Journal of Lasers in Medical Sciences

J Lasers Med Sci 2026;17:e53147

Original Article

https://journals.sbmu.ac.ir/jlms

doi:10.34172/jlms.53147

In Vitro Comparison of Er: YAG Laser and Propolis for Cavity Disinfection in Primary Teeth: Effects on Shear Bond Strength and Microleakage of Compomer Restorations

Başak Nur Beşkardeş[1*], Elif Sungurtekin Ekçi[1]

[1]Faculty of Dentistry, Department of Pediatric Dentistry, Yeditepe University, Istanbul, Türkiye

***Correspondence to**
Başak Nur Beşkardeş, Email:
basaknur.yilmaz@std.yeditepe.edu.tr

Received: August 11, 2026
Accepted: September 30, 2026
ePublished: November 9, 2026

Abstract

Introduction: Residual microorganisms following cavity preparation remain a critical challenge in restorative dentistry, particularly in pediatric patients. Cavity disinfection strategies must effectively reduce microbial load without compromising adhesive performance. The objective of this study was to evaluate the effects of three cavity disinfection methods—2% chlorhexidine gluconate (CHX), Er: YAG laser irradiation, and 30% propolis extract—on the shear bond strength (SBS) and microleakage of compomer restorations in primary molars.

Methods: Seventy-two extracted human primary second molars were allocated to two independent experimental sets for shear bond strength (SBS; n = 32) and microleakage (n = 40) analyses. Within each experiment, specimens were randomized into four groups according to the surface treatment: no disinfection (negative control), 2% chlorhexidine gluconate (CHX), Er: YAG laser irradiation, and 30% propolis extract. Following standardized cavity preparation and disinfection protocols, restorations were completed using Prime & Bond NT and Dyract XP compomer followed by 1,000 thermal cycles (5°C–55°C). Microleakage was evaluated by 0.5% basic fuchsin penetration, and SBS was determined with a universal testing device. Failure modes were categorized under stereomicroscopy, supplemented by scanning electron microscopy (SEM) for surface topography analysis.

Results: The Er: YAG laser group demonstrated significantly higher SBS values (MPa) compared to all other groups ($P = 0.023$ vs control; $P = 0.002$ vs propolis; $P = 0.001$ vs CHX). No statistically significant differences were observed among groups in terms of gingival ($P = 0.247$) or occlusal ($P = 0.416$) microleakage. SEM analysis qualitatively demonstrated a more irregular, smear-layer-free surface in representative Er: YAG specimens.

Conclusion: Under the conditions of this in vitro study, Er: YAG laser treatment increased the SBS of compomer restorations to primary dentin, without adversely affecting microleakage performance. CHX and propolis did not significantly alter SBS relative to untreated controls. These findings should be interpreted as laboratory evidence and require clinical validation.

Keywords: Er: YAG laser, Chlorhexidine, Propolis, Primary teeth, Cavity disinfection

Introduction

Dental caries represents the most prevalent oral health pathology globally and continues to represent a major public health concern, particularly among pediatric populations.[1] The development and progression of dental caries stems from a complex process involving dynamic oral biofilms, dietary factors, host susceptibility, and time.[2] Despite advances in preventive and minimally invasive dentistry, restorative treatment remains necessary in many clinical situations.

Cavity preparation is a fundamental step in restorative procedures, aimed at removing infected dental tissues without compromising remaining healthy dental structure.[3] Beyond eliminating carious lesions, this process seeks to reduce the microbial load within the cavity, thereby minimizing the risk of secondary caries and restoration failure.[4] However, it has been well documented that mechanical caries removal techniques cannot completely eradicate microorganisms from dentin surfaces.[5] Residual bacteria may persist within dentinal tubules or beneath the smear layer, potentially leading to postoperative sensitivity, pulpal inflammation, and compromised restoration longevity. To address this limitation, the use of cavity disinfectants has been recommended as an adjunct to cavity preparation.[6-8]

Beyond their antimicrobial properties, these agents may influence the bonding performance of restorative materials and the marginal sealing ability of restorations. Therefore, an ideal cavity disinfectant should provide effective microbial control without adversely affecting bond strength or increasing microleakage.[8]

Chlorhexidine gluconate (CHX) is one of the most widely

Please cite this article as follows: Beşkardeş BN, Sungurtekin Ekçi E. In vitro comparison of Er: YAG laser and propolis for cavity disinfection in primary teeth: effects on shear bond strength and microleakage of compomer restorations. J Lasers Med Sci 2026;17: e53147. doi:10.34172/jlms.53147

used cavity disinfectants given its potent antimicrobial spectrum coupled with substantivity. It has been shown to effectively reduce residual bacteria following cavity preparation and is commonly applied for the chemical management of oral biofilms. Additionally, this agent has been reported to inhibit matrix metalloproteinases, potentially contributing to the preservation of the hybrid layer.[9-10]

Propolis, a natural resinous product derived from bees, has gained attention as a potential cavity disinfectant due to its antibacterial, antiviral, antifungal, and anti-inflammatory properties.[11,12] Its effectiveness against cariogenic microorganisms such as *Streptococcus mutans*, *Lactobacillus* species, and *Candida albicans* has been demonstrated.[13,14] Due to its natural origin and biocompatibility, propolis represents a promising alternative, particularly in pediatric dentistry.

Laser-based disinfection methods have also been increasingly investigated. Lasers can effectively reduce bacterial load while simultaneously modifying the smear layer and altering surface morphology.[15,16] Among these, the Er: YAG laser has attracted significant interest owing to its strong affinity for water and hydroxyapatite. Its wavelength (2940 nm) enables efficient bacterial elimination through thermomechanical ablation.[17] Furthermore, Er: YAG laser irradiation may enhance adhesion by creating a micro-retentive surface and opening dentinal tubules. However, its effects on bond strength remain controversial, and limited data are available regarding its use in primary teeth.

Consequently, this in vitro investigation sought to assess the influence exerted by three cavity disinfection methods—2% chlorhexidine gluconate (CHX), Er: YAG laser irradiation, and 30% propolis extract—regarding microleakage properties as well as shear bond strength (SBS) for compomers within primary molars. It was hypothesized (H_0) that the application of different cavity disinfection techniques would show no significant effect on microleakage parameters or shear bonding metrics.

