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# MICROLEAKAGE EVALUATION OF COMPOSITE RESIN RESTORATION IN CLASS V CAVITIES USING ER,CR:YSGG LASER IN PRIMARY TEETH (IN VITRO STUDY)

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**ABSTRACT**

**BACKGROUND.** Marginal microleakage is a key factor in assessing cavity preparation methods, as it affects restoration longevity and can lead to secondary caries and pulpal complications. This in vitro study compared microleakage in Class V composite restorations using Er,Cr:YSGG laser and conventional carbide bur, assessed through dye penetration.

**DESIGN**. In vitro study.

**METHODS.** Twenty-two sound primary molars were randomly allocated into two groups (N=11 each), with allocation based on the technique used for Class V cavity preparation. Group I - Er,Cr:YSGG laser, Group II - carbide bur. Composite resin was utilized as cavity restorative material. Samples were subjected to thermocycling, dyed, sectioned, and analyzed under a stereomicroscope. Microleakage scores and penetration depths were compared between groups using the Mann-Whitney U test, while differences between the gingival and occlusal regions within each group were analyzed using the Wilcoxon Signed Rank test. Dentin topographic features were evaluated using scanning electron microscope.

**RESULTS.** The significance level for statistical analysis was set at $p \leq 0.05$. Microleakage at occlusal and gingival margins wasn't statistically significant between groups (p=0.945). The Er,Cr:YSGG laser showed less microleakage at occlusal margins (p=0.046). SEM showed irregular dentin surfaces in the laser group, while bur-prepared dentin appeared more regular with minimal smear layer

**CONCLUSION.** The Er,Cr:YSGG laser is a promising minimally invasive method, preserving tooth structure and patient comfort. However, surface irregularities may compromise marginal sealing and increase microleakage. Clinically, this highlights the need to optimize laser settings to improve restoration longevity and reduce complications like sensitivity and secondary caries.

**KEYWORDS:** Primary Teeth; Class V Cavity; Er,Cr:YSGG Laser; Carbide Bur.

**RUNNING TITLE**: Microleakage of Composite Restorations in Primary Teeth Using Er,Cr:YSGG Laser.

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## INTRODUCTION

Minimally invasive dentistry focuses on early caries detection and assessing the caries risk to personalize treatment. It emphasizes preserving healthy tooth structure through micro-invasive techniques and preparing cavities with minimal intervention. Additionally, it incorporates dynamic therapy using biologically active materials and modern adhesives to promote healing and effective restoration(1).

The growing preference for minimally invasive dentistry has spurred the creation of innovative instruments and materials. Among these, laser technology has become increasingly favored for its numerous advantages in modern dental practice. Erbium lasers are versatile, capable of treating both hard and soft tissues, and FDA approved for a wide range of dental procedures(2).

Er:YAG, as well as Er,Cr:YSGG, part of the erbium infrared lasers, has increasingly supplanted traditional low and high-speed dental drills in various applications. They offer equivalent clinical outcomes while reducing the discomfort felt by the patient by removing pressure sensation, noise, the need for local anesthesia in most cases, and vibration (3).

Reduced discomfort and minimal vibration associated with Er,Cr:YSGG laser preparation improve patient tolerance and cooperation, particularly in pediatric and anxious populations, which may facilitate better operator control and precision during cavity preparation. This enhanced clinical manageability can contribute to more conservative and accurate cavity designs, potentially reducing stress-induced errors that compromise adhesive sealing and lead to microleakage in composite restorations(4).

Using Er,Cr:YSGG laser, hydroxyapatite and water absorb the laser power efficiently at 2.78 µm wavelength. Ablation occurs through micro-explosions, leading to both microscopic and macroscopic irregularities. The cutting of hard tissue is believed to result, in part, from the laser energy absorbed by water microdroplets.

Laser irradiation induces both morphological and chemical alterations on the dentin surface, which may influence the performance of adhesive restorative materials, particularly in terms of microleakage(5). Specifically, The Er,Cr:YSGG laser treatment modifies dentin morphology by effectively removing the smear layer and exposing open dentinal tubules, thereby facilitating adhesive penetration and potentially enhancing bond strength(6).

However, laser-irradiated dentin often exhibits an irregular topography characterized by micro-cracks, subsurface alterations, and areas of partially melted or recrystallized mineral content (7).

