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Effect of Gamma Radiation and Lead Shielding on Microleakage and Restoration Adaptation in Teeth Restored with a Total-Etch System

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Abstract

Aim: To evaluate the effect of gamma radiation, with and without lead shielding, on microleakage and restoration adaptation in teeth subjected to radiation before and after the restoration following a total-etch bonding system. **Materials and Methods:** A total of 125 intact human teeth were selected for this study and divided into five groups. Group I (n=25) received no radiation and served as control. Group II (n=25) was radiated following a standardised protocol of 2 Gy/day, 5 days/week, for 6 weeks, totalling 60 Gy before restoration without shielding and Group III (n=25) radiated before restoration with shielding using a 0.5 mm thick lead mould shaped into a "C" tube. Group IV (n=25) was radiated after restoration without shielding and Group V (25 samples) after restoration with shielding. All teeth had standardised Class V cavities prepared on their buccal surfaces, which were then restored with a total-etch composite resin system. Microleakage was evaluated using a dye penetration method, and restoration adaptation was assessed using Scanning Electron Microscopy (SEM). Data were analysed using the Kruskal–Wallis ANOVA test. **Results:** Significant differences were observed in dye penetration and restoration adaptation among the groups. Teeth exposed to unshielded gamma radiation before cavity preparation (Group II) showed the highest microleakage and widest gaps compared to those exposed after preparation (Group IV) or any other group. **Conclusion:** Unshielded gamma radiation before cavity preparation results in greater microleakage and poorer restoration adaptation compared to post-preparation exposure. Lead shielding significantly mitigates these adverse effects.

Keywords: Gamma Radiation, Lead Shielding, Microleakage, Restoration Adaptation, Total-Etch Bonding System

1. Introduction

Head and Neck Squamous Cell Carcinoma (HNSCC) accounts for about 4.5% of all cancer cases and deaths each year, with an estimated 890,000 new cases and 450,000 deaths annually[1].

Radiation Therapy (RT) is highly effective in controlling local tumours and enhancing patient survival. Radiation-induced caries present significant challenges in dental care due to high recurrence rates and early failure of restorations, posing a lifelong risk even post-treatment[2].

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Dental composites are preferred for direct restorations due to their strong tooth bond, minimal substance loss and advantages over amalgam, including aesthetics, mercury-free composition and reduced risk of radio-mucositis during radiotherapy[3].

Effective dental restoration depends on strong adhesion between restoration and tooth structure, with the "Total-Etch" Bonding System being a key technique that enhances bond strength by etching the tooth surface to improve adhesion[3].

Radiation alters tooth structure, affecting the durability of composite restorations. Gamma radiation therapy induces morphological and compositional changes in enamel and dentin, which can adversely impact bond strength and reduce hardness, wear resistance and tensile strength of teeth[4,5]. The cumulative impact of radiation is dose-dependent, significantly influencing restoration outcomes[4,5].

Personalised shielding devices and intra-oral prostheses are employed to mitigate radiation damage[6]. This in vitro study aims to investigate the effects of gamma radiation on teeth, with and without shielding, using dye penetration and Scanning Electron Microscopy (SEM) techniques to assess microleakage and restoration adaptation.

Null Hypothesis: The null hypothesis tested is that there is no significant difference in the efficacy of dentin bonding agents on teeth exposed to radiation therapy with or without shielding, before and after restoration.

2. Materials and Method

This study aimed to evaluate the effect of gamma radiation, with or without shielding (0.5 mm thickness of lead), on the efficacy of the Total-Etch adhesive system in teeth exposed before and after restoration. A total of 125 intact, recently extracted human posterior teeth from patients aged 18-50 years who had never undergone radiotherapy were selected. After removing soft tissues and hard aggregations with an ultrasonic scaler, teeth were examined under magnification for cracks and fissures. Only teeth extracted due to periodontal or other pathologies and free from restorative treatments, caries, cusp fractures, or developmental anomalies were included.

Radiation therapy was administered using a linear accelerator with a cumulative dose of 60Gy, delivered as 2Gy per day for 5 days a week over 6 weeks. For shielding, a 0.5mm thick lead shield moulded into a "C" shape was used. Samples were arranged in an arch with 5-8 posterior teeth per side, shielded on the side opposite the radiation source, maintaining a distance of approximately 50-55 mm between exposed and shielded samples.

