

## EFFECT OF THERAPEUTIC GAMMA RADIATION ON DIAMETRAL TENSILE STRENGTH AND MICROHARDNESS OF PHOTO-CURED GLASS IONOMER CEMENTS

Khamis Hassan, BDS, MSD, PhD\*; Salwa Khier, BDS, MSc, PhD\*\*

كثيراً ما تحتوي أسنان المرضى المصابون بأورام سرطانية بالفم والذين يتعرضون لجرعات علاجية من أشعة «جاما» على حشوات متنوعة منها حشوات «الجللاس ايونومر الراتنجي» وقد يحدث تأثير سلبي على خواص هذه الحشوات عند حدوث تأثير تفاعلية بين هذه المواد المستخدمة في الحشو والأشعة العلاجية «جاما» .  
تناول هذا البحث دراسة تأثير ثلاث جرعات علاجية من أشعة «جاما» على كل من قوة الشد والصلابة الدقيقة وذلك باستخدام ثلاث أنواع من حشوات «الجللاس ايونومر» ضوئي البلمرة كما تم تمييز التركيب الجزئي لمواد الحشو قبل وبعد تعرضها لأشعة «جاما» وذلك باستخدام التحليل الطيفي بالأشعة تحت الحمراء .  
وقد أظهرت نتائج هذا البحث أن هناك زيادة دلالة إحصائية في قوة الشد لمواد البحث وذلك بعد تعرضها لأشعة «جاما» كما أظهرت النتائج عامة تحسناً في الصلابة الدقيقة لمواد الحشو بعد تعرضها لأشعة «جاما» وتعزي هذه النتائج إلى احتمال زيادة درجة بلمرة مواد الحشو «الجللاس ايونومر» المحتوية على راتنج والتي يستخدم الضوء في بلمرتها وذلك بعد تعرضها لأشعة «جاما» ولقد أظهر التحليل الطيفي بالأشعة تحت الحمراء لمواد الحشو عدم وجود أية تغييرات في تركيبها الجزئي قبل وبعد تعرضها لأشعة «جاما» .

Oral cancer patients, receiving gamma radiation as primary or supplementary treatment, commonly have a variety of dental restorations including resin-containing glass ionomer cements. 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 the diametral tensile strength (DTS) and microhardness of three photo-cured glass ionomer restorative cements were determined. It was also the objective of this study to characterize the materials before and after gamma radiation using infrared spectroscopy. The results showed a significant increase in DTS of all investigated materials upon exposure to gamma radiation. Microhardness results for all materials showed, in general, an increase after irradiation. These findings were attributed to an increase in the degree of polymerization of these resin-containing photopolymerizable restorative cements. Infrared analysis of the three materials showed no change in their molecular structure (resin component) as a result of irradiation.

### Introduction

The relatively high incidence of carcinoma of the head and neck including those of the oral cavity

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\* Formerly Professor, Department of Restorative Dental Sciences, King Saud University College of Dentistry, 7 Ibrahim Nasir St., Apt. 34, Louran, Alexandria, Egypt

\*\* Formerly Associate Professor, Department of Prosthodontic Dental Sciences, King Saud University College of Dentistry

Address reprint requests to: Prof. K. Hassan

has been reported. Gamma radiation as a primary or supplementary treatment regimen has always been, and is still, utilized for oral cancer patients.<sup>1</sup> 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 properties of these materials are adversely affected.

The effects of non-ionizing radiation on restorative dental materials were reported in the

dental literature.<sup>2,3</sup> However, very few studies were concerned with the effects of ionizing radiation on the physical properties of such restorative materials namely the composite resins.<sup>4</sup> Photocured glass ionomer restorative materials have been recently developed and introduced to the dental market and are basically the conventional glass ionomer cements with incorporation of some inorganic monomeric additives.

This study investigates the effects of gamma radiation at three therapeutic dosage levels on the diametral tensile strength and microhardness of three photo-cured glass ionomer restorative cements. It was also the objective of this study to compare the materials before and after irradiation using infrared spectroscopy for detection of any possible alterations in their chemical structure.