These microstructural changes may compromise the formation of a uniform hybrid layer, negatively impacting adhesive adaptation and increasing the risk of microleakage at the tooth-restoration interface (8). Furthermore, the inconsistent surface roughness and presence of thermal damage can interfere with resin infiltration and polymerization, particularly when self-etch adhesives are employed in isolation (7). Recent studies have demonstrated that Er,Cr:YSGG laser conditioning can adversely affect dentin bond strength and increase nanoleakage in universal adhesive systems (8).

Additionally, comparisons between laser and acid etching techniques indicate that phosphoric acid etching provides better results than laser etching for enamel surface treatment, reducing microleakage on both occlusal and gingival surfaces (9).

Moreover, the use of Er,Cr:YSGG laser has been associated with increased microleakage in composite resin restorations, emphasizing the need for careful consideration of surface treatment methods (7).

Multiple SEM studies (10-12) demonstrated that cavity preparation on primary teeth using the Er:YAG laser with various settings resulted in the smear layer's absence and exposed dentinal tubules. Dentin melting was not observed at 200 mJ or 300 mJ, but at 400 mJ, evident dentin melting and cracks were noted. Higher powers of the laser may cause dentin damage(10). Limited research has investigated the impact of the Er,Cr:YSGG laser on the topography of primary dentin as observed through SEM analysis (13, 14).

Adhesive dental restorations' durability, especially composite resins, relies heavily on the strength and longevity of the marginal seal. Inadequate seal at the margins of the restoration may permit the infiltration of oral bacteria and fluids, leading to recurrent caries, postoperative sensitivity, and adverse pulpal responses. The surface roughness of prepared tissues, along with the physical and chemical properties of restorative materials, are interconnected factors that affect leakage (15). Thus, it is essential that the marginal integrity of restorations are not impaired by laser application.

This study aimed to evaluate the impact of Er,Cr:YSGG laser cavity preparation on the microleakage of Class V composite restorations and to compare it with restorations prepared using a conventional carbide 330 bur.

The study also explored the changes in dentin topography resulting from Er,Cr:YSGG laser cavity preparation, comparing them with those induced by conventional preparation methods under scanning electron microscope with the goal of improving restoration longevity and reducing the risk of complications such as secondary caries and postoperative sensitivity.

Both cavity preparation methods are believed to allow effective bonding, though laser preparation can cause thermal damage and surface irregularities, potentially increasing microleakage. Studies show mixed results: some report higher microleakage with laser-treated surfaces (16, 17). while others find similar or superior outcomes when proper adhesives are used (18, 19).

Existing literature presents contradictory findings regarding the impact of these two methods on microleakage, with a limited number of studies specifically focusing on primary teeth. Therefore, the null hypothesis is justified based on these inconsistencies in the data.

The null hypothesis proposed that there would be no significant difference in the microleakage of composite resin restorations in primary molars with Class V cavities prepared using a tungsten carbide bur and an Er,Cr:YSGG laser.

## MATERIALS AND METHODS

### Study Settings

The study was performed at the Pediatric Dentistry, Dental Public Health, and of Dental Biomaterials departments of the Faculty of Dentistry, Alexandria University. While the scanning electron microscope part of the research was conducted at the Electron Microscope Unit of the Faculty of Science, Alexandria University.

### Ethical Consideration

Ethical approval for this study was granted by the ethics committee of Alexandria University Faculty of Dentistry (IRB No. 001056 – IORG 0008839).

### Sample size estimation

Sample size was estimated assuming 5% alpha error and 80% study power. According to Baghalian et al,(20) the overall mean (SD) microleakage values was 261.06 (113.5) µm for bur preparation and 108.35 (75.07) µm for laser preparation. Based on the difference between independent means using the highest SD = 113.5 to ensure enough study power, a sample of 10 per group was required, yielding an effect size of 1.345. This was increased to 11 samples to make up for processing errors. Total sample = Number per group x Number of groups = 11 x 2 = 22 samples.

Sample size was based on Rosner's method (21) and calculated by G*Power 3.1.9.7.(22).

**Study sample**

A total of twenty-two recently extracted sound primary molars, obtained due to orthodontic indications or natural exfoliation, were selected for this study. Teeth with existing restorations, developmental defects, or visible cracks were excluded. All specimens were examined under a light microscope to ensure the absence of enamel defects in accordance with the predefined selection criteria (23, 24). Selected Samples were kept for a month at 5 °C in artificial saliva until they were used (25).

