used to light-activate the investigated materials for 20 seconds. When light-activation was initiated, the materials contracted and deformed the glass lamina, thus resulting in displacement of the LVDT. The displacement of the LVDT was registered at two, five, 20, and 60 minutes after irradiation in a plotter (LKB Bromma 2210 2-channel recorder, Bromma, Sweden). Values of vertical linear displacement of the LVDT after 60 minutes were converted to polymerization contraction (strain measured as a percentage) using the formula:

$$e_\% = (d_\mathrm{p} \times 100)/(c_1 \times c_2 \times L_0) \qquad (1)$$

where $e_\%$ = strain (%); d_p = displacement of plotter tip on graph paper (m); c_1 = LVDT scale factor (V/m); c_2 = plotter scale factor (m/V); and L_0 = original length of sample (m).

In order to calculate the strain from the displacement of the plotter tip on the graph paper, it was necessary to determine the values of the variables c_1, c_2, and L_0. The value of c_1 was obtained by performing a calibration of the LVDT. This calibration involved measuring the voltage output of the LVDT while displacing the LVDT rod in controlled increments using a micrometer head. A linear regression was performed on these points, which led to a value of c_1 equal to 951 V/m (R^2=0.9999). The value of c_2 corresponded to the scale factor set on the plotter and was equal to 4 m/V. The original sample length L_0 corresponded to the thickness of the metallic ring in the experimental setup and was equal to 1.93 mm. Substituting these values of the variables into equation (1) demonstrated that 1 mm of displacement on the graph paper corresponded to a polymerization contraction of 0.26 μm, or the equivalent strain of 0.014%. The error associated with these measurements was approximately 2%.

Depth of Cure

The depth of cure of the investigated materials (Table 1) was assessed according to International Organization of Standards 4049.[32] Each material was inserted in a metallic mold with an orifice of 4 mm in diameter and 12 mm in depth. The mold was pressed between polyester strips covered by glass slides and placed on white filter paper. The material was light-activated (950 ± 50 mW/cm^2, bluephase, Ivoclar Vivadent) from the upper orifice during 20 seconds. Each specimen was removed from the mold, and the uncured material in the bottom was scraped

off with a plastic spatula. The height of the hardened material was measured in the center of the specimen with a micrometer (Carl Mahr GmbH, Esslingen, Germany), and this value was divided by two in order to determine the depth of cure. Triplicates were conducted for each investigated material.

Gap Formation

Gap formation was assessed in Class II cavities (vertical slot cavities) in extracted human molars using a method modified from Dewaele and others.[23] The teeth were extracted for therapeutic reasons; the research complies with the Use of Anonymous Human Biological Material Act on Research Ethics Review of Health Research Projects (from June 14, 2011), the National Committee on Health Research Ethics, Denmark. A total of 96 standardized cavities were prepared under water cooling in the approximal surfaces of the molars, with these dimensions ($\pm$0.5 mm): width, 4 mm; height, 6 mm; depth, 2 mm. The teeth were then divided into six groups (n=16): five experimental and one control. In the experimental groups, the cavities were filled with a bottom layer of the bulk-fill materials and an occlusal layer of the conventional resin composite. Cavities in the control group were filled incrementally with the conventional resin composite. Because the manufacturers recommend an occlusal coverage of the low-viscosity bulk-fill materials with a conventional resin composite to offer improved esthetics and mechanical performance,[27] the same condition was reproduced for all the investigated materials, including the high-viscosity bulk-fill materials (although this is not a recommendation from the manufacturers).

The enamel and dentin surfaces of each cavity were etched with 37.5% phosphoric acid (Gel Etchant, Kerr Italia Srl, Scafati, Italy) for 30 and 10 seconds, respectively. After rinsing for 15 seconds, the excessive water was removed without dehydrating the dentin. The primer (Optibond FL, 1 Prime, Kerr Italia Srl) was actively applied in the cavity, followed by air-drying for five seconds. The adhesive (Optibond FL, 2 Adhesive, Kerr Italia Srl) was then actively applied, air-dried for three seconds, and light-activated for 20 seconds (950 ± 50 mW/cm^2, bluephase, Ivoclar Vivadent). In the experimental groups, a 4-mm increment of the designated bulk-fill resin composite (Table 1) was inserted into the cavity and against a metallic matrix (Hawe Contoured Matrices, KerrHawe SA, Bioggio, Switzerland) and then light-activated for 20 seconds. This increment was subsequently covered by a 2-mm increment of

the conventional resin composite (Tetric EvoCeram, Ivoclar Vivadent) that was light-activated for 20 seconds. The control group was restored with four oblique increments of the conventional resin composite (Tetric EvoCeram), each light-activated for 20 seconds.