Standardised Class V cavities were prepared on the buccal surfaces of all teeth using a tapered fissure carbide bur under air-water cooling. Cavities measured 2mm in height, 4mm mesiodistally and 2mm deep, with margins in enamel and 1mm above the cementoenamel junction. Preparations were verified with a William's probe, rinsed and dried. Bonding was achieved using the total-etch technique. 35-37% phosphoric acid was applied for 20 seconds and rinsed for 40 seconds, followed by the application of Adper Single Bond 2 and light curing for 20 seconds. Teeth were restored with Valux Plus composite resin and finished with a graded series of flexible discs (Shofu, Super-Snap). Restored teeth were stored in a medium, distilled water and incubated at 37°C for 24 hours.

The 125 teeth were randomly divided into five groups based on the radiation and shielding protocol: Group I (25 samples) was not exposed to radiation; Group II (25 samples) was radiated before cavity preparation and restoration without shielding; Group III (25 samples) was radiated and shielded before cavity preparation and restoration; Group IV (25 samples) was radiated after restoration without shielding; Group V (25 samples) was radiated after restoration with shielding.

Microleakage was assessed in 20 samples from each group using a stereomicroscope. Teeth were coated with nail polish, immersed in dye for 7 days, rinsed and sectioned longitudinally to evaluate dye penetration at occlusal and gingival margins with scoring criteria from 0 (no penetration) to 3 (dye penetration involving the axial wall). Restoration adaptation was evaluated in 5 samples from each group using scanning SEM (using medium magnification, up to 500X). Samples were sectioned longitudinally, gold-sputtered and assessed for restoration adaptation. Data were statistically analysed to determine the significance of differences between groups.

Statistical Analysis: Quantitative data normality was assessed using appropriate statistical tests. For data following a normal distribution, one-way ANOVA was employed, with subsequent post hoc analysis using Tukey's Honestly Significant Difference (HSD) test to compare differences among the five groups. For data not normally distributed, the Kruskal-Wallis test was

used for comparisons. A significance level of $p < 0.05$ was established for all analyses. Statistical analyses were performed using IBM SPSS Statistics (Version 22.0).

3. Results

3.1 Microleakage

There was a significant difference between the five groups in terms of microleakage scores ($\chi^2 = 56.020$, $p < 0.001$). The median microleakage scores were highest in Group II. Detailed results are presented in Table 1.

3.2 Tooth Restoration Adaptation

Tooth restoration adaptation was normally distributed across the five groups. Thus, parametric tests (one-way ANOVA) were used for group comparisons. There was a significant difference between the groups in terms of tooth restoration adaptation ($F = 266.355$, $p < 0.001$), with Group II showing the highest mean adaptation scores. Detailed results are presented in Table 2.

The results indicated that gamma radiation significantly affected both microleakage and tooth restoration adaptation, with the most pronounced adverse effects observed in samples exposed to radiation before cavity preparation and without shielding.

4. Discussion

This study evaluated the impact of gamma radiation, both with and without shielding, on the efficacy of a total-etch bonding system. The investigation focused on microleakage and restoration adaptation, analysing the effects of radiation exposure pre- and post-restoration. Light-cured composites are widely used due to their conservative preparation, aesthetic appeal, fluid resistance, micro-mechanical bonding and reliable bond strength for clinical success. Total etch is considered the gold standard for achieving strong, reliable adhesion in dental restorations.

Group I, which was not exposed to radiotherapy, showed the lowest mean micro gap value (0.95µm ± 0.57µm) and mean microleakage score (0.50 ± 0.51), indicating optimal bonding efficacy. In contrast, radiotherapy, whether administered before or after restoration, significantly compromised bonding effectiveness. Group II, exposed to radiation before restoration without shielding, exhibited the highest mean micro gap value (18.30µm ± 1.01µm) and mean microleakage score (2.60 ± 0.50). This diminished performance is likely due to radiation-induced compositional, morphological, and metabolic changes in the dental substrate, which adversely affect the bonding process.

Radiotherapy is a multifaceted treatment approach, including curative, adjuvant, and palliative options. Radiotherapy, while effective for tumour control, can cause detrimental effects on surrounding healthy tissues. High doses and prolonged low doses of radiation lead to alterations in hard and soft tissues[7].

