DOES A LOW-SHRINK RESIN COMPOSITE INDUCE LESS STRESS AT THE ADHESIVE/DENTIN INTERFACE IN HIGH C-FACTOR CAVITIES?

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ABSTRACT

Objective: The aim of this in vitro study to compare μTBS of two low shrink, TCD- based and dimer acid-based and one flowable SDR-based bulk-fill, resin composites; on the bottom of high C-factor cavities.

Materials & methods: Thirty extracted noncarious human mandibular molars were used in the study. The occlusal enamel, in each tooth, was cut parallel to the occlusal surface, to expose a flat dentin surface. The cut teeth were randomly divided into two main groups (n=15), depending on the preparation of dentin i.e., group I: high C-factor occlusal class I cavity, and group II: flat dentin surface at the same depth of the cavity floor. Single Bond Universal adhesive was used to bond the resin composites to dentin in the two groups. Teeth in each group were further subdivided into three subgroups (n=5) according to the restorative materials used. In subgroup a: Surfil SDR flow, bulk-fill flowable resin composite. In subgroup b, TCD-DI-HEA based, Charisma Topaz, nano-hybrid resin composite. In subgroup c, DDCDMA based, N'Durance, nano-hybrid resin composite. All the samples were subjected to 5000 cycle, thermocycling. Each specimen was sectioned longitudinally in both mesio-distal and bucco-lingual directions to obtain four beams per each sample. A total of 20 sticks were collected from each subgroup and subjected to μTBS evaluation using universal testing machine and the results were then subjected to statistical analysis. The fractured surfaces were inspected under a stereomicroscope to determine the failure modes.

Results: The collected data were subjected to two way AOVA, followed by Tuky᾿s post hoc test. Dentin preparation factor afforded insignificant higher μTBS values with samples prepared in flat dentin surface compared to Samples with high C-factor class I cavities, when TCD- based, restorative material was used. DDCDMA based, ND, nanohybrid and SDR-based restorative material resulted in significant increase in the μTBS when applied to the flat dentin surfaces in comparison with the high C-factor class I cavities. The three restorative materials were arranged in a descending order from TCD- based, DDCDMA based, followed by SDR resin, with no significant difference, when applied to the flat dentin surfaces. Yet, with high C-factor class I cavity restorations, μTBS in SDR-based resin revealed the lowest significant values. Most of the failure modes are adhesive in nature.

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Conclusions: Under the conditions of the present study, it might be concluded that TCD-based low-shrink resin composite investigated in this study perform well, in terms of compensation of polymerization shrinkage at the restoration/dentin interface and μTBS in high C-factor cavities. Conversely, the investigated Dimer acid-based and low-viscosity bulk-fill material based on SDR technology demonstrated unfavorable performance in high C-factor cavities.

KEYWORDS: Low shrink, SDR technology, resin composites, microtensile bond strength, C-factor.

INTRODUCTION

Polymerization shrinkage is a terrible problem, developed with the introduction of methacrylate based resin composite restoratives. During polymerization of resin monomers, the intermolecular van der Waals spaces in the monomers, are replaced by closer covalent bonds, resulted in volumetric shrinkage of the polymer mass.[1] Although bonding to either enamel or dentin is greatly improved, the problem of adhesive failure still remains.[2] The principal convincing reason of this situation is the polymerization shrinkage and its associated stresses developed at the restoration/ tooth structure interface.[3] Several studies proved the direct relationship between these developed stresses and the restoration/tooth interface integrity, in terms of adaptation and bonding capacity.[4-7] It is assumed that, if the polymerization shrinkage stresses exceed the bonding capacity at the restoration/ tooth interface, bonding failure will occur, with subsequent gap formation along the restoration/ tooth interface.[8] In general, the volumetric shrinkage of most methacrylate based resin dental composites is ranged between 2 and 4% of the material volume.[9] The magnitude of this shrinkage is dependent on material composition[10], while the degree of developed polymerization stresses is a result of several factors including the configuration factor and the material composition.[11,12] Numerous ways have been approved to reduce and compensate polymerization shrinkage and its developed stresses[13,14] including modification in the material composition. Two main strategies have been accomplished by the manufacturers to develop the low shrink resin composites, improved filler content[15-18] and modified resin monomers.

