POLYMERIZATION SHRINKAGE AND SPHERICAL GLASS MEGA FILLERS: EFFECTS ON CUSPAL DEFLECTION

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SUMMARY
Purpose. The Authors analyzed the effect of spherical glass mega fillers (SGMF) on reducing contraction stress in dental composite resins, by means of a cavity model simulating the cuspal deflection which occurs on filled tooth cavity walls in clinical condition.
Materials and methods. 20 stylized MOD cavities (C-factor = 0.83) were performed in acrylic resin. The inner surface of each cavity was sand blasted and adhesively treated in order to ensure a valid bond with the composite resin. Three different diameter of SGMF were used (i.e. 1, 1,5, 2 mm). The samples were divided in 4 groups of 5 each: Group 1 samples filled with the composite only; Group 2 samples filled with composite added with SGMFs, Ø1mm (16 spheres for each sample); Group 3 samples filled with composite added with SGMFs, Ø1,5 mm (5 spheres for each sample); Group 4 samples filled with composite added with SGMFs, Ø2 mm (2 spheres for each sample). Digital pictures were taken, in standardized settings, before and immediately after the polymerization of the composite material, placed into the cavities. With a digital image analysis software the distances from the coronal reference points of the cavity walls were measured. Then the difference between the first and second measurement was calculated. The data were analyzed by means of the ANOVA test.
Results. A significative reduction on cavity walls deflection, when the composite resin is used in addiction with the SGMFs was observed. The SGMFs of smallest diameter (1mm) showed the better outcome.
Conclusion. The SGMFs are reliable in reducing contraction stress in dental composite resins.

Key words: composite fillers, spherical glass mega fillers; polymerization shrinkage; composite shrinkage; cuspal deflection; enamel cracks; elastic modulus.

Introduction

The polymerization shrinkage is a major concern regarding the clinical success of direct composite restorations (1, 2).
Despite the polymerization shrinkage, in the current composite resins, has been significantly reduced through the increase of the inorganic load the stress, induced on surrounding adherent dental structures, remains too high to allow to a direct filling to be used in large restorations of the posterior sectors (3-6).
Several methods have been proposed in recent years to reduce shrinkage stress through the modification of both the photo-activation protocols and the composite resins stratification techniques with encouraging results but inconclusive (7-9).
Also from the commodity-related point of view advances have been made, for instance, a new monomer, the silorane, has been recently introduced. This latter has been included in the resin matrix due to its expansive behavior during the polymerization, in order to reduce

the shrinkage of the composite resin (10).
The volumetric shrinkage, typical of composite resins during polymerization, inevitably generates stress, if the composite is tenaciously adherent to the walls of a tooth cavity, which theoretically has a stable volume. The development of this tensile force, along the adhesive interface, can result in deformation of the cavity walls if the adhesion force is strong enough, conversely it determines the separation of the restoration from the tooth. If the thickness of the residual dental tissue is thin, it may also occur of the enamel fracture (enamel crack) when this latter is not sufficiently supported by the dentin (11).
This phenomenon, together with the flow that the composite undergoes, during the setting reaction, at the level of the free surface of the restoration, which is not subject to adhesion, limits the negative effects of stress but does not cancel them completely (12, 13).
The ability of the composite to develop stress during its polymerization does depend greatly on the extent of the free surface compared with the adherent one and it's therefore strictly dependent on the cavity configuration. The ratio between adherent surface and the free surface is also defined as the cavity configuration factor (C-factor): the greater the extension of the adherent surface compared with the free one, the greater the stress that is generated during the composite polymerization (14-17).
In the present study the use of a spherical glass mega filler (SGMF) is proposed. The SGMF is introduced into the composite restoration, prior to its polymerization, in order to decrease the amount of resin matrix used and consequently also reducing the contraction, that the restoration undergoes during the polymerization. Previous works have demonstrated both *in vivo* and *in vitro* the effectiveness of this new restorative technique (18-22). The SGMF thanks to its spherical shape does not affect the flow ability of the composite during the setting reaction, while minimizing the development of interfacial stress, since the sphere shape, compared with other solid shapes, has the lower surface extension. Furthermore, the transparency of SGMF does not prevent the diffusion of light through the mass of the composite, allowing, compatibly with the maximum polymerization depth of the selected composite, to carry out a bulk polymerization (10, 12).
With this *in vitro* study, the effectiveness of SGMFs, in the reduction of the interfacial tensile stress, evaluating the cusp bending in an experimental model of cavity, was analyzed.

