

Effect of Surface Pretreatment on the Sealing Ability of Resin-Based Barriers: A Microleakage Study

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Abstract

Introduction: Resin-based barriers are used during root canal therapy to prevent salivary contamination of the pulp chamber, thereby minimizing bacterial ingress. Previous studies have reported variable sealing abilities among different resin-based barriers, with J-Temp showing the highest leakage and Liquid Dam the lowest. The purpose of this study was to investigate whether different dentin surface pretreatments influence the sealing ability of J-Temp and Liquid Dam.

Methods: Seventy-two extracted maxillary and mandibular molars received a 4 x 4 mm preparation on the buccal surface and were divided into six groups (n = 12) according to the barrier (J-Temp or Liquid Dam) and pretreatment: no treatment (NT), alcohol scrub (ALC), or dentin bonding agent (DBA). Specimens were submerged in 2% methylene blue for 24 hours while being agitated. After barrier removal, dye penetration was photographed using a Zemax microscope and analyzed on ImageJ. Two-way ANOVA with post hoc Tukey tests and independent-samples t-tests were used ($\alpha = 0.05$) for statistical analysis.

Results: For Liquid Dam, significant differences were found among pretreatments. DBA pretreatment produced significantly less leakage than NT or ALC, while NT and ALC were not significantly different. For J-Temp, no significant differences were found between the three pretreatments. Comparing the two materials, J-Temp exhibited less leakage than Liquid Dam under NT conditions, whereas Liquid Dam showed less leakage than J-Temp when a bonding agent was used.

Conclusions: Dentin bonding pretreatment significantly improves the sealing ability of Liquid Dam but has no effect on J-Temp. Surface pretreatment may mitigate inherent differences between barrier materials, potentially reducing salivary contamination risk during endodontic treatment.

Keywords: Root canal therapy, Resin-based barriers, Dentin bonding agent, Salivary contamination.

Introduction

Rubber dam isolation has been essential in endodontic practice since its introduction by Barnum in 1862, serving primarily to prevent salivary contamination during root canal procedures.¹ The American Association of Endodontists (AAE) identifies rubber dam use as the standard of care, and epidemiologic data support its importance. Lin et al. reported a statistically significant higher success rate when rubber dam isolation was used during nonsurgical root canal therapy, underscoring its contribution to favorable long-term outcomes.² Additional evidence further reinforces the role of isolation in endodontic prognosis.

Goldfein et al. found that the use of a rubber dam during post placement—a restorative phase subsequent to root canal treatment—was associated with significantly greater success compared with cases restored without isolation.³ Despite its widespread acceptance, rubber dam placement does not always ensure a fluid-tight seal. Fors et al.⁴ reported salivary leakage in 53% of teeth even when the dam appeared properly positioned, with failures most commonly occurring around clamps or in teeth with substantial structural loss. These findings suggest that the rubber dam alone may be insufficient to prevent microbial ingress under certain clinical conditions.

Preventing salivary ingress remains essential because intraradicular microorganisms are the principal etiologic factor in post-treatment apical periodontitis.⁵ Even brief exposure to saliva can rapidly contaminate the canal system, as demonstrated in classic studies,⁶ and seminal experimental work has established that pulpal and periapical disease does not develop in the absence of microorganisms.⁷ Coronal leakage is a major pathway for reinfection; Ray and Trope⁸ showed that compromised coronal restorations are strongly associated with recurrent periapical disease due to microbial ingress from the oral cavity. Achieving a reliable seal is particularly challenging in teeth with extensive caries, cervical defects, or fractured cusps, where adapting the rubber dam closely to the tooth surface becomes difficult. To address these limitations, clinicians have increasingly adopted resin-based barrier materials as adjuncts to reinforce the seal at the dam-tooth interface.