Ionising radiation causes physical changes, such as the recrystallisation of mineralised tissues and the denaturation of organic structures due to free radical

Table 1. Microleakage scores across groups

Parameter	Group I (n = 20)	Group II (n = 20)	Group III (n = 20)	Group IV (n = 20)	Group V (n = 20)	P-value
Microleakage Scores* **	0.50 ± 0.51	2.60 ± 0.50	1.50 ± 0.83	2.10 ± 0.72	1.00 ± 0.79	<0.001[1]
Tooth Restoration Adaptation* **	0.95 ± 0.57	18.30 ± 1.01	3.70 ± 0.43	7.10 ± 1.71	1.34 ± 0.59	<0.001[2]

***Significant at $p < 0.05$; [1]: Kruskal-Wallis Test, [2]: One-Way ANOVA

Table 2. Tooth restoration adaptation scores across groups

Tooth Restoration Adaptation	Group					One-Way ANOVA	
	I (n = 5)	II (n = 5)	III (n = 5)	IV (n = 5)	V (n = 5)	F	P-value
Mean (SD)	0.95 (0.57)	18.30 (1.01)	3.70 (0.43)	7.10 (1.71)	1.34 (0.59)	266.355	<0.001***
Median (IQR)	1.02 (1-1.22)	18.6 (17.8-19)	3.5 (3.4-4)	7.2 (5.6-8.3)	1.02 (1-1.7)		
Min – Max	0 - 1.5	16.8 - 19.3	3.3 - 4.3	5.2 - 9.2	0.8 - 2.2		

***Significant at $p < 0.05$

formation[8]. Additionally, radiation affects water, leading to the production of free radicals and hydrogen peroxide, which further impacts tissue integrity[9,10].

Groups III (radiated before restoration, shielded) and V (radiated after restoration, shielded) showed improved adaptation (3.70µm ± 0.43µm and 1.34µm ± 0.59µm) respectively and reduced microleakage (1.50 ± 0.83 and 1.00 ± 0.79) respectively compared to their unshielded counterparts (Groups II and IV). The use of a 0.5mm thick lead shield effectively mitigated the adverse effects of radiotherapy. The high density and atomic number of lead make it an effective barrier against radiation, significantly reducing secondary gamma rays and preserving the integrity of the adhesive system[11,12].

Suarez JCM *et al*., highlighted that the degradation of resin-bonded composites may result from factors such as debonding, chain scission, brittle fracture and colour changes within the polymer matrix[13,14].

This *in vitro* study does not fully replicate *in vivo* conditions, and its focus on the short-term effects of irradiation may not encompass long-term functional changes. High doses of gamma radiation can lead to residual radicals, potentially causing adverse reactions in hard tissues even after irradiation has ceased. Additionally, the study's clinical relevance is constrained by the lack of factors such as saliva, which influences ion exchange and remineralisation[15,16]. Variations in storage conditions, incubation time and dye immersion time of the samples could also affect the results. Future research should address these limitations and explore the long-term impacts of radiation on dental restorations.

Although radiotherapy is an effective treatment for malignant tumours, it can have detrimental effects on dental restorations, thereby impacting patient quality of life. Gamma radiation significantly compromises the sealing ability of Total-etch adhesive systems, especially with the timing of exposure. The durability of adhesive techniques on irradiated dental substrates remains a crucial issue, particularly for resins used in radiotherapy patients.

5. Conclusion

This *in vitro* study revealed that gamma radiation significantly impairs the sealing ability and adaptation of dentin adhesive systems, with a therapeutic dose of 60Gy notably reducing the effectiveness of the Total-etch adhesive system. Key findings include a pronounced increase in microleakage across nearly all samples, indicating that radiotherapy compromises the integrity of adhesive restorations. Additionally, samples exposed to gamma radiation before cavity preparation exhibited higher levels of microleakage and wider gaps than those exposed after preparation, suggesting that pre-restorative radiation exposure has a more detrimental impact on bonding efficacy. Conversely, the use of a 0.5mm thick lead shield effectively mitigated these adverse effects, improving adaptation and reducing microleakage in both pre- and post-restorative exposure groups. These results emphasise the importance of timing radiation exposure and utilising shielding to protect dental substrates during radiotherapy. Given the increasing application of adhesive restorations in radiotherapy patients, further research is necessary to optimise dental treatment protocols.

Future research should focus on long-term and in vivo studies to better understand the effects of radiotherapy on dental substrates and restorative materials, enabling the development of improved protocols to prevent or alleviate complications associated with radiotherapy.

Clinically, dental professionals should be mindful of the risks associated with radiotherapy on adhesive restorations and consider protective measures, such as personalised shielding devices, to improve patient outcomes and quality of life.

6. References

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