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RESEARCH ARTICLE
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EVALUATION OF BOND STRENGTH OF DIFFERENT DENTAL ADHESIVES TO TOOTH STRUCTURE IN PAKISTANI PATIENTS

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Abstract

Background: The efficacy of dental adhesives might vary depending on local patient characteristics, but they are essential for long-lasting bonding between restorative materials and tooth structures.

Objective: To evaluate and compare the bond strength of different dental adhesive systems to enamel and dentin in extracted teeth from Pakistani patients.

Methodology: An in vitro experimental study was conducted at Department of Dental Material, Islamabad from January to June 2024. The 126 permanent human teeth that were taken from patients in Pakistan were split evenly into three groups based on the adhesive method that was used: Universal Adhesive, Self-Etch, and Total-Etch. In accordance with the manufacturer's instructions, teeth with undamaged enamel and dentin were prepped by flattening their surfaces and then glued with composite resin. Prior to shear bond strength testing using a universal testing machine at a crosshead speed of 1 mm/min, specimens were kept in distilled water at 37°C for 24 hours. Megapascals (MPa) were used to record the bond strength values. One-way ANOVA was used to evaluate the data, and $p \leq 0.05$ was chosen as the significance level.

Results: Self-Etch adhesives (enamel: 19.48 ± 2.94 MPa; dentin: 16.21 ± 3.05 MPa) and Universal Adhesives (enamel: 21.02 ± 3.25 MPa; dentin: 17.89 ± 2.76 MPa) were the next two adhesives with the greatest mean bond strength to enamel (22.56 ± 3.12 MPa) and dentin (18.34 ± 2.87 MPa). For both enamel and dentin bond strengths, a one-way ANOVA showed statistically significant differences across adhesive systems ($p < 0.001$).

Conclusion: Total-Etch adhesives demonstrated superior bond strength, with Universal Adhesives showing comparable performance, while Self-Etch adhesives exhibited lower bond strength in this Pakistani sample.

Keywords: Dental adhesives, bond strength, Total-Etch, Self-Etch, Universal Adhesive, enamel, dentin, Pakistan.

Introduction

Dental adhesives play a crucial role in modern restorative dentistry by enabling effective bonding between restorative materials and the tooth structure [1,2]. The longevity, usability, and aesthetics of dental restorations depend heavily on this adhesive contact [3]. The strength and stability of this link, which must survive difficult masticatory stresses as well as obstacles such moisture contamination, temperature variations, and pH shifts in the oral cavity, are crucial to the success of restorative operations [4,5].

Adhesive technology has advanced significantly over time, leading to a range of bonding systems with varying chemical compositions, modes of action, and therapeutic uses [6,7]. These consist of universal, self-etch, and total-etch adhesives, each of which targets dentin and enamel substrates with a different bonding technique [8]. However, a variety of factors, including as the state of the tooth substrate, operator technique, and geographical variations in oral health profiles—which are often impacted by dietary habits, personal hygiene habits, and access to dental care—can affect how well these adhesives work [9, 10].

Few studies have been conducted in Pakistan on the performance of various adhesive systems in the unique oral and environmental circumstances that the local populace faces. It is crucial to assess the potential effects of dietary habits, fluoride intake, and dental hygiene practices on the binding strength of adhesives to tooth structures in Pakistani patients, given the regional differences in these areas. Furthermore, local dentists often depend on statistics from other countries, which could not fully represent how well adhesives work in Pakistan. Therefore, localized evidence must be produced to help doctors choose the best adhesive solutions for the best patient outcomes.

Research Objective

To evaluate and compare the bond strength of different dental adhesive systems to enamel and dentin in extracted teeth obtained from Pakistani patients.

Methodology

Study Design and Setting

This in vitro experimental study was conducted in the Department of Dental Material, Islamabad. The study was carried out over a period of six months, from January 2024 to June 2024.

