Effect of radiotherapy on resin composite bond strength and adaptation to dentin

Takako Yoshikawa, DDS, PhD (1), Alireza Sadr, DDS, PhD (1,2), and Junji Tagami, DDS, PhD (1)

(1) Department of Cariology and Operative Dentistry, Division of Oral Health Sciences, Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University (TMDU), Tokyo, Japan
(2) IB3T Laboratory, Department of Restorative Dentistry, School of Dentistry, University of Washington, Seattle, WA, USA

Purpose: To evaluate the effect of γ-ray irradiation on resin composite/dentin bond strength and the composite adaptation to the dentin cavity wall.
Materials and Methods: Half of bovine incisors were irradiated with 60 Gy γ-rays. Flat dentin surfaces were prepared on the labial side. Half of flat dentin surfaces were treated with Clearfil SE Bond. Clearfil AP-X composite was built up. After light curing and 24 h storage, the teeth were sectioned and trimmed (ca. 1 mm^2) at the adhesive-dentin interface for microtensile bond strength test. The trimmed specimens were stressed to failure. Other flat dentin surfaces were prepared cylindrical cavities. The cavities were restored with Clearfil SE Bond adhesive followed by Clearfil AP-X composite. After light curing and 24 h storage, dye penetration tests around the cavities were performed. 60 Gy γ-ray irradiation significantly decreased resin composite adaptation to the cavity wall. Bond strength data were compared using the Bonferroni test. Dye penetration test scores were analyzed using the Kruskal-Wallis and Mann-Whitney *U*-tests.
Results: There was no significant difference between irradiated dentin and non-irradiated dentin of resin composite bond strength ($p > 0.05$). However, 60 Gy γ-ray irradiation significantly decreased resin composite adaptation to the cavity wall ($p < 0.05$).
Conclusion: Irradiation with 60 Gy γ-ray had no effect on resin-dentin bond strength. However, 60 Gy γ-ray irradiation significantly decreased resin composite adaptation to the cavity wall.
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Key Words: adaptation, bond strength, dye penetration, γ-ray irradiation, resin composite

Introduction

Adhesive dentistry is an important field of dental practice. Due to eating disorders, reflux esophagitis and the aging society, incidences of tooth wear, erosion and cancer have increased; and patients with head and neck cancer will require radiotherapy. The orofacial tissues affected by radiation include the salivary glands, mucous membranes, taste buds, bone, and teeth [1]. Radiation caries is attributed to head or neck radiotherapy in the cervical area of the tooth [2]. Tooth wear and radiation caries cannot be treated using metal inlays placed for conventional Black's cavities; such teeth can be restored only using resin composites with a direct bonding technique.

Radiation induces reduction of saliva due to salivary gland lesion [3] and changes in microbial flora [4]. Most orofacial complications are dependent on radiation dose, and severe side effects occur when doses are greater than 45 Gy [5]. Radiation of 60 Gy γ-ray significantly decreased the ultimate tensile strength [6] and microhardness of dentin [7], whereas 60 Gy γ-ray significantly increased microhardness of superficial enamel [7]. Irradiation with 70 Gy γ-ray significantly decrease shear bond strength of the bovine dentinoenamel junction and may cause some damage to the biophysical properties [8].

Resin composite restorations with a direct bonding technique are indicated in cancer patients before or after irradiation. However, the effect of γ-ray irradiation on dentin is still unclear. The purpose of this study was to evaluate the effect of γ-ray irradiation on resin/dentin bond strength and resin composite adaptation to the dentin cavity wall.

Materials and Methods

Specimen preparation

The materials, components, manufacturers, batch numbers, and bonding procedures used in this study are listed in Table 1. An experimental quartz-tungsten-halogen light-curing unit (GC Corp., Tokyo, Japan), which was connected to a slide regulator, was used. This light-curing unit had a control system for lamp voltage and adjustable light intensity, which was measured using a curing radiometer (model 100, Demetron Research Corp., Danbury, CT, USA). Overall, 16 erupted intact bovine lower incisors, stored and frozen immediately after extraction, were used in this study. Half of the incisors were irradiated with 60 Gy γ-ray using a cobalt-60 therapeutic machine (RCR-120, Toshiba Co., Tokyo, Japan); this is the total absorbed dose in one course of radiotherapy in head or neck cancer patients. The labial enamel was ground using a model trimmer under running water to expose a superficial flat dentin surface and then finished with a wet 600-grit SiC paper.

