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Research Article

Evaluation of Different Resin-Based Barriers in Reducing Microleakage in Restoratively Compromised Posterior Teeth During Rubber Dam Isolation: An *Ex Vivo* Study

Carolina Becerra, DDS[1]*, Albert F. McMullen III, DDS, FACD[2], Joon Koh, DMD[1], Thomas E. Lallier, PhD[3]

[1]Postgraduate Endodontic Resident, Louisiana State University Health Sciences Center (LSUHSC), USA.

[2]Department Head and Postgraduate Director, Endodontics, Louisiana State University Health Sciences Center (LSUHSC), USA.

[3]Professor, Cell Biology and Anatomy Coordinator for Student Research, Louisiana State University Health Sciences Center (LSUHSC), USA.

***Corresponding Author**: Carolina Becerra, DDS; Postgraduate Endodontic Resident, Louisiana State University Health Sciences Center (LSUHSC), USA.

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Abstract

Introduction: The rubber dam has been a standard in endodontic practice for over 140 years, providing critical isolation to prevent microbial contamination during root canal therapy. However, studies indicate that microleakage between the rubber dam and tooth structure may still occur, potentially leading to bacterial infiltration. Various resin-based barriers have been introduced to enhance isolation and minimize leakage. This study aimed to evaluate the efficacy of four resin-based barriers in reducing microleakage during endodontic procedures.

Methods: Forty extracted human mandibular molars were selected, stored in distilled water, and standardized for experimental conditions. Standard endodontic access was created, and the mesiobuccal cusp was removed to simulate compromised tooth structure. Teeth were mounted in plaster, hydrated for two hours, and isolated using a rubber dam and clamps. Four resin-based barriers— J-Temp, Kool-Dam, Liquid Dam, and OpalDam —were applied according to manufacturer instructions. Methylene blue dye was introduced into the pulp chamber and activated three times with ultrasonic tips over 90 minutes. Following dye exposure, barriers were removed, and dye penetration was assessed under a Zumax microscope. ImageJ software was used to quantify dye penetration, and statistical analyses were performed using one-way ANOVA and post-hoc Tukey's test (significance level, $p<0.05$).

Results: All resin-based barriers exhibited varying degrees of microleakage. J-Temp demonstrated significantly greater dye penetration (mean leakage: 70.5%) compared to Kool-Dam (15.4%), Liquid Dam (12.8%), and OpalDam (15.2%) ($p<0.05$). No significant difference in leakage was observed among Kool-Dam, Liquid Dam, and OpalDam ($p=0.9$). Liquid Dam exhibited the lowest mean leakage and least variance.

Conclusion: Within the limitations of this ex vivo study, Kool-Dam, Liquid Dam, and OpalDam demonstrated superior sealing ability compared to J-Temp in reducing microleakage. When used alongside rubber dam isolation, these barriers contribute to maintaining an aseptic field during endodontic treatment, potentially improving treatment outcomes.

Keywords: *Rubber Dam, Resin-Based Barrier, Microleakage, Endodontics, Root Canal Therapy*

Introduction

The rubber dam has been an essential component in endodontic practice since its introduction by Barnum in 1862 [1]. Initially designed to isolate the treatment field and improve visibility, the rubber dam has evolved into an indispensable tool for ensuring asepsis during root canal therapy. Its role in preventing microbial contamination is widely recognized, with its use considered the standard of care for nonsurgical endodontic treatment.

The American Association of Endodontists (AAE) asserts that tooth isolation with a rubber dam during RCT is fundamental in reducing the risk of bacterial contamination of the root canal system. Failure to use a rubber dam is widely regarded as a deviation from the accepted standard of care across the United States.

The primary purpose of rubber dam isolation is to create a controlled environment that prevents the ingress of saliva, bacteria, and crevicular fluid into the working field. Bacteria are the principal etiological factors in pulpal and periapical disease, and their introduction during root canal therapy is a key contributor to treatment failure [2-4]. Research has demonstrated that bacterial contamination is strongly associated with post-treatment complications, emphasizing the necessity of stringent aseptic protocols. The main objective of endodontic treatment is to prevent and treat bacterial contamination inside of the root canal system in order to retain the tooth and its function [5]. A study by Lin et al. [6] highlighted the beneficial impact of rubber dam use on long-term treatment outcomes, reporting a survival probability of 90.3% for teeth treated under rubber dam isolation compared to 88.8% for those treated without it. Although the absolute difference in survival probability appears modest, the large sample size of over half a million cases resulted in a statistically significant distinction between the two groups.