Materials and methods

SGMFs preparation

Soda lime glass balls (SLGBs) (Rgpballs, Cinisello Balsamo - MI, Italy) of different diameter (i.e. 1, 1.5, and 2mm) (Figure 1a) were selected for this study. Their chemical composition was previously determined by means of an electronic micro-probe (Camebax Microbeam, Cameca, Gennevilliers Cedex, France) (18). The chemical composition is indicated in Table 1.
The SDGBs were previously acid etched with a 40% hydrofluoridric acid (Suprapur®, Merk Millipore, Darmstadt, Germany) for 20 sec and then washed with deionized water for 3 min, followed by acetone (Emplura®, Merk Millipore, Darmstadt, Germany) for further 3 min prior to be dried in a preheated thermostatic oven (SCN 58 DG; Enrico Bruno, Torino, Italy) (100°C) for 10 min. The SLGBs were then silanized with a mixture of silane methacrylate, phosphoric acid methacrylate and sulphide methacrylate in etanol solution (Monobond Plus, Vivadent, Schaan/Liechtenstein) for 60 sec. The silanated SDGBs were dried, in the above-mentioned preheated thermostatic oven, at 80°C for 10 minutes, then left at room temperature for 1h prior to be covered with a photocurable mixture of Bis-GMA (60%wt.) and

Table 1 - SLGBs chemical composition.

Na	P	F	Si	Al	Ca	Mg	S	Cl	Zn	Sn	O
3.03%	0.07%	1.25%	32.45%	3.12%	5.45%	0.99%	0.02%	0.01%	0.01%	0.01%	43.72%

triethylene glycol dimethacrylate (40%wt.) (Heliobond, Vivadent, Schaan/Liechtenstein). Three groups, of approximately 300 units each, of SGMFs, were thus prepared.

Samples preparation

Using 5 polyvinylsiloxane impression (GLS-Pro, Prochima, Calcinelli di Saltara - PU, Italy), of a master model, 20 copies, made of a self-curing acrylic resin (Sintodent shade A3.5, Sintodent, Rome, Italy), were performed.

The master model reproduced a stylized mesial-occlusal-distal cavity 3 mm deep, 3 mm long and 4 mm wide (Figure 1b), whose C factor was equal to 0.83.

To improve the bond, of the micro-hybrid, light-curing composite material (Esthetic shade A2, Surgi, Lainate - MI, Italy) with the acrylic resin, the cavities were sandblasted with glass beads (average granulometry 80µ, pressure 50PSI) and treated with an adhesive (Prime & Bond NT, Dentsply Sirona, York, Pennsylvania, US), then light-cured for 40sec. Subsequently the cavities were treated with Heliobond also cured for 40 sec. The curing lamp (Command II, Kerr, Orange, US) had a light intensity of 200 mW/mm^2, previously measured with a portable radiometer (Curing Radiometer model 100, Demetron Research Corp., New York, US).

The 20 samples were then divided into four groups of 5 samples each:

a) Group 1 (B) samples filled with the composite only (Figure 1b, c);

b) Group 2 (BP) samples filled with composite added with SGMFs, of 1 mm of diameter (16 spheres for each sample) (Figure 1b, d);

c) Group 3 (BM) samples filled with composite added with SGMFs, of 1,5 mm of diameter (5 spheres for each sample) (Figure 1b, e);

d) Group 4 (BG) samples filled with composite added with SGMFs, of 2 mm of diameter (2 spheres for each sample) (Figure 1b, f).