Evolutions in the monomer composition have been introduced to overcome polymerization shrinkage. Initially, the low molecular weight monomers, like TEGDMA, were added to the high viscous Bis-GMA and UDMA monomer to optimize resin viscosity, allow proper filler loading and increase degree of conversion of the monomer mixture. Unfortunately, these diluents have increased reactive species per volume unite; led to increase in the polymerization shrinkage of the resin composite.[19] One strategy to compensate this problem is to partially or completely replace the low viscosity diluent monomers with a series of high molecular weight monomers. In this direction the low molecular weight TEGDMA is replaced by higher molecular weight monomers, such as ethoxylated Bis-GMA monomer, Bis-EMA, which is the Bis-GMA analogue with low viscosity. This lowered viscosity is gained through absence of hydroxyl groups in the monomer that produce hydrogen bonding.[20] Another high molecular weight monomer is the hydrogenated dimer acid based dimethacrylates.[21-24] The high molecular-weight of this monomer with the decreased initial double-bond concentrations and low viscosity, motivate synthesis of this type of monomer to reduce polymerization contractions. Dimer acid is a derivative of an essential fatty acid, linoleic acid, comprises the main ingredient in many vegetable oils. Dimer acid methacrylates afforded decreased polymerization contraction,

with increased degree of conversion. Added to that, the relatively low cross-linking density of this monomer could produce a high flexible polymer but with decreased elastic modulus. For the same reason, the high molecular weight methacrylic acid derived, tricyclodecane (TCD) urethane, monomer based resin composites were launched to dental markets. This low viscosity monomer has a rigid back bone, similar to that of Bis-GMA, that results in low shrinking behavior.[14,22] The low viscosity of this monomer make it suitable to replace the diluents responsible for the high contraction of resins. In addition, high degree of conversion is achieved through the high reactivity of the acrylic acid ester containing urethane groups, in conjunction with the rigid structure of the TCD skeleton.[23]

A substantial development in the polymerization reaction dynamics is the incorporation of a photoactive group, photoinitiator, in a modified urethane-based methacrylate resin, to slow radical polymerization rate. This genuine lowered curing stresses is particularly exist in case of low filler loading. These patented resins are based on the stress decreasing resin, SDR, technology. It has been shown that this material resulted in great flexibility that allow dissipation of shrinkage stress.[24,25]

Shrinkage stresses are induced when the polymerization shrinkage is restrained by the bond at the restoration/tooth interface, pulling the polymerized resin composite material apart of the cavity walls.[26] The degree of stress development is influenced by the restored cavity shape and configuration, C-factor. The C-factor can be defined as the ratio between the bonded to the unbounded surface area of the restoration.[27-29] It is evident that C-factor negatively affects the restoration performance, including the microtensile bond strength.[27-31] The increased C-factor, associated with either class I or V cavities, increases the developed polymerization stresses at the restoration/tooth interface. These stresses are in competition with the bond strength of the polymerized materials, influence the partial or complete debonding of the restoration. As a rule, studies conducted to evaluate bond strengths to flat dentin surfaces, measure the adhesives or restorative systems performance. Several studies[32-34] were conducted to investigate the influence of the restorative materials per se on the bonding characteristics, through evaluation of μTBS in high C-factor cavities.

Through the previous introduction, distinct variations in the composition of resin phases of low-shrink resin composites available, so it is interesting to evaluate and compare the μTBS of materials representing the different modifications previously mentioned, applied in a high C-factor cavities, under polymerization shrinkage stresses. The materials to be tested are three resin composites with high molecular weight monomers, Surfil SDR flow (SDR), Charisma Topaz (ChT) and N·Durance (ND). The null hypothesis was there is no difference in the microtensile bond strength of the low-shrink high molecular weight tested materials, bonded to flat dentin or high C-factor dentin cavity walls.

MATERIALS AND METHODS

The description of the selected materials under the main category of low-shrink resin composites, with one universal adhesive system are presented in table 1. Thirty extracted human mandibular molars without any defects or restorations were collected from the Oral surgery department, Faculty of Dentistry, Mansoura University. Mesio-distal and bucco-lingual dimensions of the collected teeth were measured to ensure that all the teeth have almost similar dimensions. Teeth were collected due to periodontal problems. For disinfection, teeth were stored in a 0.5% chloramine-T solution for no more than 30 days. Before preparation, for ease of use, teeth were mounted, in acrylic resin (Acroston, under exclusive license of Acroston Dental Company-Cairo, Egypt), with the aid of Poly vinyl chloride rigid cylinders.

