©Operative Dentistry, 2007, **32-4**, 356-362

The Influence of C-factor, Flexural Modulus and Viscous Flow on Gap Formation in Resin Composite Restorations

E Moreira da Silva • GO dos Santos • JGA Guimarães
AAL Barcellos• EM Sampaio

Clinical Relevance

Resin composites with high viscous flow and low flexural modulus may reduce gap formation in resin composite restorations.

SUMMARY

This study analyzed the influence of C-factor, flexural modulus and viscous flow on gap formation in resin composite restorations. Two resin composites, a mini-filled hybrid (P 60) and a nanofilled (Supreme), were used. The flexural modulus was obtained from bar-shaped specimens submitted to three-point bending. Viscous flow was obtained from the difference between the initial and final diameter of resin composite disks submitted to a load of 10 N for 120 seconds. Gap analysis was conducted in three types of cylindrical cavities (C-factor of 1.8, 2.6 and 3.4) that were prepared on the occlusal surfaces of human molars. The gap width at the dentin-resin composite interface was measured using a 3D scanning system (Talyscan 150). The data were analyzed by ANOVA and Student-Newman-Keuls' test, *t*-test and linear regression analysis (α=0.05). The cavities with C-factor 3.4 presented the highest Gap formation (p<0.0001). The lowest Gap formation was found in cavities restored with Supreme resin composite (p<0.0001). P 60 presented significantly higher flexural modulus and lower viscous flow than Supreme (p<0.0001). Regression analyses detected a significant influence of flexural modulus and viscous flow on gap formation (p<0.05).

*Eduardo Moreira da Silva, DDS, MSc, PhD, associate professor, Department of Restorative Dentistry, School of Dentistry, Federal Fluminense University, Rio De Janeiro, Brazil

Gustavo Oliveira dos Santos, DDS, graduate student (Master's degree), Department of Restorative Dentistry, School of Dentistry, Federal Fluminense University, Rio De Janeiro, Brazil

José Guilherme Antunes Guimarães, DDS, MSc, PhD, associate professor, Department of Restorative Dentistry, School of Dentistry, Federal Fluminense University, Rio De Janeiro, Brazil

Alexandre de Araújo Lima Barcellos, DDS, MSc, PhD, associate professor, Department of Restorative Dentistry, School of Dentistry, Federal Fluminense University, Rio De Janeiro, Brazil

Eduardo Martins Sampaio, BSc, MSc, PhD, associate professor, Adhesion and Adherence Laboratory, Department of Mechanical Engineering, Estate University of Rio de Janeiro, Rio De Janeiro, Brazil

*Reprint request: Rua São Paulo, No 28, Campus Valonguinho, Niterói, RJ, CEP 24040-110, Brazil; e-mail: emsilva@vm.uff.br

DOI: 10.2341/06-104

INTRODUCTION

Since their development, several improvements have been made to the physical and mechanical properties of resin composites,[1] which have permitted their safe application in posterior tooth restorations.[2-3] However, one of the shortcomings that still remain as a challenge to the longevity of resin composite restorations is the shrinkage generated during polymerization reaction.[4] During polymerization, the intermolecular spaces of 0.3-0.4 nm between the dimethacrylate monomers of their polymeric matrix, maintained by Van der Waals forces, are reduced by the conversion of C=C bonds and the establishment of C-C bonds with lengths of 0.15 nm between polymer chains.[5] In clinical practice, this phenomenon leads to stress development, gap formation and potential bacterial presence at the tooth-resin composite interface.[6]

In addition to polymerization shrinkage, several other factors may influence shrinkage stress and gap development at the tooth-resin composite interface. Feilzer and others[7] showed that shrinkage stress is related to the configuration factor, C-factor, defined as the ratio of bonded to unbonded surfaces of the restoration. According to the aforementioned authors, in cavities with a C-factor of less than 1, shrinkage stress develops slowly and the resin composite remains bonded to the cavity walls. Braga and others,[8] using a photoelastic analysis, showed that cylindrical cavities with the same volume of resin composite developed numerically higher fringe orders at internal angles when the C-factor was higher. The extent of shrinkage stress is also dependent on the viscoelastic properties of the resin composite.[4] At a given polymerization shrinkage, the most rigid resin composite will produce the highest shrinkage stress and, consequently, increase gap formation at the tooth-resin composite interface.[4,9]

Some published studies have shown that shrinkage stress can be relieved by resin composite flow relaxation.[10-11] The resin composite flow is influenced by factors related to its formulation, such as type and content of filler particle.[11-12] In a study about the influence of filler content and size on composite properties, Li and others[13] showed that, when the filler level was increased, so was the resin composite stiffness.