Materials and Methods

Ethical Approval

The present research was conducted in accordance with the principles of the Declaration of Helsinki. Prior to specimen collection, written informed consent was secured from the parents or legal guardians of all pediatric patients providing extracted teeth. Following ethical approval, all experimental protocols and data acquisition were executed between March 2026 and June 2026.

Specimen Selection and Sample Size Calculation

To achieve adequate statistical power, an a priori power analysis was executed utilizing G*Power 3.1 software. Based on an effect size of 0.67, a significance threshold (α) of 0.05, and a target power of 80%, the required sample size for shear bond strength (SBS) testing was computed as at least eight samples per group (overall n = 32). Similarly, considering an effect size of 0.57, microleakage evaluation necessitated a minimum cohort of ten samples per group (overall n = 40).

A total of seventy-two extracted human primary second molars were selected and allocated into two independent specimen sets: 32 teeth were used exclusively for SBS testing, and 40 teeth were used exclusively for microleakage evaluation. No tooth was used in either experiment. Primary second molars were selected to improve anatomical standardization because their larger crown dimensions permitted standardized preparation for the respective experimental protocols. Tooth selection was guided by the following inclusion parameters: carious lesions not exceeding one-third of the crown, absence of previous restorations, extraction due to physiological or pathological root resorption, and sufficient remaining crown structure for the assigned preparation. Teeth with extensive caries, restorations, enamel defects (such as fluorosis or hypoplasia), cracks, or structural anomalies were excluded.

After extraction, soft tissue debris was removed from all teeth, which were then stored in distilled water replaced on a weekly basis. To preserve dentin integrity, testing was completed within six months.

Materials

The materials used in this study, including their manufacturers and compositions, are presented in Table 1.

Shear Bond Strength (SBS) Test Specimen Preparation

To prepare the thirty-two primary second molars assigned to SBS testing, occlusal enamel was sectioned with a low-speed precision diamond saw (Isomet 1000, Buehler, USA) under water cooling. Sectioning was executed parallel to the cementoenamel line, approximately 1 mm beneath the dentinoenamel border, in order to obtain a flat dentin surface for standardized bonding. This sectioning procedure was performed only on the teeth assigned to SBS testing and was independent of the Class V cavity preparation used in the separate microleakage specimen set.

For smear layer standardization, exposed dentinal surfaces were ground with 600-grit silicon carbide abrasive paper under continuous water flow. Each specimen was then embedded in autopolymerizing polymethylmethacrylate resin (Imicryl SC©, Konya, Turkey), ensuring that the prepared dentin surface remained exposed and oriented perpendicular to the direction of loading.

Table 1. Materials used in the study

Material	Manufacturer	Composition
2% CHX	Microvem, Sakarya, Turkiye	2% Chlorhexidine Gluconate, Distilled water
Er: YAG Laser	Hoya ConBio, California, USA	Versawave DE-Light, 2940 nm
30% Propolis Extract	Prepared in laboratory	30% Crude Propolis Extract in Ethanol
Dyract XP®	Dentsply, Konstanz, Germany	UDMA, TEG-DMA, TCB resin, Strontium-fluoro-phosphosilicate glass
Prime&Bond® NT	Dentsply, Konstanz, Germany	Di-trimethacrylate resins, PENTA, Photocatalysts, Acetone

Microleakage Test Specimen Preparation

To assess microleakage, forty primary second molars, not involved in SBS testing, were cleaned using a prophylaxis paste while keeping the crowns intact. Standard Class V cavities were prepared on the buccal surface utilizing a high-speed handpiece equipped with a diamond bur under continuous water irrigation.

The cavity dimensions were kept constant at 4 mm in width (mesiodistally), 3 mm in height (occlusogingivally), and 2 mm in depth. To restrict all preparation borders strictly to enamel, the cervical wall was set 1 mm above the cementoenamel junction.

Cavity Disinfection Procedures

For both SBS and microleakage experiments, samples were allocated at random into four groups based on the cavity disinfection technique:

- **Group 1 (CHX):** A 2% chlorhexidine gluconate solution (Microvem, Sakarya, Turkey) was applied to the dentin/cavity surfaces using a sterile cotton pellet for 20 s, followed by gentle air-drying for 10 s.
- **Group 2 (Er: YAG Laser):** Dentin/cavity surfaces were irradiated using an Er: YAG laser system (Versawave, Hoya ConBio, California, USA; wavelength: 2.94 μm) operating at 100 mJ/pulse, 15 Hz, and 1.5 W output power (pulse duration: 140 μs, 15% water / 15% air spray). The focal spot diameter was 0.6 mm, correspınding to an energy density (fluence) of approximately 35.37 J/cm^2 per pulse. A 600-μm-diameter quartz fiber tip was held perpendicular (90°) to the target at a 1–2 mm working distance for 30 s. The tip was moved in a controlled, sweeping, scanning motion across the entire prepared dentin surface in SBS specimens; in Class V cavities, irradiation was systematically directed over the cavity floor, all internal walls, line angles, and margins to ensure uniform coverage and avoid prolonged irradiation of any single site.
- **Group 3 (Propolis):** To prepare the 30% propolis extract, 30 g of crude propolis was dissolved in 70% ethanol and continuously agitated on a shaker for 3 days. The solution was filtered through Whatman No. 1 filter paper and evaporated at 50°C. The resulting resinous mass was re-dissolved in 70% ethanol to obtain a 30% concentration. This extract was applied to the dentin surface for 20 s and air-dried for 10 s.
- **Group 4 (Negative Control):** No disinfection procedure was performed.

Restorative Procedures

Subsequent to disinfection, bonding procedures were conducted across all samples using Prime & Bond® NT (Dentsply, Konstanz, Germany). Prime & Bond® NT is an etch-and-rinse adhesive; however, in the present study it was used with Dyract XP (Dentsply, Konstanz, Germany) following the manufacturer-recommended no-etch technique for Dyract compomer restorations. Accordingly, no separate phosphoric acid etching step was performed. The bonding agent was agitated on the dentinal surface for 20 s, gently air-thinned for 5 s for solvent elimination, and photo-polymerized for 20 s with a broad-spectrum LED light-curing system (Bluephase Style; Ivoclar Vivadent, Schaan, Liechtenstein).