After the restorative procedure, the teeth were stored in water for 10 minutes prior to preparation for the gap analysis. Specimens were not subjected to thermocycling or cyclic loading, so that the effect of the restorative material alone could be assessed. The gap formation between the restorative materials and the dentin was assessed in faciolingual (n=6) or mesiodistal (n=10) sections. Each section was sequentially ground with wet paper discs #220, #500, and #1000 (Labopol-1, Struers A/S, Rødovre, Denmark) and polished with aluminum oxide powder to obtain a flat and regular surface. After polishing, each section was rinsed with pressurized water, dried with absorbent paper, and then analyzed in the light microscope (Orthoplan, Ernst Leitz GmbH, Wetzlar, Germany) under 510× magnification. The dentin-restoration interface was analyzed at seven sites in the faciolingual sections (Figure 1): the midgingival wall, the faciogingival and linguogingival angles, and two sets of points along the dentinal facial and lingual walls where the largest gaps and its corresponding direct opposite locations were observed. In the mesiodistal cuts, six reference points were used to analyze the dentin-restoration interface (Figure 1): the gingival cavosurface margin, half the distance of the gingival wall, the axiogingival angle, and respectively one-fourth, one-half, and three-quarters of the height of the dentinal axial wall. The size of the gaps in the different locations was measured using a reference scale visible in the objective of the microscope. A mean gap was calculated for each individual section, and an average gap formation was obtained for each investigated material from the combined mesiodistal and faciolingual sections.

Statistical Methods

Polymerization contraction and depth of cure were analyzed by a one-way analysis of variance test and the Tukey honestly significant difference (HSD) post hoc test. Due to their lack of normal distribution, gap measurements were analyzed by the Mann-Whitney U-test, each group being compared against the control group. Possible correlations between the investigated properties were analyzed using the Pearson test. The level of significance was 5%.
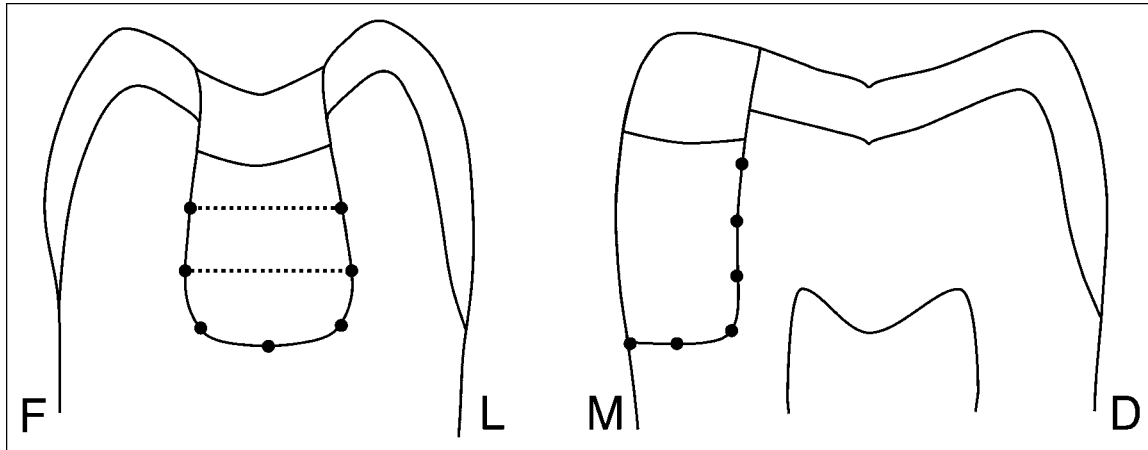
Figure 1. *The schematic drawing represents with dots the locations where the gaps between the restorative materials and dentin were assessed, both in faciolingual (FL) or mesiodistal (MD) sections.*

RESULTS

Significantly different polymerization contraction (Figure 2) was observed between the investigated materials ($p<0.001$). The conventional resin composite Tetric EvoCeram presented the lowest polymerization contraction, not significantly different from SonicFill ($p=0.061$) but significantly lower than Tetric EvoCeram Bulk Fill ($p=0.001$, Table 2). The low-viscosity bulk-fill resin composites demonstrated higher polymerization contraction: SDR and x-tra base showed an intermediate behavior, whereas Venus Bulk Fill presented the highest polymerization contraction ($p<0.001$, Table 2).