This study investigated the influence of C-factor, flexural modulus and viscous flow on gap formation in resin composite restorations. The research hypothesis tested was that the resin composite with the highest viscous flow and lowest flexural modulus would lead to a reduced gap formation.

METHODS AND MATERIALS

Two commercially available resin composites, both chosen in accordance with their different types of filler particles, were tested: a minifilled hybrid resin composite (P 60) and a nanofilled resin composite (Supreme, 3M ESPE, St Paul, MN, USA). Both materials have the same polymeric matrix (Bis-GMA, Bis-EMA, TEGDMA and UDMA). Compositions of the materials are described in Table 1.

All the specimens in this study were photoactivated with a quartz-tungsten-halogen unit (Optilux 501, Kerr, Danbury, CT, USA) operating at an irradiance of 850 mW/cm^2 for 20 seconds. The radiant exposure (17 J/cm^2) was calculated as the product of the irradiance of the curing unit using a radiometer (model 100, Demetron Inc, Danbury, CT, USA) and the time of irradiation.

Flexural Modulus

The resin composites were applied in a bar-shaped steel split mold (1 x 2 x 10 mm) positioned over a glass plate. After filling the mold to excess, the material surfaces were covered with a polyester strip and glass slide and compressed with a device (500 g) to extrude excess material. The specimens were light-cured from the top with two overlapping footprints (2 x 850 mW/cm^2 for 20 seconds). The specimen dimensions were recorded using a digital caliper (MPI/E-101, Mitutoyo, Tokyo, Japan). After 24 hours of dry storage at 37°C, the specimens were submitted to three-point bending with a 6 mm span between the supports in a universal testing machine with a load cell of 50 N (DL 10000, Emic, Curitiba, PR, Brazil) at a crosshead speed of 0.5 mm/minute. The Flexural modulus (GPa) was calculated from the linear portion of the load/deflection curve using the following equation:

$$\mathrm{FM} = \frac{l^3 F}{4wh^3 d}$$

where FM is the flexural modulus, l is the length between the supports, F is the applied load, w is the width of the specimen, h is the height of the specimen and d is the deflection at load F. Ten specimens were produced from each resin composite.

Viscous Flow

The viscous flow was based on the method described by Peutzfeldt and Asmussen.[9] Briefly, a Teflon split mold

Table 1: *Composition of the Resin Composites Used in This Study*

Resin Composite	Composition
P 60	Filler: 61 vol% silica/zirconia filler with mean particle size of 0.6 µm
	Polymeric matrix: Bis-GMA, Bis-EMA, UDMA TEGDMA
Supreme	Filler: 59.5 vol% combination of aggregated zirconia/silica cluster filler with primary particles size of 5-20 nm, and non-agglomerated 20 nm silica filler.
	Polymeric matrix: Bis-GMA, Bis-EMA, UDMA TEGDMA

with a 4.0 m diameter and 3.0 mm height (37.68 µl in volume), placed over a glass plate, was filled with resin composite. The mold was removed and the resin composite was covered with a second glass plate. A device with a load of 10 N was immediately applied to the upper glass plate for 120 seconds. The diameter of the resulting resin composite disk was recorded at four points, spaced at 45°, using a digital caliper (MPI/E-101, Mitutoyo, Tokyo, Japan). The viscous flow was computed as the difference between the initial diameter and the mean values for the final diameter of the resin composite disks. Five specimens were produced from each resin composite.

