ORIGINAL ARTICLE

Impact of Different Cavity Preparation Techniques on Dentin Bond Strength.

Basem Mohammed Abuzenada [1]

ABSTRACT

Background

The durability and effectiveness of dental restorations are greatly affected by the strength of the dentin bond. Adhesion between dentin and restorative materials may be affectedby several cavity preparation processes, including conventional, laser, and air abrasion. Examining how various cavity preparation methods affect dentin bond strength is the goal of this research.

Materials and Methods

The cavity preparation method was determined by randomly assigning 80 removed human molars to one of four groups: conventional rotary (control), laser, air abrasion, or ultrasonic. After the appropriate procedure was used to prepare each tooth, a composite resin substance with a bonding agent was used to repair it. Specimens were tested for microtensile bond strength after being stored in distilled water for 24 hours. Statistical analysis was performed using one-way ANOVA followed by Tukey's post hoc test, with a significance threshold of $p<0.05$. The findings were reported in megapascals (MPa).

Results

The bond strength values (mean ± SD) for the groups were Group 1 (Conventional rotary): 28.5 ± 4.2 MPa, Group 2 (Laser): 22.3 ± 3.8 MPa, Group 3 (Airabrasion): 25.7 ± 3.6 MPa, Group 4 (Ultrasonic): 27.1 ± 4.0 MPa. Statistical analysis showed that the conventional rotary and ultrasonic groups demonstrated significantly higher bond strengths compared to the laser group ($p<0.05$). The air abrasion group exhibited intermediatebond strength values, but no significant difference was observed between air abrasion and theother techniques.

Conclusion

Conventional rotary and ultrasonic techniques provide superior dentin bond strength compared to laser cavity preparation. Air abrasion yields comparable results to conventional methods but did not outperform them. Laser preparation significantly reduces bond strength, suggesting that it may require modified bonding protocols for optimaladhesion.

Keywords

Dentin bond strength, cavity preparation techniques, composite resin, laser, air abrasion, ultrasonic, microtensile bond test.

INTRODUCTION

The success and longevity of dental restorations depend largely on the strength of the bond between restorative materials and tooth structure, particularly dentin. Achieving optimal bond strength ensures the durability of the restoration and reduces the risk of microleakage, post-operative sensitivity, and secondary caries. Various techniques have been developed to prepare dental cavities, each of which may influence the bonding efficacy to dentin (1). Traditionally, the conventional rotary method has been the gold standard for cavity preparation, but newer methods such as laserablation, air abrasion, and ultrasonic preparation have gained popularity due totheir minimally invasive nature (2,3).

The conventional rotary technique, which uses high-speed drills, effectively removes carious tissue but can cause micro-cracks and smear layer formation, potentially interfering with adhesion (4). Laser cavity preparation, on the other hand, offers advantages such as precise tissue removal and reduced patient discomfort, but concerns have been raised about its ability to form a surface conducive to strong bonding (5). Similarly, air abrasionand ultrasonic techniques are considered less aggressive alternatives, producing less thermal damage and reducing microleakage,but their effects on dentin bonding are still under investigation (6).

1. Associate Professor, Faculty of Dentistry, King Abdul Aziz University, Jeddah, Saudi Arabia, Batterjee Medical College, Jeddah Saudi Arabia, E-mail: Bmabuzenada@kau.edu.sa

Correspondence:

Basem Mohammed Abuzenada, Associate Professor, Faculty of Dentistry, King Abdul Aziz University, Jeddah, Saudi Arabia, Batterjee Medical College, Jeddah Saudi Arabia, E-mail: Bmabuzenada@kau.edu.sa

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Recent studies have compared the bond strengths of different cavity preparation techniques, but results are inconsistent. Some have suggested that laser-prepared cavities exhibit reduced bond strength due to a lack of micromechanical retention (7), while others argue that air abrasion and ultrasonic methods may provide bond strengthscomparable to or even superior to conventional methods (8,9). Given the variation in findings, further investigation is warranted to clarify the impact of these preparation techniques on dentin bond strength and provide clinical guidance.

Examining the bond strength of dentin after preparation using four distinct methods is the objective of this research: conventional rotary, laser, air abrasion, and ultrasonic. Byanalyzing the microtensile bond strength, we hope to determine which method provides the most reliable adhesion between the restorative material and dentin.

Materials and Methods Sample Selection

We stored 80 whole human molars in a 0.9%salt solution at 4 degrees Celsius until we required them. The teeth that were inspected did not have any obvious defects, including cracks or fractures. Based on the method of cavity preparation, the teeth were randomly divided into four groups, each with twenty teeth:

Bonding Procedure

Group 1: Conventional rotary(control)

Group 2: Laser

Group 3: Air abrasion

Group 4: Ultrasonic

Cavity Preparation

Standardized Class I cavities, 4 mm in depthand 3 mm in width, were prepared in the occlusal surface of each tooth. The different techniques were used as follows:

Group 1 (Conventional rotary): Cavities were prepared using a high- speed diamond bur with water coolant.