Resin-based barriers—such as Liquid Dam, Kool-Dam, OpalDam, and J-Temp—are light-cured, flowable methacrylate materials whose manufacturers originally intended them for different clinical purposes. Liquid Dam, Kool-Dam, and OpalDam are marketed primarily as gingival protective barriers used during in-office bleaching procedures to shield soft tissues from peroxide exposure,⁹ whereas J-Temp, although compositionally similar, is described by its manufacturer as a temporary resin formulated to provide structure for isolation clamping and to act as a barrier to endodontic irrigants. Despite these differing indications, all four materials share similar flowable methacrylate chemistry and have been adopted in endodontics to reinforce rubber dam isolation, as described clinically by Patel et al.¹⁰ and further examined experimentally in recent investigations. However, these materials differ considerably in physical and mechanical behavior. Kharouf et al.¹¹ demonstrated substantial variation among commercially available barrier resins in viscosity, compressive strength, solubility, and enamel bonding, with SEM imaging revealing pronounced surface microporosity following chemical challenges. These findings indicate that resin-based barriers may not perform uniformly under clinical conditions.

Consistent with this variability, Becerra et al.¹² evaluated microleakage in four resin barriers—J-Temp, Kool-Dam, Liquid Dam, and OpalDam—using an internal dye-activation model in restoratively compromised posterior teeth. They found that J-Temp exhibited the greatest leakage (70.5%), while Liquid Dam (12.8%), Kool-Dam (15.4%), and OpalDam (15.2%) showed significantly lower leakage, with Liquid Dam demonstrating the least variability. These findings highlight substantial differences in sealing performance among materials marketed for similar purposes.

The condition of the enamel and dentin surfaces may influence how effectively resin-based barriers achieve a seal. Adhesive studies have shown that bonding to enamel and dentin depends on surface characteristics such as surface energy, wettability, and the ability of resin to penetrate conditioned dentinal tubules and to create a hybrid layer with exposed collagen fibers.¹³ An incomplete hybrid layer with voids and weak bonding areas increases the risk of debonding, microleakage, and nanoleakage.¹⁴ To improve bonding between dentin and adhesive, various surface treatments have been proposed, including the application of rubbing alcohol. Rubbing alcohol reduces the overall residual water content of dentin and stabilizes the exposed collagen fibers for improved hybrid layer formation.¹⁵ Moreover, application of a universal adhesive may improve the adaptation and sealing behavior of resin-based barriers by improving the bond between the barrier and the tooth surface.¹¹ To the authors' knowledge, there is no publication evaluating the efficacy of these pretreatment strategies in improving the performance of resin-based barriers under conditions relevant to endodontic isolation.

Building upon the findings of Becerra et al.,¹² the present study focuses on the two extremes of barrier performance—J-Temp and Liquid Dam—and evaluates how three surface conditions (no treatment [NT], alcohol scrubbing [ALC], and universal adhesive application [DBA]) affect microleakage in a 2% methylene blue static immersion model. In contrast to Becerra's pressure-driven, internally activated dye method, the present study assesses leakage using an external, diffusion-based approach designed to simulate salivary contamination. The null hypotheses were that (a) tooth surface pretreatment would not influence leakage for either material, and (b) no significant difference would be observed between J-Temp and Liquid Dam under any pretreatment condition.

Materials and Methods

Specimen Preparation

Seventy-two extracted human molars with or without open apices were selected based on the absence of caries, cracks, or restorations and were stored in diluted sodium hypochlorite solution until use. A 4 x 4 mm preparation was made on the buccal surface of the teeth using a #557 carbide bur (Komet Dental, Lemgo, Germany) with copious water spray.

Experimental Groups

The resin-based barriers studied in this experiment were J-Temp (Ultradent, South Jordan, Utah, USA) and Liquid Dam (Vista Apex, Racine, Wisconsin, USA). Teeth were randomly assigned to six groups (n = 12):

Group	Barrier Material	Pretreatment
1	Liquid Dam	No treatment (NT)
2	J-Temp	No treatment (NT)
3	Liquid Dam	Alcohol scrub (ALC)
4	J-Temp	Alcohol scrub (ALC)
5	Liquid Dam	Dentin bonding agent (DBA)
6	J-Temp	Dentin bonding agent (DBA)

In all groups, the prepared dentin was dried with an air syringe for 5 seconds immediately before barrier placement.

- **NT:** no further surface pretreatment.
- **ALC:** scrubbed with 70% isopropyl alcohol for 10 seconds, then air-dried.
- **DBA:** Adhese Universal VivaPen (Ivoclar Vivadent, Schaan, Liechtenstein) was applied, air-thinned, and light-cured for 20 seconds per manufacturer instructions.