Gap Measurement

The gap analysis steps are illustrated in Figure 1. The occlusal surfaces of 30 human molars stored in an aqueous solution of 1% chloramine for two weeks and frozen in distilled water for less than three months were wet ground in a polishing machine (DPU-10, Struers, Copenhagen, Denmark), with 150 and 600 grit SiC papers until flat dentin surfaces were obtained. Cylindrical cavities 5.0 mm in diameter and three different depths (A=1.0, B=2.0 or C=3.0 mm) were prepared in all flat dentin surfaces using a diamond bur (#4054, KG Sorensen, SP, Brazil) in a high-speed handpiece fixed in a special sample aligning device. The cavity depths were controlled by using a digital caliper (MPI/E-101, Mitutoyo, Tokyo, Japan). The teeth were randomly assigned to six groups of five each. The C-factor was obtained using the following formula:

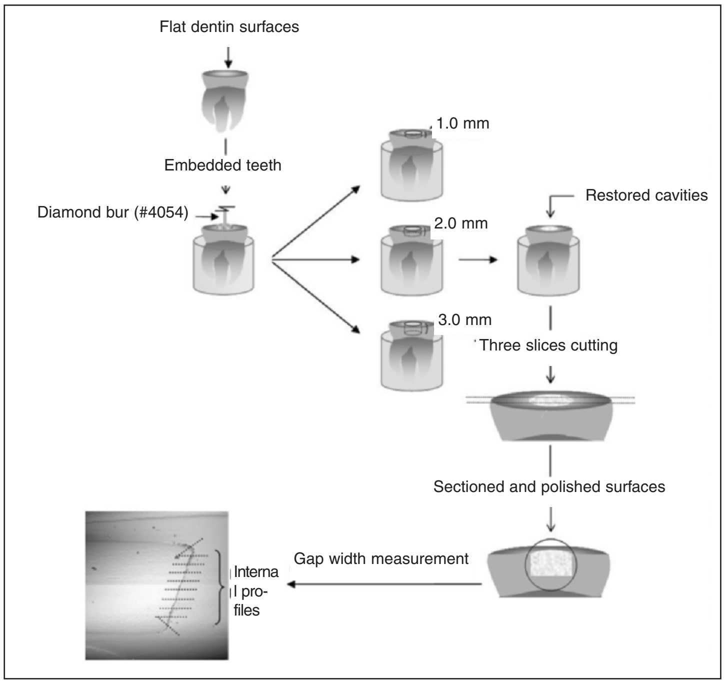

Figure 1: *Schematic illustration of the gap analysis.*

$$\mathrm{C} - factor = \frac{(2\pi rh) + \pi r^2}{\pi r^2}$$

where r is the cavity radius and h is the cavity depth.

Therefore, C-factors for the three cavities were: A=1.8; B=2.6 and C=3.4. The cavities were bonded with the Single Bond 2 adhesive system (3M ESPE, St Paul, MN, USA) in accordance with the manufacturers' instructions, and the resin composites were inserted in one increment using a flat-sided instrument (Suprafill #1, SSWhite, Rio de Janeiro, Brazil). The resin composites were covered with a polyester strip and photoactivated (850 mW/cm^2 for 20 seconds). After storage in distilled water at 37°C for seven days, finishing and polishing procedures were performed with sequential Sof-Lex discs (3M ESPE). The teeth were longitudinally sectioned in a buccolingual direction through the restorations using a diamond disk (KG Sorensen, São Paulo, SP, Brazil). Three slices were obtained for each restoration. The sectioned surfaces were polished with 1200-grit SiC sandpaper (DPU–10, Struers, Copenhagen, Denmark) and ultrasonicated in distilled water for five minutes. The sectioned surfaces were analyzed in a 3D-scanning system (Talyscan 150, Taylor Hobson, Leicester, England) using a space of 1 µm in the scanning direction (x) and 60 µm in the direction (y) at a scanning speed of 1000 µm/second. The images were leveled and roughness profiles of tooth-restoration surfaces were obtained. The gap width was analyzed at 10 positions for each slice floor.

Statistical Analysis

The statistical analysis was performed with Statgraphics 5.1 Software (Manugistics, Rockville, MD, USA). The flexural modulus and viscous flow data were analyzed separately by *t*-test. The gap formation data were analyzed by two-way and one-way ANOVA with Student-Newman-Keuls' test for multiple comparisons. Linear regression analysis was performed to determine the relationship between gap width and flexural modulus and between gap width and viscous flow. All statistical analysis was performed at a significance level of α=0.05

RESULTS

The *t*-test showed that the flexural modulus of P 60 was higher (Figure 2) and statistically different from Supreme (p<0.0001). P 60 showed significantly lower viscous flow (Figure 3) than Supreme (p<0.0001). The linear regression analyses detected a positive correlation between flexural modulus and gap width (r^2=1.0/p<0.05) and a negative correlation between viscous flow and gap width (r^2=-1.0/p<0.05).