Depth of cure (Figure 3) was, in general, improved for the bulk-fill resin composites when compared with the conventional resin composite ($p<0.001$). SonicFill demonstrated depth of cure statistically similar to that of the conventional resin Tetric EvoCeram ($p=0.056$; Table 2). The low-viscosity bulk-fill resin composites x-tra base and Venus Bulk Fill demonstrated significantly higher depth of cure compared with the low-viscosity bulk-fill resin composite SDR ($p<0.001$) or the high-viscosity bulk-fill resin composite Tetric EvoCeram Bulk Fill ($p<0.001$) (Table 2).

In general, the low-viscosity bulk-fill resin composites investigated in this study demonstrated higher polymerization contraction and depth of cure. A significant positive correlation was identified between the polymerization contraction and the depth of cure of the investigated materials ($r^2=0.806$, $p<0.001$).

Gap formation (Figure 4) was significantly larger for x-tra base ($p=0.005$) and Venus Bulk Fill ($p=0.016$) when compared with the conventional resin composite (Tetric EvoCeram) (Table 2). No significant difference in gap formation was observed between the conventional resin composite and SDR ($p=0.880$), Tetric EvoCeram Bulk Fill ($p=0.925$), or SonicFill ($p=0.243$) (Table 2).

Gap formation was positively correlated with depth of cure of the investigated materials ($r^2=0.736$, $p=0.029$). No significant correlation was observed between gap formation and polymerization contraction of the investigated resin composites ($r^2=0.599$, $p=0.71$). However, because a pattern was identified within the results and one particular material seemed to stand out from the others, a second Pearson correlation test was conducted, this time excluding SDR. With the exclusion of SDR, a strong positive correlation was identified between gap formation and polymerization contraction (excluding SDR: $r^2=0.975$, $p=0.002$), thus indicating that this material has a different behavior from the other investigated materials (Figure 5).

DISCUSSION

Gap formation is the consequence of an interaction among several factors,[1,13,15] which adds complexity to understanding this phenomenon. This study focused on two of the factors involved in gap formation: polymerization contraction and depth of cure.

Because the polymerization contraction of most of the bulk-fill materials was higher than that of a conventional resin composite (Figure 2), the first null hypothesis was rejected. The low-viscosity bulk-fill resin composites containing lower filler volume (Venus Bulk Fill, SDR, and x-tra base) demonstrated higher polymerization contraction values. Converse-
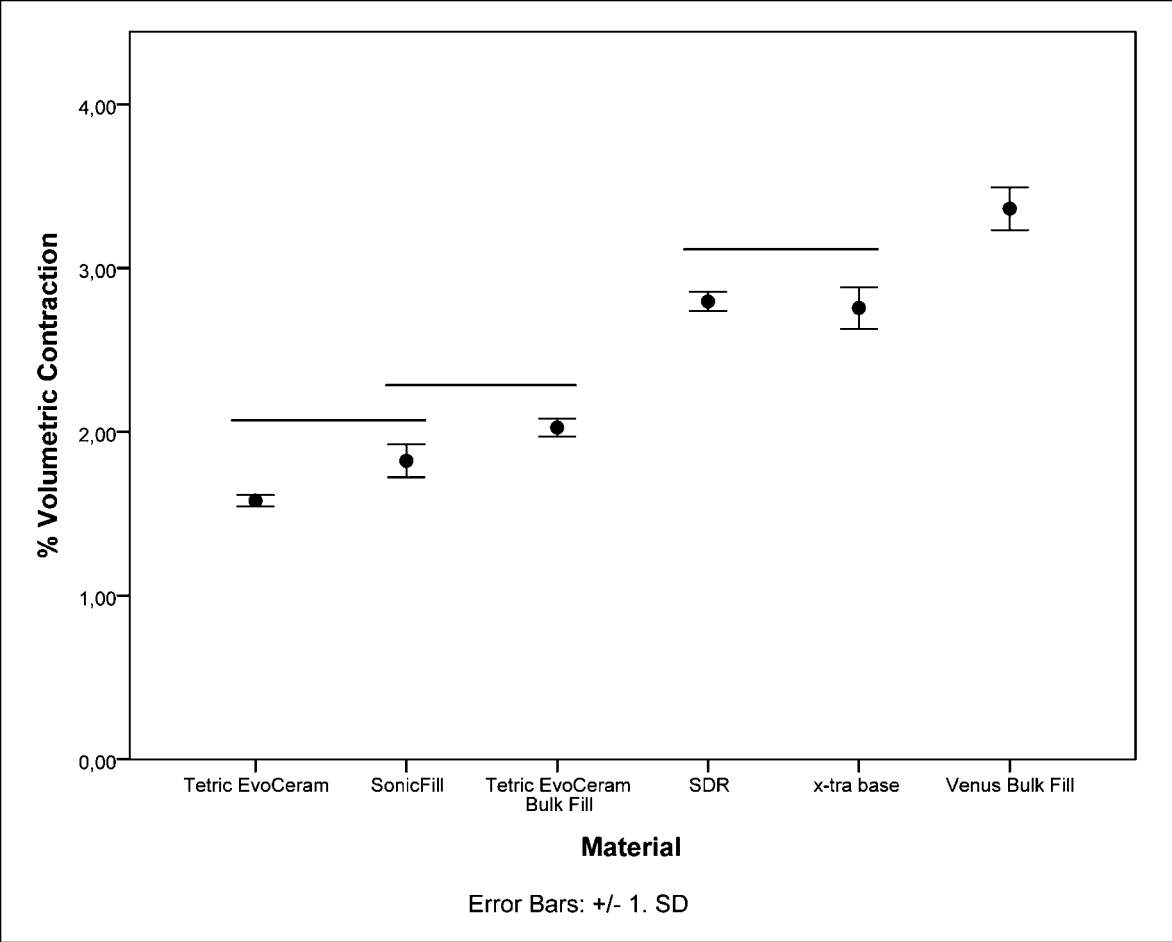
Figure 2. *Polymerization contraction (%) for the investigated materials obtained 60 seconds after light-activation using the bonded-disc method. The horizontal lines indicate the homogeneous grouping obtained from the Tukey HSD post hoc test.*