Barrier Placement and Dye Challenge

Each root was coated with nail varnish to prevent apical leakage. For teeth with open apices, the apices were sealed internally with Filtek Supreme Ultra packable composite (3M ESPE, St. Paul, Minnesota, USA) and then coated with nail varnish around the resin. The assigned barrier was placed into the preparation and light-cured for 20 seconds.

All specimens were submerged in 2% methylene blue dye for 24 hours while continuously agitated on a laboratory shaker to enhance dye penetration.

Leakage Measurement

After dye immersion, the resin barriers were carefully removed using a periodontal scaler. The teeth were not sectioned. Standardized photographs of each preparation were obtained under a Zumax dental operating microscope (Zumax Medical Co., Ltd., Suzhou, China). A periodontal probe was positioned adjacent to the preparation in each image and used as the calibration reference. Images were imported into ImageJ (NIH, Bethesda, Maryland, USA), and the known millimeter markings on the probe were used to convert pixel measurements to linear distances. For each specimen, four linear dye-penetration measurements were recorded along the axial wall of the preparation: two corresponding to the greatest extent of observable penetration and two corresponding to the least. An average of the four measurements was calculated for each specimen.

The total preparation depth at each location was measured using the same calibration. Percentage penetration was calculated as

$$\text{Percent Penetration} = \frac{\text{Penetration Depth}}{\text{Total Depth}} \cdot 100$$

Percentage values were used to normalize leakage across specimens, as natural tooth curvature and minor variations in preparation dimensions occasionally resulted in deviations from the intended 4 × 4 mm cavity size.

Statistical Analysis

Statistical analysis was performed using two-way ANOVA followed by post hoc Tukey tests to compare pretreatment conditions within each material. In addition, multiple independent-samples t-tests were performed with an adjusted significance threshold to minimize Type I error. For the two-way ANOVA, statistical significance was set at $\alpha = 0.05$. For the independent-samples t-tests, α was set at 0.017.

Results

Table 1. Summary of leakage values for the experimental groups.

Group	Barrier Material	Pretreatment	Mean (%)	Standard Deviation (%)
1	Liquid Dam	NT	71.0	28.2
2	J-Temp	NT	40.1	22.6
3	Liquid Dam	ALC	63.0	35.7
4	J-Temp	ALC	44.3	21.7
5	Liquid Dam	DBA	20.7	6.8
6	J-Temp	DBA	33.8	15.4

Leakage values are summarized in Table 1 and Figure 1. Two-way ANOVA showed significant effects of sealing material ($p = 0.032$) and surface treatment ($p < 0.001$) on leakage. In addition, the interaction between sealing material and surface treatment was significant ($p = 0.006$). Post hoc testing showed that DBA pretreatment resulted in a significant reduction in leakage compared with no treatment or alcohol pretreatment ($p < 0.001$). No significant difference was found between no treatment and alcohol pretreatment ($p = 0.957$). Pairwise comparisons using the adjusted significance threshold showed significantly lower leakage for J-Temp than for Liquid Dam under NT conditions ($p = 0.007$), no significant difference between materials under ALC conditions ($p = 0.137$), and significantly lower leakage for Liquid Dam than for J-Temp under DBA conditions ($p = 0.014$).

The total preparation depth at each location was measured using the same calibration. Percentage penetration was calculated as

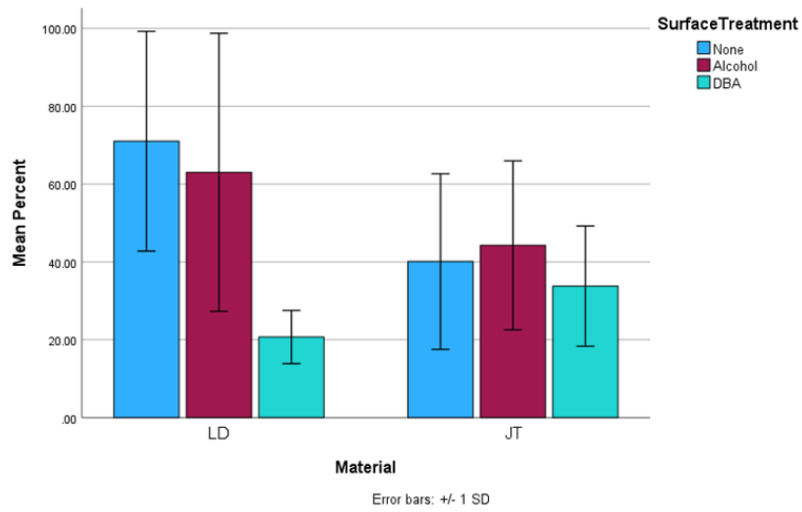


Figure 1. Summary of mean leakage percentages for all experimental groups.

