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Influence of therapeutic dose gamma radiation and MRI on structure and mechanical properties of resin-composites dental materials

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ABSTRACT

The objective of this study was to investigate the influence of gamma radiation dose, at the therapeutic dosage, and magnetic resonance imaging (MRI) on microstructure, molecular structure and mechanical properties of Filtek Z250 and Silorane composite materials. X-ray diffraction patterns and IR spectrographs showed a change in microstructure and molecular structure of Filtek Z250 and Silorane composite materials as a result of irradiation dose by gamma and 1.5 T MRI radiations. The experimental data showed that, Filtek Z250 composite material is much harder before irradiated and more affected by gamma radiation dose than that silorane composite material. But the effects of MRI (1.5 T) on both composite materials are nearly the same. The bending strength and breaking load values of Filtek Z250 and Silorane composite materials are decreased by increasing gamma radiation dose but its increased by exposure to MRI (1.5 T) radiation.

KEYWORDS

Filtek Z250;
Silorane;
Gamma radiation;
Magnetic resonance imaging;
Structure;
Vickers hardness;
Bending strength;
FTIR spectrum.

INTRODUCTION

Resin-composites are one of the most common and widely used materials in dentistry and gamma radiation as a primary or supplementary treatment regimen is utilized for oral cancer patients. Also, magnetic resonance image could be used on head and neck region, so, these patients commonly have dental restorations fabricated of a variety of dental materials. Consequently, any interactive effects by the incident beam on such dental materials might be of clinical significance if properties of these materials are adversely affected. These composites consist of a polymerizable resin matrix, reinforcing glass particles fillers, and silane coupling agents. Significant improvements have been achieved in the fillers, resins, filler-matrix bonding, and cure conditions for dental-polymer-matrix composites[1,2]. However, all contemporary composite materials shrink during polymerization, resulting in a volumetric reduction ranging from 1.5 to 5% depending on the molecular structure of the monomer, the amount of filler, and the rate of cure[3]. Low-shrink composite has been introduced in dentistry in the 2007s. Polymerization process of low-shrink composite occurs via cationic ring-opening addition polymerization reaction which results in lower polymerization shrinkage, compared to the dimethacrylate-based composite which polymerizes via free-radical addition polymerization[4,5]. Differences in mechanical and physical properties exhibited by novel low-shrink resin-based composite formulations com-

pared with conventional methacrylate may contribute to the clinical success of the candidate material[6]. However, together with healthy tissue, the dental restorations may be irradiated during fractionation and could receive a significant amount of radiation dose[7,8]. Little is known about the direct exposure of ionizing radiation on dental materials[9-13] and the exposure results are still unclear[6]. Some mechanical properties of dental materials changed proportionally with increasing gamma radiation dose[10,11,13]. However, the effects of ionizing radiations on the structure and physical properties of low-shrink composite resins that have been recently developed and introduced to the dental market were not investigated. So, the aim of this study was to investigate the effects of therapeutic gamma radiation dose and magnetic resonance imaging on the structure and mechanical properties of Filtek Z250 and Silorane composite materials as low-shrink composite resins.

MATERIALS AND METHODS

Two commercial restorative materials, Filtek Z250 resin composite material (shade A, 3M, St. Paul, MN, USA) and Silorane resin composite material were selected for this study. Ten specimens were prepared from each type of resin composite. The specimens were tested with respect to structure, molecular structure and Vickers microhardness. Unpolymerized material was applied in Teflon mold with dimensions 25mm in length×2mm in width×2mm in height. To ensure that the resin composite would be well distributed within the mold, 0.5kgf was applied for 30 s to the material. Glass slides were used to prevent inhibition of surface polymerization due to the presence of oxygen. The specimens were then photocured with a visible light curing unit (Visilux2, 3M Company, ST., Paul, MN, USA) for 40 s on each of the two covered slides. Structure (The phase analysis) of used specimens was performed on the flat surface of all specimens using an X–ray Diffractometer (Dx-30, Shimadzu, Japan) of Cu-Kα radiation with λ = 1.54056 Å at 4.5Kv and 35mA and Ni-filter in the angular range 2θ ranging from 0 to 60° in continuous mode. Molecular structure of used specimens was performed using Mattson 5000 FTIR Spectrometer, Spectral Analysis Unit, Chemistry Department, Faculty of Science, Mansoura University. Vickers hardness (Hv) was measured for all samples using a digital Vickers microhardness tester (Model FM-7, Tokyo, Japan) at 10 g indentation loads for 5 sec each. This load was sufficiently small to suppress any tendency to crack the specimen, which can grossly affect the hardness measurements. For each sample, 7 indentations were made randomly on the top surface. Five measurements were recorded for each sample and the mean value of 5 specimens (n = 5) for each sample was used. The exposure factor was magnetic resonance imaging dose of 1.5 T from a 1.5 T MR Scanner (Signa Harizon, GE medical systems, Milwaukee, WIS). For flexural strength and modulus of elasticity, the specimens were subjected to testing in a universal testing machine (Instron Ltd, High Wycombe, UK) with a constant cross-head speed of 1.00±0.10 mm/min. The flexural strength (σ) were calculated using the following equation,