The gap formation results are presented in Figure 4. Two-way ANOVA showed that C-factor and resin composite independent factors had a significant effect on

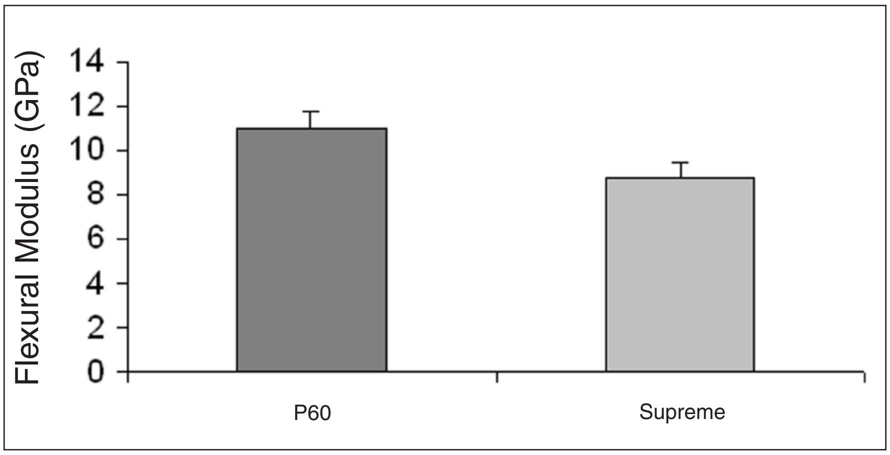

Figure 2: *Mean flexural modulus (GPa) for each resin composite.*

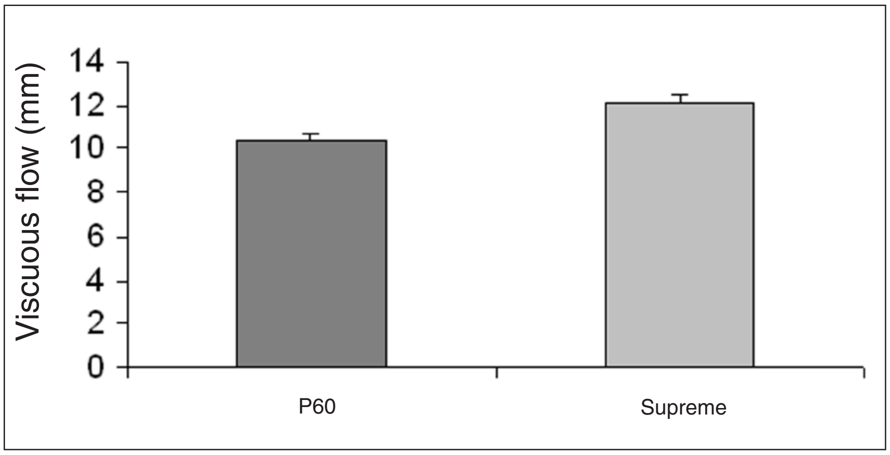

Figure 3: *Mean viscous flow (mm) for each resin composite.*

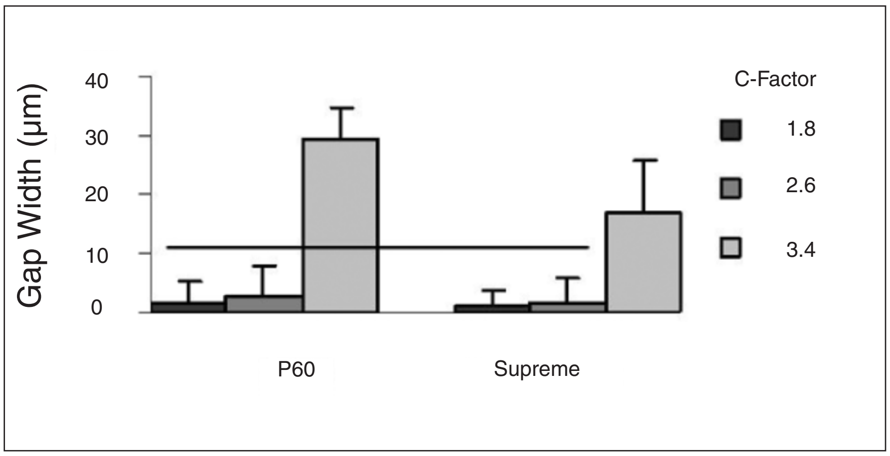

Figure 4: *Mean gap width (µm) for resin composite and C-factor. Columns under the same horizontal line are not statistically different (α=0.05).*

gap formation ($p<0.0001$). The lowest gap formation was found for cavities restored with Supreme resin composite. The Student-Newman-Keuls' test showed that the cavities with C-factor = 3.4 had a higher gap formation than those with 2.6 and 1.8 C-factors ($p<0.0001$), which showed no statistical difference between them ($p>0.05$).