Regarding the SBS evaluation, Dyract XP compomer (Dentsply, Konstanz, Germany) was built up within a transparent cylindrical mold measuring 3 mm across and 4 mm in height. Compomer placement was executed in 2-mm increments, with each layer photo-cured separately for 20 s.

To assess microleakage, Class V cavity preparations were filled using the same compomer under identical light-curing conditions.

Thermocycling

Prior to thermal aging, all restored samples were incubated in distilled water at 37°C for 24 hours. Subsequently, specimens underwent 1,000 thermal cycles ranging from 5°C to 55°C using a thermocycling apparatus (Salibrus Technica, Boston, USA), with a dwell period of 30 s per temperature bath.

Shear Bond Strength (SBS) Testing and Fracture Mode Analysis

To determine shear bond strength, samples were loaded in a universal mechanical testing device (INSTRON 3345, USA). A blunt metal chisel positioned at 90° exerted a shearing force directly onto the compomer-dentin junction at a constant crosshead rate of 0.5 mm/min until specimen fracture occurred.

Bond strength values (MPa) were determined according to the formula:

SBS (MPa) = Maximum force (N) / Bonded surface area (mm^2)

Following mechanical testing, debonded surfaces were examined under 40 × magnification with a stereomicroscope (Zeiss Discovery V20 SteREO, Germany) to classify failure patterns:

- **Adhesive failure:** Debonding localized predominantly at the dentin-resin interface, with restorative material remaining on less than 20% of the surface.
- **Cohesive failure:** Fracture occurring mainly within the dentin substrate or compomer material, exceeding 80% surface involvement.
- **Mixed failure:** Co-existence of both adhesive and cohesive features, with each pattern accounting for 20% to 80% of the area.

SEM was utilized as a qualitative adjunct to illustrate representative fracture topographies rather than for primary quantification. For supplemental qualitative evaluation, one representative sample from each failure category was gold/palladium sputter-coated and analyzed using scanning electron microscopy (SEM) (Carl Zeiss, EVO 40, Germany).

Microleakage Evaluation

To prevent apical dye ingress, root tips of all microleakage

samples were obturated using composite resin. Tooth surfaces were subsequently coated with two layers of nail varnish, leaving a 1-mm exposed band around the restoration boundaries.

Samples were submerged in a 0.5% basic fuchsin solution for 24 hours, thoroughly flushed, and sliced in a buccolingual direction with a precision low-speed diamond saw (Isomet 1000, Buehler, USA).

To avoid post-cutting dye migration, sectioned specimens were gently flushed with distilled water and briefly air-dried. Digital documentation and microscopic inspection were immediately conducted under a stereomicroscope (40 × magnification).

Dye penetration extent along occlusal and gingival walls was graded according to Santini et al.[18]:

- Score 0 = No evidence of dye penetration;
- Score 1 = Dye infiltration extending up to one-third of cavity depth;
- Score 2 = Dye infiltration extending up to two-thirds of cavity depth;
- Score 3 = Dye infiltration reaching the complete cavity depth;
- Score 4 = Dye infiltration involving the axial wall.

Statistical Analysis

NCSS 2007 software was employed to conduct all statistical evaluations. Normal distribution of continuous SBS data was verified via the Shapiro-Wilk test, while equality of variances (homoscedasticity) was assessed using Levene's test.

Table 2. The mean shear bond strength values across the groups

	Shear-Bond Strength (MPa)
Negative Control	11.72 ± 1.94
Er: YAG Laser	15.65 ± 1.66
Propolis	10.49 ± 4.02
Chlorhexidine (CHX)	10.05 ± 1.89
p‡	0.001*

‡One-Way ANOVA Test
*$P<0.05$

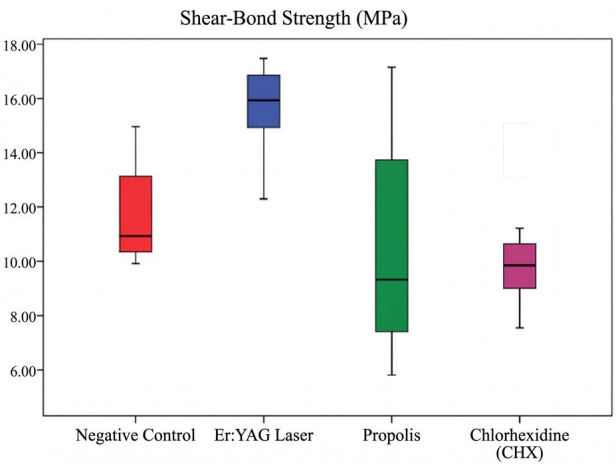


Figure 1. The distribution of mean shear-bond strength across different groups

Having satisfied the prerequisites for normality and homogeneity of variance, group comparisons for SBS values were executed using one-way analysis of variance (ANOVA), followed by Tukey's post hoc test for pairwise comparisons.

Non-parametric evaluation of ordinal microleakage scores was carried out through the Kruskal-Wallis test, with Dunn's multiple comparison test applied where appropriate.

Categorical failure-mode distributions were evaluated using the Chi-square test. The threshold for statistical significance was set at $P<0.05$.

Results

Shear Bond Strength (SBS)

The mean shear bond strength (SBS) values (MPa) for all experimental groups are presented in Table 2 and Figure 1. The descriptive statistics (mean ± standard deviation) were as follows: Negative Control (11.72 ± 1.94), Er: YAG Laser (15.65 ± 1.66), Propolis (10.49 ± 4.02), and Chlorhexidine (CHX) (10.05 ± 1.89).

Statistical evaluation via one-way ANOVA demonstrated significant inter-group variance ($P=0.001$), confirming that the choice of cavity disinfection protocol significantly influenced adhesion performance.

Subsequent post-hoc evaluation via Tukey's test indicated that the Er: YAG laser group achieved significantly higher SBS values than all other test conditions. Specifically, Er: YAG irradiation yielded marked improvements over the negative control ($P=0.023$), propolis ($P=0.002$), and CHX ($P=0.001$) (Table 3).

Conversely, no significant variation was found among the negative control, propolis, and CHX groups ($P>0.05$), confirming that these treatment modalities did not alter adhesion compared to untreated dentin.

The Er: YAG laser group therefore demonstrated the highest mean SBS values among the four experimental groups; variability is presented descriptively in Figure 1.