**Randomization technique, allocation**

Samples which fulfilled the inclusion criteria were assigned randomly based on cavity preparation technique using a computer generated list of random numbers (version 1.0.0) (26) to one of the two parallel arms of the study, Experimental group (Group I) prepared by Er,Cr:YSGG laser (n=11) and Control group (Group II) prepared by conventional tungsten carbide bur (n=11).

**Grouping**

The selected teeth were randomly allocated to two groups according to the cavity preparation procedure: Group I (n=11): prepared by Er,Cr:YSGG laser (Experimental Group).

Group II (n=11): prepared by conventional tungsten carbide bur (Control Group).

**Blinding**

The statistician was blinded to the group allocation of each sample, while a blinded independent technician prepared the samples for microleakage testing and the scanning electron microscope imaging. Additionally, another blinded observer evaluated the microleakage scores of the specimens. Therefore, this study was designed as a triple-blinded experimental in vitro study.

**Methods**

**Sample preparation**

A pumice slurry fluoride free and a rubber cup were used to clean the primary molars (25). After being fully sealed with sticky wax, Each tooth was vertically embedded in a cylindrical mold filled with chemically cured acrylic resin (Duralay, Reliance Dental Mfg. Co., Itasca, IL, USA), ensuring that the cementoenamel junction remained 1 mm above the resin surface to allow standardized cavity preparation and handling (27).

**Cavity preparation, Conditioning, and restoring**

A standardized class V cavity, measuring 2 mm in width, height, and depth, was created on the buccal surface of each tooth.

To minimize operator-induced bias, cavity preparations were standardized by employing fixed parameters for both Er,Cr:YSGG laser and conventional bur techniques. The cavity preparation techniques were performed by a single operator under controlled conditions, minimizing variability. Additionally, the operator underwent comprehensive training and calibration sessions to ensure consistency and reproducibility across all samples.

Furthermore, to minimize operator-induced bias, an external blinded evaluator independently verified the laser settings and cavity dimensions in both groups, enhancing the reliability of the cavity preparation process (28, 29).

The samples were prepared by the following procedure**:**

**Group I (Experimental Group):** Er,Cr:YSGG laser (Biolase Technology, Inc., California, USA) was used to produce the cavities with a wavelength of 2,780 nm, pulse length of 140–200 µs, and repetition rate of 20 Hz. A fiber optic system was used to deliver laser energy to a sapphire tip (Biolase Technology, Inc., California, USA.) that was 600 µm in diameter and 6 mm long. The recommended settings for cutting enamel and dentin were as follows: 3 W power, 85% water flow, and 85% air flow for enamel , and 2 W power, 65% air flow, and 55% water flow for dentin(30). The laser was held manually next to a marked ruler in non-contact mode to regulate and standardize the 1 mm distance between the laser beam source and the target.

**Group II (Control Group):** Using a high-speed hand piece and water spray cooling, the cavities were prepared with a 330-carbide bur (Komit, Florida, USA). For every five preparations, a fresh bur was utilized. A pre-calibrated periodontal probe served as a reference tool for measuring the cavity depth in both groups to ensure consistency (20).

Excess moisture was removed by gently air-drying all the samples before they were etched for 15 seconds with 37% phosphoric acid (Meta Biomed Co., Colmar, USA), followed by a 20-second rinse as per the manufacturer's guidelines.

In line with the manufacturer's recommendations (31), cavities were carefully dried using a moist cotton pellet. A single coat of adhesive system (3M Single Bond Universal, 3M ESPE, Nessus, Germany) was subsequently applied and evenly distributed on the etched surface with a fully saturated applicator, with gentle agitation for 20 seconds. The adhesive was then light cured (Shofu Inc., Kyoto, Japan) for 10 seconds. Thereafter, the cavities were filled with composite resin material (3M™ Filtek™ Z350 XT Universal Restorative Composite, 3M ESPE, Nessus, Germany) and followed by light-curing for 40 seconds. Finishing and polishing of the restorations were done by using white Points (Shofu Inc., Kyoto, Japan).

The samples were maintained in distilled water at a temperature of 37°C(32) for 24 hours Before undergoing 1,000 thermocycling cycles at temperatures ranging from 5°C to 55°C.". Once thermocycling was completed, the teeth were coated with double layers of nail varnish, creating a 1 mm border around the restoration margin. The samples were then soaked in a 2% methylene blue solution at 37°C for a day, rinsed for 30 minutes, and bisected longitudinally in the buccolingual direction through the center of the restoration to create two equal halves (20).

