Influence of gamma radiation on microshear bond strength and nanoleakage of nanofilled restoratives in Er, Cr:YSGG laser-prepared cavities

Engy Fahmy Abaza[1], Ahmed Abbas Zaki[2], Haytham Samir Moharram[2],
Amal Alaa El Din El Batouti[1], Asmaa Aly Yassen[3]

[1]Department of Health Radiation Research, National Centre for Radiation Research and Technology, Cairo, Egypt,
[2]Department of Medical Laser Applications, National Institution of Laser Enhanced Sciences, Cairo University, Cairo, Egypt,
[3]Conservative Dentistry Department, Faculty of Dentistry, Cairo University, British University in Egypt, Cairo, Egypt

Correspondence: Dr. Engy Fahmy Abaza
Email: engy.abaza@live.com

ABSTRACT

Objective: To evaluate the effect of gamma radiation on microshear bond strength and nanoleakage of nanofilled restoratives in laser-prepared cavities. **Materials and Methods:** Twenty-eight flat buccal dentin surfaces were prepared for microshear bond strength test. Er, Cr:YSGG laser was used to prepare another 28 Class V cavities on the buccal surfaces of the molars. All teeth were divided into four groups; 1st group: Application of Filtek Z350 nanocomposite material, 2nd group: As the 1st group and then exposure to gamma radiation, 3rd group: Application of Ketac N100 nanoglass ionomer, and the 4th group: As the 3rd group and then gamma irradiated. The bond strength test was performed after storage in artificial saliva for 24 h. For the nanoleakage test, teeth were submerged in a solution of ammoniacal silver nitrate, sectioned, and then examined under a scanning electron microscope. The collected data were statistically analyzed. **Results:** Nanocomposite showed higher bond strength values than nanoglass ionomer. Despite the fact that gamma radiation did not decrease nanocomposite bond strength, it decreased nanoglass ionomer bond strength. Nanoglass ionomer-restored cavities showed higher silver ion penetration than nanocomposite in both control and gamma-irradiated groups. **Conclusion:** Gamma radiation has no effect on bond strength and nanoleakage of nanocomposite so that it can be placed before radiotherapy. On the other hand, the bond strength of nanoglass ionomer was adversely affected by gamma radiation.

Key words: Bond strength, Er, Cr:YSGG laser, gamma radiation, nanoglass ionomer, nanocomposite, nanoleakage

INTRODUCTION

The vital line of treatment for oral cancer patients is the radiotherapy with a dose ranging between 40 and 70 Gy causing side effects to the adjacent healthy tissues.[1] This irradiation may affect their restored teeth. Even with the great advancements in the field of dental restorations, no enough data are available on the effect of radiotherapy on them.

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The high filler content and reduced particle size of nanofilled restorative materials improve their mechanical and esthetic behavior.[2] Simultaneously, as an efficient alternative for conservative cavity preparation, Er, Cr:YSGG laser has been introduced. Its high water and hydroxyapatite absorption lead to selective removal of carious tissue.[3]

The degree of success of the dental restoration is mainly determined by the bond strength and the marginal adaptation.[4] The primacy of microshear bond strength test is obtaining more than one specimen from a single tooth.[5]

Nanoleakage occurs at the bottom of the hybrid layer where dentinal and oral fluid can slowly invade the interface causing degradation of the bonding system.[6] Numerous researchers have been performed to determine the marginal quality of resin composite fillings in cavities prepared by erbium laser.[7,8] However, evaluating gamma radiation effect on laser-prepared cavities restored with nanorestorative materials is deficient.

Thus, this study is aimed at determining gamma radiation effect on bond strength and nanoleakage of esthetic restorations in laser-prepared cavities. The null hypothesis established for this research is that there is no variation between the control and gamma-irradiated groups in terms of microshear bond strength and nanoleakage.

MATERIALS AND METHODS

The materials' name, composition, and manufacturer used in this study are presented in Table 1.

Teeth selection and preparation of specimens

Fifty-six freshly extracted human third molars, free of caries and cracks, were collected from 20 to 36 years old patients. They were randomly distributed among eight groups using an excel sheet. Teeth were cleaned with ultrasonic cleaner, stored in weekly changed distilled water, and used in 3 months.