Table 2: *Average Contraction (%) and Depth of Cure (mm), With Respective Standard Deviations, as well as Median Dentin Gap Formation and Range (μm) for Each Investigated Resin Composite*

Composite	Contraction, %[a]	Depth of Cure, mm[a]	Gap, μm[b]
Venus Bulk Fill, Heraeus	3.36 (0.13) D	5.57 (0.28) D	Median, 10.2*
			Range, 3.6-31.7
SDR, Dentsply Caulk	2.80 (0.06) C	4.34 (0.15) C	Median, 6.1
			Range, 3.3-33.0
x-tra base, Voco	2.76 (0.13) C	5.68 (0.21) D	Median, 9.3*
			Range, 5.2-36.6
Tetric EvoCeram Bulk Fill, Ivoclar Vivadent	2.03 (0.05) B	3.82 (0.08) BC	Median, 6.6
			Range, 3.2-21.1
SonicFill, Kerr	1.83 (0.10) AB	3.43 (0.07) AB	Median, 7.1
			Range, 3.9-18.0
Tetric EvoCeram, Ivoclar Vivadent	1.58 (0.04) A	2.90 (0.28) A	Median, 6.2
			Range, 3.0-12.3

[a] *For contraction and depth of cure, different letters represent significant differences (Tukey HSD post hoc test, $p<0.05$).*
[b] *Median dentin gap formation and range (μm) from the combined mesiodistal and faciolingual sections of teeth restored with the investigated materials.*
* *For dentin gap formation, indicates significant differences between the bulk-fill resin composites and the conventional composite (Mann-Whitney U-test, $p<0.05$).*