Using a stereomicroscope (OLYMPUS stereomicroscope sz11, Olympus optical co. Ltd,2-43-2, Hatagaya shibuyaka, Tokyo, Japan), both halves of each sample were examined. The image was displayed on a computer screen for analysis after the extent of dye penetration at the occlusal and cervical edges of the restorations was assessed at a 20x magnification (33). The highest microleakage score for each sample was recorded in Qualitative manner by a four-point qualitative scale (34). A score of 0 indicated no dye penetration, whereas a score of 3 meant that the dye had penetrated all the way to the cavity floor along the cavity edge (Table.1). Marginal microleakage was quantitatively measured in micrometers (µm) using a stereomicroscope.

**Scanning Electron Microscope Study of Prepared Cavities**

From each group two extra random cavities that weren't included in the sample size were prepared for analysis with scanning electron microscope (JEOL Ltd., Tokyo, Japan) to investigate the variations in dentin topographic features following preparation with a carbide bur as well as Er,Cr:YSGG laser using the subsequent methodology:

All samples underwent dehydration by sequentially exposing them to progressively higher concentrations of ethyl alcohol (50%, 70%, 95%), followed by absolute alcohol. They were then vacuumed and coated with a gold-palladium layer prior to SEM examination (35, 36).

**Statistical Analysis**

The Shapiro-Wilk test and Q-Q plots were used to evaluate normality. Microleakage dye penetration scores and penetration depth were not normally distributed. Quantitative data were expressed as mean, median, standard deviation, minimum, and maximum values, while qualitative data were illustrated as count and percentage.

The Mann-Whitney U test was used to compare microleakage scores and penetration depth between groups. Differences in these variables between the gingival and occlusal regions within each group were analyzed using the Wilcoxon Signed Rank test. Each test was conducted as two-tailed, with a significance threshold of $p \leq 0.05$. Data was analyzed using IBM SPSS, version 23 for Windows, Armonk, NY, USA.

## RESULTS

**Dye penetration assessment**

Qualitatively, the median overall microleakage score in the laser group was 1.00 (0.00-2.00); while in the bur group was 1.00 (0.00-3.00). The microleakage scores between the laser and bur groups did not show a statistically significant difference ($p = 0.94$).

In the laser group, occlusal margins demonstrated significantly lower microleakage compared to gingival margins *(p = 0.04)*. While in bur group, no statistically significant difference in microleakage was observed between the occlusal and gingival margins *(p = 0.60)*, (Table.2)

Quantitatively, the depth of dye penetration, measured in micrometers, showed no statistically significant difference between the two groups *(p = 0.714)* or between the occlusal and gingival margins within the same group. (laser, occlusal median= 145.97, gingival median = 332.45 *(p = 0.17);* bur, occlusal median = 0, gingival median = 342.72 *(p = 0.57)*).

Yet, despite the non-significance, the occlusal margins in both groups exhibited less microleakage than cervical margins (Table.3).

**Table 1.** Criteria for the microleakage scoring.

| Scores | Description |
|---|---|
| **0** | No dye penetration. |
| **1** | Dye penetration through cavity margin reaching the enamel tissue. |
| **2** | Dye penetration through cavity margin reaching the dentin tissue. |
| **3** | Dye penetration through cavity margin reaching the cavity floor. |