Table 1 Study materials

Materials and Manufacturer	Components	Batch No.
Clearfil SE Bond Kuraray Noritake Dental	Primer: MDP, HEMA, hydrophillic aliphatic, dimethacrylates, colloidal silica, photoinitiator, accelerators, water	00577A
	Bond: MDP, HEMA, Bis-GMA, hydrophobic aliphatic methacrylate, microfiller (colloidal silica), photoinitiator, initiator, accelerators	00817A
Clearfil AP-X Kuraray Noritake Dental	silanated barium glass filler, silanated silica filler, silanated colloidal silica, Bis-GMA, TEGDMA, photoinitiator, catalyst, accelerators, pigments, others	01118A

MDP, 10-methacryloyloxydecyl dihydrogen phosphate; HEMA, 2-hydroxyethyl methacrylate; Bis-GMA, bisphenol A-glycidyl methacrylate; TEGDMA, triethyleneglycol dimethacrylate
Procedures: (a) apply primer for 20 s; (b) dry with gently air-blowing; (c) apply adhesive; (d) gently air-blow; (e) light-cure for 10 s

Tensile bond strength measurement

Other exposed superficial flat dentin surfaces were painted with a varnish (Protect Varnish, Kuraray Noritake Dental Co., Tokyo, Japan), leaving a flat bonding area of length 3 mm × width 4 mm. The teeth were treated with a Clearfil SE Bond (Kuraray Noritake Dental Co.) adhesive. After curing of the adhesive, a resin composite (Clearfil AP-X, Kuraray Noritake Dental Co.) of length 3 mm × width 4 mm × height 2 mm was built up for the micro-tensile bond strength (μTBS) test. The composites were light cured for 40 s using a light intensity of 600 mW/cm^2. After completion of light curing, the specimens were stored in water maintained at 37°C in the dark for 24 h. After the storage, the restored non-irradiated/irradiated specimens were serially sectioned perpendicular to the bonded surfaces creating 1-2, about 1-mm thick slabs using a diamond saw (ISOMET, Buehler, Lake Bluff, IL, USA) under copious water lubrication. The remaining dentin thickness (RDT) from the resin-dentin bond to the nearest portion of the pulp chamber was measured in each slab, and the specimens were trimmed into an hour-glass shape with the narrowest portion (ca. 1 mm^2) located at the adhesive-dentin interface using a diamond point (#211, Shofu Co., Kyoto, Japan) with copious air-water spray. Finishing was performed with a superfine diamond point (#SF114S, Shofu Co.) in a high-speed handpiece.

The trimmed specimens were mounted on a μTBS jig (KDA, Tokyo, Japan) [9] with cyanoacrylate adhesive (Model repair II blue, Dentsply-Sankin, Otawara, Japan) and stressed to failure in tension at 1 mm/min in a universal testing machine (EZ test, Shimazu, Kyoto, Japan). Each of seven tensile bond strength results was compared and analyzed using the Bonferroni test at a significance level of 5%.

Scanning electron microscopy observation of fractured surfaces

After the tensile bond strength test, each fractured dentin specimen was fixed in 10% neutral buffered formalin

[9]. The dentin and composite paired specimens were then trimmed and viewed using scanning electron microscope (SEM; JSM-5310LV; JEOL, Tokyo, Japan). The specimens were placed on SEM stubs and coated with gold sputter to microscopically assess the failure patterns. The fractured surfaces were classified into four groups: interfacial failure, mixed failure, cohesive failure within the resin (adhesive layer or composite), or cohesive failure within the dentin.