Failure Mode Distribution and SEM Analysis

The overall distribution of fracture patterns across all experimental groups is presented in Table 4. Statistical evaluation using the Chi-square test revealed comparable fracture pattern proportions between groups ($P=0.149$).

In the negative control group, failures were predominantly adhesive (50%), followed by cohesive (37.5%) and mixed failures (12.5%). The Er: YAG laser group exhibited a

Table 3. Comparative analysis of intergroup shear-bond strength

Tukey Multiple Comparisons Test	*P*
Negative Control / Er: YAG Laser	**0.023***
Negative Control / Propolis	0.774
Negative Control / Chlorhexidine (CHX)	0.572
Er: YAG Laser / Propolis	0.002*
Er: YAG Laser / Chlorhexidine (CHX)	**0.001***
Propolis / Chlorhexidine (CHX)	0.986

*$P<0.05$

distinct pattern, with the highest rate of mixed failures (50%), and an equal distribution of adhesive (25%) and cohesive (25%) failures.

In contrast, the propolis and CHX groups demonstrated a predominance of adhesive failures, accounting for 62.5% and 75% of failures, respectively. No cohesive failures were observed in these two groups. The overall failure-mode distribution showed no statistically meaningful variation between groups ($P=0.149$).

SEM analysis provided qualitative confirmation of these findings. In the Er: YAG laser group, the exposed dentin demonstrated a characteristic micro-irregular morphology with crater-like depressions resulting from laser ablation. Complete elimination of the smear layer was observed, and the surface appeared conducive to micromechanical locking. Cohesive fracture patterns and the presence of granular material within surface irregularities further supported enhanced adhesion (Figure 2A, B).

In the propolis group, SEM images revealed a combination of adhesive and cohesive fracture features, with limited penetration of the adhesive material into dentinal tubules (Figure 2C, D). The CHX group predominantly exhibited adhesive failures, with visible adhesive remnants on the dentin surface, indicating weaker interfacial bonding (Figure 2E, F).

Table 4. Distribution of fracture types among groups

Fracture Type	Adhesive		Cohesive		Mixed	
Negative Control	4	50.00%	3	37.50%	1	12.50%
Er: YAG Laser	2	25.00%	2	25.00%	4	50.00%
Propolis	5	62.50%	0	0.00%	3	37.50%
Chlorhexidine (CHX)	6	75.00%	0	0.00%	2	25.00%
P	0.149					

+Chi-square Test
*$P<0.05$

Microleakage Assessment

The mean microleakage scores at the gingival and occlusal margins are summarized in Table 5 and Figure 3. Kruskal-Wallis non-parametric testing demonstrated comparable outcomes across all groups regarding microleakage at both gingival ($P=0.247$) and occlusal ($P=0.416$) margins.

Although not statistically significant, a consistent trend was observed across all groups, with gingival microleakage scores generally higher than occlusal scores. This finding suggests greater susceptibility to leakage at the gingival margin.

Among the groups, the highest mean gingival microleakage was observed in the CHX group, while the Propolis group displayed maximum occlusal microleakage ratings. Conversely, Er: YAG laser application consistently yielded the lowest leakage scores across both gingival and occlusal boundaries, though such variations lacked statistical significance.

Representative stereomicroscopic images of dye penetration (Figure 4) further illustrated the variability in leakage patterns among the groups. Despite these variations, the overall findings indicate that none of the tested cavity disinfection methods adversely affected the marginal sealing ability of compomer restorations.

Table 5. Mean microleakage scores at gingival and occlusal margins

	Microleakage Gingival		Microleakage Occlusal	
	Mean ± SD	Median (IQR)	Mean ± SD	Median (IQR)
Negative Control	1.70 ± 1.34	1.5 (0.75-3)	1.60 ± 1.43	1 (0.75-2.5)
Er: YAG Laser	1.60 ± 1.71	1 (0-3.25)	1.10 ± 1.20	1 (0-1.25)
Propolis	2.50 ± 1.78	3.5 (0.75-4)	1.90 ± 1.85	2 (0-4)
Chlorhexidine (CHX)	2.80 ± 1.75	4 (0.75-4)	0.70 ± 0.82	0.5 (0-1.25)
p*	0.247		0.416	