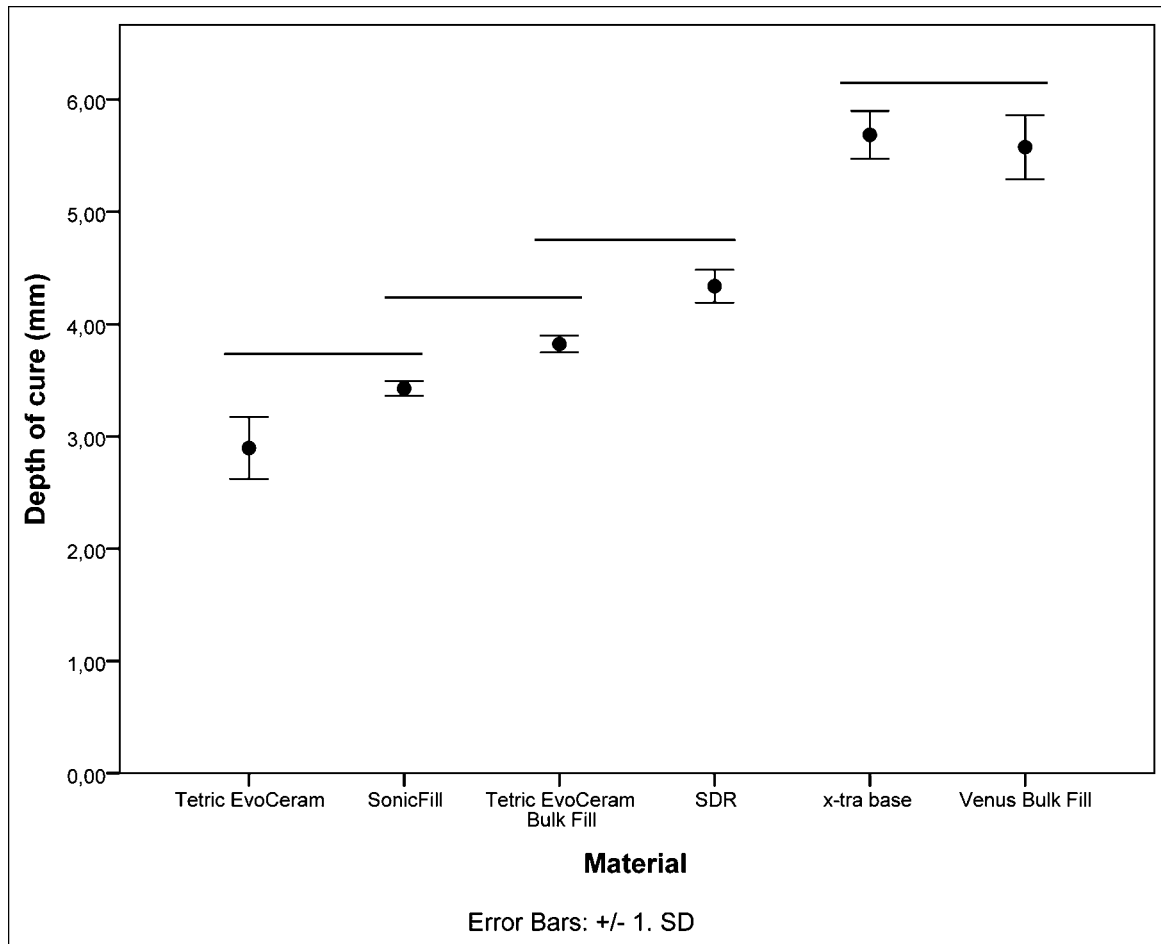
Figure 3. *Depth of cure (mm) of the investigated materials according to ISO 4049. The horizontal lines indicate the homogeneous grouping obtained from the Tukey HSD post hoc test.*

ly, high-viscosity bulk-fill resin composites with higher filler fraction (SonicFill and Tetric EvoCeram Bulk Fill) presented polymerization contraction values closer to the conventional resin composite (Tetric EvoCeram). An increase in the filler content can, to a certain extent, reduce the polymerization contraction[13,14] due to the decrease in the monomer content in relation to the filler-to-monomer ratio. In general, the polymerization contraction of all the investigated materials was between 1.58% and 3.36%, which is considered acceptable when compared with the polymerization contraction of the resin composites currently available on the market.

The depth of cure for most of the bulk-fill materials was improved when compared with the conventional resin composite (Figure 3). Nevertheless, the second null hypothesis was partially accepted due to the fact that SonicFill demonstrated a depth of cure statistically similar to that of the conventional resin composite Tetric EvoCeram. With

