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## Abstract

The characterization of the physical properties of dental resin composites is fraught with difficulties relating to significant intra and inter test parameter variabilities and is relatively time consuming and expensive. The main aim of this study was to evaluate whether optical fibre Brag grating (FBG) sensing system may become a viable tool to study dental material characteristics. Of particular focus was the potential for the system to demonstrate a multi parameter all-in-one feature. A miniature FBG was embedded in six different dental resin composites and employed as a sensor to evaluate linear polymerization shrinkage, thermal expansion and water sorption. This study demonstrates how optical fibre technology can provide simple and reliable methods of measuring the critical physical properties of dental composites. In addition due to the embedding and preservation of the sensor within the samples multiple parameters can be tested for with the same sample.



## Keywords

evaluation, technology, sensing, grating, bragg, fibre, properties, physical, dental, composites, resin


## Disciplines

Engineering | Science and Technology Studies


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# Fibre Bragg Grating Based Characterization System for Dental Resin Composites

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**Abstract:** The characterization of the physical properties of dental resin composites is fraught with difficulties relating to significant intra and inter test parameter variabilities and is relatively time consuming and expensive. The main aim of this study was to evaluate whether optical fibre Brag grating (FBG) sensing system may become a viable tool to study dental material characteristics. Of particular focus was the potential for the system to demonstrate a multi parameter all-in-one feature. A miniature FBG was embedded in six different dental resin composites and employed as a sensor to evaluate linear polymerization shrinkage, thermal expansion and water sorption. This study demonstrates how optical fibre technology can provide simple and reliable methods of measuring the critical physical properties of dental composites. In addition due to the embedding and preservation of the sensor within the samples multiple parameters can be tested for with the same sample.

**OCIS codes:** (060.2370) Fibre optic sensors; (060.3735) Fiber Bragg gratings

## 1. Introduction

Dental composites have become the material most often employed in the restoration of teeth [1], due to many factors including greater aesthetic demands, toxicity concerns and trends toward the conservative management of dentitions. Some of the characteristic properties of dental composites that are of interest to clinicians include polymerization shrinkage stress and strain, degree and depth of curing, fracture strength and toughness, elastic modulus, surface hardness and wear, thermal expansion coefficient and water sorption characteristics. A more reliable and all-in-one characterization tool will less parameter variability would be highly beneficial for dental materials research. Fibre-optic sensing technology is a powerful and potentially rich technology that is currently implemented in a wide variety of applications, where the optical fibre itself is acting as the sensor head [2]. Due to their miniature size (250 µm diameter) it is possible to embed the fibre optic sensor into the dental composites without impacting the inherent material properties. Among the different type of fibre-optic sensors, fibre Bragg gratings (FBGs) [3], are widely used and considered as the most popular technology for implementing in monitoring systems and the preferred choice for many composite materials. Only a few medical studies using FBG sensors have been reported [4-6] for dental material characterization. Initial work reported in measurement of shrinkage strain and water absorption in dental composites shows promising results. With the feasibility of the approach is already demonstrated, the focus should be more on a comprehensive study to develop a multi parameter sensing tool, where one embedded sensor can provide all the necessary characteristic properties of the dental composite. In this paper a miniature FBG sensor is embedded in a range of commercially available dental composites to characterize linear polymerization shrinkage, thermal expansion and water sorption are evaluated using a single sensor embedded in one sample.

## 2. Materials, Methods and Experimental Program

Commercially available dental composites that represents different types such as- fibre reinforced, bulk fill, nano hybrid and flowable- are used in this study. The selections of the samples were based on a criterion to satisfy a broad range of materials with different type and varying percentage of resin and filler content. The sample set consists of materials that are nano-hybrid to fibre reinforced with resin volume ranging from 29% (Nulite) to 55% (SDR). The FBG used in the study are 3 mm long FBGs with peak reflected wavelength of 1550 nm with a reflectivity greater than 70%. The grating is fabricated on singlemode silica fibre with polyimide buffer coating and has a diameter of circa 150 µm.