*Kruskal Wallis Test
*$P<0.05$

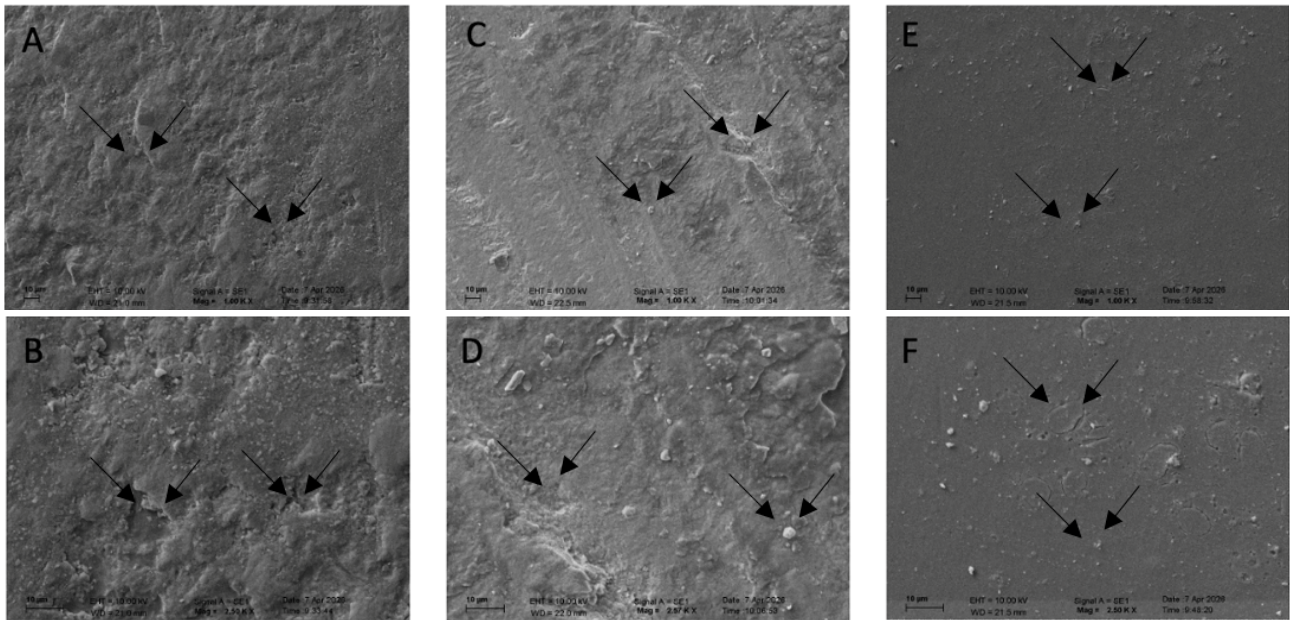


Figure 2. Scanning electron microscopy (SEM) images of fracture surfaces. (A, B) Er: YAG laser group at 1000× and 2500×: cohesive fracture. (C, D) Propolis extract group at 1000× and 2500×: mixed fracture. (E, F) CHX group at 1000× and 2500×: adhesive fracture

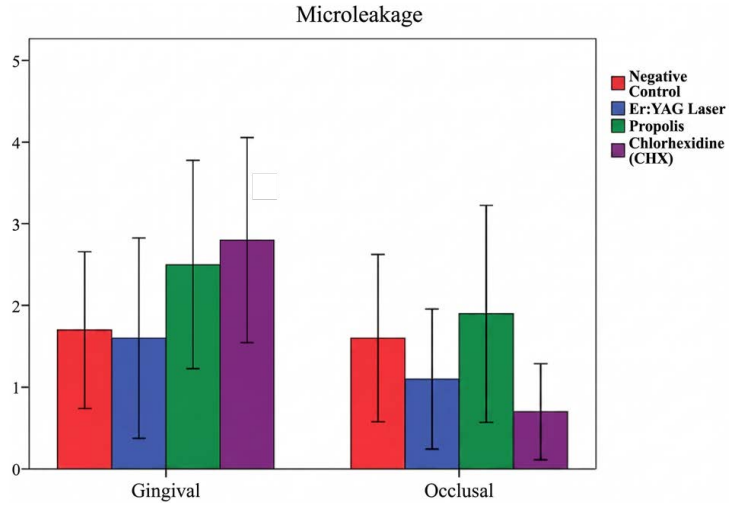


Figure 3. The mean microleakage scores across various groups

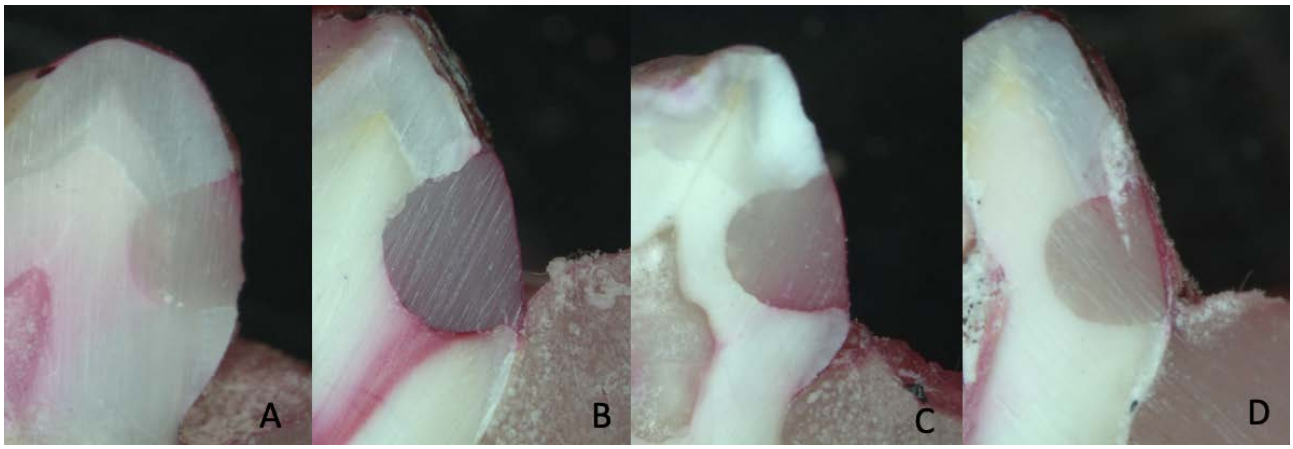


Figure 4. Representative stereomicroscope images of dye penetration. (A) Er: YAG Laser group: Score 1 (occlusal), Score 0 (gingival). (B) Propolis group: Score 1 (occlusal), Score 4 (gingival). (C) CHX group: Score 0 (occlusal), Score 3 (gingival). (D) Negative Control group: Score 2 (occlusal), Score 0 (gingival)

Discussion

This *in vitro* investigation analyzed how distinct cavity disinfection approaches—specifically 2% CHX, Er: YAG laser conditioning, and 30% propolis extract—affect the bonding performance and microleakage properties of compomers in primary teeth. According to the empirical data, the null hypothesis was rejected in part. Whereas significant intergroup differences were detected concerning SBS, microleakage scores demonstrated no statistically significant variation.

Primary teeth exhibit structural and compositional differences compared to permanent teeth, including higher organic content, lower mineralization, and variations in dentinal tubule density and diameter.[19,20] These characteristics may influence adhesive performance and justify the use of primary teeth in the present study to ensure clinical relevance. Dyract XP was chosen since compomeric materials represent a mainstay in pediatric dentistry due to their fluoride-releasing capability, favorable handling qualities, and proven clinical application in primary dentition.[21] Prime&Bond NT was applied in strict adherence to the manufacturer's non-etching instructions for Dyract restorations, which should not be confused with a classic self-etch mechanism.

Thermocycling was applied to reproduce thermal fluctuations; specimens underwent 1,000 cycles between 5 °C and 55 °C (30-second dwell time) to simulate intraoral aging.[22] Assessment of shear bond strength was preferred due to its high reproducibility and capability to emulate clinical loading conditions, despite recognized drawbacks relative to microtensile testing.[23]

Shear Bond Strength

The Er: YAG laser group demonstrated significantly higher SBS than all other groups, attributed to laser-induced thermomechanical ablation. Unlike chemical disinfectants, laser irradiation removes the smear layer and creates a micro-roughened dentin surface, enhancing micromechanical interlocking. SEM analysis confirmed this mechanism through opened dentinal tubules and irregular microtopography, supported by a higher prevalence of mixed and cohesive failures.