a mean depth of cure of 3.43 mm, SonicFill also failed to comply with the requirement from ISO 4049, which states that the individual values for depth of cure of a material shall be no more than 0.5 mm below the value stated by the manufacturer.[32] The manufacturer of SonicFill states that the material has adequate depth of cure up to 5-mm increments based on hardness and degree of conversion data; yet, this study followed the ISO 4049. Because the method proposed by ISO 4049 tends to overestimate the depth of cure when compared with hardness profiles,[8,33] especially for bulk-fill resin composites,[8] it is surprising that SonicFill did not perform better in the current study. Tetric EvoCeram Bulk Fill also showed a depth of cure slightly lower than the value advertised by its manufacturer, as has been previously reported.[8] However, together with the other investigated low-viscosity bulk-fill resin composites (SDR, Venus Bulk Fill, and x-tra base), Tetric EvoCeram Bulk Fill demonstrated higher depth of cure when compared with the conventional resin
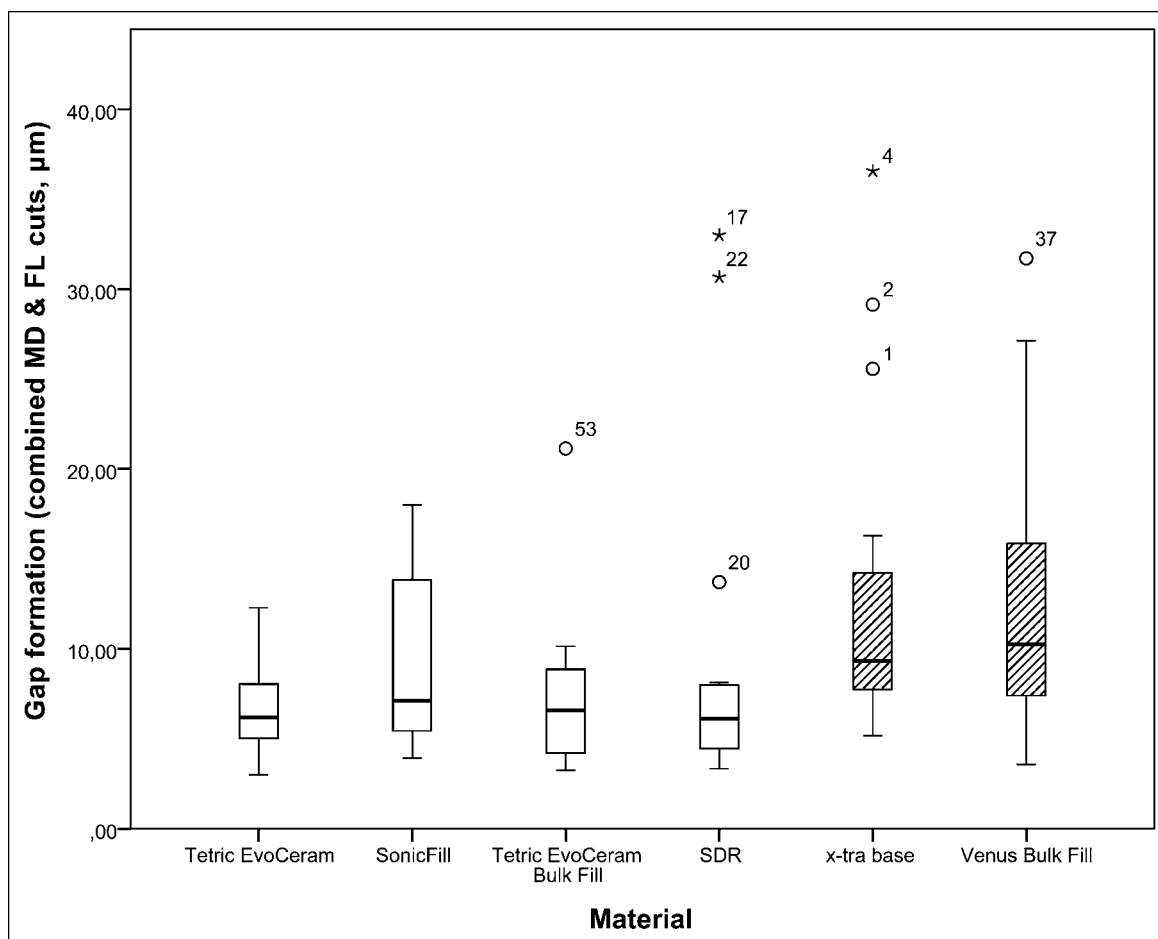
Figure 4. *Gap formation (median, minimum, and maximum, in μm) between the investigated materials and the dentin from combined mesiodistal (MD) and faciolingual (FL) sections. The striped boxes identify the materials for which gap formation was significantly larger than that of the conventional resin composite (Tetric EvoCeram), according to the Mann-Whitney U-test.*

composite. Higher depth of cure has been reported earlier for bulk-fill resin composites[8,9] due to improvements in their initiator system[8] and increased translucency.[7,8]

Among the many factors involved in gap formation, the quality and compliance of the adhesive bond play an important role in maintaining good contact between the resin composite and the cavity walls.[1,11,13,24-26,34] This is most critical in the absence of enamel, which was the case in the gingival margins of the cavities examined in this study. Therefore, a recognized, good-quality bonding system[34] was used that minimized the chance of gap formation due to poor bonding and allowed examination of the role of restorative materials in gap formation. It should be emphasized, however, that different outcomes may result from diverse bonding systems,[26] and perhaps a distinct behavior would have been observed had other bonding systems been investigated in this study.