Microshear bond strength specimen's preparation

Twenty-eight molars ($n = 7$), except the buccal surface, were mounted in self-curing acrylic resin (Acrostone, Egypt). A high-speed superfine diamond bur was used to remove enamel from the buccal surfaces and to reveal flat dentin surfaces.[10] The surfaces were checked by a magnifying lens to confirm complete removal of enamel and then polished according to Adebayo *et al*. in 2012.[11] Er, Cr:YSGG laser was used in a focused mode to irradiate the dentin surfaces for 10 s (Biolase),[12] with parameters of 4 W power, 20 Hz repetition rate, and 50/30% air/water coolant.[13]

The prepared teeth were classified into four groups. In the first and second groups, application of Single Bond Universal Adhesive was performed according to the manufacturer's instructions and then light cured using Dr's Light LED light-curing unit RF America IDS (1600 mW/cm^2). A radiometer was used after curing every 10 specimens to ensure adequate curing intensity for all specimens. Before the bond light-curing, two vinyl Tygon tubes with diameter ±0.8 mm and height 2 mm were sited on each dentin surface. The resin composite (Filtek Z350) was packed into the tubes using dental pluggers. Over it, a transparent matrix strip was positioned and light-cured for 20 s at zero distance. The mean microshear bond strength of each tooth was calculated from these two readings to get a total number of 28 mean values in MPa.

In the third and fourth groups, Ketac Nano Primer was applied according to the manufacturer's instruction and then light cured. The nanoglass ionomer

Table 1: Materials and methods

Material and trade name	Composition	Manufacturer
Nanocomposite (Filtek™ Z350) Shade A2	Bis-GMA, UDMA, TEGDMA, and Bis-EMA resins, nonagglomerated fillers 4-11 nm zirconia, 20 nm silica, and an aggregated zirconia/silica cluster fillers (0.6-10 µ). The filler loading is 78.5% by weight	3M ESPE, Dental Products, St. Paul, MN, USA
Self-etch adhesive (Single Bond Universal)	HEMA, monomer MDP, Dimethacrylate resins, VBCP, filler, ethanol, water, initiators, and silane	
Nanoglass ionomer (Ketac™ N100) Shade A3	Polyalkenoic acid VBCP, HEMA, Deionized water, fluroaluminosilicate glass (1 µ), surface-treated silica/zirconia nanofillers (5-25 nm), and nanoclusters (1-1.6 µ). The filler loading is 69% by weight	
Self-etch primer (Ketac Nano Primer)	VitreBond™ copolymer, HEMA, water, and photoinitiator	
Artificial saliva	Na_3PO_4 - 3.90 mM, $NaCl_2$ - 4.29 mM, KCl - 17.98 mM, $CaCl_2$ - 1.10 mM, $MgCl_2$ - 0.08 mM, H_2SO_4 - 0.50 mM, $NaHCO_3$ - 3.27 mM, and distilled water. The pH was set at a level of 7. 2.[9]	

VBCP: VitreBond™ copolymer, MDP: Methacryloxydecyl dihydrogen phosphate

(Ketac N100) was packed into the Tygon tubes and light cured for 20 s.

Application of gamma radiation

The second and fourth groups were irradiated by fractionated gamma radiation at a dose of 60 Gy, three times a week (day after day) for 1 week (20 Gy/3 fractions/week).[14] The radiation was carried out using 137 Cesium Gamma Cell 40 at the Atomic Energy Authority, with a dose rate 0.708 rad/sec at the time of experiment. A solution of artificial saliva was used to store all groups for 24 h.

Microshear bond strength test assessment

The specimens were fixed in an Instron Machine (Model 3345; Instron Universal Testing Machine, England Instruments, with a load cell of 5 KN, and data record was done using computer software BlueHill 3 Instron). An orthodontic wire loop (diameter = 0.14 mm) was wrapped around the base of the bonded microcylinder assembly and aligned with the loading axis of the movable upper compartment of the machine. The force was loaded to failure, at a crosshead speed of 0.5 mm/min. Calculations of the microshear bond strength values were performed and expressed in MPa. The obtained results did not include resin cylinders with premature failure.

Nanoleakage specimen's preparation

Class V cavities, with the dimensions according to Marotti *et al*. in 2010, were prepared in the buccal surfaces of the other 28 selected teeth.[15] To standardize the cavity outline, a window with the selected width and length was cut on a stainless steel matrix band and the depth was measured by a periodontal probe. Hence, three readings were obtained from each cavity to get a total number of 84 readings from all the teeth, and the mean nanoleakage value was obtained for each tooth. At the cervical third of the teeth, all cavities were prepared, 2 mm occlusal to the cementoenamel junction using Er, Cr:YSGG laser with parameters 6 W in enamel and 4 W in dentin.[16] The nanocomposite was packed in a bulk using a plastic instrument. Ketac Nano Primer was applied and the nanoglass ionomer was packed and light cured as in the case of microshear bond strength specimens. Half of the specimens were exposed to gamma radiation and stored as previously mentioned.