These outcomes align closely with the observations of Hubbezoğlu and Alıcı,[24] who demonstrated increased bond strength following Er: YAG laser application, as well as Farahat et al,[25] who reported that laser disinfection did not adversely affect bonding performance. Conversely, conflicting evidence exists in the literature. For instance,

Monghini et al.[26] alongside Ramos et al.[27] noted reduced bond strength following laser irradiation, while Ceballos et al.[28] suggested that thermal effects of laser treatment may denature collagen fibrils and impair resin infiltration.

Inter-study inconsistencies likely stem from differences in laser parameters, adhesive systems, and dentin substrates. Here, Er: YAG irradiation (100 mJ/pulse, 15 Hz, 1.5 W, 35.37 J/cm^2) yielded the highest SBS. Similar parameters reportedly create micro-retentive primary dentin without structural damage when adequately cooled.[29] Although continuous sweeping and cooling minimized heat buildup, thermal safety cannot be definitively confirmed without direct surface temperature measurements.

In contrast, the CHX group exhibited the lowest mean SBS values, although it did not differ significantly from the control group. This finding accords with earlier reports by Say et al.[30] and Ersin et al,[31] which reported that CHX does not adversely affect bond strength in primary teeth. However, the predominance of adhesive failures in this group suggests that CHX may not improve bond strength.

Conversely, Bilgili Can et al.[4] reported that CHX reduced MDP-incorporating universal adhesive performance via competitive calcium-binding inhibition. Similarly, our CHX group exhibited predominant adhesive failures under SEM, indicating a weaker interface. This difference likely stems from variations in bonding composition, specifically the presence of MDP.

The propolis group showed SBS values similar to the control group, with no statistically significant differences. This aligns with findings by Öznurhan et al,[32] Arslan et al,[33] and de Moraes Porto et al,[34] confirming propolis does not impair adhesive performance. SEM revealed limited resin penetration vs. the laser group, explaining the unenhanced bond strength.

Microleakage

In this investigation, microleakage levels at both the gingival and occlusal margins showed no statistical significance across the experimental groups. These findings indicate that none of the tested cavity disinfection methods compromised the marginal seal of compomer restorations in primary teeth.

Despite the absence of statistical significance, a consistent trend was observed across all groups, with higher microleakage scores at the gingival margin than at the occlusal margin. This observation is consistent with previous studies[35,36] reporting increased susceptibility to marginal leakage in the cervical region. This phenomenon may be attributed to structural differences between cervical enamel and dentin, including reduced enamel thickness, increased permeability, and reduced mineralization, all of which may compromise adhesive sealing.[37]

With respect to CHX, the current data corroborate the reports of Palaz et al[38] and Turkistani et al,[39] who reported that CHX application does not significantly influence the microleakage performance of dentin bonding systems. This suggests that CHX, despite its antimicrobial action, does not interfere with the formation of a stable adhesive interface or marginal seal.

Similarly, Arslan et al.[3] evaluated the effects of various cavity disinfection methods, including laser, CHX, propolis, and ozone, and reported no significant differences in microleakage when these agents were used in conjunction with contemporary adhesive systems. These findings support the notion that modern adhesive systems may be relatively tolerant of surface modifications induced by disinfectants.

Consistent with the present results, ElMansy et al.[40] also demonstrated that propolis application did not result in significant differences in microleakage compared with untreated control groups. The biocompatible and non-aggressive chemical nature of propolis may explain its minimal impact on the adhesive interface.

The absence of a significant adverse microleakage effect for propolis is also consistent with the broader pattern reported for cavity disinfection protocols used with contemporary adhesive restorations.[3] Nevertheless, because propolis composition varies with botanical and geographic origin, the present findings apply specifically to the 30% extract and the protocol tested.

Although not statistically significant, Er: YAG laser-treated specimens showed lower occlusal and gingival microleakage. Smear layer removal and micro-retentive changes may improve adhesive adaptation; however, surface modifications do not necessarily enhance marginal sealing. Previous work evaluating cavity disinfection and leakage-related outcomes in compomer restorations similarly indicates that surface modification and marginal leakage do not necessarily change in parallel.[6]

Despite the substantial SBS increase after Er: YAG irradiation, microleakage was not significantly reduced, confirming that bond strength and marginal seal do not necessarily correlate. While SBS reflects localized micromechanical retention under unidirectional load, Class V microleakage is governed by 3D marginal sealing, polymerization shrinkage, and C-factor. Thus, laser-enhanced roughness increases shear resistance without fully preventing microscopic dye penetration.[41-43]

This distinction is crucial for Class V cavities, where the gingival margin lies in thinner cervical enamel with distinct prism orientation and smaller surface area. Furthermore, laser irradiation produces heterogeneous microtopography rather than uniform sealing, meaning dentin retention gains may be offset by polymerization stresses. Consequently, the lack of significant microleakage differences indicates that Er: YAG did not measurably enhance marginal sealing under these conditions, rather than equivalence among methods.

Overall, our findings demonstrate that the tested cavity disinfection methods can be safely applied without compromising the marginal sealing ability of restorations in primary teeth. This finding is clinically relevant, as it supports the use of adjunctive disinfection protocols without increasing the risk of microleakage-associated complications such as secondary caries or marginal discoloration.

Conclusion

Within the limitations of this in vitro study, the following conclusions can be drawn:

- The Er: YAG laser irradiation for cavity disinfection resulted in a statistically significant increase in the shear bond strength of compomer restorations to primary tooth dentin, demonstrating superior bonding performance compared to all other groups.
- The use of 2% CHX and 30% propolis extract exerted no negative impact on bond strength, indicating that these agents can be safely used without compromising adhesive performance.
- None of the evaluated cavity disinfection methods—Er: YAG laser, CHX, or propolis—had a negative impact on microleakage along either occlusal or gingival restoration borders.
- Although without statistical significance, the Er: YAG laser group displayed the lowest microleakage scores, implying a potential positive effect on marginal adaptation.
- Er: YAG laser irradiation can be regarded as a highly successful cavity disinfection modality in pediatric restorative dentistry due to its combined antibacterial efficacy and ability to enhance bond strength without compromising marginal integrity.
- CHX and propolis represent clinically acceptable and safe alternative cavity disinfectants, particularly in settings where laser technology is not available.

