THERAPEUTIC GAMMA RADIATION: EFFECTS ON MICROHARDNESS AND STRUCTURE OF CURRENT COMPOSITE RESTORATIVE MATERIALS

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ABSTRACT

Oral cancer patients, receiving gamma radiation as primary or supplementary treatment, commonly have a variety of dental restorations including composite resins. Any interactive effects between the incident therapeutic beam and such materials might be of clinical significance if properties of these materials are adversely affected. In this investigation the effects of gamma radiation at three therapeutic dosage levels on microhardness of three current composite restorative materials were determined. It was also the objective of this study to detect any possible alterations in the chemical structure of these materials after gamma radiation using infrared spectroscopy. The results showed, in general, a significant increase in mean microhardness values (P<0.05) of all investigated materials upon exposure to gamma radiation with the exception of Point-4 composite resin at the dosage level of 2000 rads. These findings were basically attributed to an increase in the degree of polymerization of such restorative materials. Infrared analysis of the tested materials showed no change in the molecular structure of their resin component as a result of gamma irradiation.

Key words: *Gamma radiation, Effects on composites.*

INTRODUCTION

The relatively high incidence of carcinoma of head and neck including that of oral cavity has been reported; and gamma radiation as a primary or supplementary treatment regimen has always been and is still being utilized for these patients.[1] These patients commonly have dental restorations fabricated of a variety of dental materials. Consequently, any interactive effects by the incident therapeutic beam on such dental materials might be of clinical significance if the physical properties of these materials are adversely affected. One important property of such materials is the surface microhardness which is used to predict their wear resistance and the ability to abrade or be abraded by other contacting materials. Additionally, surface microhardness is an indication of the mechanical performance of restorations under biting forces as the material's hardness is related to its proportional limit and strength. [2-5]

Composite resin restorative materials have been extensively used for restoring anterior and posterior teeth. Recently, nanofill and nanohybrid composite resin materials with finer inorganic filler particles are produced by means of advanced technology. This has resulted in a more durable restoration that can be less abraded and have harder surfaces.[6-10]

Infrared spectroscopy is the most widely used, simple, reliable and rapid technique for quantitative and qualitative analysis and characterization of biomaterials including polymers. Since each molecule has uniquely characteristic pattern of vibrations, it produces a unique characteristic set of absorption bands in the IR spectroscopy. This pattern serves as a fingerprint of the molecule. The aliphatic C=C bonds have a specific absorption band at 1638 cm^{-1}, and is usually used as a direct indicator to the degree of polymerization.[11,12]

The effects of non-ionizing radiation on the surface and bulk properties of composite restorative materials were reported in the dental literature.[13,14] However, little is known about the effect of the ionizing radiation on such properties of composite resins and particularly the current nanofilled composites. This study investigated the effects of gamma radiation at three therapeutic dosage levels on the microhardness of three currently available dental composite resins. It was also the objective of this study to compare these materials before and after irradiation using infrared spectroscopy for detection of any possible alterations in their chemical structure.

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MATERIALS AND METHODS

Three currently available composite resins were used in this study and their particulars are presented in Table 1. A total of 120 cylindrical composite resin specimens (6mm diameter, 6mm thickness) were prepared in cylindrical Teflon molds and were used in this study. Forty specimens were fabricated from each of the three materials and were randomly divided into two groups (I and II) of 20 each. Specimens in Group I were used for microhardness testing, while those in Group II were used for infrared spectroscopy. All investigated composite materials were used according to the respective manufacturer's directions. The materials were injected into the Teflon molds in 2mm increments and gently packed. Then, each increment was light-cured for 30 seconds using Heliolux light-curing unit (Vivadent, Amherst, NY, USA). The last increment was light-cured in contact with a plastic strip to ensure that the surface was smooth and parallel to the bottom of the mold. All specimens were then stored in distilled water at 37°C for 24 hours before irradiation.

Specimens in each group were then randomly divided into four subgroups (1-4) of five specimens each. Specimens in subgroups l, 2 and 3 were exposed to gamma radiation at therapeutic dosage levels of 2000, 4000 and 6000 rads, respectively using cobalt radiotherapy machine. Specimens in subgroup 4 received no gamma radiation and were used as control. The radiotherapy machine is basically a lead box which contains the decaying radioactive Cobalt-60 that produces gamma radiation.[15] The specimens to be irradiated were exposed to Cobalt-60 by removing the shutter of the lead box. Then all irradiated specimens were stored in distilled water at 37°C for 1 hour prior to testing.