Despite the use of a bonding system of recognized quality, none of the restorations were gap-free, as shown previously.[11] Some of the bulk-fill materials resulted in wider gaps than those observed for a conventional resin composite (Figure 4), despite their lower contraction stresses and the lower flexural modulus reported in an earlier study.[4] Therefore, the third null hypothesis was rejected. In the present study, the gaps were wider at the gingival walls, which is in accordance with previous data.[35] Gap formation was observed in all specimens, although to different extents. This is in contradiction with the data published by Roggendorf and others,[26] who observed predominantly gap-free margins in the absence of thermomechanical loading. Possible explanations for the different results, other than the different methods used for analyzing the gaps, are that the previously mentioned authors used MOD cavities. The increased compliance of an MOD cavity, when compared with the vertical slot cavities
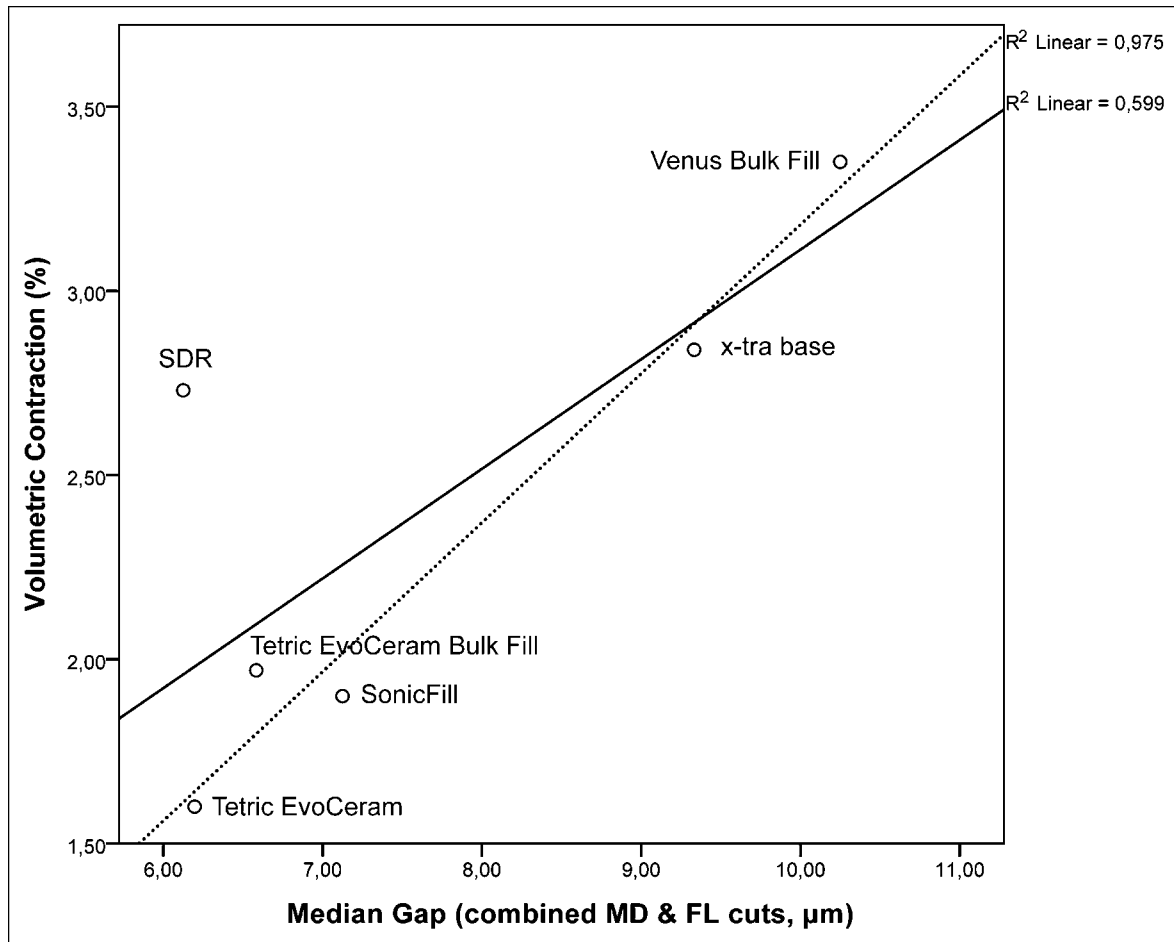
Figure 5.   *Linear fit for gap formation (median from combined mesiodistal and faciolingual sections) and polymerization contraction (%) from the Pearson correlation test for all investigated materials (solid line, $r^2=0.599$) and with the exclusion of SDR (dotted line, $r^2=0.975$).*