TABLE (1) Restorative materials used

Material	Filler loading	Composition	Manufacturer
SureFil SDR flow	Microhybrid 68wt%/44vol%	Resin: EBPADMA, TEGDMA, Modified UDMA Filler: Barium-alumino-fluoro-borosilicate glass, Strontium alumino-fluoro-silicate glass	Dentsply Caulk, Milford, DE, USA
Charisma Topaz	Nanohybrid 73wt%/58vol%	Resin: TCD-DI-HEA, UDMA Filler: Barium Aluminium Fluoride glass, pre-polymerized fillers	Heraeus Kulzer, Hanau, Germany
N·Durance	N a n o - h y b r i d 80wt%/65vol%	Resin: DDCDMA, EBPADMA, UDMA Filler:Ytterbium Fluoride, Barium Glass, Silica	Septodont, France
Single Bond Universal Adhesive		MDP monomer, Dimethacrylate, HEMA, ethanol, water, Vitrebond copolymer (methacrylate modified polyalkenoic acid)	3M/ESPE, St Paul, MN, USA

EBPADMA, Ethoxylated Bisphenol A dimethacrylate; TEGDMA, Triethyleneglycol dimethacrylate; TCD-DI-HEA, Bis-(acryloyloxymethyl) tricyclo (5.2.1.02,6) decane; UDMA,urethane dimethacrylate; DDCDMA, Dimer Dicarbamate Dimethacrylate; EBPADMA,Ethoxylate Dimethacrylate; Bis-GMA, bisphenylglycidyl dimethacrylate; Bis-EMA, ethoxylated bisphenol-A dimethacrylate

Teeth preparation

The occlusal enamel, in each tooth, was cut parallel to the occlusal surface, using a diamond saw (Isomet4000, BuehlerLtd, LakeBluff, IL, USA) under water cooling, to remove the occlusal enamel and expose a flat surface of superficial dentin. The cut teeth were randomly divided into two main groups (n=15), depending on the preparation of dentin i.e., group I: high C-factor occlusal class I cavity, and group II: flat dentin surface.

In group I, to be sure that the entire occlusal cavity was prepared completely in dentin, a permanent marker was used to border a square area, of 4*4mm, at the middle of the prepared flat dentin surface. A rectangular occlusal cavity was prepared in each tooth, using a #560 high speed fissure carbide bur (MANI Inc, JAPAN), with air/water coolant, and the cavity floor was verified using # 014 inverted cone diamond. The dimensions of the prepared cavity were 4±0.1mm wide and 3.5±0.1 mm deep with a 4.5 C-factor. In group II, the occlusal flat dentin surface was further cut, using an Isomet, cervical

to the first cut with 3.5±1 mm, simulating the depth of the prepared cavity in group I. All the prepared dentin surfaces were washed with a copious water stream and dried before adhesive application.

Application of the restorative systems

Single Bond Universal adhesive was applied in a self-etch (SE) mode following the manufacturer's instructions. A thick layer of SE adhesive was applied to the dry and clean dentin surfaces in both groups, using a microbrush, with rubbing action for 20 seconds. The adhesive was then dried with compressed air for about 5 seconds, to ensure complete vaporization of the solvent, then light cured, with a LED curing unite (LEDition, IvoclarVivadent, Germany) at a light intensity of 800 mW/cm2, for 10 seconds. Teeth in each group were further subdivided into three subgroups (n=5) according to the restorative materials used. In subgroup a: Surfil SDR flow, bulk-fill flowable resin composite was inserted to fill the entire depth of the prepared cavity, in group I; while in group II a square metallic mold with the same dimensions