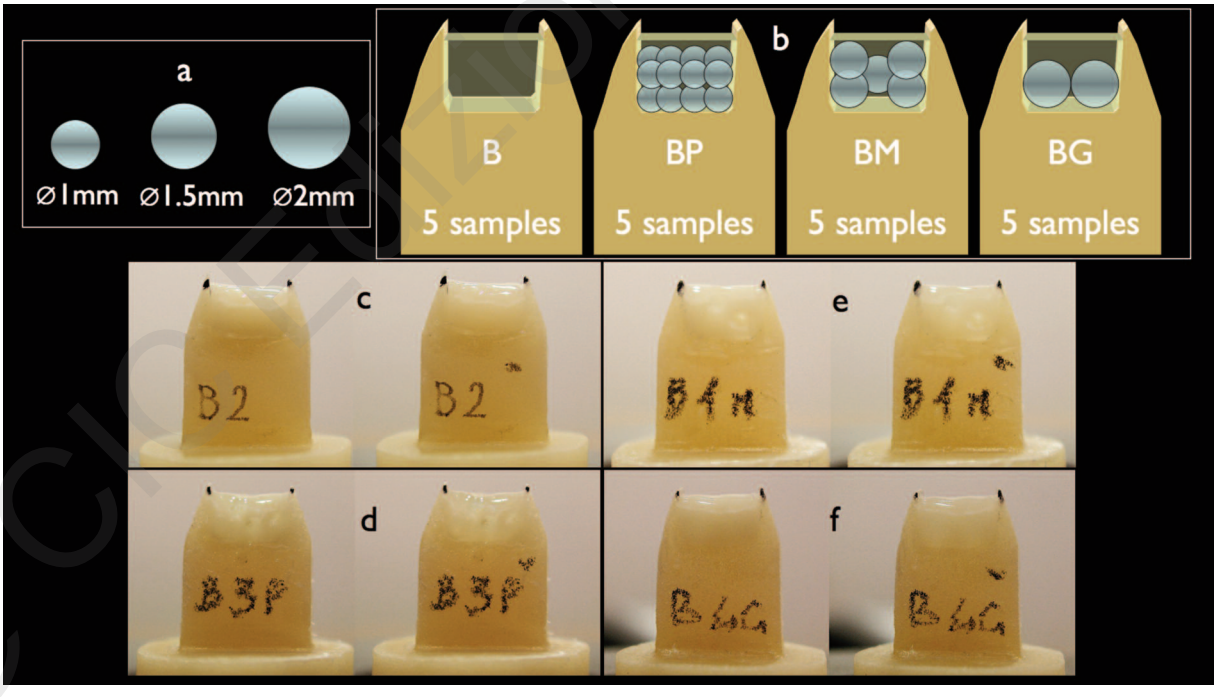

Figure 1
a) The spherical glass mega fillers (SGMFs), in the 3 available diameters; b) the 4 groups of samples of 5 each; c-f) samples, before (left) and after (right) the polymerization, for each group analyzed.

Pictures were taken, with a digital camera (Cool Pix 990, Nikon, Tokyo, Japan), before and immediately after the polymerization of the composite material, placed into the cavities. Every sample was mounted on a fixed support at a distance of 3 cm from the lens of the digital camera. This latter was always held in the same position and actuated by means of a remote control. The photo-activation of the filling, placed in each sample, was carried out for 40 sec.

The resulting digital images were analyzed with digital image analysis software, using Windows OS (Image Pro Plus 4.1, Media Cybernetics) (Figure 2). In particular the distances from the coronal reference points of the cavity walls were measured. Then the differences between the first and second measurement were calculated.

Statistical analysis

The data were statistically compared, within the groups, by means of the analysis of variance (ANOVA), carried out with a confidence level of 95% ($\alpha = 0.05$) (Primer Biostatistics Ver. 4.02i; McGraw-Hill Comp., US).