Despite its effectiveness, rubber dam isolation alone is not always sufficient to prevent microbial leakage. Studies have reported that in approximately 53% of cases, microleakage occurs between the rubber dam and tooth structure, even when no overt signs of contamination are present [7]. Bacterial infiltration has been attributed to gaps between the rubber dam and tooth, particularly around clamp interfaces and areas of extensive caries. Among the identified bacterial species in cases of leakage, *Streptococcus salivarius* is one of the most frequently detected, further underscoring the risk of contamination [8]. In cases where the tooth structure is compromised due to caries or fractures, achieving an optimal seal with primary rubber dam isolation alone becomes increasingly challenging.

To mitigate these limitations, several resin-based barriers have been developed to complement rubber dam isolation. These materials function as sealing agents, filling gaps between the rubber dam and the tooth structure to enhance isolation. Commonly used products, such as J-Temp, OpalDam, Kool-Dam, and Liquid Dam, are syringe-delivered, light-cured materials that vary in viscosity, rigidity, and composition. Research suggests that the application of elastic adhesive barriers significantly reduces microleakage, with some materials capable of bridging larger gaps when applied in conjunction with rubber dam isolation [9]. These barriers are frequently placed at clamp interfaces and over irregular tooth surfaces where decay has been removed, reinforcing the isolation provided by the rubber dam.

Given the challenges associated with compromised tooth structure and the need for additional isolation measures, the present study aimed to evaluate the efficacy of different resin-based barriers in preventing microleakage at the tooth-material interface. The experimental design involved simulating compromised tooth conditions by removing the mesiobuccal cusp and subsequently reconstructing the defect using resin-based barrier materials. The hypothesis of this study is that the application of resin-based barriers improves rubber dam isolation and reduces bacterial and saliva contamination, ultimately contributing to improved treatment outcomes.

Materials and Methods

Specimen Selection and Preparation

Forty extracted mandibular and maxillary molars were selected based on the absence of cracks, fractures, or stains. Teeth were stored in distilled water until use. Standard endodontic access was created with a high-speed handpiece using a #557 bur (Komet USA, Rock Hill, South Carolina) and refined with an Endo-Z bur (Komet USA, Rock Hill, South Carolina). Coronal pulp was removed using #2 and #4 round burs (Komet USA, Rock Hill, South Carolina) and canals were located and enlarged with a Vortex Blue orifice opener (Dentsply Sirona, Charlotte, North Carolina). To simulate compromised tooth structure, the mesiobuccal cusp was resected about 2 millimeters above the cemento-enamel junction (CEJ). Apical leakage was prevented by coating the root apices with clear nail polish before embedding specimens in plaster (Figure 1A). Teeth were then hydrated for two hours prior to resin barrier application.

Experimental Groups and Barrier Application

The rubber dam (Natural Rubber Latex, Medium-Blue, Elastic-Dam, Coltene, Altstätten, Switzerland) was placed using a standard rubber dam frame and clamps. Initial microscopic images were obtained at 1.6x magnification (Figure 1B and C) (Zumax Microscope, Zumax Medical Co., Ltd, Suzhou, China).

The four experimental resin-based barriers—J-Temp (Ultradent, South Jordan, Utah), Kool-Dam (Pulpdent, Watertown, Massachusetts), Liquid Dam (Vista Apex, Racine, Wisconsin), and OpalDam (Ultradent, South Jordan, Utah)—were applied per manufacturer instructions and light-cured using a Woodpecker LED curing unit (iLED Curing Light Wireless, Guilin Woodpecker Medical Instrument Co., Ltd, Guili, Guangxi, China) (Figure 1D and E).

Dye Penetration and Microleakage Analysis

Following barrier application, methylene blue dye 1% (Compass Laboratory, Mena, Arkansas) was introduced into the pulp chamber using a syringe and left in place for 90 minutes (Figure 1F). The dye was activated three times (20 seconds per canal) using a Woodpecker ultrasonic tip (Endo 3 Ultrasonic Endo Activate Device, Guilin Woodpecker Medical Instrument Co., Ltd, Guili, Guangxi, China). After dye exposure, high-vacuum suction was used to remove residual dye. Resin barriers were gently removed with hand instruments, and post-experimental microscopic images were captured (Figure 1G). Dye penetration was assessed at three locations (direct buccal, direct mesial, and mesio-buccal line angle) using ImageJ software (University of Wisconsin). The percentage of leakage was calculated based on the total dentin thickness and dye penetration extent (Figure 2).