of the prepared cavity in group I, 4±0.1mm wide and 3.5±0.1 mm deep, was used to buildup resin composite above the flat dentin surface. All the applied resin composites were photo-cured for 20 seconds, using a LED curing unite at a light intensity of 800 mW/cm2. In subgroup b, TCD-DI-HEA based, Charisma Topaz, nanohybrid resin composite was applied, to either the prepared cavity or the metallic mold, in a horizontal incremental technique. Two increments were applied; with increment thickness not exceed 2 mm. The increment thickness was verified using a graduated periodontal probe. Each increment was photo-cured, using a LED curing unite at light intensity of 800 mW/cm2, for 20 seconds. In subgroup c, DDCDMA based, N'Durance, nano-hybrid resin composite was applied in the same manner discussed in subgroup b. After photo-curing, excess materials were removed with a diamond finishing stone (TR-25EF, Mani, Japan) under air/water cooling, and then the samples were polished with Sof-lex XT polishing system (3M ESPE, St. Paul, MN, USA). All the samples in the two groups were then stored in distilled water, in an incubator, at 37±1oC for 24 hours. Samples were subjected to 5000 cycle, thermocycling (SD Mechatroniks thermocycler, Germany), between 5-55oC with 20 seconds dwell time and 5 seconds transfer time.

Microtensile bond strength test (μTBS)

The center of each specimen, in the two groups, was sectioned longitudinally in both mesio-distal and bucco-lingual directions across the bonded interface of the cavity floor, along the long axis of the crown, with Isomet cutting machine and water coolant. Three parallel cuts were made in each direction to obtain four sticks of 0.9±1mm² cross-sectional area. Each tooth was then horizontally cut at the cemento-enamel junction to obtain beams. A total of 20 beams were collected from each subgroup and subjected to μTBS evaluation using universal testing machine (*Instron, MA, USA*). Each beam was attached to a custom made jig, utilized for mounting of beams into the universal testing machine using cyanoacrylate glue ((Zapit; DAVA, Corona, CA, USA) and then a tensile load was applied at a cross head speed of 0.5 mm/min, until the beam fractured. Bond strength was calculated in MegaPascal *(BluehillLite software, Instron, MA, USA)*, and the results were then subjected to statistical analysis. Steps of specimen preparation in high C-factor cavities are illustrated in figure 1.
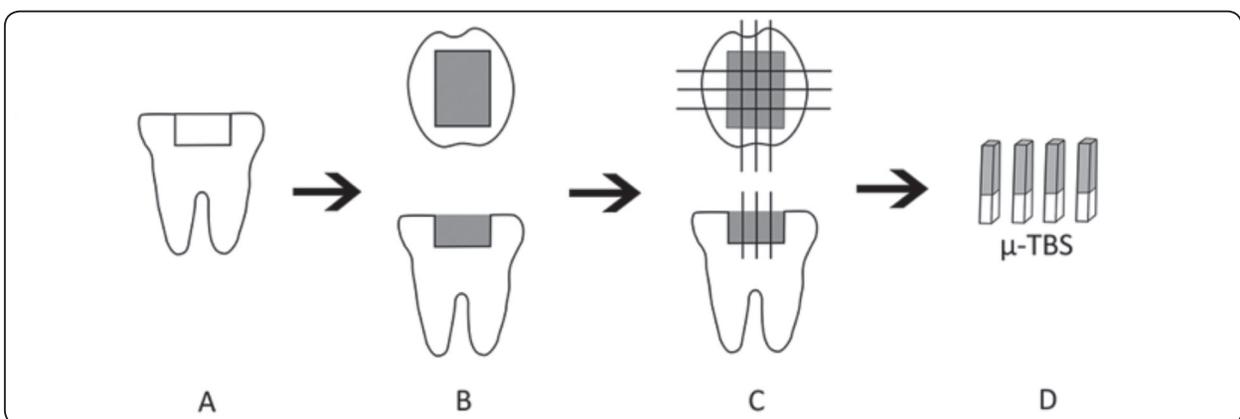

Figure 1: Schematic illustration of specimen preparation in high C-factor cavity.

Failure mode

After fracture of the beams, the fractured surfaces were inspected under a stereomicroscope (Olympus, SZ61, Tokyo, Japan) at X40 magnification to determine the failure mode. The modes of failure were classified into, adhesive failure if the fractured surface was completely present at dentin/restoration interface; cohesive failure if the fracture is completely present in the resin composite or in dentin; or mixed failure if the failures is present with adhesive/cohesive modes.

RESULTS

Microtensile bond strength results (μTBS)

The data were scaled using Microsoft excel software and analyzed using SPSS V.20.0. Two-way analysis of variance (ANOVA) indicated significant differences for dentin preparation and restorative materials factors (p <0.05), table 2. The mean μTBS values were subjected to Tuky's post hoc test and tabulated in table 3, to compare the differences between each two subgroups.