**Table 2.** Comparison of microleakage scores between the Laser cavity preparation and bur Cavity Preparation.

| | | Laser (n=11) | Bur (n=11) | *p* value |
|---|---|---|---|---|
| **Occlusal** | Score 0 | 5 (45.5%) | 6 (54.5%) | 0.853 |
| | Score 1 | 6 (54.5%) | 4 (36.4%) | |
| | Score 2 | 0 (0%) | 0 (0%) | |
| | Score 3 | 0 (0%) | 1 (9.1%) | |
| | Mean ±SD | 0.55 ±0.52 | 0.64 ±0.92 | |
| | Median (Min - Max) | 1.00 (0.00 – 1.00) | 0.00 (0.00 – 3.00) | |
| **Gingival** | Score 0 | 4 (36.4%) | 5 (45.5%) | 0.780 |
| | Score 1 | 4 (36.4%) | 3 (27.3%) | |
| | Score 2 | 3 (27.3%) | 3 (27.3%) | |
| | Score 3 | 0 (0%) | 0 (0%) | |
| | Mean ±SD | 0.91 ±0.83 | 0.82 ±0.87 | |
| | Median (Min - Max) | 1.00 (0.00 – 2.00) | 1.00 (0.00 – 2.00) | |
| ***p* value** | | 0.046* | 0.608 | |
| **Overall** | Score 0 | 4 (36.4%) | 5 (45.5%) | 0.945 |
| | Score 1 | 4 (36.4%) | 2 (18.2%) | |
| | Score 2 | 3 (27.3%) | 3 (27.3%) | |
| | Score 3 | 0 (0%) | 1 (9.1%) | |
| | Mean ±SD | 0.91 ±0.83 | 1.00 ±1.10 | |
| | Median (Min - Max) | 1.00 (0.00 – 2.00) | 1.00 (0.00 – 3.00) | |

*Statistically significant difference at $p$ value≤0.0

**Table 3.** Comparison of depth (µm) among the study groups.

| | | Laser (n=11) | Bur (n=11) | *p* value |
|---|---|---|---|---|
| **Occlusal** | Mean ±SD | 228.48 ±291.85 | 189.91 ±325.35 | 0.551 |
| | Median (Min - Max) | 145.97 (0.00 – 857.81) | 0.00 (0.00 – 1065.86) | |
| **Gingival** | Mean ±SD | 302.36 ±265.34 | 270.58 ±277.40 | 0.812 |
| | Median (Min - Max) | 332.45 (0.00 – 680.69) | 342.72 (0.00 – 670.78) | |
| ***p* value** | | 0.176 | 0.176 | |
| **Overall** | Mean ±SD | 265.42 ±264.02 | 230.25 ±221.84 | 0.714 |
| | Median (Min - Max) | 239.21 (0.00 – 746.33) | 215.78 (0.00 – 704.29) | |

**Scanning electron microscope study of prepared cavities**

Scanning electron microscope micrographs of dentin cavities from both groups were captured at X1600 magnification. Cavities prepared with a bur displayed a smooth, open dentinal tubules and consistent dentin surface, insignificant amount of smear layer, and intact odontoblastic processes (Fig.1). In contrast, the laser-treated cavities showed exposed dentinal tubules, an uneven, rough surface, and no smear layer., and the presence of cracks and fissures (Fig.2,3).

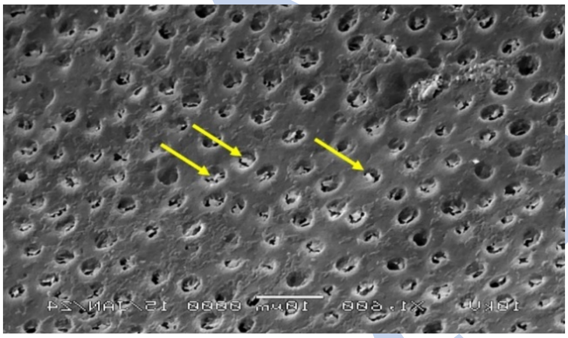

**Figure 1**: SEM scan of dentin after carbide bur cavity preparation showing regular surface with patent dentinal tubules with viable odontoblastic processes (yellow arrow) and minimal amount of smear layer

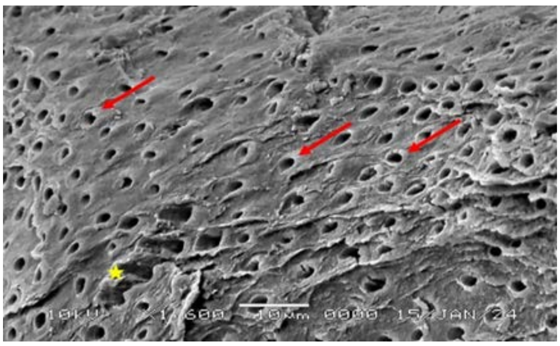

**Figure 2**: SEM scan of dentin after Er,Cr:YSGG laser cavity preparation showing irregular surface with protruding peritubular dentin (red arrow), signs of melting (yellow star) and absence of smear layer.