#### Materials and Methods

Three different brands of encapsulated resin-modified glass ionomer restoratives were used in this study (Table 1). By strict definition, Dyract-PSA is classified as a modified composite or fluoride releasing resin rather than a resin-modified glass ionomer. While recognizing the controversy over nomenclature, a single term is used in this paper for simplicity.<sup>5</sup>

A total of 180 cylindrical specimens were prepared and used in this study. Sixty specimens were fabricated from each material and were ran-

domly divided into three groups (A-C) of 20 each. Specimens in Group A were used for diametral tensile strength (DTS) testing, while those in Group B were subjected to microhardness testing. Specimens in Group C were used for infrared spectroscopy. The cylindrical specimens (6mm diameter, 6mm thickness) in all groups were fabricated in cylindrical teflon molds. All glass ionomer materials were used according to the respective manufacturer's direction. The materials were injected into the molds in 1m increments and gently packed. Then each increment was light-cured for 30 seconds using Poly lite 1000\* visible light curing unit. 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 of five each, where specimens in subgroups 1, 2 and 3 were exposed to gamma radiation at therapeutic dosage levels of 2000, 4000 and 6000 rads, respectively using a 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.<sup>6</sup>

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. All specimens in Group A were subjected to DTS testing. They were loaded till fracture using a Universal Testing Machine<sup>8</sup> at a crosshead speed of 0.5 mm/min. The DTS was calculated using the equation  $T=2P/7i dl$ , where P is the fracture load, d is the specimen diameter and l is the specimen length.

\*Pro-Den System, Inc., Portland, Oregon, USA.

<sup>5</sup>Lloyd Instr. Ltd., Segenswarth, W. Fareham, UK

Table 1. The investigated photo-cured glass ionomer restoratives.

Brand	Components	Manufacturer
Fuji IILC (capsules)	Fluoroaluminosilicate glass; copolymer of maleic acids and acrylic acids, HEMA, H <sub>2</sub> O	GC, America, Chicago, IL, USA
Photac-Fil (Aplicap)	Fluoroaluminosilicate glass; copolymer of maleic acids and acrylic acid monomers, oligomers, H <sub>2</sub> O	ESPE-PremierCorp., Norristown, PA, USA
Dyract-PSA	UDMA resin, TCB resin, Strontium fluorosilicate glass	De Trey/Dentsply, Weybridge, UK

\* Thonemann et al<sup>8</sup>.

Specimens in Group B were subjected to microhardness testing using a Micromet\* microhardness tester. Three indentations were made at each specimen surface using a 20g load for 15 seconds. The diagonals of the three indentations were measured, averaged and converted to a single Knoop Hardness Number (KHN) value.<sup>7</sup>

Specimens in Group C for each material were used for determining any possible effect of gamma radiation on the chemical structure of the investigated materials using an infrared Spectrophotometer IR-400<sup>5</sup>. 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<sup>-1</sup> and 650 cm<sup>-1</sup> (wave numbers). The double-beam optical null method is the base for detecting the absorbance of the specimens.

DTS and microhardness values of the investigated materials were statistically analyzed using a two-way analysis of variance (ANOVA), followed by Tukey multiple comparison test with the value of statistical significance set at the P<0.05 level.

### Results

Table 2 presents the diametral tensile strength values (kg/cm<sup>2</sup>) of all investigated photo-cured glass ionomer restoratives after gamma irradiation. The data indicated that diametral tensile strengths of all tested materials, after gamma irradiation in three therapeutic dosage levels, exhibited an increase as compared to those tested before gamma irradiation. This increase was significant (P<0.05) for all the materials, except for Photac-Fil at dosage levels of 2000 and 4000 rads. For all investigated materials, DTS values also showed a significant increase (P<0.05) with the increase in irradiation dosage from 2000 to 6000 rads, except for Photac-Fil. The Fuji II LC and Photac-Fil

\*Buehler Ltd., Lake Bluff, Illinois, USA.  
Shimazu Infrared Spectrophotometer IR-400, Japan

Table 2. Diametral tensile strength (kg/cm<sup>2</sup>)<sup>a</sup> of photo-cured glass ionomer restoratives after gamma irradiation.