Dentin preparation factor afforded insignificant higher μTBS values (p <0.05) with samples prepared in flat dentin surface compared to Samples with high C-factor class I cavities, when TCD-DI-HEA based, ChT, nanohybrid restorative material was used. However, DDCDMA based, ND, nanohybrid and SDR microhybrid restorative materials resulted in significant increase in the μTBS (p < 0.0001) when applied to the flat dentin surfaces in comparison with the high C-factor class I cavities.

TABLE (2) Two-Way ANOVA test Results (Both factors significantly influenced the results)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1099.686[a]	5	219.937	130.242	.000
Intercept	110039.943	1	110039.943	65163.194	.000
Dentine	416.641	1	416.641	246.726	.000
Material	610.683	2	305.341	180.816	.000
Dentine * Material	72.362	2	36.181	21.426	.000
Error	192.510	114	1.689		
Total	111332.139	120			
Corrected Total	1292.196	119			
R Squared = .851 (Adjusted R Squared = .844)					

TABLE (3) Tukey post Hoc Multiple comparison test results of restorative materials and C-factor

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
F_SDR	20	30.0635[b]	1.93775	.43329	29.1566	30.9704	27.17	33.87
F_Chairsma	20	33.4355[d]	1.02822	.22992	32.9543	33.9167	31.72	35.03
F_N'Durance	20	32.9370[d]	1.27305	.28466	32.3412	33.5328	30.85	34.85
C_SDR	20	24.2385[a]	1.08617	.24287	23.7302	24.7468	22.79	26.13
C_Chairsma	20	31.3200[c]	1.30123	.29096	30.7110	31.9290	28.80	33.18
C_N'Durance	20	29.6975[b]	.90906	.20327	29.2720	30.1230	27.79	31.11
Total	120	30.2820	3.29527	.30082	29.6864	30.8776	22.79	35.03

Each two dissimilar letters revealed a significant difference between groups.

The three restorative materials were arranged in a descending order from TCD-DI-HEA based, ChT, resin composite (33.4355), DDCDMA based, ND, resin composite (32.9370) followed by SDR microhybrid resin (30.0635), with no significant difference, when applied to the flat dentin surfaces. Yet, with high C-factor class I cavity restorations, μTBS in TCD-DI-HEA based, ChT, resin (31.3200) is significantly higher than in DDCDMA based, ND, resin (29.6975), while SDR revealed the lowest significant value (24.2385).

Failure modes

Failure mode distribution, adhesive, cohesive or mixed, for the two dentin preparations and resin composites were presented in table 4. The high C-factor class I cavity showed prominent adhesive failure, followed by mixed failure, cohesive failure in composite and cohesive failure in dentin. Flat dentin surface revealed mostly adhesive failure, to be followed by mixed failure, cohesive in dentin and cohesive in resin composite.

SDR resin composite, in high C-factor cavities, have the highest failure percentage in adhesive interface, to be followed by mixed and cohesive in resin composite, while with flat dentin surfaces failure modes were arranged in a descending order from adhesive, mixed and cohesive in either resin composite or cohesive in dentin. ChT resin composite, in high C-factor cavities, have highest failure percentage in adhesive interface, to be followed by mixed and cohesive in resin composite, while with flat dentin surfaces failure modes were arranged in a descending order from adhesive, mixed and cohesive in resin composite. ND resin composite, in high C-factor cavities and flat dentin surfaces, have highest failure percentage in adhesive interface, to be followed by mixed, and cohesive in either resin composite or dentin.

DISCUSSION

At present, evolutions in direct resin composites are focused on elimination or even minimizing the polymerization shrinkage of resin composites and associated stresses developed. Clinically, the polymerization shrinkage and its stresses can be compensated using several ways such as photo-curing modes and equipments; and incremental techniques of resin composites application.[35] Actually, the perfect way to eliminate shrinkage and stresses is to use shrink-free resin composite. Yet, this hopeful material is not discovered.[1,7,10-14] Because it is known that obtaining a high bond strength to dentin is competed with resultant Stresses from polymerization shrinkage of the restorative materials, hence low-shrink resin composite is the most important request at present.[36,37]