Representative photomicrographs of samples are presented in Figure 5.

DISCUSSION

The service life of a resin composite restoration is dependent on several factors, including the cavity-composite interface sealing.[14-15] From this viewpoint, investigations related to the gap formation mechanism and factors related to this phenomenon are crucial to improving the clinical longevity of resin composite restorations. During the polymerization reaction, the resin composite undergoes a gelation process in which the material is transformed from a viscous-plastic to a rigid-elastic phase.[4] The exact moment of this transformation is called the "gel point." Before the gel-point is reached, shrinkage stress from polymerization can be compensated by the resin composite intrinsic flow.[16] However, stress generated after the gel-point can compete with interfacial adhesion and be deleterious to cavity sealing.

In clinical practice, control of shrinkage stress can be attempted from three points: by using light-curing modes that extend the post-gel phase, allowing for more composite flow during the initial polymerization reaction phase,[17-18] by using the resin composite incremental technique, which reduces the ratio of the bonded to unbonded surfaces of resin composite[4] or by choosing resin composites with low polymerization shrinkage and intrinsic high viscoelastic flow capacity.[9-10,13,19]

According to Feilzer and others,[7] the majority of clinical restorations have C-factor values of approximately 1 to 2. Today, however, improvement in adhesive systems and resin composites have encouraged dental practitioners to build deeper restorations that have a high C-factor. As a consequence, a cavity with a C-factor of 3.4 was introduced in this study in order to simulate a more realistic clinical situation. Braga and others,[8] analyzing the influence of cavity dimensions on shrinkage stress and microleak-