Given the inherent limitations of in vitro studies, further long-term in vivo investigations are required to validate these findings and to assess their clinical applicability under functional conditions.

Authors' Contribution

Conceptualization: Basak Nur Beskardes, Elif Sungurtekin Ekci
Data Curation: Basak Nur Beskardes
Formal Analysis: Basak Nur Beskardes, Elif Sungurtekin Ekci
Funding Acquisition: Basak Nur Beskardes
Investigation: Basak Nur Beskardes
Methodology: Basak Nur Beskardes, Elif Sungurtekin Ekci
Project Administration: Basak Nur Beskardes, Elif Sungurtekin Ekci
Resources: Basak Nur Beskardes
Software: Basak Nur Beskardes
Supervision: Elif Sungurtekin Ekci
Validation: Basak Nur Beskardes, Elif Sungurtekin Ekci
Visualization: Basak Nur Beskardes, Elif Sungurtekin Ekci
Writing–Original Draft: Basak Nur Beskardes, Elif Sungurtekin Ekci
Writing–Review & Editing: Basak Nur Beskardes, Elif Sungurtekin Ekci

Competing Interests

The authors declare that they have no competing interests.

Ethical Approval

This study was reviewed and approved by the Yeditepe University Clinical Research Ethics Committee (Approval No: 2024–KAEK–21/1244, dated 13.03.2026). Written informed consent was obtained from the parents of all patients whose extracted teeth were included in this study.

Funding

This research received no external funding.

References

1. Li X, Li R, Wang H, Yang Z, Liu Y, Li X, et al. Global burden of dental caries from 1990 to 2021 and future projections. Int Dent J 2025;75(5):100904. doi:10.1016/j.identj.2025.100904
2. Nyvad B, Crielaard W, Mira A, Takahashi N, Beighton D. Dental caries from a molecular microbiological perspective. Caries Res 2013;47(2):89-102. doi:10.1159/000345367
3. Arslan S, Yazici AR, Görücü J, Pala K, Antonson DE, Antonson SA, et al. Comparison of the effects of Er, Cr: YSGG laser and different cavity disinfection agents on microleakage of current adhesives. Lasers Med Sci 2012;27(4):805-11. doi:10.1007/s10103-011-0980-4
4. Bilgili Can D, Dundar A, Barutcugil Ç. Effect of cavity disinfection protocols on microtensile bond strength of universal adhesive to dentin. Odovtos Int J Dent Sci 2023;24(3):91-102. doi:10.15517/ijds.2022.50966
5. Warreth A. Dental caries and its management. Int J Dent 2023;2023:9365845. doi:10.1155/2023/9365845
6. Arslan I, Baygin O, Tuzuner T, Erdemir F, Canakci A, Korkmaz FM. The effects of cavity disinfection on the nanoleakage of compomer restorations: an in vitro study. Eur Oral Res 2020;54(1):16-24. doi:10.26650/eor.20200053
7. İşcan Yapar M, ÇeliK N, Seven N. Effect of different cavity disinfectants on bond strength of a posterior composite. Turk Klin J Dent Sci 2017;23(2):96-101. doi:10.5336/dentalsci.2017-54719
8. Dey S, Deshmukh S. Cavity disinfection with natural agents and their efficacy: a review on recent literature. Antiinfect Agents 2024;22(3):1-9. doi:10.2174/0122113525285948231215115 20
9. Alp Ş. Novel cavity disinfectants and their effects: a review. J Contemp Med Sci 2024;10(3):178-84. doi:10.22317/jcms.v10i3.1488
10. Bektaş Ö. Cavity disinfection in operative dentistry–review. J Int Dent Sci 2023;9(2):68-76. doi:10.21306/dishekimligi.1128565
11. Malhotra S, Gupta VK. Use of propolis in pediatric dentistry. J Dent Allied Sci 2014;3(2):93.
12. Özdem B, Erdoğan E. Effects of propolis on oral health and oral cavity cancers. HRU Int J Dent Oral Res 2024;4(2):74-81. doi:10.61139/ijdor.1535333
13. Kodgi V, Shetty P, Thimmaiah C, Thomas NA, Vergis BA, Shetty K. Comparative assessment of antimicrobial activity of propolis and chlorhexidine on salivary isolates of *Candida albicans* and *Streptococcus mutans* in children with severe early childhood caries: an in vitro study. Int J Clin Pediatr Dent 2024;17(5):591-5. doi:10.5005/jp-journals-10005-2875
14. Abozaid D, Elwakeel E, Mohamed MA, Bahnsawy MA, Eldebawy M, Elraggal A, et al. Effects of propolis-modified glass ionomer cement on antimicrobial activity and physico-mechanical properties: a systematic review. Odontology 2026;114(2):468-93. doi:10.1007/s10266-025-01209-y
15. Zhang OL, Yin IX, Yu OY, Luk K, Niu JY, Chu CH. Advanced lasers and their applications in dentistry. Dent J (Basel) 2025;13(1):37. doi:10.3390/dj13010037
16. Barenghi L, Barenghi A, Scribante A, Pellegrini M, Spadari F. Laser-assisted dentistry, safety, and cross-infection control: a narrative review. J Appl Pharm Sci 2025;15(3):001-21. doi:10.7324/JAPS.2025.210316
17. Fiegler-Rudol J, Skaba D, Kawczyk-Krupka A, Wiench R. Antibacterial and bactericidal effects of the Er: YAG laser on oral bacteria: a systematic review of microbiological evidence. J Funct Biomater 2025;16(6):209. doi:10.3390/jfb16060209
18. Santini A, Ivanovic V, Ibbetson R, Milia E. Influence of cavity configuration on microleakage around class V restorations bonded with seven self-etching adhesives. J Esthet Restor Dent 2004;16(2):128-35; discussion 36. doi:10.1111/j.1708-8240.2004.tb00020.x
19. Crăciunescu EL, Negruţiu ML, Romînu M, Novac AC, Modiga C, Caplar BD, et al. Dental anatomy and morphology of