$$\sigma = 3Pl/2bh^2$$

where (P) represent the maximum load in N, (l) the distance in mm between the support (20mm), (h) the height of specimen in mm measured immediately prior to testing and (b) is the width of the specimen in mm measured immediately prior to testing.

Results of x-ray

X-ray diffraction patterns of Filtek Z250 and Soloraine composite materials are shown in Figure 1 and 2. The intensity of the main peak could be considered as an indentation of the degree of crystallinity for both used materials. Also intensity is a function of shape, size and concentration of scattering objects. Crystal size can be determined using the Scherrer equation[14]:

$r = \frac{k\lambda}{B\cos\theta}$, where λ is the wave length of used radiation (1.50456 A°), k is approximately unity and B is the half width of reflection. Figure 1 shows that the broad peak (half width of reflection) for Filtek Z250 is decreased by exposure it to gamma radiation and MRI. But the broad peak (half width of reflection) for Soloraine is increased by exposure it to gamma radiation and MRI as shown in figure 2. The irradiation produced a change in microstructure the intensity (crystallitnity), broadness (crystal size) and position (place of atoms or orientation).

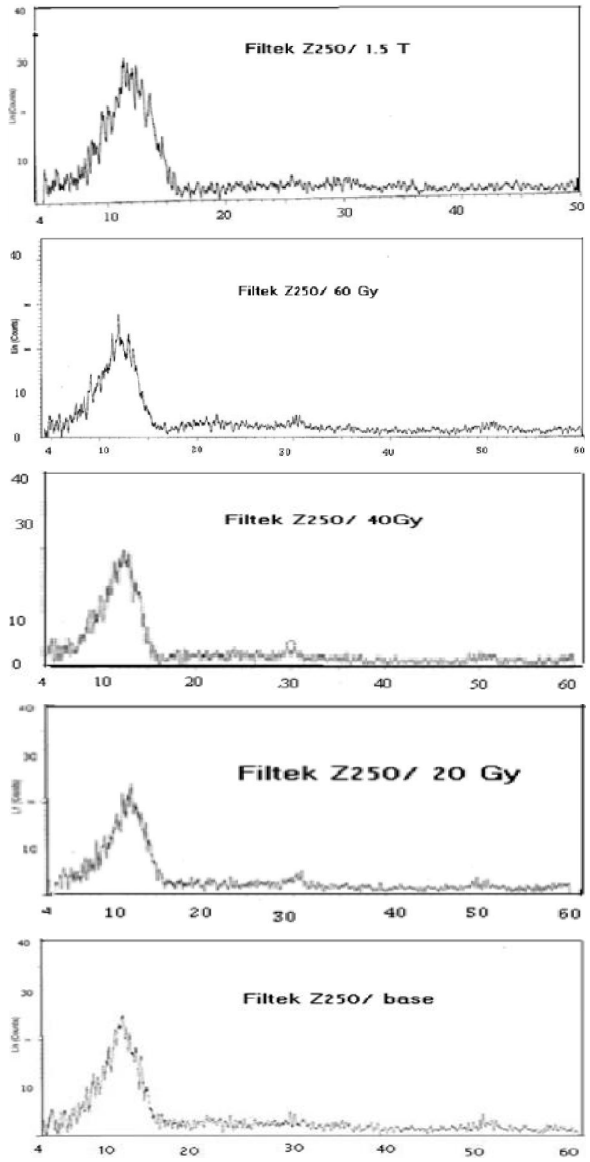

Figure 1: X-ray diffraction patterns of Filtek before and after irradiated by gamma and 1.5 T (NMR) radiations