Specimens in Group I were subjected to microhardness testing using a Micromet microhardness

TABLE 1: INVESTIGATED COMPOSITE RESINS*

Brand	Manufacturer	Type	Resin matrix	Filler Size (µm)	Filler degree (%w/w)
Filtek Supreme	3M Dental Products St. Paul, MN USA	Nanofil	Triethyleneglycol Dimethacrylate Urethane Dimethacrylate, Bis-EMA, Bis-GMA	Zirconia-Silica (0.6- 1.4)	78.5
Artemis	Vivadent, Schaan, Germany	Microhybrid	Urethane Dimethacrylate, Triethyleneglycol	Ba-Al Fluorsilicate (0.04-3.0)	75-78
Point-4	SDS/Kerr Orange, CA,USA	Ultra-small	Bis-GMA, Triethyleneglycol DMA	Barium aluminoborosilicate glass and fumed silicon dioxide (0.4)	76

* According to information provided by the manufacturers.

TABLE 2: MICROHARDNESS (VHN) VALUES* OF INVESTIGATED COMPOSITE RESINS AFTER EXPOSURE TO GAMMA RADIATION AT DIFFERENT DOSAGE LEVELS

Gamma Radiation Dosage Levels (rads)	Composite Resin Materials		
	Filtek Supreme	Artemis	Point-4
Control (No radiation)	120.4±0.1	66.3±5.2	70.2±1.8
2000	124.3±3.7	66.5±1.9	71.9±3.7**
4000	126.1±2.6	68.8±2.6	75.8±2.7
6000	128.7±4.4	75.2±1.0	79.8±5.4

* Mean ± SD, ** Not significant (p>0.05)

tester (Buehler Ltd., Lake Bluff, Illinois, USA) with a Vickers diamond indentor. Three indentations were made at each specimen surface using a 300 g load for 15 seconds. The indentation depth numbers of the three indentations were taken from the dial gauge, averaged, and then converted to a single Vickers Hardness Number (VHN) value. The mean microhardness values of the investigated materials were statistically analyzed using a Two -way analysis of variance (ANOVA), followed by Turkey's HSD multiple range test with the value of statistical significance set at the $P < 0.05$ level.

Specimens in Group II for each composite resin material were used for detection of any possible effects of gamma radiation on their chemical structure using an infrared Spectrophotometer IR -400 (Shimazu Infrared Spectrophotometer IR-400, Japan). In addition, comparison of the spectra, before and after irradiation was made for any alterations in peak position, magnitude or width. The spectrophotometer records the transmittance of a specimen at any frequency in IR region between 4000 cm^{-1} and 650 cm^{-1} (wave numbers). The double-beam optical null method is the base for detecting the absorbance of the specimens.[15,16]

RESULTS

The mean microhardness (VHN) values of the composite restoratives after gamma irradiation are listed in Table 2 and depicted in Fig. 1.

VHN mean values of the tested materials after gamma irradiation at the three therapeutic dosage levels showed an increase compared to those tested before irradiation. With the exception of Point-4 irradiated at a dosage level of 2000 rads, this increase in microhardness was significant ($P<0.05$) for all investigated materials. For all tested materials, VHN mean