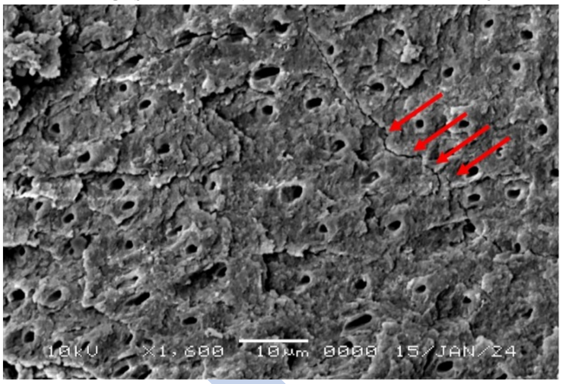

**Figure 3**: SEM scan of dentin after Er,Cr:YSGG laser cavity preparation showing irregular surface with protruding peritubular dentin (red arrow), flaking and absence of smear layer.

## DISCUSSION

The purpose of this study was to investigate how different cavity preparation techniques affect the microleakage of primary teeth's composite resin restorations, with the findings being further explained through scanning electron microscope analysis of the primary dentin surface following cavity preparation.

Pulp response to restorative materials is primarily influenced by the level of microleakage, which refers to the gap between composite resin and cavity wall, which can become occupied with oral fluids, supplying an environment that is favorable for the growth of new bacteria.

Because of mechanical fatigue brought on by frequent chewing forces, the variations in temperature of the oral environment, and most importantly the direction of polymerization shrinkage forces, microleakage then happens when bacteria and their toxins seep through the cavity walls and the restoration (37).

Microleakage reflects the passage of fluids, bacteria, and ions at the tooth-restoration interface, which may lead to postoperative sensitivity, marginal staining, secondary caries, and eventual restoration failure, particularly in Class V cavities where gingival margins are more prone to adhesive failure due to proximity to dentin and cementum (38). Thus, Microleakage offers more direct quantifiable insights into the sealing ability of adhesive restorations.

Nanoleakage, by contrast, focuses on the ultrastructural level, detecting nanometer-scale porosities and fluid infiltration within the hybrid layer of the adhesive often resulting from bonding process and adhesive material used. Although it offers informative data about potential long-term degradation of the hybrid layer, it has less established clinical relevance regarding restoration longevity and patient outcomes (39).

Various methods for assessing microleakage have been proposed in the literature, with dye penetration being among the most commonly used. In this in vitro study, the organic dye technique was employed, using 2% methylene blue due to its low molecular weight and excellent penetrability (40).

In vitro studies provide a highly controlled and standardized environment for evaluating microleakage, enabling accurate manipulation of critical variables such as cavity dimensions, laser parameters, and restorative protocols without the biological variability present in clinical conditions. This level of control improves the reproducibility and validity of results, making it particularly effective for isolating the influence of cavity preparation techniques, including Er,Cr:YSGG laser and traditional bur preparation (41).

Moreover, in vitro experiments exclude confounding patient-related factors such as salivary contamination, occlusal stress, and inconsistent oral hygiene, all of which may compromise the consistency of in vivo findings (42). Furthermore, ethical concerns, especially when working with pediatric patients, make in vitro testing a safer and more feasible initial approach before translating findings into clinical applications (43).

The key benefits of utilizing the Er,Cr:YSGG laser in this research include its excellent affinity to water and hydroxyapatite, effectively cutting dental hard tissues, eliminating smear layer formation, bactericidal properties, and generating microscopic surface irregularities that can serve as an alternative to acid etching (19).

Several investigations stated that the laser cavity preparation gave less microleakage than bur cavity preparation (19, 44-46), while others found no difference in microleakage between both techniques (34, 37, 40, 47). Owing to insufficient contrasting data, the possible advantages of using the Er,Cr:YSGG laser for aided cavity preparation were investigated in this study and contrasted it with the gold standard conventional cavity preparation by tungsten carbide bur in relation to class V composite restoration microleakage.

Because class V cavities are more easily adjustable in distance with laser tip from tooth substance; Compared to other cavity types; class V cavities appear to be superior models for evaluating microleakage. Furthermore, microleakage is very crucial when it comes to class V restorations, particularly at the gingival margin. Marrotti et al.(2010) (48) and Lupi Pegurier (2007) (49) in their studies on class V restorations of permanent molars demonstrated that acid etching following Er,Cr:YSGG laser application reduces microleakage. Therefore, the acid etching process was incorporated into this study.