permanent teeth. In: Ardelean LC, Rusu LC, eds. Human Teeth - From Function to Esthetics. London: IntechOpen; 2023. doi:10.5772/intechopen.110223
20. Danevitch N, Frankenberger R, Lücker S, Gärtner U, Krämer N. Dentin bonding performance of universal adhesives in primary teeth in vitro. Materials (Basel) 2023;16(17):5948. doi:10.3390/ma16175948
21. Büyüksalih AA, Boran S, Demirel A, Ökte Z. Evaluation of shear bond strength of compomer repaired with different protocols. Cumhur Dent J 2025;28(3):370-4. doi:10.7126/cumudj.1659233
22. International Organization for Standardization (ISO). Dentistry—Testing of Adhesion to Tooth Structure (ISO/TS 11405:2015). Geneva: ISO; 2015.
23. Thatphet P, Prawatvatchara W, Klaisiri A, Sriamporn T, Thamrongananskul N. Effect of dentin surface pretreatments and thermocycling on the shear bond strength of resin cement: an in vitro study. J Compos Sci 2026;10(2):106. doi:10.3390/jcs10020106
24. Hubbezoğlu İ, Alıcı O. The efficacy of four cavity disinfectant solutions and two different types of laser on the micro-shear bond strength of dentin adhesives. Cumhur Dent J 2018;21(1):9-17. doi:10.7126/cumudj.389990
25. Farahat F, Davari A, Ghasemzadeh Z. Effect of Er: YAG laser versus chlorhexidine disinfection on dentin bond strength of two adhesive systems. J Dent Mater Tech 2025;14(3):141-6. doi:10.22038/jdmt.2025.85683.1780
26. Monghini EM, Wanderley RL, Pécora JD, Palma Dibb RG, Corona SA, Borsatto MC. Bond strength to dentin of primary teeth irradiated with varying Er: YAG laser energies and SEM examination of the surface morphology. Lasers Surg Med 2004;34(3):254-9. doi:10.1002/lsm.20023
27. Ramos RP, Chimello DT, Chinelatti MA, Nonaka T, Pécora JD, Palma Dibb RG. Effect of Er: YAG laser on bond strength to dentin of a self-etching primer and two single-bottle adhesive systems. Lasers Surg Med 2002;31(3):164-70. doi:10.1002/lsm.10106
28. Ceballo L, Toledano M, Osorio R, Tay FR, Marshall GW. Bonding to Er-YAG-laser-treated dentin. J Dent Res 2002;81(2):119-22. doi:10.1177/154405910208100207
29. Wang JH, Yang K, Zhang BZ, Zhou ZF, Wang ZR, Ge X, et al. Effects of Er: YAG laser pre-treatment on dentin structure and bonding strength of primary teeth: an in vitro study. BMC Oral Health 2020;20(1):316. doi:10.1186/s12903-020-01315-z
30. Say EC, Koray F, Tarim B, Soyman M, Gülmez T. In vitro effect of cavity disinfectants on the bond strength of dentin bonding systems. Quintessence Int 2004;35(1):56-60.
31. Ersin NK, Candan U, Aykut A, Eronat C, Belli S. No adverse effect to bonding following caries disinfection with chlorhexidine. J Dent Child (Chic) 2009;76(1):20-7.
32. Oznurhan F, Ozturk C, Ekci ES. Effects of different cavity-disinfectants and potassium titanyl phosphate laser on microtensile bond strength to primary dentin. Niger J Clin Pract 2015;18(3):400-4. doi:10.4103/1119-3077.151774
33. Arslan S, Yazici AR, Gorucu J, Ertan A, Pala K, Ustun Y, et al. Effects of different cavity disinfectants on shear bond strength of a silorane-based resin composite. J Contemp Dent Pract 2011;12(4):279-86. doi:10.5005/jp-journals-10024-1047
34. de Moraes Porto IC, de Almeida DC, de Oliveira Costa GV, Sampaio Donato TS, Nunes LM, Gomes do do Nascimento TC, et al. Mechanical and aesthetics compatibility of Brazilian red propolis micellar nanocomposite as a cavity cleaning agent. BMC Complement Altern Med 2018;18(1):219. doi:10.1186/s12906-018-2281-y
35. Estafan AM, Estafan D. Microleakage study of flowable composite resin systems. Compend Contin Educ Dent 2000;21(9):705-14.
36. Ramos RP, Chimello DT, Chinelatti MA, Dibb RG, Mondelli J. Effect of three surface sealants on marginal sealing of class V composite resin restorations. Oper Dent 2000;25(5):448-53.
37. Leevailoj C, Cochran MA, Matis BA, Moore BK, Platt JA. Microleakage of posterior packable resin composites with and without flowable liners. Oper Dent 2001;26(3):302-7.
38. Palaz E, Ölmez A, Hatipoğlu Palaz Z. Effects of boric acid and chlorhexidine as cavity disinfectants on microleakage and microshear bond strength in primary teeth. Children (Basel) 2026;13(3):417. doi:10.3390/children13030417
39. Turkistani A, Sonbul HM, Almarzouki M. Influence of chlorhexidine dentin disinfection on universal adhesive performance: interfacial adaptation and bond strength assessments. PLoS One 2024;19(12): e0315036. doi:10.1371/journal.pone.0315036
40. ElMansy MM, Tadros SS, Saleh RS, Abdelmonem R, El Menoufy H, Shawky N. Comparative evaluation on the effect of different cavity disinfectant nano gels; chlorohexidine, propolis, liquorice versus diode laser in terms of composite microleakage (comparative in vitro study). BDJ Open 2023;9(1):49. doi:10.1038/s41405-023-00176-2
41. Heintze SD. Clinical relevance of tests on bond strength, microleakage and marginal adaptation. Dent Mater 2013;29(1):59-84. doi:10.1016/j.dental.2012.07.158
42. Aranha AC, Turbino ML, Powell GL, Eduardo Cde P. Assessing microleakage of class V resin composite restorations after Er: YAG laser and bur preparation. Lasers Surg Med 2005;37(2):172-7. doi:10.1002/lsm.20208
43. Navarro RS, Gouw-Soares S, Cassoni A, Haypek P, Zezell DM, de Paula Eduardo C. The influence of erbium: yttrium-aluminum-garnet laser ablation with variable pulse width on morphology and microleakage of composite restorations. Lasers Med Sci 2010;25(6):881-9. doi:10.1007/s10103-009-0736-6