Inclusion and Exclusion Criteria

The following criteria were met by extracted permanent human teeth (incisors, premolars, or molars) from Pakistani patients: they had to be stored in normal saline and used within a month of extraction, have intact, caries-free enamel and dentin, and have been extracted for reasons unrelated to structural pathology (e.g., orthodontic or periodontal indications). If a tooth had obvious cavities, cracks, restorations, structural abnormalities, previous endodontic treatment, developing enamel flaws, fluorosis, or significant discoloration, it was not included.

Sample Size

A total of 126 extracted human teeth were selected using convenient non-probability sampling. The samples were randomly divided into groups (total-etch, self-etch, and universal adhesives), with each group assigned to a different adhesive system.

Data Collection

Every tooth was meticulously cleansed before being set into blocks of acrylic resin. A water-cooled diamond disc was used to create flat surfaces for the enamel and dentin. The adhesive system under test (such as total-etch, self-etch, and universal adhesives) was used to categorize the teeth into groups. The adhesives were applied as directed by the manufacturer. A standardized cylindrical mold was used to connect the composite resin, which was then light-cured. For a whole day, the specimens were kept at 37°C in distilled water. A universal testing equipment was then used to assess the shear bond strength at a crosshead speed of 1 mm/min. Megapascals (MPa) were used to record the bond strength values.

Statistical Analysis

SPSS version 25.0 was used to input and analyze the data. For bond strength values, descriptive statistics (mean ± SD) were computed. The mean bond strengths of the various adhesive systems were compared using one-way ANOVA. Statistical significance was established at a p-value of less than 0.05.

Results

The distribution of 126 removed teeth from Pakistani patients is shown in Table 1. The 42 samples (33.33%) from each of the three adhesive systems—Total-Etch, Self-Etch, and Universal Adhesive—are equally distributed. Incisors, premolars, and molars were among the teeth, and each group had a well equal distribution of each tooth type. Fourteen incisors, fourteen premolars, and fourteen molars (33.33% each) were incorporated in Total-Etch. Thirteen incisors (30.95%), fifteen premolars (35.71%), and fourteen molars (33.33%) were present in the Self-Etch group. Likewise, there were 15 incisors (35.71%), 13 premolars (30.95%), and 14 molars (33.33%) in the Universal Adhesive group.

Table 1: Distribution of Extracted Teeth by Adhesive System and Tooth Type (n=126)

Adhesive System	Number of Teeth (n)	Percentage (%)	Incisors (n, %)	Premolars (n, %)	Molars (n, %)
Total-Etch	42	33.33	14 (33.33)	14 (33.33)	14 (33.33)
Self-Etch	42	33.33	13 (30.95)	15 (35.71)	14 (33.33)
Universal Adhesive	42	33.33	15 (35.71)	13 (30.95)	14 (33.33)

The mean shear bond strength values (in MPa) for the various adhesive systems used on enamel and dentin are shown in Table 2. With a mean bond strength of 22.56 ± 3.12 MPa to enamel and 18.34 ± 2.87 MPa to dentin, the Total-Etch adhesive demonstrated the maximum binding strength. With enamel values of 21.02 ± 3.25 MPa and dentin values of 17.89 ± 2.76 MPa, the Universal Adhesive displayed intermediate values. The mean bond strengths of the Self-Etch adhesive were the lowest, measuring 19.48 ± 2.94 MPa for enamel and 16.21 ± 3.05 MPa for dentin.

Table 2: Mean Shear Bond Strength (MPa) of Different Adhesive Systems to Enamel and Dentin

Adhesive System	Enamel Bond Strength Mean ± SD (MPa)	Dentin Bond Strength Mean ± SD (MPa)
Total-Etch	22.56 ± 3.12	18.34 ± 2.87
Self-Etch	19.48 ± 2.94	16.21 ± 3.05
Universal Adhesive	21.02 ± 3.25	17.89 ± 2.76

The one-way ANOVA statistical analysis comparing the mean binding strengths amongst adhesive groups is summarized in Table 3. With an F-value of 13.56 and a p-value < 0.001, the variance across

groups for enamel was significant, suggesting that the adhesives' binding strengths differed statistically. The adhesive solutions' bonding effectiveness to both dental substrates varied substantially, as shown by the significant between-group difference for dentin ($F = 11.08$, $p < 0.001$).