Table (4) Persentage distribution of failure modes

Dentin preparation	Restorative materials	Mode of failure			
		Adhesive	Cohesive in dentin	Cohesive in composite	Mixed
High C-factor	Surfil SDR	60	-	10	30
	Charisma	70	-	10	20
	N`Durance	60	10	10	20
Flat dentin	Surfil SDR	40	10	10	40
	Charisma	70	10	-	20
	N`Durance	60	10	10	20

Microtensile bond strength of resin composites to dentin is the influence of several factors, involving the material composition, elastic modulus and polymerization contraction, [38] in addition to the challenging effect of cavity C-factor.[26,29-33,37] In this study, the increase in the cavity C-factor significantly decreases the values of μTBS, when the bulk-fill SDR and N'Durance resin composites were used, while with Charisma Topaz resin composite, changing the cavity C-factor insignificantly decrease the μTBS values. The calculated C-factor for class I occlusal cavity and flat dentin surface, in the study, are 4.5 and 0.2 respectively. The keyword of these results is the flow relaxation of the polymerized resin. In the low C-factor flat dentin, polymerized resin freely flows through the free unbounded five walls, with large surface area. When restoring a high C-factor cavity, the opposite is true, where the resin is attached to five walls, with severely limited flow. If the developed polymerization stress exceed bond strength, resin/dentin interface separation occur leading to bond failure.[11,33,37,39] The results of the present study are in agreement with several studies[32-34,40,41] in which the flat surface dentin preparation demonstrates no influence on polymerization stress propagation and μTBS of resin composites to dentin, while the increase in the C-factor adversely affects μTBS values, in relation to the materials' polymerization contraction values. Failure modes are mostly adhesive in nature indicating that polymerization contraction does exceed the restoration/dentin adhesive interface. The null hypothesis was rejected, as increased C-factor significantly impair bonding to dentin when Dimer acid-based and SDR based resin composites were used, while the TCD-based material sill have, although insignificant, effect on bonding capacity in high C-factor cavities. In addition TCD-based resin composite showed the significant highest bond strength, with Dimer-based resin composite is significantly higher bond strength than SDR- based one.

In the present study Bis-GMA monomer is completely substituted with UDMA formulations, in the three tested materials, with a variety of added other monomers. The low viscosity formulations of urethane dimethacrylate (UDMA) became widely common for dental resin composites, to overcome limitations of Bis-GMA and the diluents TEGDMA. The low viscous, flexible UDMA copolymers generally donate higher flexural strength, elastic modulus and hardness, than Bis-GMA, with higher monomer to polymer comversion. [42-44]

The nanohybrid resin composite Charisma Topaz revealed the highest μTBS values, regaredless the dentin preparations, which are significant in comparison with SDR based resin composite, but significant in comparison with N'Durance in high C-factor only. This result confirms that ChT posses a detectable low-shrink property that could compensate stresses at the restoration/resin interface. The corner stone for the superior results obtained with Charisma Topz nanohybrid resin composite is the resin matrix composition. The nanohybrid Charisma resin composite is composed of a unique high molecular weight Bis-(acryloyloxymethyl) tricyclo (5.2.1.02,6) decane (TCD-DI-HEA) monomer, with a rigid backbone (tricyclodecane). Regardless the degree of high c=c conversion, the decreased monomer vibration allows closer distance between the unpolymerized monomers, with high packing density. During polymerization, small changes in the cross-linking monomers distance, reduces polymerization shrinkage.[14,45-47] Added to that, it posses low viscosity, enough to replace low molecular weight diluents in resin composites, with high reactivity of the acrylic acid esters.[14,22,23] Marchesi et al[14] and de Oliveira et al[48] reported that TCD-DI-HEA containing resin composites induced significantly reduced polymerization stresses.