Sticky wax was used to seal the root apices and two layers of nail varnish were used to coat the entire tooth, except for 1 mm apart from the margins of the restoration.[17] Then, the specimens were submerged in a solution of 50% ammoniacal silver nitrate (pH 9.5) for 24 h in a dark chamber.[18] Teeth were then thoroughly rinsed in distilled water and immersed in a photodeveloping solution for 8 h under a fluorescent light.[19]

Nanoleakage test assessment

The selected specimens were divided buccolingually across the restoration center with a diamond saw in a cutting machine (IsoMet 4000; Buehler, Lake Bluff, IL, USA), under a water coolant. They were polished using a graded series of Soflex discs (3M Co.) in the descending order from the course to fine one and then ultrasonically cleaned to remove the smear layer. Finally, one section of each preparation was examined by a X-ray microanalyzer (Module Oxford 6587 INCA X-sight) attached to JEOL JM-5500 LV scanning electron microscopy using high vacuum mode at 20 KV. Electron dispersive analytical X-ray (EDAX) analysis was also performed to identify the presence of metallic silver particles. Three points at the interfaces between the teeth and the restorations (occlusal and gingival) were selected for scanning and EDAX quantification. The mean percentage of the silver ion deposition was calculated.[20]

Statistical analysis

Data were collected and analyzed using IBM SPSS Statistics for Windows, Version 23.0 (Armonk, NY: IBM Corp., USA). All normally distributed continuous data are presented. Two-way ANOVA was done to examine the main effects and interactions relating to types of filling and tested groups on microshear bond strength (MPa) or nanoleakage (Ag %), respectively. Independent sample *t*-test was used to examine if there were any differences found between groups.

RESULTS

Microshear bond strength values are presented in Table 2 and Figure 1.

Table 2: The mean and descriptive statistics for microshear bond strength results of all tested groups

	Nanocomposite		Nanoglass ionomer		*P*
	Mean	SD	Mean	SD	
Control group	11.7	1.8	0.86	0.074	0.0001***
Gamma-radiated group	12.5	1.04	0.37	0.059	0.0001***
P	0.197 (NS)		0.0001***		

*** Significant at $P \leq 0.05$. NS: Not significant, SD: Standard deviation

Nanoleakage values are shown in Table 3 and Figure 2.

Representative photomicrographs were taken at magnification ranges from ×200 to ×300, as presented in Figures 3-6. For the nanocomposite groups, either control or gamma irradiated, the gap size corresponds to the low Ag% as shown in Figures 3 and 4. However, both the nanoglass ionomer groups revealed wider gap size that corresponds to the higher Ag% in relation to the nanocomposite groups as shown in Figures 5 and 6.

DISCUSSION

In the minimally invasive dentistry field, Er, Cr:YSGG laser was approved to be an effective and conservative tool. Among its numerous advantages, it induces less vibration and noise, preserves more tooth structure, eliminates the need for anesthesia, and has an antibacterial effect.[3] As the restorative procedures are extremely stressful for patients receiving head and neck radiotherapy, laser became the most beneficial tool for the treatment of such patients who seek for a comfortable and painless procedure while restoring their teeth.[21] Bonded restorations tend to be the most efficient methods to restore irradiated teeth. However, by literature reviewing, many controversies were revealed regarding the success of such restorations.

In the current study, microshear bond strength showed significant higher bond strength values of

Table 3: The mean and descriptive statistics for nanoleakage values in Ag% of all tested groups

	Nanocomposite		Nanoglass ionomer		*P*
	Mean	SD	Mean	SD	
Control group	1.18	0.63	2.32	0.35	0.001**
Gamma-radiated group	0.9	0.43	2.07	0.28	0.0001***
P	0.355 (NS)		0.168 (NS)		

, * Significant at $P \leq 0.05$. NS: Not significant, SD: Standard deviation

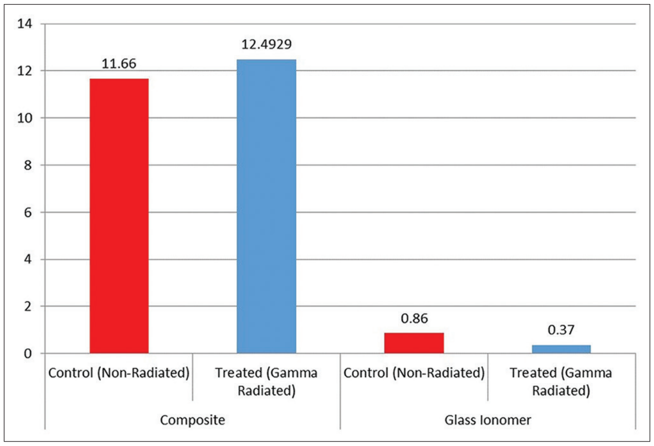

Figure 1: Column chart of microshear bond strength mean values for the tested groups