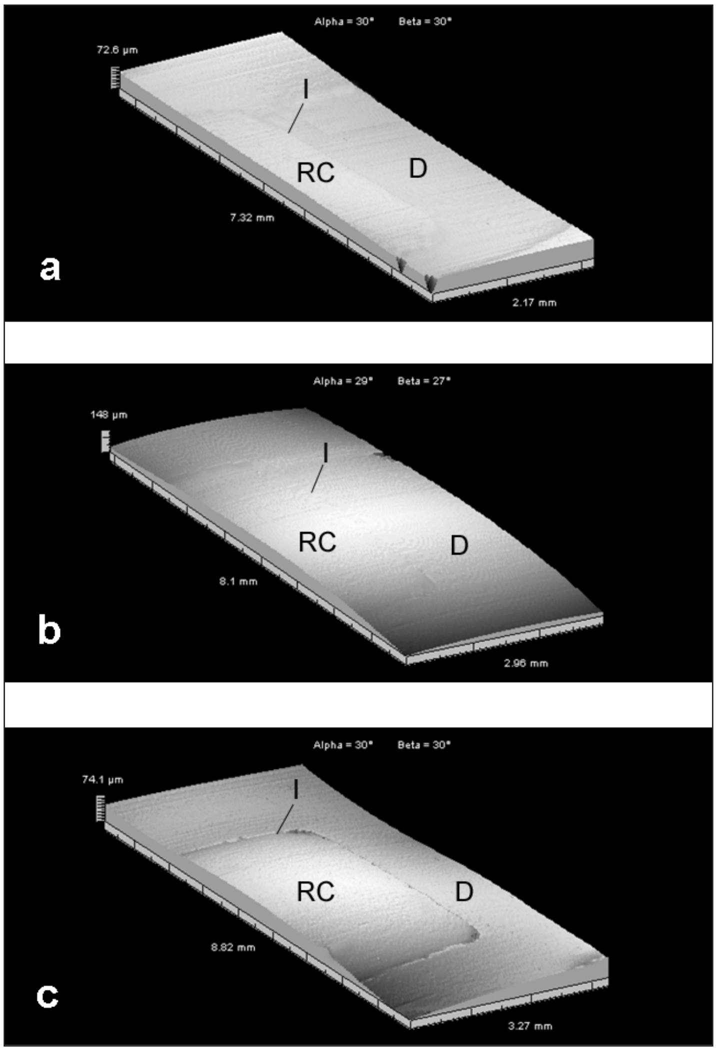

Figure 5: *Representative photomicrographs of samples. In (a) and (b), cavities with 1 mm depth (C-factor 1.8) and 2 mm depth (C-factor 2.6), respectively. No gap could be observed at the tooth-resin composite interfaces. In (c), a cavity with 3 mm depth (C-factor 3.4). Gap formation can be observed along the tooth-resin composite interface. (D) dentin; (RC) resin composite; (I) interface.*

age in composite restorations, showed that cavity depth had a stronger influence on both responses than diameter. Based on this finding, cavity diameters in this study were kept constant (5.0 mm) and the C-factor was varied as a function of cavity depths (1.0, 2.0 and 3.0 mm).

Figures 2 and 3 show the results of flexural modulus and viscous flow. Supreme was less stiff and more viscous than P 60. Since the two resin composites have the same polymeric matrix (Bis-GMA, Bis-EMA, UDMA and TEGDMA) and approximately the same filler content, this result was related to differences in the type of filler particles found in their compositions (Table 1). Several published studies that analyzed these properties for Durafill VS, a microfill composite with particle sizes ranging from 0.04 to 0.06 µm, similar to those present in Supreme, would support this thought.[19-20]

The resin composite factor results showed that cavities restored with Supreme presented a lower gap formation than those restored with P 60. The first factor that could explain this result is the highest viscous flow presented by Supreme (Figure 3). In the early phase of the Supreme polymerization reaction, the interfacial shrinkage stress could be compensated for by its high viscous flow.[21] This finding is in agreement with Peutzfeldt and Asmussen,[9] who found a negative correlation between viscous flow and gap formation in resin composite restorations. Moreover, according to Sakaguchi and others,[16] the viscous behavior of the resin constituent of composites can potentially be used to reduce stress in the composite through stress relaxation. Also, some previous studies showed that interfacial stress and marginal failure are correlated with the flexural modulus of resin composites.[22-23] From this viewpoint, the lowest flexural modulus presented by Supreme could have increased its plastic flow, principally in the early, rigid stage of the polymerization reaction[10,24] and, consequently, less shrinkage stress was transferred to the resin-dentin interface. This thought is supported by a recent study by Kahler and others,[25] who developed an analytical model of shrinkage stress and investigated the effect of restorative material properties on stresses at the dentin-restoration interface. It was shown that resin-based restorative materials with a lower Young's modulus could lead to less stress at the restoration interface.

Recent clinical studies have analyzed the retention rate of non-carious Class V lesions restored with resin composites with contrasting stiffness (microfill x hybrid).[29-30] These studies did not find any significant difference in retention rate between resin composites after 36 and 24 months, respectively. According to the authors of these studies, the major reason for the similar behavior between the resin composites was the efficiency of the dentin adhesives used to bond the cavities (in both studies, a three-step dentin adhesive was used: PermaQuick and Scotchbond Multi-Purpose, respectively). While, in the current study, a two-step dentin adhesive was used (Single Bond 2, 3M ESPE), it does not seem reasonable to consider this aspect alone to justify differences between the results obtained for the current study and the aforementioned studies. Indeed, other aspects, such as beveling of the cavity margins, the difference in cavity geometry (cylindrical in this study versus saucer shaped in the cited studies) and, principally, the influence of the oral environment, must be taken into consideration in order to make comparisons between the results obtained for this *in vitro* study and the aforementioned clinical studies.

Another aspect of Supreme behavior that should be considered is the light-scattering effect produced by its filler particles. According to a semi-empirical equation suggested by Clewell,[26] light scattering would be increased when the filler particle diameter is about half the wavelength of the activating light. If light scattering is increased, light intensity is attenuated. The non-agglomerated silica nanoparticles with a mean size of 20 nm (Table 1) may have caused a light-scattering effect in Supreme. From this premise, it is reasonable to speculate that, in 3.0 mm deep cavities, the degree of conversion could be reduced and, consequently, polymerization shrinkage[24-28] and gap formation.