Next to Charisma Topaz, a singular nanohybrid resin composite with dimer acid based methacrylate, N'Durance, confer slightly lower but comparable

μTBS values in flat dentin surfaces, and significant lower μTBS in high C-factor. The composition of the resin matrix is, Dimer Dicarbamate Dimethacrylate (DDCDMA), Ethoxylate Dimethacrylate (EBPADMA) and UDMA. The high molecular weight dimer acid-based monomer was developed in an attempt to reduce volumetric shrinkage during polymerization with decreased initial double-bond concentrations. The hydrogenated dimer acid derived monomer contains a core structure with an aromatic moiety, urethane groups, and two side arms. Reduced polymerization shrinkage, shrinkage stress and high degree of conversion were observed for dimer acid homopolymers.[21-24] In addition, high flexibility but low elastic modulus of the polymerized material is the profit of low cross-link density of the low viscosity dimer acid dimethacrylates. When comparing N'Durance with a nanohybrid resin composite containing TCD-DI-HEA (Venus Diamond), N'Durance possesses unnoticeable inferior properties in terms of flexural strength, modulus of elasticity values, with shrinkage and shrinkage stress values[45,46,49,50], that could produce higher stress at the cavity walls in high C-factor cavities.

Another high molecular weight monomer incorporated in N'Durance resin matrix is Ethoxylatedbisphenol A dimethacrylate (Bis-EMA). This monomer is a Bis-GMA analogue with higher molecular weight but without the strong secondary molecular interactions given by hydroxyl groups, which reduces its viscosity and allows for higher DC and better mechanical properties to be achieved. Lower viscosity of BisEMA may be attributed to the absence of hydrogen bonding due to the lack of hydroxyl groups.[20] This high molecular weight monomer is used mainly to completely or partially replace the low molecular weight diluent monomers, such as TEGDMA. Combination of Bis-EMA with conventional monomers such as UDMA or Bis-GMA, has been found to provide lowered polymerization shrinkage.[51]

Flat dentin surface revealed lowest, although insignificant, μTBS values when Surfil SDR flow resin composite was tested. Nevertheless, the high C-factor cavities resulted in significant impairment in the μTBS when restored with this material. This is an indication that Surfil SDR flow develops high polymerization shrinkage with high stress. In Surfil SDR flow resin matrix, the traditionally used Bis-GMA is totally replaced by modified urethane dimethacrylate (UDMA) and Ethoxylate Dimethacrylate (EBPADMA). In addition, triethylene glycol dimethacrylate (TEGDMA) is added as a diluent. TEGDMA is a flexible low viscous monomer that allows higher incorporation of inorganic fillers and improves handling characteristics. Unfortunately, addition of TEGDMA impairs the physical and mechanical properties of the final product.[52-55] Although TEGDMA flexibility donates the increased degree of conversion, the higher number of reactive species per volume unit contributes to increase in polymerization shrinkage of its respective composite.[19,51] Incorporation of TEGDMA in SDR may be the explanation of inferior μTBS obtained with this material in the two test groups. The significant decrease in the μTBS in class I, high C-factor maximizes the role of polymerization contraction and the developed stress at the adhesive/dentin interface.[37,39]

Although the modified UDMA monomer, incorporated photoactive polymerization modulator, regulates the polymerization stress of the Surfil SDR flow resin phase, through the SDR technology[25,] without reduction of the polymerization rate[56]; the filler content was remarkably reduced, 68wt% and 44vol%. Filler loading in Surfil SDR flow is reduced in an attempt to increase translucency and depth of cure.[57-59] There is an inverse linear relationship between the filler loading and polymerization shrinkage, where the lower filler content increases the amount of resin phase. The increased resin content in the composite increases the reactive site per unit volume, with increased polymerization shrinkage and decreased mechanical properties.[60-63]

Benetti et al.,[62] demonstrated that the low-viscosity bulk-fill resin composites produced a significantly higher depth of cure but a significant higher polymerization contraction.

Most of researches to study the impact of polymerization contraction and polymerization stress have been reported directly through mechanical testing[64] or indirectly through measurements of cuspal deflection[65], microleakage assessments.[66] In the present study, polymerization contraction stress was indirectly assessed through the μTBS measurements in a high C-factor class I cavity. The results of this study might confirm expectations arise from previous researchs[45-50] suggested low-shrink resin composites as hopeful esthetic restorative alternatives. However, long-term clinical investigations of low-shrink resin composites still required before recognition of validity of these materials.

CONCLUSIONS

Under the conditions of the present study, it might be concluded that μTBS is a material and configuration factor dependent. TCD-based low-shrink resin composite investigated in this study perform well, in terms of compensation of polymerization shrinkage at the restoration/dentin interface and μTBS in high C-factor cavities. Conversely, the investigated Dimer acid-based and low-viscosity bulk-fill material based on SDR technology demonstrated unfavorable performance in high C-factor cavities.

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