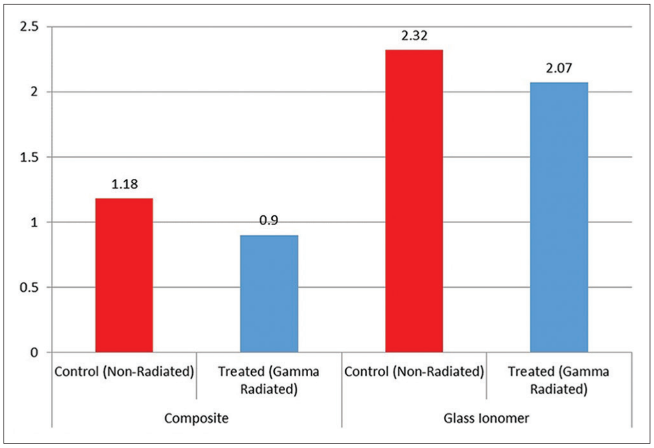

Figure 2: A column chart of nanoleakage mean values for the tested groups

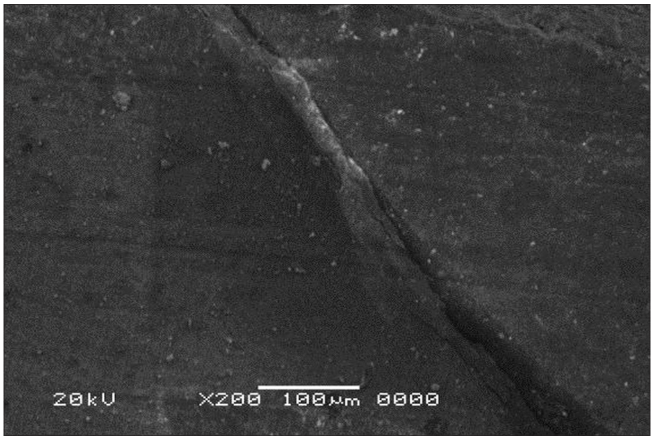

Figure 3: Images of tooth–restoration interface for the nanocomposite control group

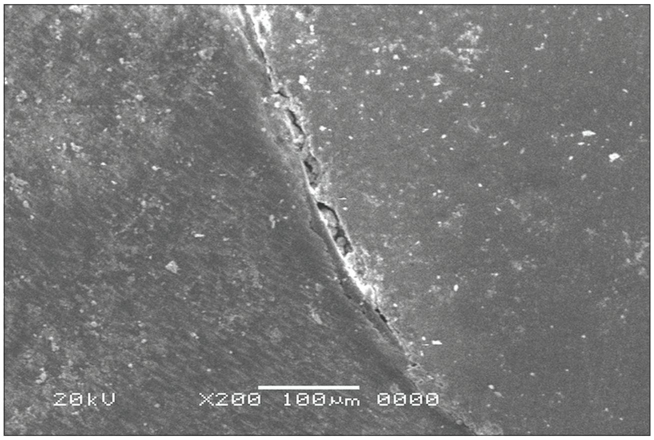

Figure 4: Images of tooth–restoration interface for the nanocomposite gamma-radiated group

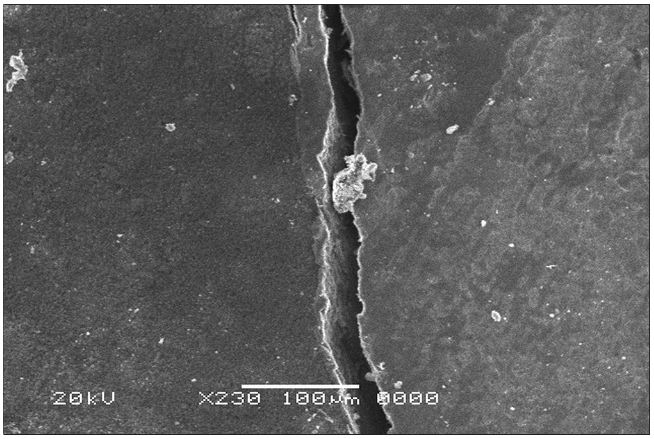

Figure 5: Images of tooth–restoration interface for the nanoglass ionomer control group