Results

The differences between the distances, measured from coronal reference points of the cavity walls, before and after the polymerization, are showed in Table 2.

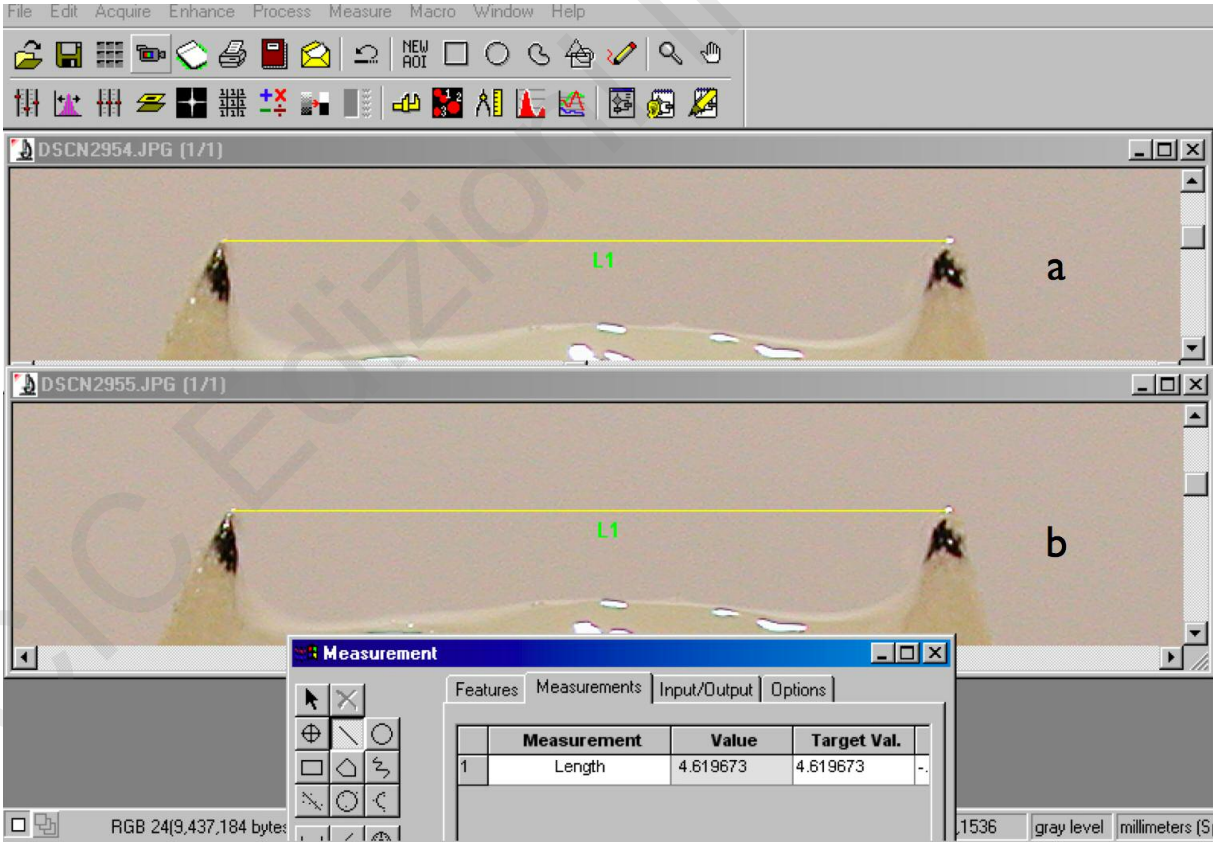

Figure 2
For each sample, the distances from the coronal reference points of the cavity walls were measured before (a) and immediately after (b) the polymerization, by means of a digital image analysis software.

Table 2 - The calculated differences between the distances, measured from coronal reference points of the cavity walls, before and after the polymerization.