Evaluation of marginal sealing and cavity wall adaptation

Cylindrical cavities 1.5 mm in depth, 3 mm in diameter, and a C-factor of 3 were prepared on the flat dentin surfaces of each tooth using a diamond point (#CR30, ISO No. 068 030, GC Corp.) under copious air-water spray. Each of the seven cavities was treated with Clearfil SE Bond adhesive (Kuraray Noritake Dental Co.). After the adhesive was cured, the cavities were bulk-filled with Clearfil AP-X resin composite (shade A3, Kuraray Noritake Dental Co.). The composites were light cured with an intensity of 600 mW/cm^2 for 40 s. After completion of light curing, the specimens were stored in water maintained at 37˚C in the dark for 24 h. The dye penetration test was used to determine the degree of adaptation to the cavity margins and walls. This test was performed by placing a 1.0% acid red propylene glycol solution (Caries Detector, Kuraray Noritake Dental Inc.) at the margin of the restoration for 5 s, followed by rinsing with water and gentle blow-drying. The extent of dye penetration was observed with a stereo-microscope (20× magnification). A photographic record of each specimen was acquired at this stage.

The specimens were then longitudinally cut in half using a diamond saw microtome (77 model, Bronwill Scientific Inc., NY, USA) under running water, the dye was reapplied to the sections, and images were acquired to observe the gaps. In these images, the length of dye penetration along the cavity margins and walls was measured using a digitizer (KD 4300 model, Graphtec Co., Tokyo, Japan). The degree of marginal leakage was determined by the length of dye penetration, measured as a percentage of the total length of the cavity margin. Dye penetration along the cavity walls was calculated as a percentage of the total cavity wall length. This area was referred to as the cavity wall-resin gap. The dye penetration test scores were compared using the Kruskal-Wallis and Mann-Whitney *U*-tests.

Results

The tensile bond strength results and RDT of the non-irradiated and irradiated groups are shown in Table 2. There was no significantly different RDT or μTBS between the non-irradiated and irradiated groups ($p > 0.05$).

The results of the failure modes determined by SEM observation are shown in Table 3. Most of the fracture surfaces of the non-irradiated group show cohesive failure within the dentin. The fractured surface of the irradiated group shows the same number of cohesive failures within the dentin as well as the mixed failure. Figure 1 shows cohesive failure within the dentin for the non-irradiated group. Figure 2 shows cohesive failure within the dentin for the irradiated group.

Table 2 Microtensile bond strength and RDT of γ-ray irradiated and non-irradiated groups [mean (SD)]

	RDT (mm)	μTBS (MPa)
Non-irradiated	2.1 (0.1)	57.8 (5.9)
Irradiated	2.0 (0.2)	53.5 (6.2)

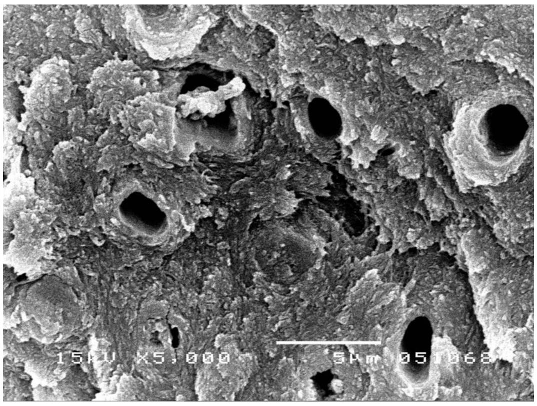

Fig. 1 Fractured surface of non-irradiated dentin side specimen. Failure mode indicated cohesive failure within the dentin (5,000×).

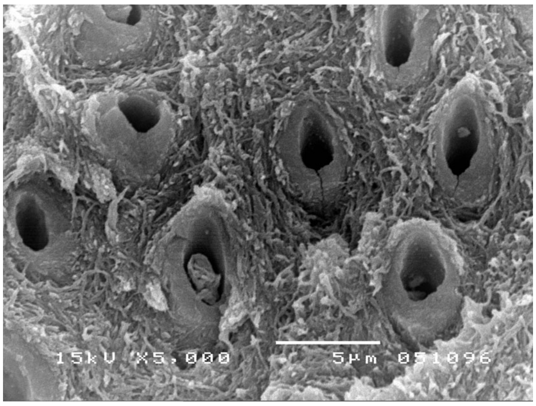

Fig. 2 Fractured surface of irradiated dentin-side specimen. Failure mode indicated cohesive failure within the dentin (5,000×).

