INFLUENCE OF SILICA MICRO-PARTICLES LOADING ON THE FLEXURAL PROPERTIES OF DENTAL RESIN COMPOSITES

SAAD OMAR ALSHARIF, MD AKIL HAZIZAN, ARIFIN AHMAD ZAINAL

School of Materials and Mineral Resources Engineering, Universiti Sains Malaysia, 14300 Nibong Tebal, Penang, Malaysia, email: saadelsharif@yahoo.com, hazizan@eng.usm.my, zainal@eng.usm.my

The objective of this study was to evaluate the influence of silica (SiO_2) micro-particles loading on the flexural properties of dental resin composites (DRCs). The DRCs were prepared from a resin matrix comprising Bis-phenol A-glycidyl methacrylate (Bis-GMA) as a base monomer and triethylene glycol dimethacrylate (TEGDMA) as a diluent monomer mixed with SiO_2 micro-particles as a reinforcement filler in a ratio of 40, 50 and 60 wt%. The samples were then light-cured using a LED TPC 60. The density (g/cm^3) of the DRC samples was determined according to the ASTM D792-98 standard. The values of flexural strength (FS) and flexural modulus (FM) were determined using the three-point bending test according to the ISO 4049:2009 standard. The results revealed that the density values of the DRCs increased as the SiO_2 loading increased. The FS values decreased as the loading of the SiO_2 increased from 84.52 to 53.2 MPa. In contrast, the FM values increased as the SiO_2 loading was increased from 1.55 to 7.51 GPa. There were significant differences ($p<0.05$) in the values of FS and FM when the composites contained different amounts of SiO_2 micro-particles. The SiO_2 micro-particles used for reinforcement of the resin matrix had an effect on the flexural properties of the DRCs.

Keywords: Flexural properties, Silica, Dental resin composites

INTRODUCTION

For the past three decades, efforts have been directed towards the development of dental resin composites (DRCs) to match not only the chemical and mechanical properties of dental enamel, but its appearance as well. DRCs based on polydimethacrylate monomers together with filler treated with silane are widely used in a variety of dentistry applications. Bisphenol A-glycol methacrylate (Bis-GMA) and triethylene glycol dimethacrylate (TEGDMA) are the most commonly used resins in DRCs. The chemical treatments are frequently added to ensure good polymer-filler adhesion (Benyahia and Merrouche, 2014). The most widely used silane in DRCs is 3-methacryloxypropyltrimethoxysilane (γ-MPS). The coupling agents are known to be effective in improving the properties of the resulting composite system (Chuayjuljit *et al.*, 2014). The mechanical properties of the DRCs basically depend on the filler content, size and morphology; therefore, the filler particles play an important role in determining the mechanical properties of DRCs. Increasing the filler content and reducing the average filler size is an approach in producing DRCs for posterior restorations which require adequate strength and wear resistance to endure mastication forces (Manhart *et al.*, 2000). Several studies documented that DRCs are influenced by several factors such as filler ratio, size and morphology (Kim *et al.*, 2002; Zhang *et al.*, 2005). According to ISO 4049:2009 standards, the flexural strength of DRCs materials must not be lower than 50 MPa. Recently, several studies about flexural properties of DRCs have been studied by various researchers (Rodrigues *et al.*, 2007; Rüttermann *et al.*, 2008; Samuel *et al.*, 2009).

To date, only few data on the effects of the SiO_2 particles on the flexural properties of the DRC have been recorded. Therefore, the aim of the present study was to prepare DRCs reinforced with SiO_2 at different ratios, and evaluate their FS and FM properties.

MATERIALS AND METHODS

In this study, the Bis-GMA monomer was purchased from Esschem, Essington (USA), and TEGDMA monomer, γ-MPS, Camphorquinone (CQ), dimethylaminoethyl methacrylate (DMAEMA) were purchased from Sigma-Aldrich (Germany), and the SiO_2 particles were purchased from Sibelco (Malaysia). The resin matrix was fabricated from a blend of Bis-GMA and TEGDMA (75/25) wt%, respectively. The CQ was added to the resin matrix as an initiator followed by the addition of DMAEMA as an accelerator. The SiO_2 particles were treated by an amount of 10 wt% of γ-MPS relative to the amount of filler. Three different ratios of treated SiO_2 particles 40, 50, and 60 wt% were added into the resin matrix, respectively. The procedure was in accordance to Zandinejad *et al.* (2006). Ten samples of each formulation of the prepared DRC were used to determine the density, apparent porosity, FS and FM. The density and apparent porosity test of the DRC samples were carried out according to the ASTM D792:2008 test method-A for testing solid plastics in water. The FS and FM tests were carried out according to the ISO 4049:2009 standard. The samples were light-cured by using a LED *TPC* 60 unit. The FS and FM tests were performed with a three-point bending test using Instron 3366, at a cross-head speed of 0.75 mm/min.

STATISTICAL ANALYSES

Statistical analyses were conducted with SPSS statistics version 19. The data was subjected to one-way analysis of variance (ANOVA) followed by Tukey's *post-hoc*. The level of statistical significance was considered as $p< 0.05$.