The C-factor independent factor result was expected. It has been demonstrated that polymerization shrinkage stress increases with high C-factors.[7] In this study, the resin composites were submitted to 17 J/cm^2. This radiant exposure is adequate for polymerizing the full depth of resin composites in 3.0 mm deep cavities.[31] Since only one adhesive system was used to bond the cavities (Single Bond 2, 3M ESPE), the results were analyzed considering only the shrinkage stress generated at the resin-dentin interface.

Gap formation was higher in cavities with C-factor = 3.4 than in those cavities with 2.6 and 1.8 C-factors. Moreover, all the cavities with C-factor = 3.4 presented a gap at the tooth-resin composite interface. On the other hand, in groups with C-factors of 1.8 and 2.6, only slices from one cavity per group showed gap formation at the tooth-resin composite interface. From a clinical viewpoint, this finding is extremely important, since the absence of gap would increase the service life of resin composite restorations. Interpretation of these results may be based on the fact that, in cavities with a C-factor of 1.8 and 2.6, the composite relaxation provided by the unbonded surface, which was the same for both cavities, was more efficient for relieving shrinkage stress generated during the polymerization reaction.[7,13] On the other hand, the greater depth of cavities with a C-factor of 3.4 increased the bonded interface. Thus, wall-to-wall shrinkage was increased, as was the gap formation. These results agree with previous studies. Yoshikawa and others[32] found that cavity-wall gap formation significantly increased when the C-factor increased from 2.3 to 3 and concluded that a C-factor of 2.3 can be considered low. Furthermore, Loguercio and others[33] showed that linear polymerization shrinkage and gap width were higher when the C-factor increased from 0.3 to 3.0. An important aspect was that these authors measured the linear polymerization shrinkage of resin composite inside the restored cavities. In addition, some previous studies have shown that the increase in the C-factor also has a harmful effect on the bond strength of adhesive systems to dentin.[33-34]

CONCLUSIONS

The results of this study supported the proposed hypothesis. It was possible to conclude that the choice of resin composites with high viscous flow, associated with a low flexural modulus could be more adequate for reducing gap formation in resin composite restorations. Deep cavities were found to increase gap formation.

(Received 11 August 2006)

References

1. Bowen RL (1963) Properties of a silica-reinforced polymer for dental restoration *Journal of the American Dental Association* **66(1)** 57-64.
2. Christensen GJ (1998) Amalgam vs composite resin *Journal of the American Dental Association* **129(12)** 1757-1759.
3. Geurtsen W & Schoeler U (1997) A 4-year retrospective clinical study of Class I and Class II composite restorations *Journal of Dentistry* **25(3-4)** 229-232.
4. Davidson CL & Feilzer AJ (1997) Polymerization shrinkage and polymerization shrinkage stress in polymer-based restoratives *Journal of Dentistry* **25(6)** 435-440.
5. Venhoven BA, de Gee AJ & Davidson CL (1993) Polymerization contraction and conversion of light-curing BisGMA-based methacrylate resins *Biomaterials* **14(11)** 871-875.
6. Eick JD & Welch FH (1986) Polymerization shrinkage of posterior composite resins and its possible influence on postoperative sensitivity *Quintessence International* **17(2)** 103-111.
7. Feilzer AJ, de Gee AJ & Davidson CL (1987) Setting stress in composite resin in relation to configuration of the restoration *Journal of Dental Research* **66(11)** 1636-1639.
8. Braga RR, Boaro LC, Kuroe T, Azevedo CL & Singer JM (2006) Influence of cavity dimensions and their derivatives (volume and "C" factor) on shrinkage stress development and microleakage of composite restorations *Dental Materials* **22(9)** 818-823.
9. Peutzfeldt A & Asmussen E (2004) Determinants of *in vitro* gap formation of resin composites *Journal of Dentistry* **32(2)** 109-115.
10. Davidson CL & de Gee AJ (1984) Relaxation of polymerization contraction stresses by flow in dental composites *Journal of Dental Research* **63(2)** 146-148.
11. Davidson CL, de Gee AJ & Feilzer AJ (1984) The competition between the composite-dentin bond strength and the polymerization contraction stress *Journal of Dental Research* **63(12)** 1396-1399.
12. Munksgaard EC, Hansen EK & Kato H (1987) Wall-to-wall polymerization contraction of composite resins versus filler content *Scandinavian Journal of Dental Research* **95(6)** 526-531.
13. Li Y, Swartz ML, Phillips RW, Moore BK & Roberts TA (1985) Effect of filler content and size on properties of composites *Journal of Dental Research* **64(12)** 1396-1401.
14. Hilton TJ (2002) Can modern restorative procedures and materials reliably seal cavities? *In vitro* investigations. Part 1 *American Journal of Dentistry* **15(3)** 198-210.
15. Misra A, Spencer P, Marangos O, Wang Y & Katz JL (2004) Micromechanical analysis of dentin/adhesive interface by the finite element method *Journal of Biomedical Materials Research* **70(1)** 56-65.