Group 2 (Laser): Cavities were prepared using an Er

laser (2.94 µm wavelength, 300 mJ, 10 Hz) with a non-contact handpiece.

Group 3 (Air abrasion): Cavities were prepared using an air abrasion device with 50 µm aluminum oxide particles at 80 psi.

Group 4 (Ultrasonic): Cavities were prepared using a piezoelectric ultrasonic scaler with a diamond- coated tip under water irrigation.

All cavity preparations were completed by a single operator to ensure consistency.

After the specimens were prepared for the cavities, they were cleaned with distilled water and let to air dry. The dentin surfaces that had been prepped were then coated with a universal adhesive system (Single Bond Universal, 3M ESPE) in accordance with thedirections provided by the manufacturer. The adhesive was subjected to a 20-second light curing process utilising a 1200 mW/cm² LEDcuring device.

For each cavity, 2 millimetres of composite resin (Filtek Z250, 3M ESPE) was put in layers and then light-cured for 20 seconds. Polishing and finishing each repair was doneusing a set of Sof-Lex discs (3M ESPE).

Microtensile Bond Strength Test

The teeth that were repaired were placed in distilled water and kept at 37°C for one day. Using a diamond saw and water as an irrigating agent, the teeth were cut longitudinally into slabs with a cross- sectional area of approximately 1 mm² after storage. The microtensile testing apparatus (Micro Tensile Tester, Bisco Inc.) was attached to each slab using cyanoacrylateadhesive.

Tensile force applied at a crosshead speed of half a millimetre per minute stretched the slabs until they gave way. To find the megapascal (MPa) bond strength, the

millimeter-squared bond area was divided bythe Newtonian load at failure.

Group 2: Laser	22.3	3.8
Group 3: AirAbrasion	25.7	3.6
Group 4: Ultrasonic	27.1	4.0

Statistical Analysis

To find out whether there were any significant differences between the groups, we used one-way ANOVA to look at the bondstrength data. At a significance level of $p<0.05$, Tukey's test was used to do post hoc

Bond Strength Comparison

Conventional rotary

(Group 1) comparisons. Mean ± standard deviation (SD) was used to represent the data.

RESULTS

A variety of cavity preparation processes were tested and evaluated for their microtensile bond strength values. The results are summarized in **Table 1**, with each group's average bond strength values (MPa) and their respective standard deviations (SD).Several groups showed statisticallysignificant differences ($p<0.05$).

Table 1: Microtensile Bond Strength (MPa) of Different Cavity Preparation Techniques exhibited the highest mean bond strength (28.5 ± 4.2 MPa), followed closely by the **Ultrasonic group (Group 4)** with a bond strength of 27.1 ± 4.0 MPa.

Group	Mean Bond Strength(MPa)	Standard Deviation(SD)
Group 1: Conventional Rotary (Control)	28.5	4.2

Laser-prepared cavities (Group 2) showed the lowest bond strength (22.3 ± 3.8 MPa), significantly lower than the other groups ($p<0.05$).
Air abrasion (Group 3) presented intermediate bond strength values (25.7 ± 3.6 MPa), which were not significantly different from the **Conventional rotary** or **Ultrasonic** groups ($p>0.05$).

Failure Mode Analysis

The types of bond failures observed during the microtensile testing were recorded as either adhesive, cohesive, or mixed failures. **Table 2** summarizes the failure modes for each group.

DISCUSSION

The **Laser group (Group 2)** showedThe findings of this study indicate that the choice of cavity preparation technique significantly affects the bond strength between dentin and restorative material. The highest bond strengths were observed in the **Conventional rotary (Group 1)** and **Ultrasonic (Group 4)** groups, while the the highest percentage of adhesive failures (60%), indicating weakerbonding to the dentin surface.

. **Ultrasonic-prepared cavities(Group 4)** had the highest proportionof cohesive

Table 2: Failure Mode Distributionway ANOVA ($p<0.05$). The bond strength ofthe Laser group (Group 2) was found to be considerably lower than that of the Conventional rotary and Ultrasonic groups, as validated by the post hoc Tukey's test($p<0.05$). When comparing the Air abrasion and Conventional rotary groups, no statistically significant difference was found.

