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Research Paper

A comparison of resin-modified glass-ionomer and resin composite polymerisation shrinkage stress in a wet environment

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ABSTRACT

Objective: The aim of this study was to investigate the polymerisation shrinkage stress under water of four resin-modified glass-ionomers and three resin composite materials.
Methods: Transparent acrylic rods (5 mm diameter × 30 mm) were prepared and secured into drill chucks connected to a universal testing machine. A plastics cup was placed around the lower rod and a distance of 1.00 mm was established between the prepared surfaces which provided a C-factor of 2.5. For composite only, an adhesive layer (Scotchbond Universal Adhesive) was placed on the rod ends and cured to achieve a bond with the rod end. Materials were placed between the rods and a strain gauge extensometer was installed. Materials were light cured for 40 s and the plastics cup was filled with ambient temperature water. To determine polymerisation shrinkage stress (σ_{pol}) three specimens of each material were tested for a 6-h period to determine mean maximum σ_{pol} (MPa), σ_{pol} rate (MPa/s) and final σ_{pol} (MPa). ANOVA and post hoc Tukey tests were used to determine significant differences between means.
Results: The highest mean maximum σ_{pol} of (5.4 ± 0.5) MPa was recorded for RMGIC and (4.8 ± 1.0) MPa for composite. The lowest mean final σ_{pol} of (0.8 ± 0.4) MPa was recorded for RMGIC. For mean maximum $\sigma_{pol,}$ σ_{pol} rate and final σ_{pol} there were significant differences between materials within groups, although no significant difference ($p > 0.05$) was observed when comparing the RMGIC group to the composite group.
Conclusion: When comparing mean $\sigma_{pol,}$ maximum $\sigma_{pol,}$ and σ_{pol} rates between individual RMGIC and composite materials significant differences ($p < 0.05$) were observed. However when comparing the group RMGIC to composite no significant differences ($p > 0.05$) were observed. The null hypothesis that there is no difference in the short term σ_{pol} of RMGIC materials when compared to composite materials is only partly rejected.

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Relevance: Limited information is available on the comparison of RMGIC and resin composite σ_{pol} levels. This study provides information on the short term levels in a wet environment and will assist in understanding the initial σ_{pol} rates RMGIC place in cavities.

1. Introduction

Photo-polymerisation of adhesively bonded resin composite creates a level of polymerisation shrinkage stress (σ_{pol}) on the adhesive interface which remains after curing is complete (Braga et al., 2005; Giachetti et al., 2006). Resin composite σ_{pol} has been shown to contribute to cuspal deflection (Campodonico et al., 2011; Kim and Park, 2011; Suliman et al., 1993; Tantbirojn et al., 2004; Versluis et al., 2011), enamel cracking (Christensen et al., 1999), marginal gap formation (Huang et al., 2002; Irie et al., 2002) and microleakage (Calheiros et al., 2004; Gerdolle et al., 2008b; Heintze et al., 2008). Secondary caries is the most common reason for replacement in posterior restorations (Kim et al., 2013; Kopperud et al., 2012). The majority of σ_{pol} investigations have been performed on resin composite materials, and investigate σ_{pol} over a short time frame in the absence of water (Braga et al., 2005). Some stress relief of resin composite σ_{pol} can be achieved by the material placement method and by hygroscopic expansion associated with water absorption (Versluis et al., 2011).

The placement of resin-modified glass-ionomer (RMGIC) liners beneath resin composite has been found to significantly reduce volumetric polymerisation contraction (Alomari et al., 2001; Davidson, 1994; Ferracane et al., 2006; Ikemi and Nemoto, 1994; Tolidis et al., 1998). RMGIC restorations have been shown to convert initial inward cuspal contraction to expansion after 1 week (Versluis et al., 2011). Feilzer et al. (Feilzer et al., 1995) found two restorative RMGICs reversed initial σ_{pol} in a wet environment and recommended early water exposure to minimise σ_{pol}. In order to establish criteria for successful RMGIC placement procedures, it would be useful to detail their σ_{pol} to provide an understanding of stresses present at the RMGIC bond interface in their initial setting stages. However limited additional information is available on the rates and maximum level of RMGIC σ_{pol} compared to current generation resin composite materials such as 'bulk fill' materials that claim up to 5 mm depth of cure.

The aim of the study was to test the null hypothesis that there is no difference in the σ_{pol} of RMGIC materials in a wet environment when compared to resin composite materials.

2. Materials and methods

The name, manufacturer and composition of each material are detailed in Table 1. Two of the three tested composites were "bulk fill" materials. Transparent acrylic rods (5 mm diameter × 30 mm long) were prepared by diamond saw (ISOMET® 1000 precision sectioning saw; Buhler, Lake Bluff, IL, USA). Rods were polished at one end with 1200-grit silicon carbide paper and air abraded (Microetcher II; Danville Materials Inc, San Ramon, CA) with 50 μm aluminium oxide (ALOX 50-μm; BN 2980; Argibond, Cheltenham, Australia) until a uniform surface was achieved, cleaned with oil-free compressed air until the surfaces were clean, and firmly secured into upper and lower drill chucks connected to a single column universal testing machine (Model 5942; Instron, Norwood, MA) fitted with a 500-N static load cell. A small plastics cup was placed around the lower rod and a distance of 1.00 mm was established between the prepared surfaces (Fig. 1a) prior to separating the surfaces for material placement.

To ensure resin composite material adhesion to the rods, a single thin layer of a universal adhesive (Scotchbond Universal Adhesive; 3M/ESPE, Seefeld Germany) was placed onto the rod ends and cured as per manufacturer's instructions. Materials were placed directly onto the lower rod. Manual adjustment of the crosshead was used to move the rods to the pre-determined 1.00 mm position (Fig. 1b) and excess material around the rods was removed with a flat plastic instrument. The plastics cup was positioned in order to permit submersion of the material and a 10-mm strain gauge extensiometer (Model 2630-101; Instron Norwood, MA) with an accuracy of ±0.5% was placed into position (Fig. 1c).

The testing machine software (Bluehill 2 Materials Testing Software; Instron, Norwood, MA) maintained the 1-mm distance between the rods via feedback from the linear strain gauge. A 30.00-dB strain gauge proportional gain was set and all measurements on the testing machine were calibrated to zero. Approximately 80 s after the beginning of the test, materials were light-cured from one side using a 1200 mW/cm^2 LED curing light (Radii Plus; SDI Limited, Bayswater) for 40 s at a distance ~5 mm. Intensity of the LED curing light was tested prior to each test with a LED radiometer (LED radiometer; SDI Limited, Bayswater). Immediately after light curing a syringe was used to fill the cup with ambient temperature water to cover the material.

Additional water was supplied with micro-bore plastics tube fitted with a metal outlet inserted into a variable speed peristaltic pump (MasterflexR C/L; Cole-Parmer, Vernon Hills, IL) (Fig. 1d). A pump setting was established to maintain the required water level in the plastics cup throughout the test.

Three specimens of each material were tested for a 6-h period to determine mean maximum σ_{pol} (MPa), σ_{pol} rate (MPa/s) and final σ_{pol} (MPa). The maximum σ_{pol} was determined by the maximum tensile shrinkage force (N) divided by the rod cross sectional area (mm^2). The polymerisation rate at each data point was calculated from the difference in σ_{pol} divided by the time period between the previous data point. The final σ_{pol} was determined at 6 h after the start of the test.

2.1. Statistical analysis

A statistical analysis package was used to analyse data (PASW Statistics V18, SPSS INC, Chicago, IL) using ANOVA