16. Sakaguchi RL, Wiltbank BD & Murchison CF (2004) Contraction force rate of polymer composite is linearly correlated with irradiance *Dental Materials* **20(4)** 402-407.

17. Mehl A, Hickel R & Kunzelmann KH (1997) Physical properties and gap formation of light-cured composites with and without "softstart-polymerization" *Journal of Dentistry* **25(3-4)** 321-330.

18. Uno S & Asmussen E (1991) Marginal adaptation of a restorative resin polymerized at reduced rate *Scandinavian Journal of Dental Research* **99(5)** 440-444.

19. Labella R, Lambrechts P, Van Meerbeek B & Vanherle G (1999) Polymerization shrinkage and elasticity of flowable composites and filled adhesives *Dental Materials* **15(2)** 128-137.

20. Vaidyanathan J & Vaidyanathan TK (2001) Flexural creep deformation and recovery in dental composites *Journal of Dentistry* **29(8)** 545-551.

21. Ferracane JL (2005) Developing a more complete understanding of stresses produced in dental composites during polymerization *Dental Materials* **21(1)** 36-42.

22. Kemp–Scholte CM & Davidson CL (1990) Marginal integrity related to bond strength and strain capacity of composite resin restorative systems *Journal of Prosthetic Dentistry* **64(6)** 658-664.

23. Feilzer AJ, de Gee AJ & Davidson CL (1990) Relaxation of polymerization contraction shear stress by hygroscopic expansion *Journal of Dental Research* **69(1)** 36-39.

24. Stansbury JW, Trujillo-Lemon M, Lu H, Ding X, Lin Y & Ge J (2005) Conversion-dependent shrinkage stress and strain in dental resins and composites *Dental Materials* **21(1)** 56-67.

25. Kahler B, Kotousov A & Borkowski K (2006) Effect of material properties on stresses at the restoration-dentin interface of composite restorations during polymerization *Dental Materials* **22(10)** 942-947 .

26. Clewell DH (1941) Scattering of light by pigment particles *Journal of Optical Society American* **31(8)** 521-527.

27. Sakaguchi RL & Berge HX (1998) Reduced light energy density decreases post-gel contraction while maintaining degree of conversion in composites *Journal of Dentistry* **26(8)** 695-700.

28. Peutzfeldt A & Asmussen E (2005) Resin composite properties and energy density of light cure *Journal of Dental Research* **84(7)** 659-662.

29. Van Meerbeek B, Kanumilli PV, De Munck J, Van Landuyt K, Lambrechts P & Peumans M (2004) A randomized, controlled trial evaluating the three-year clinical effectiveness of two etch & rinse adhesives in cervical lesions *Operative Dentistry* **29(4)** 376-385.

30. Browning WD, Brackett WW & Gilpatrick RO (2000) Two-year clinical comparison of a microfilled and a hybrid resin-based composite in non-carious Class V lesions *Operative Dentistry* **25(1)** 46-50.

31. Unterbrink GL & Muessner R (1995) Influence of light intensity on two restorative systems *Journal of Dentistry* **23(3)** 183-189.

32. Yoshikawa T, Burrow MF & Tagami J (2001) The effects of bonding system and light curing method on reducing stress of different C-factor cavities *Journal of Adhesive Dentistry* **3(2)** 177-183.

33. Loguercio AD, Reis A & Ballester RY (2004) Polymerization shrinkage: Effects of constraint and filling technique in composite restorations *Dental Materials* **20(3)** 236-243.

34. Price RB, Dérand T, Andreou P & Murphy D (2003) The effect of two configuration factors, time, and thermal cycling on resin to dentin bond strengths *Biomaterials* **24(6)** 1013-1021.