Group	Adhesive Failure(%)	Cohesive Failure (%)	Mixed Failure (%)
Group 1:Conventional Rotary	40	30	30
Group 2:Laser	60	25	15
Group 3:Air Abrasion	50	20	30
Group 4:Ultrasonic	35	40	25

failures (40%), suggesting strong internal bonding within the composite.

. The **Conventional rotary group (Group 1)** exhibited a balanced distribution of adhesive, cohesive, and mixed failures.

Statistical Analysis

There were significant variations in binding strength across the groups, as shown by one-

Laser-prepared cavities (Group 2) exhibited the lowest bond strengths. These results align with previous studies suggesting that traditional mechanical preparation methods, such as rotary instruments, provide better micromechanical retention compared to newer techniques like laser ablation (1,2).

Conventional Rotary Preparation

Because of its efficacy in removing cavities and in creating a roughened dentin surface that improves bonding, the traditional rotary approach is still considered the norm for cavity preparation. This study confirmed previous research by Banerjee et al. (3) and Pashley et al. (4) that rotary-prepared dentin surfaces maintain a strong smear layer,

leading to better adhesive penetration and micromechanical interlocking, as the conventional rotary group exhibited the highest bond strength (28.5 ± 4.2 MPa).

Ultrasonic Preparation

Ultrasonic cavity preparation also performed well in this study, with bond strength values (27.1 ± 4.0 MPa) similar to the conventional rotary technique. This may be attributed to the precise, minimally invasive nature of ultrasonic instruments, which generate less thermal damage and microcrackingcompared to rotary tools. Previous studies have suggested that ultrasonic instrumentsresult in a more homogeneous smear layer, improving resin-dentin adhesion (5). Bavbek et al. (6) also reported comparable bond strengths between ultrasonic and rotary preparation, supporting the idea that ultrasonic methods may be a viablealternative for achieving reliable bond strength.

Laser Preparation

The laser preparation group demonstrated significantly lower bond strength (22.3 ± 3.8 MPa) than the conventional rotary andultrasonic groups. This finding is in agreement with earlier research by Ramos etal. (7), who found that laser-prepared dentin surfaces lacked the microretentive features necessary for strong bonding. Laser ablationtends to produce a smooth, glassy surface that

inhibits the infiltration of adhesive into the dentin, reducing the mechanical retention of the bond (8). Furthermore, the thermal effects of laser ablation may cause denaturation of collagen fibers, further compromising bond strength (9). Modifications to bonding protocols, such as the use of self-etching adhesives or laser-specific primers, may be necessary to improve the bond strength with laser-prepared cavities.

Air Abrasion Preparation

Air abrasion exhibited intermediate bond strength values (25.7 ± 3.6 MPa), which werenot significantly different from those of the conventional rotary or ultrasonic groups. Airabrasion produces a roughened dentin surface by blasting aluminum oxide particles, which may enhance adhesive penetration andretention (10). However, its bond strength was not superior to conventional techniques,possibly due to the variability in surface morphology created by the abrasive particles. Shahabi et al. (11) reported similar findings, concluding that air abrasion is an effective technique for cavity preparation but does not consistently outperform traditional methods.

Failure Mode Analysis

The failure mode analysis further supports the bond strength data. The laser group showed the highest percentage of adhesive failures (60%), indicating weaker bonding tothe dentin surface. Conversely, the

conventional rotary and ultrasonic groups showed higher proportions of cohesive and mixed failures, suggesting stronger internal bond integrity within the composite resin andadhesive interface (12). This trend is consistent with studies that have shown loweradhesive failure rates with rotary-prepared cavities due to the enhanced micromechanical retention provided by the roughened dentin surface (13).

Clinical Implications

From a clinical perspective, the results of this study suggest that conventional rotary and ultrasonic preparation techniques are more reliable for achieving strong dentin bonds. Laser preparation, while advantageous in certain clinical scenarios such as soft tissue management and minimally invasive dentistry, may require additional bonding steps or specialized adhesives to improve its performance (14). Air abrasion, though comparable in bond strength to traditional methods, may be reserved for specific cases where its minimally invasive properties are beneficial.

Limitations and Future Directions

The study's in vitro design means its findingsmay not be generalisable to the real world, where factors including humidity regulation, individual patients' differences, and occlusal forces play a role in bond performance. Further studies should focus on in vivo comparisons of these techniques, as well as long-term evaluations of bond durability. Additionally, investigations into the optimization of laser bonding protocols may help address the lower bond strength observed with this technique.

CONCLUSION

Conventional rotary and ultrasonic cavity preparation techniques offer superior dentin bond strength compared to laser and air abrasion methods. While laser preparationmay require modified bonding protocols to improve its efficacy, conventional methods continue to provide the most reliable outcomes for adhesive bonding in restorativedentistry.

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