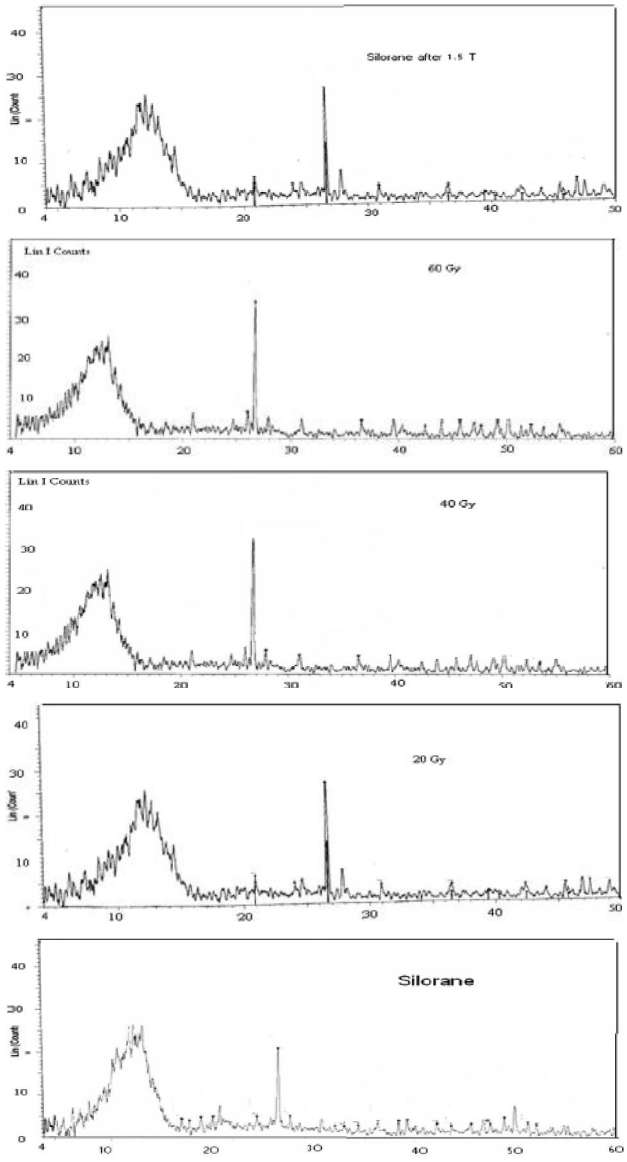

Figure 2: X-ray diffraction patterns of Silorane before and after irradiated by gamma and 1.5 T (NMR) radiations

Results of IR

FTIR spectroscopy has been proven to be a useful tool for determining the changes of molecular structure upon blending, irradiation, heat treatment and solvent compositions[15]. FTIR spectroscopy has been investigated for Filtek Z250 and Soloraine composite materials in the range starting from 500 to 3900cm^{-1} in transmission. The FTIR spectrum of Filtek Z250 and Soloraine composite materials are shown in figure (3) and (4). The IR spectra of Filtek Z250 composite material exhibited medium IR bands at 1726cm^{-1} corresponding to the ester group ($COOCH_3$). These bands are assigned to organic matrix Bis- GMA and this agree with the Sideridou et al results[16]. Also IR spectra exhibited strong and weak and very broad IR bands at ~1100 and ~3420cm^{-1} corresponding to C-O and C-H and that is agree with all references and hand books. The intensity (weak, medium or strong), shape (broad or sharp), and position (cm^{-1}) in the spectrum are changed due the effects of gamma radiation and MRI doses.

Results of mechanical properties

Hardness is a property with a low coefficient of variation when compared with other mechanical properties tested. In general hardness is defined as 'Resistance of material to plastic deformation', usually by

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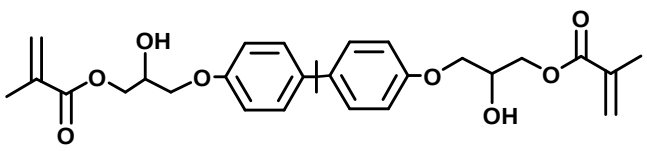