	Mean	St. Dev.
B	0.0561	0.011
BG	0.0435	0.0023
BM	0.035	0.01
BP	0.03	0.0064

Significative differences were observed for: B *vs* BG (p = 0,022); B *vs* BM (p = 0,011); B *vs* BP (p = 0,001); BP *vs* BG (p = 0,004).
While not significative differences were found for: BG *vs* BM (p = 0,119); BM *vs* BP (p = 0,374).
Furthermore the volume and the area of each SGMF were calculated so as so both the total volume and the total area, developed by the SGMFs, for each sample pertaining to the three different groups (Tables 3 and 4).

Discussion

As already described in previous papers, the use of SGMFs gives several advantages: significantly they contribute to the reduction of the adhesive interface solicitation; help to improve the marginal seal in interproximal cavities with cervical margins on the root cementum, facilitate the light diffusion in the context of the filling material; allow to carry out a bulk polymerization; shift to a more coronal level, the shrinkage stress facilitating its dissipation by the cuspal compliance (18-22).
This is relevant since sometime lost teeth can be cause of legal quarrel (23, 24) since they can be replaced with dental implant (25-77) or orthodontic treatment (78-84).
In our settings (C-factor 0.83) the use of SGMFs gave a significant contribution on reducing the tensile stress on the experimental cavity walls ØB *vs*. BG (p = 0,022); B *vs*. BM (p = 0,011); B *vs*. BP (p = 0,001); BP *vs* BG (p = 0,004), furthermore the small size SGMFs (Ø1mm) surprisingly have a greater ability to dissipate the interfacial tensile stress than those of larger

Table 3 - The volume and the area of each SGMF was calculated.

Radius Sphere (mm)	Volume (mm^3)	Area (mm^2)
0,5	0.5	3.14
0.75	1.8	7.1
1	4.2	12.6

Table 4 - The total volume and the total area, developed by the SGMFs, for each sample, pertaining to the three different groups.

Radius (ØSphere)	Total volume (mm^3)	Total area (mm^2)
BP, Ø 1 mm (16)	8.3	50.2
BM, Ø 1,5 mm (5)	8.8	35.3
BG, Ø 2 mm (2)	8.4	25.1

diameter (i.e. Ø2 mm) BP *vs*. BG (p = 0,004). On the contrary not significative advantages were found, comparing the spheres 2 mm wide with those 1.5 mm wide Ø BG *vs*. BM (p = 0.119), the same as between these latter and those 1 mm wide Ø (BM *vs*. BP (p = 0.374). These findings can be easily explained because the SGMFs of 1.5 mm wide, offer exactly an intermediate performance among those of 2 mm and the 1 mm.

However, the fact that the smaller diameter SGMFs enable a greater dissipation of the tensile stress, despite these, compared to the higher diameter with a SGMF equal volume, develop a practically double surface extension (Tables 3-4), does not find an easy explanation.

The SFMFs are similar to small inlays, which are submerged in the composite restoration. Obviously, keeping the same spheres volume, the overall inlays' adherent surface increases if the diameter of the spheres is reduced.

So the SGMFs are able to reduce the mass of composite required to fill the cavity reducing its contraction, but at the same time creating an additional adherent surface, which increases the C-factor, especially in the case of spheres with smaller diameter.

As previously demonstrated by other Authors (14), the presence of a C-factor particularly unfavorable, as in the case of the inlays with a good marginal fit, the shrinkage stress developed from thin composite cement thickness, is efficiently dissipated by the deformability (compliance) of the substrate to which it is adherent. In our experimental model both the C-factor and the compliance were particularly favorable because the modulus of elasticity (E) of the acrylic resin (2.65 GPa) is much lower than dentin (18.3 GPa) (2, 8, 11, 14). Thus our finding may be attributable to the high compliance of the substrate that is able to compensate the resulting shrinkage stress.

Even if previous studies analyzed both *in vivo* and *in vitro*, the effectiveness of SGMFs in composite direct fillings, further studies will be needed to evaluate the ability of SGMFs, of different diameter, to reduce the shrinkage stress when the C-factor is particularly unfavorable.

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