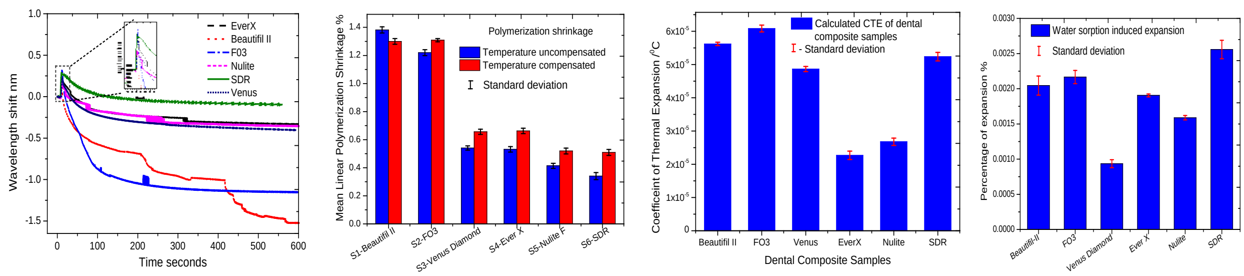
A schematic diagram of an FBG interrogation used in this study is depicted in Fig 1(a). A commercial FBG interrogator which has a capability to resolve 5 pm wavelength change with a data acquisition rate of 1 kHz is used. A broadband source with a spectral range of 1530-1570 nm was used and the reflected signal from the FBG was directed to the interrogator via fibre optic circulator. The experimental setup to measure the characteristics such as polymerization shrinkage, thermal expansion coefficient (CTE) and water absorption are also shown in Fig 1(b-d) respectively and the cured samples are shown in Fig 1(e).


(a) (b) (c) (d) (e)

Fig 2. (a) Schematic diagram of the FBG sensor based characterization system (a) polymerization shrinkage (c) thermal expansion (d) and water sorption measurement setup (e) cured dental samples used for the study.

## 4. Results and Discussion

The measured curing responses and mean linear polymerization shrinkage for all the dental samples is shown in Fig 2(a) and Fig 2(b) respectively. Repeated studies with three sets of all the samples with embedded FBGs are conducted. Sample FO3 has the highest shrinkage sample SDR has the least. The standard deviations of the measurements are also shown in Fig 2(b). The largest standard deviation (SD) recorded was 0.21, which shows high repeatability and reliability. The curing characteristics such as curing/polymerization shrinkage rate of the dental composites can also be obtained from Fig 2(a). The measured rate of wavelength change (which is a measure of shrinkage rate) for FO3 is 0.012 nm/sec, while for SDR it is 0.0027 nm/sec for the first 100 seconds. The calculated mean CTE of the dental composites sample is shown in Fig 2(c). A highest CTE of 6.01E-5 is measured for FO3 while the lowest was for EverX and Nulite F which was 2.359E-5 and 2.677E-5 respectively. The largest SD recorded was 1.27E-6 indicating that the experimental setup and applied temperature was highly stable and that FBG sensor provides consistent results. To demonstrate the difference in water sorption characteristics of dental composites, the mean percentage of expansion due to water absorption for the whole range of samples tested is shown Fig 2(d). The results show that SDR exhibits the highest expansion (0.00265%), whereas Venus Diamond shows the lowest (0.000975%). The water sorption also follows the same trend as the thermal expansion and mainly due to the resin volume content in the material. The obtained values are repeatable and the standard deviation is also shown in Fig 2(d). The largest recorded standard deviation in this test data was 0.000135.




(a) (b) (c) (d)

Fig 2. (a) Characteristic properties of dental samples obtained by the embedded FBG sensors (a) curing profile (b) polymerization shrinkage (b) thermal expansion (c) percentage of expansion due to water sorption.

## 4. Conclusions

Physical properties of the dental resin composites were evaluated using a miniature optical fibre Bragg grating sensor embedded in the material. Using a single sensor embedded in the material, the properties such as polymerization shrinkage, thermal expansion and water sorption of dental composite materials were obtained. The curing characteristics and the rate of curing can also be obtained using the embedded FBG. The experimental results based on a range of commercially available dental materials were analysed and it can be confirmed that fibre optic sensing method can be adopted as an alternative to existing traditional methods and this method can avoid the testing conditions variability while obtaining the multiple characteristics properties of the dental composites.

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