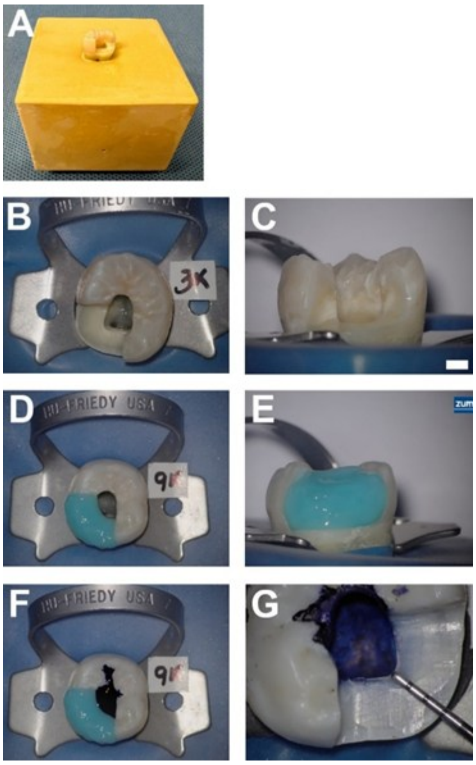

Figure 1. Examples of teeth during the experimental procedure. *(A) Embedded tooth specimen in plaster; (B and C) example of removal of the mesiobuccal cusp; (D and E) Teeth with placement of a resin-based barrier; (F) Teeth after placement and activation of Methylene Blue; (G) Dentinal thickness measurement.*

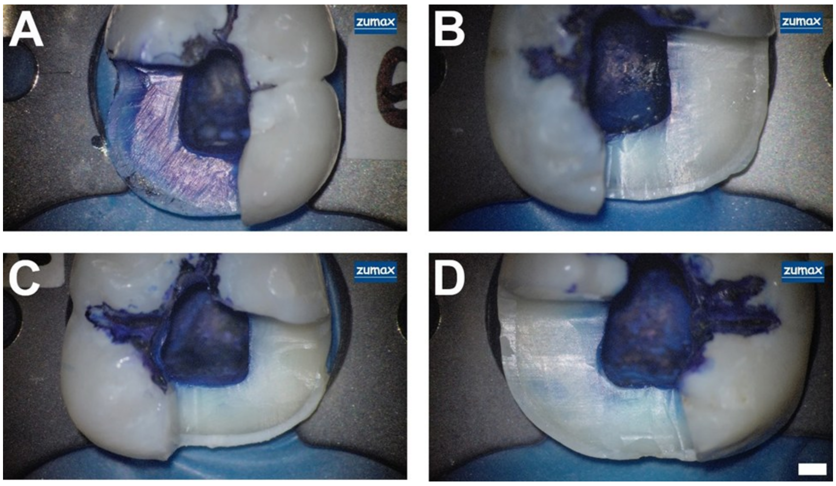

Figure 2. *Image of the specimen at 1.6x magnification under the Zumax microscope after removal of the resin barrier to evaluate the depth of penetration of the Methylene Blue dye. (A) J-Temp, (B) Kool Dam, (C) Liquid Dam, (D) Opal Dam.*

Statistical Analysis

One-way ANOVA was used to determine significant differences in leakage among the four groups. Post-hoc Tukey's test was performed for pairwise comparisons, with statistical significance set at $p<0.05$.

Results

All barriers exhibited some degree of dye penetration, but significant differences were observed among materials (Figure 3). J-Temp showed the highest mean leakage (70.5%: Figure 2A), while Kool-Dam (Figure 2B), Liquid Dam (Figure 2C), and OpalDam (Figure 2D) demonstrated significantly lower leakage levels (15.4%, 12.8%, and 15.2%, respectively) ($p<0.05$). No significant differences were noted among Kool-Dam, Liquid Dam, and OpalDam ($p=0.9$). Liquid Dam had the lowest mean leakage and minimal variance.