Bis-GMA

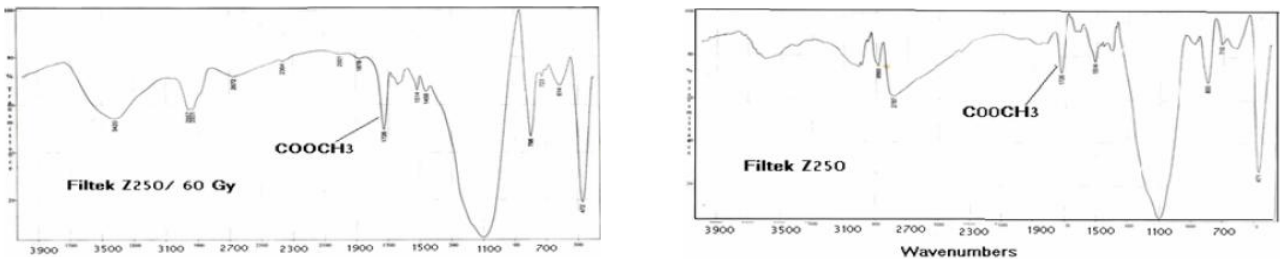

Figure 3 : FTIR spectrum of Filtek Z250 composite material

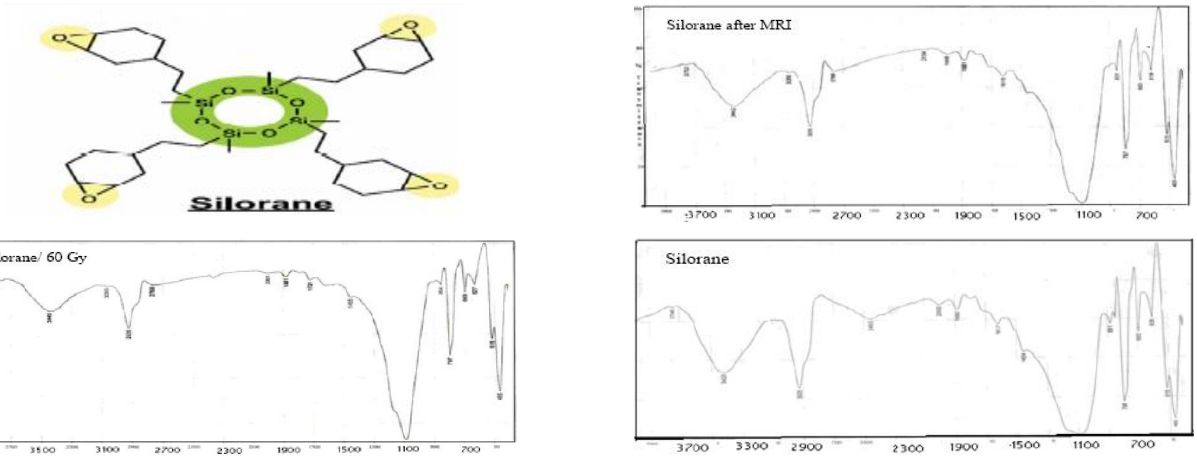

Figure 4 : FTIR spectrum of soloraine composite material

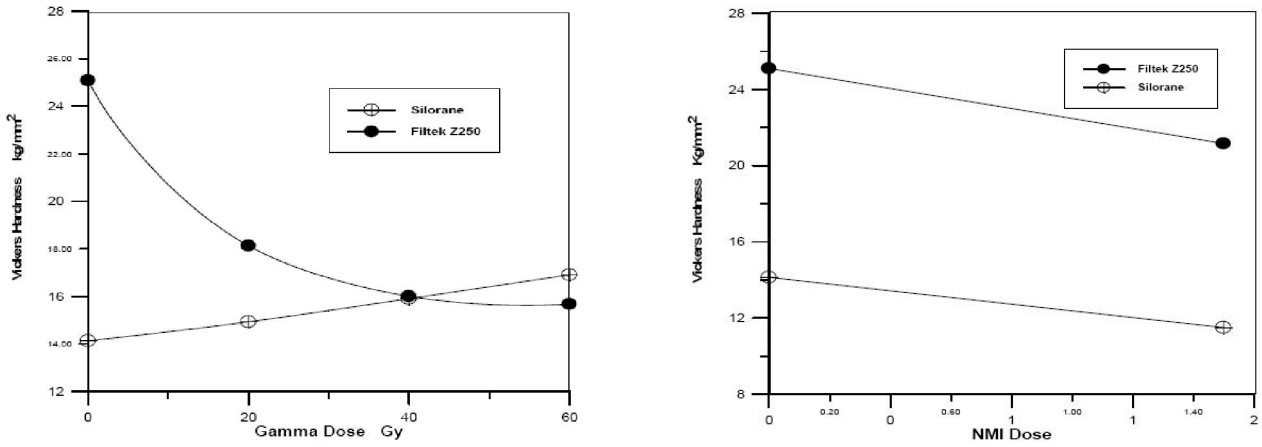

Figure 5 : Vickers hardness of Filtek Z250 and Silorane after radiated by gamma and 1.5 T (NMR) radiations

indentation. However, the term hardness may also refer to stiffness or temper or resistance to scratching abrasion, or cutting.