RESULTS AND DISCUSSION

Figure 1 shows the effect of the filler loading on the density and porosity of the DRC. The density of the composites increased proportionally as the loading of the filler particles increased. As the particles of SiO_2 have a higher density relative to the resin matrix, the addition of the filler, therefore, increased the composites' density. These findings are in agreement with Lim *et al.* (2006) who reported that the densities of the high-density polyethylene or ultra-high molecular weight polyethylene/high-density polyethylene blend increased with the increasing loading of the filler. It can be also noted that the DRCs' apparent porosity value was found to be inconsistent as the loading of the filler increased, whereby the DRC samples reinforced with 50 or 60 wt% of SiO_2 particles showed a similar porosity value. Moreover, the results indicated a higher porosity value of DRC reinforced with 50 or 60 wt% of SiO_2 than the porosity value of the DRC reinforced with 40 wt% of SiO_2 particles. It is possible that the increase in the level of porosity is intrinsically linked to the processes taking place during the mixing and the procedure of compression moulding.

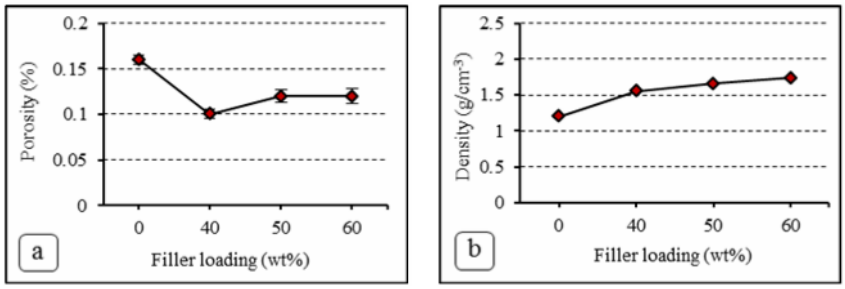

Figure 1. Effect of filler loading on the: (a) density, and (b) apparent porosity of the DRC

Figure 2 shows the effect of SiO_2 particles loading on the FS and FM of the DRCs. The results indicated that when the filler particles' loading increased in the resin matrix, there was a slight decrease in the values of the FS. A statistically significant decrease in the DRC's value of FS was found (p<0.05). This finding was attributed to an increase in the loading of inadequately shaped filler particles. John *et al.* (2001) reported that a polymer which is reinforced has a higher specific strength compared to a non-reinforced polymer. It may also be associated with an increase in the loading of fillers with a large particle size. A number of researchers (Qi *et al.*, 2006; Zhang *et al.*, 2005) claimed that to improve the matrix's mechanical properties the key factor was the dispersion of the small sized particles. These findings are similar to an observation made by Pereira *et al.* (2003) who observed that the composites' FS decreased in comparison to the FS of a pure polymer. According to the ISO 4049:2009 standard, the FS value ought not be less than 50 MPa. In this study, the resin matrix filled with 60 wt% of SiO_2 particles had a FS value which reached 53.2 MPa. This is in line with the ISO 4049:2009 standard which is considered within acceptable limits for applications in dentistry.

The values of the FM improved as the amount of filler loading was increased. Statistically as the filler loading increased the values of the FM significantly increased (p<0.05). The increasing FM value was attributed to an increase in the loading of the filler in the resin matrix. In this study, these findings are similar to the work done by Kim *et al.* (2002) and Alamri and Low (2012) who established that the polymer composites' mechanical properties were associated to the loading of the filler. Several researchers have detected a significant correlation between the percentage of the filler by volume percentage (Ikejima *et al.*, 2003) or the filler by weight (Sabbagh *et al.*, 2002) and the composites' flexural properties.

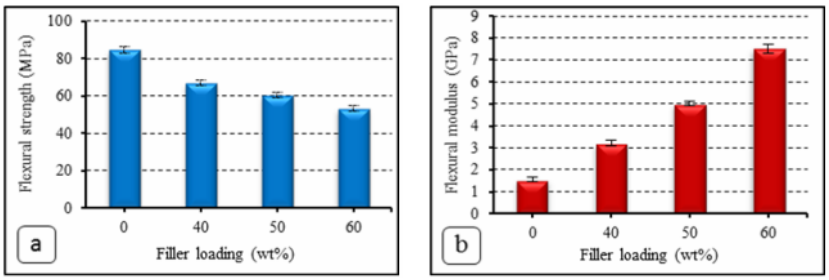

Figure 2. Effect of SiO_2 particles loading on the: (a) FS, and (b) FM of the DRC

CONCLUSIONS

The density of the DRCs increased as the loading of the SiO_2 particles increased, while the value of porosity of the resin matrix when reinforced with different ratios of the SiO_2 particles was found to be inconsistent. It is possible that the increase in the level of porosity is intrinsically linked to the processes that taking place during the mixing and the procedure of compression moulding. However, the FS value of the DRCs decreased as filler loading increased. According to the ISO 4049:2009 standard the FS values of the DRCs in this study are suitable to be used in dentistry. On the other hand, the FM value of the DRCs increased as filler loading increased.

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