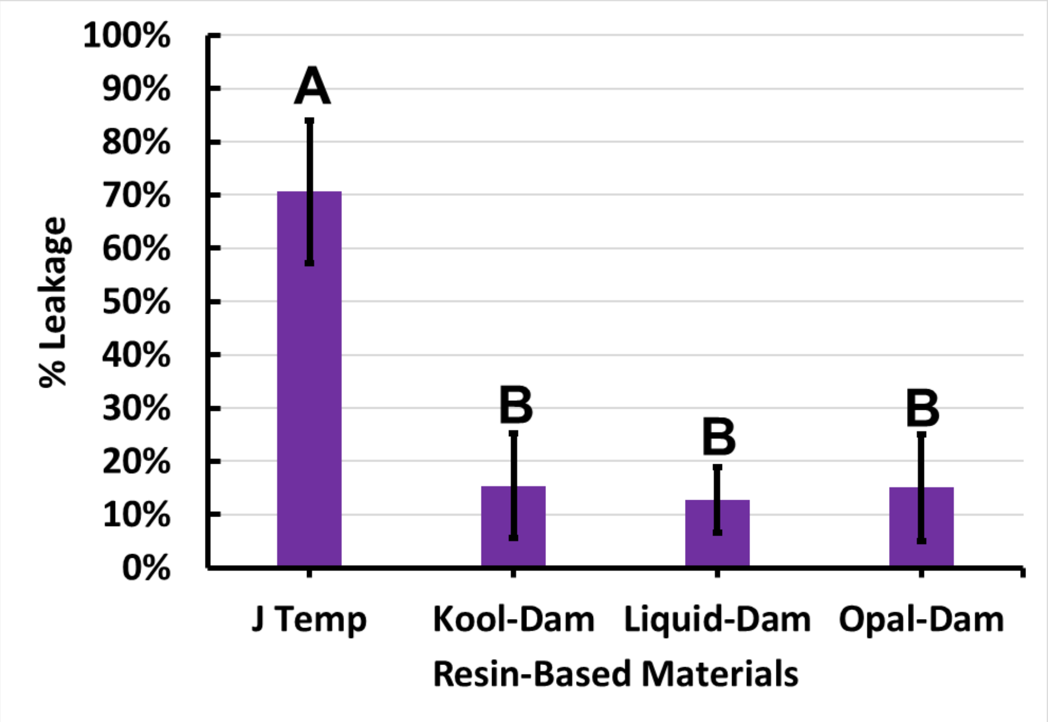

Figure 3. *Percentage of Leakage*

Discussion

Microleakage was observed in all groups, though resin-based barriers improved rubber dam isolation to varying degrees; without any barrier, there would be 100% leakage. J-Temp exhibited the highest leakage. Being the only radiopaque material tested, its formulation as a temporary restoration material may impact its sealing ability, warranting further study. Future research should also investigate whether pre-treatment steps, such as isopropyl alcohol drying or dentin bonding agent application, enhance the efficacy of resin barriers.

The findings of the present study align with prior research evaluating dam seal materials in enhancing rubber dam isolation. A similar study by Patel et al. [10] assessed the sealing efficacy of three dam seal materials, including Liquid Dam and Kool-Dam, and concluded that Kool-Dam demonstrated superior effectiveness in controlling saliva seepage around the clamp and teeth. Moreover, the present study corroborates their assertion that the use of dam sealing materials is particularly valuable when isolating teeth with extensive structural loss or irregular surfaces. The results indicate that resin-based barriers can serve as effective supplementary materials to enhance the performance of traditional rubber dam isolation techniques. Given that compromised tooth structures present greater challenges in achieving a complete seal, these findings further support the necessity of integrating dam seal materials into routine endodontic practice.

One limitation of this experiment is that the dye was placed inside the tooth to simulate salivary leakage, whereas, in a normal clinical situation, saliva would enter from the external environment. This methodological difference raises the question of whether the interface between the resin barrier and enamel is more effective at preventing leakage when tested in an outside-in direction rather than the in-out direction used in this study.

Future studies should explore whether such differences impact sealing efficacy and whether alternative testing methods could provide further insights into the clinical performance of these barriers.

Conclusion

Among the four resin-based barriers tested, OpalDam, Liquid Dam, and Kool-Dam demonstrated superior sealing efficacy compared to J-Temp. When used adjunctively with rubber dam isolation, these barriers contribute to maintaining an aseptic field, potentially improving endodontic treatment success.

Conflict of Interest

The authors declare no conflict of interest.

Acknowledgement

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