Brand	Not Irradiated	Irradiation Dosage (rads)		
		2000	4000	6000
Fuji II LC (capsules)	357 ±15.9 <sup>a</sup>	397.8±23.9	367± 12.1	411± 26.1
Photac-Fil (Aplicap)	336.4±14.3 <sup>b,c</sup>	341.7±16.7 <sup>cd</sup>	358.2±21.8 <sup>cd</sup>	369.8118.9 <sup>a</sup>
Dyract-PSA	382.4±16.7	388 ±11.3	408.6± 18.7	428.6± 22.7

a: Mean ± S.D.  
b: No significant difference within columns at P>0.05  
c: No significant difference within rows at P>0.05  
d: No significant difference at P>0.05 within the three irradiation dosage levels.

showed no significant difference (P>0.05) from each other before gamma irradiation.

Microhardness values (KHN) of all photo-cured glass ionomer restoratives after gamma irradiation are listed in Table 3. KHN values of all tested materials, after gamma irradiation in three therapeutic dosage levels, showed an increase as compared to those tested before irradiation. This increase was significant (P<0.05) for all materials, except for Fuji II LC at a dosage level of 2000 rads. For all materials, KHN values also showed a significant increase (P<0.05) with increased irradiation dosage from 2000 to 6000 rads, with the exception of Photac-Fil. KHN value of Photac-Fil was not significantly higher (P>0.05) than those of Fuji II LC before gamma irradiation.

The infrared spectra of the investigated materials before gamma radiation appeared to be identical. Similar spectra of the tested materials following gamma radiation were also obtained at three

Table 3. Microhardness (KHN)<sup>a</sup> of photo-cured glass ionomer restoratives after gamma irradiation.

Brand	Not Irradiated	Irradiation Dosage (rads)		
		2000	4000	6000
Fuji II LC (capsules)	29.8 ±6.2 <sup>a</sup>	31.6±3.4 <sup>c</sup>	33.8 ±2.1	36.1 ±3.9
Photac-Fil (Aplicap)	32.8 ±3.5 <sup>a</sup>	33.7 ±8.5 <sup>a</sup>	35.2 ± 5.9 <sup>a</sup>	35.8 ±9.8 <sup>a</sup>
Dyract-PSA	34.2 ±4.5	38.2 ± 6.3	36.2 ±8.1	41.4 ±8.2

a: Mean ±S.D.  
b: No significant difference within columns at P>0.05  
c: No significant difference within rows at P>0.05  
d: No significant difference at P>0.05 within the three irradiation dosage levels.

therapeutic dosage levels. Representative spectra obtained for Photac-Fil before and after gamma irradiation are shown in Figure 3. The before-irradiation spectrum exhibited peaks at the positions of A = 3600 Wn, B = 2100 Wn, C = 1850 Wn, and D = 1050 Wn. The before- and after-gamma radiation spectra were compared for detection of any alteration in the chemical structure of the representative photo-cured glass ionomer restorative material as indicated by changes in peak position, magnitude or width. Variations in the absolute peak position by up to 5 cm<sup>-1</sup> are within the accuracy of the experimental setup. The spectral comparison of pre- and post-gamma radiation of Photac-Fil [Fig. 1] illustrated no shift in the position of the peaks (A to D). Furthermore, no detectable changes in the width of the peaks or their magnitude, i.e. peak height, were noted. All gamma-radiated specimens at three therapeutic dosage levels appeared similar to those which received no gamma radiation as to their color, with no visible (10 x) signs of size or surface changes.

**Discussion**

The results of this study showed, in general, a significant increase in the DTS values for the investigated photo-cured (resin-modified) glass ionomer restorative materials after gamma radiation at three dosage levels as shown in Table 2 and Figure 3. This increase in DTS could be attributed to the possible effect of the incident therapeutic radiation beam on the carbon-to-carbon bond in the organic monomeric additives, incorporated to modify the conventional glass ionomer restorative materials. The carbon-to-carbon bond, an essential chemical structure component in these organic resin additives which connects the polymeric molecules in a chain reaction, would bear a post-radiation high energy that would result in an increased DTS.