Microhardness test were conducted using a digital Vickers microhardness tester model (FM-7) applying a load of 10gm for 5 seconds via a Vickers diamond pyramid as seen in figure 5. This load was sufficiently small to suppress any tendency to cracking, which can grossly affect the hardness measurements. The results show that, Vickers hardness value

TABLE 1 : Bending strength and breaking load of Filtek Z250 and Silorane before and after radiated by gamma radiation

(A) Silorane

Sample	Thickness (cm)	Width (cm)	Span (cm)	Breaking load (kg)	Bending strength (kg/cm^2)	Bending strength (N/mm^2)
Base	0.160	0.220	2.00	1.93	1028.054	100.818
20 Gy	0.180	0.230	2.00	1.73	696.457	68.299
40 Gy	0.170	0.210	2.00	1.52	751.359	73.683

(B) Filtek Z250

Sample	Thickness (cm)	Width (cm)	Span (cm)	Breaking load (kg)	Bending strength (kg/cm^2)	Bending strength (N/mm^2)
Base	0.146	0.200	2.00	1.73	1217.395	119.386
20 Gy	0.160	0.210	2.00	1.22	680.804	66.764
40 Gy	0.169	0.215	2.00	1.54	752.368	73.782

of Filtek Z250 composite material is decreased by increasing gamma radiation dose but Vickers hardness value of Soloraine composite material is slightly increased. Vickers hardness values of Filtek Z250 and Soloraine composite materials are decreased by exposure it to MRI dose. Also bending strength and breaking load values of Filtek Z250 and Soloraine composite materials are decreased by increasing gamma radiation dose as seen in TABLE 1.

DISCUSSIONS

However, the effects of radiation on the structure and physical properties of low-shrink composite resins that have been recently developed and introduced to the dental market were not investigated. So, the aim of this study was to investigate the effects of gamma radiation dose, at the therapeutic dosage (20, 40 and 60Gy), and magnetic resonance imaging, 1.5 T (MRI) on the microstructure, molecular structure and mechanical properties of conventional and low-shrink composite resins.

Interaction of high energy radiation with Filtek Z250 and Soloraine composite materials due change in the intensity and the width (brooding) of x-ray diffraction peaks as seen in figure 1 and 2, that is mean the microstructure (crystallinity and crystal size) is effected by increasing/or exposure to radiations doses. Also the irradiation produced a change in the intensity, shape and position of some bands, figure 3 and 4 such as C-O, O-H and $COOCH_3$ and that is agree with previous results[15,17,18].

The Vickers hardness value of Filtek Z250 composite material is decreased by increasing gamma radiation dose/or exposure to 1.5 T, figure 5, and that is agree with the previous results[12,19]. That is may be because the ionizing radiation could break established bonds which results in a decrease in hardness or promotes simultaneously the linking and breaking the bond. Also these results confirmed by our x-ray studies which reflect that the ionizing radiation decreased crystallinity and increased crystal size of filler at the surface reducing its hardness.

The Vickers hardness value of Soloraine composite material is increased by increasing gamma radiation dose, figure 5, and that is agree with the previous results[9-11,13]. That is may be because the ionizing radiation could due excitation which improve the link among chains. Also these results confirmed by our x-ray studies which reflect that the ionizing radiation increased crystallinity and decreased crystal size of filler with disturbed it on the surface increasing its hardness.

The bending strength and breaking load values for Filtek Z250 and Soloraine composite materials are decrease by increasing gamma radiation dose, TABLE 1. That is may be because the ionizing radiation breaks the bond inside the matrix in composite materials.

CONCLUSION

1 X-ray diffraction patterns and IR spectrographs showed a change in microstructure and molecular structure of Filtek Z250 and Silorane composite materials as a result of irradiation dose by gamma and MRI radiations which affects on its mechanical properties.

2 Vickers microhardness, bending strength and breaking load values of Filetk Z250 composite material is decreased as results of irradiation by gamma doses.

3 Vickers microhardness value of Silorane composite material is increased as results of irradiation by gamma doses.

4 Bending strength and breaking load values of Silorane composite material is decreased as results of irradiation by gamma doses.

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