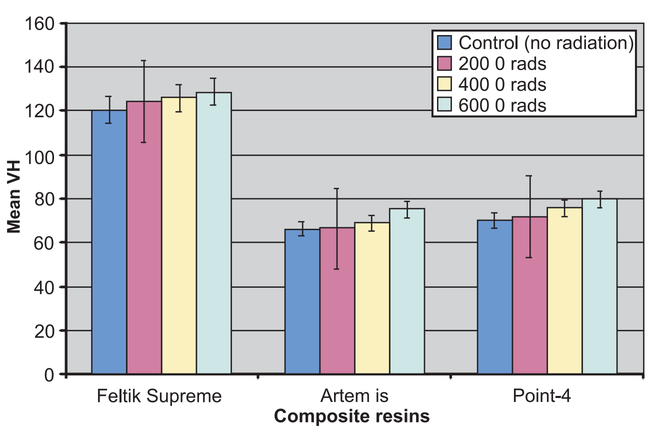

Fig. 1. Mean (VHN) and SD Values of Tested Composite Resins

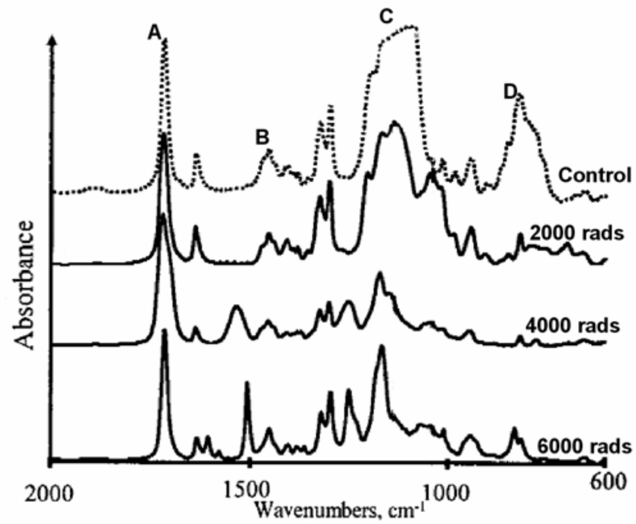

Fig. 2. Representative IR Spectra Obtained Before and After Gamma Radiation for Filtek Supreme Composite Resin

values also showed a significant increase ($P<0.05$) with increased irradiation dosage from 2000 to 6000 rads, with the exception of Artemis. Before gamma irradiation, VHN mean values for Filtek Supreme were significantly higher ($P>0.05$) than those for Artemis and Point-4 composite materials.

The infrared spectra of the investigated composite materials before gamma radiation appeared to be identical. Following gamma radiation, IR spectra obtained at the three therapeutic dosage levels were found to be also similar for all tested materials. IR spectra obtained before and after gamma irradiation for Filtek Supreme composite resin were used as representative and are shown in Figure 2. The before- and after- irradiation spectra exhibited peaks at the positions of A = 1700 WN, B = 1500 WN, C = 1100 WN, and D = 800 WN.

The IR spectra of the before- and after- gamma radiation were compared for detection of any alteration in the chemical structure of the investigated composite resins materials. This alteration is indicated by changes in peak position, magnitude or width. Variations in the absolute peak position by up to 5 cm^{-1} are within the accuracy of the experimental setup. Comparison of the representative pre- and post-gamma radiation spectra of Filtek Supreme (Figure. 2) illustrated no actual shift in the position of the peaks (A - D). Furthermore, no detectable change in the width of the peaks or their magnitude, i.e. peak height, was noted. Additionally, all gamma-radiated specimens at the three therapeutic dosage levels revealed no apparent changes in color, size and surface roughness when compared to the control specimens.

DISCUSSION

The results of this study (Table 2 and Fig. 1) showed, in general, a significant increase in the mean VHN values for the investigated composite resin materials following gamma radiation at the three dosage levels. This increase in post-radiation microhardness could be attributed to the continued polymerization arising from the incident therapeutic radiation beam which, in turn, could result in increased degree of polymerization.[17,18] This increase in polymerization degree of the investigated photo-cured composite materials could be further explained by the fact that the gamma radiation used in this study possesses a short wavelength (0.001 -0.1 nm). The short wavelength of gamma radiation exhibits a greater intensity and higher penetration power of composite resin materials compared to those of the visible curing light (470 nm) which is commonly used to perform polymerization of composite resins.

The higher VHN values (Table 2) obtained in this study for Filtek Supreme composite resins were expected because of the presence of zerconia nanofillers in their matrix (Table 1). These zerconia nanofillers are claimed by the manufacturers to present opportunities for enhancement of the physical and handling features of the materials as well as maintaining their high wear resistance.

The IR spectra of pre- and post-gamma radiated materials investigated in this study (Figure 2) revealed no changes in the peak position, magnitude or width which clearly indicate no alteration in their chemical structure following gamma radiation with no possible degradation of the polymer molecules. The unaltered chemical structure of the investigated materials after gamma radiation could be attributed to the high energy, borne by the carbon-to-carbon bond in the organic monomer, which may overcome any molecular disruption caused by the incident therapeutic radiation beam.[15] Furthermore, the observed maintenance of the color, size and surface smoothness of the gamma radiated composite resin specimens, as compared to the control specimens reflected no adverse effects of the therapeutic gamma radiations at the three dosage levels used in this investigation.

CONCLUSIONS

Based on the results of this study, the following conclusions can be drawn:

1 Gamma radiation at the three therapeutic dosage levels had a positive effect on the investigated composite resin materials as indicated by the significant increase in their microhardness.

2 The nanofilled Filtek Supreme composite resins exhibited the highest microhardness values before and after exposure to gamma radiation, followed by Point-4 and Artemis composites.

3 Gamma radiation at the three therapeutic dosage levels did not cause molecular degradation of the investigated composite resin materials result in no alteration of their chemical structure.

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