The microleakage scores recorded in this study between laser cavity preparation and bur cavity preparation and measured qualitatively by two blinded calibrated trained operators using scoring system, and quantitatively under stereomicroscope magnification measured in micrometers, exhibited no statistically significant difference. These results were consistent with share of researchers, and they suggest that both techniques offer comparable sealing ability when restoring Class V cavities with composite resin (34, 50-53).

Clinically, this implies that laser preparation can be used without compromising marginal integrity, thereby allowing clinicians to benefit from its advantages, such as reduced vibration, minimal noise, and increased patient comfort especially in pediatric dentistry (34).

Consequently, the study's null hypothesis was accepted.

Scanning electron microscope (SEM) analysis of dentin surface following Er,Cr:YSGG laser cavity preparation revealed pronounced topographical alterations, including the absence of a smear layer, irregular surface morphology, micro-cracks, gaps, and areas of flaking. These features reflect extensive microstructural changes such as melted and resolidified dentin with prominent peritubular dentin and coagulation necrosis of odontoblastic processes with empty patent dentinal tubules.

The bur cavity group, on the other hand, showed a smooth, uniform surface of dentin with patent dentin tubules and a negligible smear layer. In bur group, SEM scans showed that the odontoblastic processes were evident and viable which enables remineralization of dentin at dentin- restoration interphase (54).

Previous SEM analyses of cavities prepared with the Er,Cr:YSGG laser have demonstrated distinct morphological characteristics, including exposed enamel rods, pronounced peritubular dentin, widely open dentinal tubules, surface flaking, and a complete absence of the smear layer, findings that are consistent with the observations reported in the present study (34, 36).

The morphological changes result from rapid localized heating and ablation during laser irradiation, which can expose dentinal tubules, modify surface energy, and potentially enhance adhesive penetration. On the other hand, the presence of surface defects, particularly thermal cracks and fusion zones, may adversely affect the long-term integrity of the adhesive interface by creating zones of mechanical weakness or stress concentration under masticatory forces (55).

To mitigate the surface defects observed following Er,Cr:YSGG laser cavity preparation, several strategies have been proposed. These include optimizing laser parameters, such as energy levels, pulse duration, and cooling techniques, to minimize thermal damage and micro-irregularities (55). Additionally, the combination of laser preparation with modification of laser tip design, the use of appropriate etchants or primers and enhanced cooling techniques have been suggested to enhance surface regularity and bonding performance (56-58) . These adjustments are critical for improving the clinical outcomes of laser-prepared cavities.

Therefore, while the immediate marginal seal achieved with laser preparation appears clinically acceptable, the altered dentin topography must be carefully considered, as it may influence the durability and performance of resin-dentin bonding over time. Further longitudinal and in vivo studies are needed to fully understand how these laser-induced changes affect the long-term success of restorations.

## CONCLUSION

This study suggests that the Er,Cr:YSGG laser is a viable alternative to carbide bur for minimally invasive cavity preparation, offering advantages such as reduced noise, less vibration, and a decreased need for dental anesthesia, which could improve patient comfort during procedures. While the microleakage results showed no significant difference between the laser and bur groups, the non-significant increase in microleakage does not strongly suggest the laser's disadvantages, but it highlights the need for careful consideration of surface quality when using lasers.

The SEM analysis revealed microscopic defects on the dentinal surface after laser cavity preparation, which could impact long-term restoration performance, potentially leading to adhesive failure or premature restoration breakdown. These defects, while not significantly influencing microleakage, emphasize the importance of refining laser parameters and ensuring appropriate surface treatment to optimize bonding quality and long-term outcomes.

Given these findings, further research is essential to refine laser techniques, evaluate their clinical implications in larger, more diverse populations, and address the limitations of this study, particularly regarding sample size, laser parameter optimization, and clinical application of microleakage results

**Limitations of the study**

1. Need for In Vivo Validation: As this was an in vitro study, it does not fully replicate the complex environment of the oral cavity. To confirm the clinical relevance of our findings, future in vivo studies are necessary.
2. Fixed Laser Parameters: Only one set of Er,Cr:YSGG laser parameters was used. Exploring different laser settings could provide deeper insights into optimizing outcomes
3. Limited Range of Preparation Techniques: The study compared only laser and conventional bur methods. Including other preparation techniques would allow for a more comprehensive evaluation.

**Conflict of interest**

The authors declare that they have no conflicts of interest.

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