The results of this study illustrated, in general, a significant increase in KHN following gamma

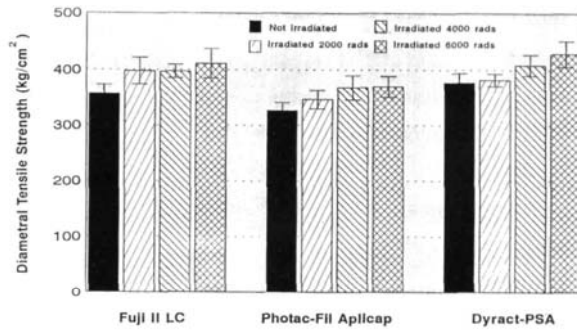


Figure 1. Diametral tensile strength (kg/cm<sup>2</sup>) of photo-cured glass ionomer restoratives after gamma irradiation.

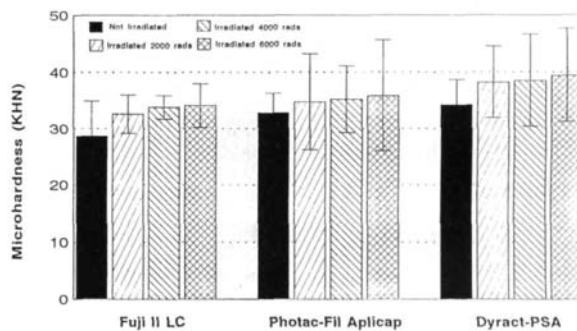


Figure 2. Microhardness (KHN) of photo-cured glass ionomer restoratives after gamma irradiation.

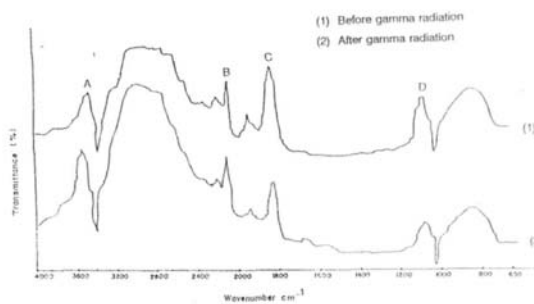


Figure 3. Representative infrared spectra of Photac-Fil before and after gamma irradiation.

radiation in three dosage levels (Table 3 and Fig. 2). This increase in post-radiation microhardness may be attributed to the continued polymerization arising from the incident therapeutic radiation beam which, in turn, may lead to increase in the degree of polymerization. The increased polymer-

ization degree of the investigated photo-cured glass ionomer materials<sup>8</sup> may be explained by the fact that the gamma radiation possesses short wavelength. The short wave length of gamma radiation (0.001 - 0.15nm)<sup>9</sup> exhibits a greater intensity and higher penetration power than that of the visible light (470nm)<sup>10</sup> used to achieve polymerization of these photo-cured glass ionomers.

The slightly higher DTS and KHN values (Tables 2 and 3) obtained in this study for Dyract-PSA were less than expected and were surprising since the composition of Dyract-PSA (Table 1) is more of a composite resin-like material rather than of a glass ionomer cement.

The post-irradiation effects on DTS and KHN observed in this study are consistent with those of a previous study<sup>4</sup> reporting on composite resins.

The infrared spectra [Fig. 3] of pre- and post-gamma radiated materials investigated in this study revealed no changes in the peak position, magnitude or width. The unaffected peaks of the irradiated materials indicate no alteration in their chemical structure following gamma radiation. The unaltered chemical structure of the investigated materials after gamma radiation could be due to the high energy, borne by the carbon-to-carbon bond in the organic monomeric additives, which may overcome any molecular disruption caused by the incident therapeutic radiation beam resulting in no degradation of the polymer molecules.

#### Conclusion

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

- Gamma radiation, as a primary or supplementary treatment regimen for oral cancer patients, at the therapeutic dosage levels of 2000, 4000 and 6000 rads had no adverse effects on the color, size and surface of the investigated photo-cured glass ionomer materials.
- Gamma radiation at three therapeutic levels had an effect on the tested properties of the photo-cured glass ionomers investigated, as it increased their diametral tensile strength and microhardness.
- Gamma radiation at three therapeutic dosage levels did not alter the chemical structure of the investigated materials as reflected by the infrared spectroscopy.

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