used in this study, is a consequence of the flexibility of the cusps and the possibility of cuspal deflection.[5,13,19] The vertical slot, on the other hand, is a more rigid model with less mobility of the cavity walls, and induced stresses are therefore more likely to result in the rupture of the bonding, with subsequent gap formation.

A further analysis of our results demonstrated that the high-viscosity bulk-fill resin composites with reduced polymerization contraction (SonicFill and Tetric EvoCeram Bulk Fill) resulted in similar gap formation when compared with the conventional resin composite. It is acknowledged that polymerization contraction of a material is not the sole factor involved in the development of contraction stresses[12,15] and gap formation around cavity margins.[5,10,11] This fact was confirmed in part during this study: When all of the investigated materials were taken into account, no correlation was observed between polymerization contraction and gap forma-

tion. Nevertheless, polymerization contraction is one of the most important factors[13] affecting the development of contraction stresses,[11,12,14] which may to a certain extent help to explain gap formation. The results from the present study further support the fact that the polymerization contraction plays a role in stress development, and consequent gap formation, around cavity margins. Indeed, when a second Pearson correlation test excluding SDR was performed between gap formation and polymerization contraction, a significant and strong correlation was present (Figure 5). A strong linear correlation between polymerization contraction and its resulting stresses has been previously reported for most resin composites by Kleverlaan and Feilzer.[14]

Despite the higher polymerization contraction of SDR when compared with Tetric EvoCeram, Sonic-Fill, and Tetric EvoCeram Bulk Fill, its gap formation was not significantly higher. Previous results for Tetric EvoCeram Bulk Fill have demon-

strated lower contraction stresses than for a conventional resin composite.[4] Positive results regarding gap formation were reported earlier for SDR, in a thermomechanical loading setup, when compared with conventional resin composites using different adhesive systems.[26] Other than the previously reported reduced polymerization contraction stresses,[3-5] a possible explanation for the positive results around SDR margins may be its lower flexural modulus[3,4,27] combined with its slower contraction rate,[3,4] which allowed the material to partially counteract the effect of polymerization contraction, thus resulting in gap formation similar to that of the conventional resin composite. The elastic modulus of resin composites has been considered an important aspect for both the polymerization contraction and development of polymerization contraction stresses.[4,12,14,15] Furthermore, a direct relationship between polymerization stress,[21,22] polymerization contraction,[23] and marginal integrity has been demonstrated *in vitro*. Additionally, in a current ongoing clinical study, restorations made with the recently developed bulk-fill resin composite SDR covered with a conventional resin composite were not yet significantly different from restorations made with a conventional resin composite following the three-year evaluation.[36]

The majority of studies regarding the development of polymerization contraction stress have been reported through mechanical testing[13] or indirectly through measurements of cuspal deflection[20] combined with microleakage assessments.[5,19] In the present study, an indirect appraisal of the polymerization contraction stresses generated by bulk-fill resin composites was assessed by gap formation. Although the application of laboratory results in clinical practice is limited or maybe uncertain, the results from this study further corroborate perspectives from previous research[2-5,8,25-27] that point out bulk-fill resin composites as promising restorative alternatives. However, further laboratory and long-term clinical investigations of bulk-fill resin composites remain necessary[6,36] before we can conclude that this new category of materials performs as well as the conventional resin composite.

CONCLUSIONS

Within the limitations of the present study, it is possible to conclude that the investigated high-viscosity bulk-fill resin composites (Tetric EvoCeram Bulk Fill and SonicFill) demonstrated, to some extent, polymerization contraction values and gap formation similar to the conventional resin composite, although their depth of cure was marginally below the values claimed by their respective manufacturers. Conversely, some of the investigated low-viscosity bulk-fill materials (x-tra base and Venus Bulk Fill) demonstrated higher contraction and unfavorably larger gap formation despite improved depth of cure, when compared with the conventional composite. One particular bulk-fill material (SDR) had improved depth of cure and comparatively low gap formation despite higher polymerization contraction.

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 article.

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