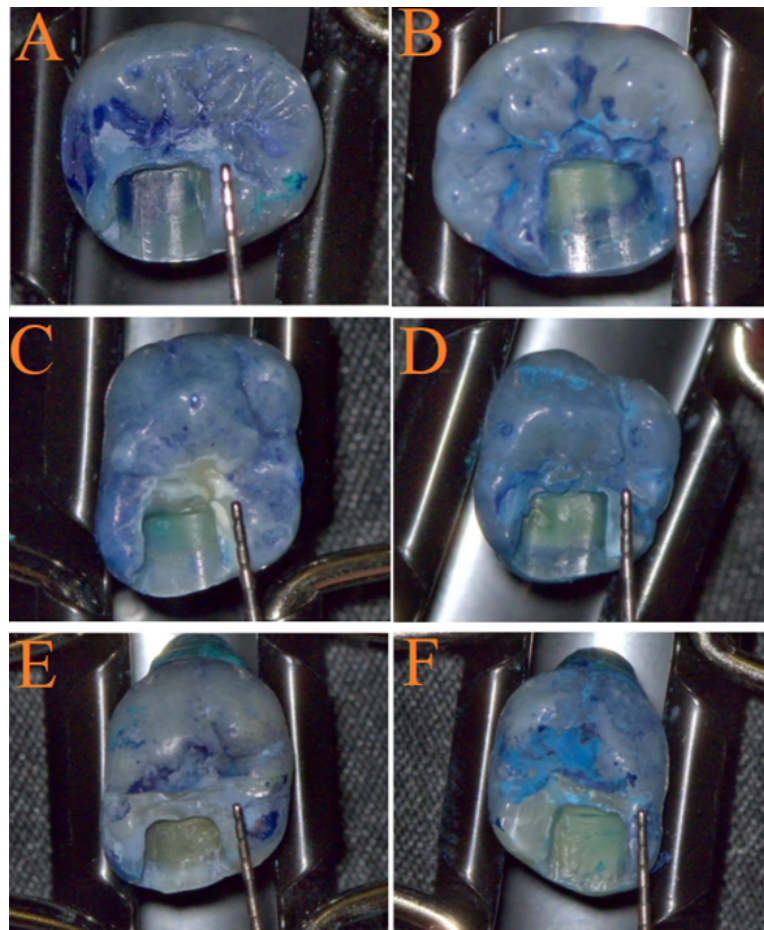


Figure 2. Images used for analysis on ImageJ after dye immersion for 24 hours. A) LD-NT. B) JT-NT. C) LD-ALC. D) JT-ALC. E) LD-DBA. F) JT-DBA.

Discussion

This study examined how different surface pretreatments influence the sealing ability of two commonly used resin-based barriers, J-Temp and Liquid Dam, using a passive external 2% methylene blue immersion model. The findings show that dentin bonding agent (DBA) pretreatment significantly improved the sealing performance of Liquid Dam, whereas J-Temp was unaffected by any pretreatment strategy. These results indicate that the sealing effectiveness of each material is strongly dependent on both the substrate condition and the nature of the leakage challenge.

Under untreated (NT) conditions, J-Temp exhibited substantially less leakage than Liquid Dam, a pattern that contrasts with the results of Becerra et al.,¹² who found that J-Temp exhibited the highest microleakage and Liquid Dam the lowest. This reversal likely reflects the fundamentally different methodologies used in these two studies; Becerra et al.¹² used an internal, ultrasonically activated model which generated a pressure-driven challenge that forces dye through the material–tooth interface, whereas in the present study, a salivary contamination scenario was simulated in which dye movement is governed primarily by passive diffusion. As these two testing environments emphasize different failure modes, the results of these two studies are not necessarily contradictory, and each reflects the performance of the resin-based barriers under different clinical conditions.

