Evaluation of Polymerisation Shrinkage of Randomly Oriented Micro-Sized Fibre Reinforced Dental Composites Using Fibre-Bragg Grating Sensors and Their Correlation with Degree of Conversion

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Abstract : Reinforcing dental composites with micro-sized fibres can significantly improve the physio-mechanical properties of dental composites. The short fibres can be oriented randomly within dental composites, thus providing quasi-isotropic reinforcing efficiency unlike unidirectional/bidirectional fibre reinforced composites enhancing anisotropic properties. Thus, short fibres reinforced dental composites are getting popular among practitioners. However, despite their popularity, resin-based dental composites are prone to failure on account of shrinkage during photo polymerisation. The shrinkage in the structure may lead to marginal gap formation, causing secondary caries, thus ultimately inducing failure of the restoration. The traditional methods to evaluate polymerisation shrinkage using strain gauges, density-based measurements, dilatometer, or bonded-disk focuses on average value of volumetric shrinkage. Moreover, the results obtained from traditional methods are sensitive to the specimen geometry. The present research aims to evaluate the real-time shrinkage strain at selected locations in the material with the help of optical fibre Bragg grating (FBG) sensors. Due to the miniature size (diameter 250 µm) of FBG sensors, they can be easily embedded into small samples of dental composites. Furthermore, an FBG array into the system can map the real-time shrinkage strain at different regions of the composite. The evaluation of real-time monitoring of shrinkage values may help to optimise the physio-mechanical properties of composites. Previously, FBG sensors have been able to rightfully measure polymerisation strains of anisotropic (unidirectional or bidirectional) reinforced dental composites. However, very limited study exists to establish the validity of FBG based sensors to evaluate volumetric shrinkage for randomly oriented fibres reinforced composites. The present study aims to fill this research gap and is focussed on establishing the usage of FBG based sensors for evaluating the shrinkage of dental composites reinforced with randomly oriented fibres. Three groups of specimens were prepared by mixing the resin (80% UDMA/20% TEGDMA) with 55% of silane treated $BaAlSiO_2$ particulate fillers or by adding 5% of micro-sized fibres of diameter 5 µm, and length 250/350 µm along with 50% of silane treated $BaAlSiO_2$ particulate fillers into the resin. For measurement of polymerisation shrinkage strain, an array of three fibre Bragg grating sensors was embedded at a depth of 1 mm into a circular Teflon mould of diameter 15 mm and depth 2 mm. The results obtained are compared with the traditional method for evaluation of the volumetric shrinkage using density-based measurements. Degree of conversion was measured using FTIR spectroscopy (Spotlight 400 FT-IR from PerkinElmer). It is expected that the average polymerisation shrinkage strain values for dental composites reinforced with micro-sized fibres can directly correlate with the measured degree of conversion values, implying that more C=C double bond conversion to C-C single bond values also leads to higher shrinkage strain within the composite. Moreover, it could be established the photonics approach could help assess the shrinkage at any point of interest in the material, suggesting that fibre-Bragg grating sensors are a suitable means for measuring real-time polymerisation shrinkage strain for randomly fibre reinforced dental composites as well.

Keywords : dental composite, glass fibre, polymerisation shrinkage strain, fibre-Bragg grating sensors
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