Table 3 Failure mode

	Interfacial failure	Mixed failure	Cohesive failure in resin	Cohesive failure in dentin
Non-irradiated	0	3	0	4
Irradiated	1	3	0	3

Table 4 Degree of marginal leakage and cavity-wall gap formation [%: mean (SD)]

Marginal leakage		Cavity-wall gap formation	
Non-irradiated	Irradiated	Non-irradiated	Irradiated
0	0	4.5 (9.0) [a]	24.4 (9.2) [a]

Same superscript lower-case letters indicate significant differences in the strength of bonding substrates ($p < 0.05$).

Degree of marginal leakage and cavity wall gap formation are shown Table 4. Both of non-irradiated and irradiated groups showed complete marginal sealing. However, 60 Gy γ-ray irradiation significantly decreased resin composite adaptation to the cavity wall ($p < 0.05$).

Discussion

There was no significantly different tensile bond strength between the irradiated and non-irradiated groups. Clearfil SE Bond adhesive showed complete marginal sealing, regardless of γ-ray irradiation. It has been reported that 60 Gy γ-ray irradiation showed no effect on resin composite tensile bond strength of human flat dentin with four different dentin bonding agents using divided irradiation for 6 weeks [10], supporting that 60 Gy γ-ray irradiation was ineffective on resin composite bond strength to the flat dentin surfaces. Clearfil SE Bond showed high tensile bond strength to the superficial flat dentin surface and the flat dentin wall [11]. Therefore, Clearfil SE Bond adhesive showed excellent marginal sealing to both non-irradiated and irradiated dentin substrates.

On the other hand, 60 Gy γ-ray irradiation significantly decreased resin composite adaptation to the cavity wall. Non-irradiated dentin surface showed well defined dentinal tubles (Fig. 1). However, irradiated dentin surface showed dentin collagen fibers (Fig. 2). It has been reported 60 Gy γ-ray significantly decreased the ultimate tensile strength [6] and microhardness of dentin [7]. Moreover, 70 Gy γ-ray irradiation significantly decreased shear bond strength of the bovine dentinoenamel junction and may cause some damage to dentin collagen fibers [8].

In this study, resin composite bond strength to flat dentin was not affected by γ-ray irradiation, whereas resin composite adaptation to Class V cavities was affected. γ-ray irradiation significantly decreased resin composite adaptation to the cavity wall. We previously reported that C-factor affects resin composite bond strength [12-15] and adaptation to the cavity wall [16-18]. C-factor of composite restoration on flat dentin is less than 1, whereas that of composite restoration on the cylindrical cavity is 3. When C-factor is less or equal than 1, composite restoration is likely to survive polymerization; and when it is more than 1, composite restoration shows lower bond strength [12,13] and decreased adaptation to the cavity wall [16-18].

Therefore, dentin collagen destruction by γ-ray irradiation and C-factor seemed to decrease resin composite adaptation to the cavity wall of irradiated dentin, suggesting that resin composite with Clearfil SE Bond adhesive was affected by γ-ray irradiation damage of dentin on cavity restoration. Further research is required to confirm the effect of γ-ray on resin composite bond and adaptation to the same cavity shape.

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Correspondence to:
Dr. Takako Yoshikawa
Department of Cariology and Operative Dentistry, Division of Oral Health Sciences,
Graduate School of Medical and Dental Sciences, Tokyo Medical and Dental University (TMDU),
1-5-45, Yushima, Bunkyo-ku, Tokyo 113-8549, Japan
Fax: +81-3-5803-0195 E-mail: yoshikawa.ope@tmd.ac.jp

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