Effect of Silica Nanofiber Reinforcement on Viscosity and Modulus of Dental Composites

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Introduction: The popularity of tooth colored restorations is on the rise both among dentists and patients for use in the anterior and posterior restorative applications. Specifically, tooth colored composite resins are being widely used as direct restorative materials today. Recently, clinical studies have shown the increased success of these dental composites reinforced with micrometer and nanometer sized fillers in load bearing applications, such as Class I and II restorations (J Am Dent Assoc. 2003;134:463-472). Generally, silica based fillers are used because their refractive index matches that of the tooth, and a silane coupling agent provides a strong interface for effective load transfer between the matrix and the reinforcement. Recent studies have shown that nanofibers processed from polymeric materials such as Nylon 6 (Tian M. Polym. 2007;48:2720-2728), Polyvinyl Alchohol and Poly-L-Lactic Acid (Dodiuk-Kenig H. J Nanomaterials. 2008;2008:6) used as reinforcement show improved mechanical properties of bis-phenol A-glycidyldimethacrylate (bis-GMA) based composites. A combination of silica nanofibers and ceramic fillers is thus hypothesized to improve the modulus of dental composites. This study investigated the effect of 0.2% silica nanofiber addition on the rheological properties of bis-GMA based dental composites, and demonstrated improvement in mechanical parameters, particularly modulus and creep resistance.

Methods: A bis-GMA based low viscosity resin or flowable composite resin (FCR) prefilled 65% by weight with ceramic particulate fillers was used as a control. Silica nanofibers were manually mixed 0.2% by weight (Mettler Toledo AG204 Columbus, Ohio) into the prefilled FCR to obtain nanofiber reinforced flowable composite resins (NF-FCR). The two groups were tested using the parallel plate (diameter= 25mm) fixture of the Rheometer (AR 2000, TA Instruments, New Castle, Delaware USA). The distance between the plates was fixed at 1 mm. Strain sweeps employed 0.1-100.0% strain at a shear rate of 1.0 s-1 to identify the high and low shear rate modulus values. After the linear viscoelastic range was determined, a frequency sweep was performed at 25 °C. Creep experiments were used to observe the change in compliance of the material. The specimens were conditioned at 37 °C for the creep experiment, representative of the average normal oral temperature.

Results: The strain sweep showed that the addition of 0.2% nanofiber reinforcement to the FCR improved the storage modulus compared to the control. A four-fold increase in modulus with reinforcement was observed at 0.3% strain (Figure 1a). The frequency sweep (Figure 1b) showed a nominal difference in viscosity with shear rate with addition of the nanofibers. Both the control and the 0.2% nanofiber reinforced specimens exhibited shear thinning. Creep analysis (Figure 1c) showed a 14% increase in creep resistance of the reinforced sample compared to the control at t=500s.

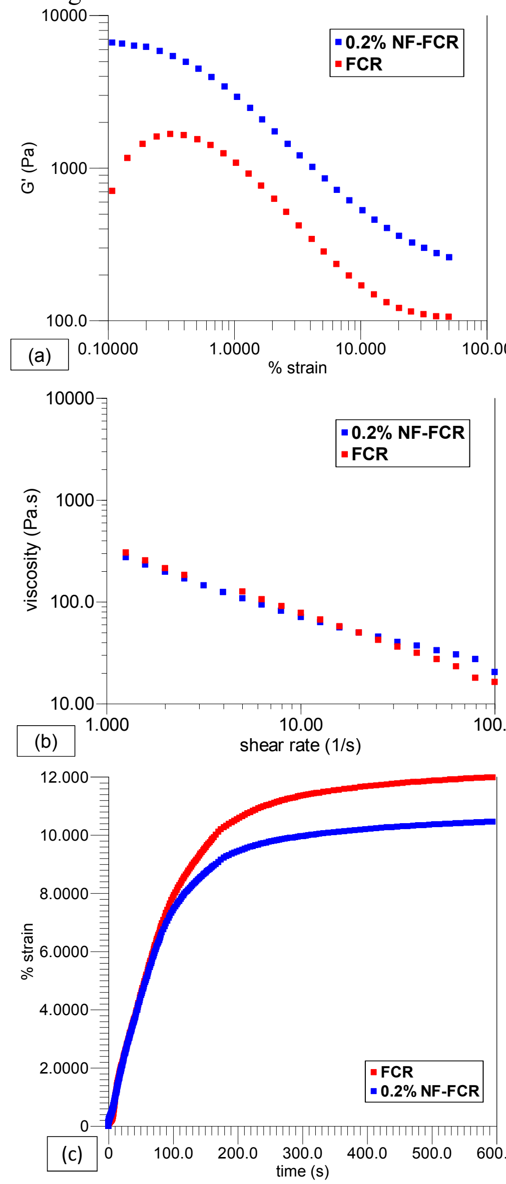

Figure1. Representation of (a) the storage modulus versus % strain plot of the neat and 0.2% reinforced flowable dental composite, (b) the effect of 0.2% reinforcement on the viscosity, and (c) % creep strain with time.

Conclusions: The addition of 0.2% silica nanofibers significantly improved the storage modulus of the flowable dental composite. In addition, the minimal increase in viscosity observed will likely retain the handling characteristics of the flowable composites while making them more resistant to creep. The results suggest that dental composites with the given combination of fillers will show improved clinical performance. A possible extension of this study should include an exhaustive analysis of silica nanofiber reinforcements on the overall mechanical properties of these dental composites.