These methodological differences also help explain the divergent material behavior. J-Temp is a rigid temporary resin formulated to provide structural support and resist irrigant penetration during endodontic procedures. Its stiffness and lower permeability may reduce passive dye diffusion under static immersion, even though it may not resist displacement when subjected to pressure or vibration. Liquid Dam, in contrast, may depend more heavily on intimate adaptation and micromechanical interaction with the surface beneath it. When placed on untreated dentin during passive immersion, the absence of an adhesive interface likely resulted in microgapping and increased dye diffusion, accounting for its higher leakage in the NT groups.

The significant improvement in Liquid Dam performance following DBA pretreatment aligns with the adhesive principles described in the introduction. Universal adhesives increase surface energy, promote resin wetting, and create a hybridized interface that reduces microleakage. Incorporation of a bonded layer beneath Liquid Dam likely improved marginal adaptation and restricted dye movement, resulting in markedly reduced leakage. Moreover, the improved leakage resistance observed with DBA application may be explained by the direction of polymerization shrinkage during light curing. Light curing initiates polymerization reactions that reduce material volume and result in shrinkage. Without DBA, the shrinkage occurs away from the tooth and toward the light source. However, the presence of the bonding layer results in polymerization shrinkage toward the bonded surface and away from the light source.¹⁶ This results in lower microleakage observed in the presence of a separate DBA layer. The absence of any comparable effect for J-Temp suggests that its sealing behavior is primarily determined by the intrinsic properties of the cured material rather than by adhesive interaction with dentin.

Taken together, these findings help reconcile variations among microleakage studies. Under pressure-driven conditions such as Becerra et al.'s,¹² Liquid Dam performs well; under passive diffusion without pretreatment, J-Temp performs better. These results underscore that leakage is influenced not only by the chemistry and mechanics of the barrier material, but also by the directionality of dye movement, magnitude of mechanical forces, and the substrate environment. Such contextual differences are critical when interpreting and comparing resin barrier performance across studies.

From a clinical perspective, these results suggest that Liquid Dam provides a more predictable seal when used in conjunction with a dentin bonding agent, particularly in teeth with significant structural compromise where salivary leakage poses a risk. When dentin pretreatment is impractical—such as in cases with active bleeding, moisture contamination, or when time is limited—J-Temp may offer greater consistency because its sealing performance does not depend on substrate conditioning.

Ultimately, these findings emphasize that the sealing effectiveness of resin-based barriers depends on both material characteristics and dentin surface preparation. Because preventing salivary ingress is central to minimizing microbial contamination during endodontic therapy, optimizing pretreatment—especially when using materials such as Liquid Dam—may enhance the reliability of isolation during multi-visit procedures or treatment interruptions.

Limitations

Several considerations should be taken into account when interpreting these findings. Dye penetration does not directly equate to clinical microbial contamination, as methylene blue differs from bacteria in size, shape, motility, and biochemical behavior, and its diffusion through microscopic gaps does not necessarily reflect microbial penetration. Nevertheless, dye-based leakage models remain widely used because they provide a sensitive and reproducible means of comparing the relative sealing ability of dental materials under controlled conditions.

Leakage was also assessed without sectioning the specimens. Although this approach preserved the external morphology of the preparations, removal of the cured resin barriers—particularly in specimens pretreated with a dentin bonding agent—was technically challenging and may have introduced variability in the exposed interface. Sectioning the specimens would have allowed more direct visualization of the margin and may have yielded a more precise assessment of interfacial adaptation.

Conclusion

Within the limits of this *in vitro* study, dentin bonding agent pretreatment significantly improved the sealing ability of Liquid Dam, whereas J-Temp showed no measurable benefit from any surface pretreatment. Under untreated conditions, J-Temp demonstrated lower leakage than Liquid Dam; however, when used in conjunction with a bonding agent, Liquid Dam provided the most effective seal. These results suggest that the performance of resin-based barriers depends on both material properties and dentin surface preparation. When a highly reliable seal is required, pairing Liquid Dam with a universal adhesive may enhance isolation reliability during endodontic procedures.

Conflict of Interest

The authors deny any conflict of interest related to this study.

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