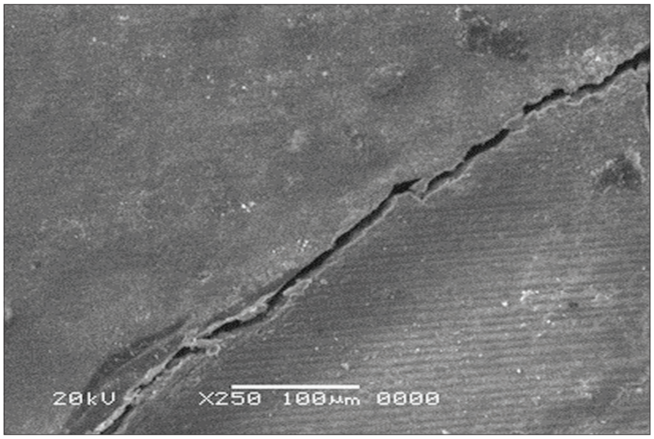

Figure 6: Images of tooth–restoration interface for the nanoglass ionomer gamma-radiated group

the nanocomposite than those of nanoglass ionomer [Table 2 and Figure 1]. This could be referred to the self-etching adhesives used with nanocomposite that allows resin penetration into the dentinal tubules and infiltration to the underlying demineralized dentin forming a hybrid layer. Another factor that enhances wetting of dentin is the hydrophilicity of HEMA adhesive group.[22] Application of nanoglass ionomer following the primer, without any intermediary bonding material, lowers the values of microshear bond strength.[23] Moreover, the increased viscosity of glass ionomer restorations decreases the penetration of the material through the full depth of the available irregularities of the prepared surfaces.[24]

In this study, the results revealed insignificant increase in the values of the bond strength for the investigated nanocomposite after gamma radiation. This was in relative agreement with Seif *et al*. in 2013,[14] who reported an increase in the bond strength of nanocomposite significantly after gamma radiation due to the continued polymerization arising from the incident gamma radiation beam increasing the degree of polymerization. The nanoglass ionomer-restored specimens showed extremely statistical significant decrease in the microshear bond strength values after gamma radiation. That was in accordance with Yesilyurt *et al*. in 2008, who stated that the setting reaction of glass ionomer and its bonding to dentin was directly affected by irradiation.[25]

Table 3 and Figures 2-6 show that none of the tested restorative materials completely eliminated nanoleakage due to the high C-factor of Class V cavities, which accentuate the effect of the polymerization shrinkage stresses. This was supported by Price *et al*. in 2003, who found that pathways become available for dye penetration in cavities with high C-factor which decreased the bond strength.[26]

Our study showed high significant increase in nanoleakage of nanoglass ionomer restorations than nanocomposite restorations in both groups due to the micromechanical bonding in the nanocomposite-restored cavities. Furthermore, mild self-etch adhesives, which are less sensitive to moisture, have characteristic property that lies in incomplete elimination of hydroxyapatite from the interaction zone which protects the collagen against hydrolysis, as well the available calcium has a chemical interaction with specific adhesive monomers which provide stronger adhesion.[27]

Toledano *et al*. in 2003 reported that nanoglass ionomer had higher penetration due to its great susceptibility to water sorption and solubility than resin composite.[28] The bonding mechanism of nanoglass ionomer depends mainly on chemical bonding rather than micromechanical bonding, which is an important factor in resisting polymerization shrinkage stresses in high C-factor cavities Class V cavities.[29]

Our results showed nonsignificant decrease of the nanoleakage values in the gamma-irradiated groups in both nanocomposite and nanoglass ionomer restorations than the control group. This was in harmony with Bulucu *et al*. in 2009[30] and Seif *et al*. in 2013,[14] who stated that irradiation did not influence the microleakage in Class V cavities.

In this study, there is no relationship between the bond strength results and the nanoleakage values because the cavity margins were totally located in dentin in the bond strength test. However, in nanoleakage test, the margins were located in enamel leading to difference in the polymerization shrinkage stresses.[31] The null hypothesis for this study was partially accepted.

CONCLUSION

1. Therapeutic dose of gamma radiation has minimal effect on the microshear bond strength and nanoleakage of nanocomposite
2. The microshear bond strength of nanoglass ionomer is adversely affected by gamma radiation while nanoleakage is not affected
3. Nanocomposite is more suitable as a restorative material for cancer patients than nanoglass ionomer.

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Conflicts of interest

There are no conflicts of interest.

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