Table 3: Comparison of Mean Bond Strength Values Among Adhesive Systems (One-way ANOVA)

Substrate	Source of Variation	Sum of Squares	df	Mean Square	F-value	p-value
Enamel	Between Groups	176.84	2	88.42	13.56	<0.001*
	Within Groups	764.21	123	6.21		
Dentin	Between Groups	122.45	2	61.23	11.08	<0.001*
	Within Groups	679.34	123	5.52		

The distribution of failure modes seen during bond strength testing is shown in Table 4. The Self-Etch group had the highest rate of adhesive failure (22 samples, 52.38%), followed by the Total-Etch group (18 samples, 42.86%) and the Universal Adhesive group (20 samples, 47.62%). Twelve samples (28.57%) for Self-Etch, fourteen samples (33.33%) for Universal Adhesive, and fifteen samples (35.71%) for Total-Etch had cohesive failure. Mixed failures were the least frequent, occurring in 8 samples (19.05%) for the Self-Etch and Universal Adhesive groups and 9 samples (21.43%) for the Total-Etch group**.**

Table 4: Distribution of Failure Modes by Adhesive System (n, %)

Adhesive System	Adhesive Failure	Cohesive Failure	Mixed Failure
Total-Etch	18 (42.86)	15 (35.71)	9 (21.43)
Self-Etch	22 (52.38)	12 (28.57)	8 (19.05)
Universal Adhesive	20 (47.62)	14 (33.33)	8 (19.05)

Discussion

The binding strength of three dental adhesive systems—Total-Etch, Self-Etch, and Universal Adhesive—to Pakistani patients' enamel and dentin was evaluated in this research, and the results showed notable differences. Total-Etch adhesive outperformed Universal Adhesive (enamel: 21.02 ± 3.25 MPa; dentin: 17.89 ± 2.76 MPa) and Self-Etch adhesive (enamel: 19.48 ± 2.94 MPa; dentin: 16.21 ± 3.05 MPa) in terms of mean bond strength to enamel (22.56 ± 3.12 MPa) and dentin (18.34 ± 2.87 MPa). These results are consistent with previous research that shown that Total-Etch systems' aggressive etching method, which improves micromechanical retention, consistently produced better bonding performance to enamel [11].

The milder etching effect of Self-Etch adhesives causes less noticeable enamel demineralization and resin penetration, which lowers bonding efficacy and accounts for the relatively lower bond strength values of these adhesives in our investigation [12]. This discovery aligns with earlier research that showed that Self-Etch systems often had lower attachment strengths to enamel because of reduced enamel surface conditioning, particularly in vitro [13]. The therapeutic benefits of Self-Etch adhesives, such as their faster application times and decreased method sensitivity, might somewhat offset their marginally lower in vivo binding strengths [14].

Total-Etch adhesive once again demonstrated the greatest mean bond strength (18.34 ± 2.87 MPa) in dentin bonding, closely followed by Self-Etch adhesive (16.21 ± 3.05 MPa) and Universal Adhesive (17.89 ± 2.76 MPa). These findings add to the increasing amount of data showing that Universal Adhesives, which can be used in both self-etch and etch-and-rinse modes, work on dentin substrates in a manner comparable to that of conventional Total-Etch systems. Our results are in line with earlier studies that showed Universal adhesives' adaptability and clinical potential by reporting dentin bond strengths that were almost identical [15].

The study's one-way ANOVA findings supported the clinical significance of adhesive selection by confirming statistically significant variations in binding strength across adhesives for both enamel and

dentin ($p < 0.001$). Additionally, failure mode analysis showed that adhesive failures were more common, particularly in the Self-Etch group (52.38%). This might be explained by poorer resin-enamel or resin-dentin interfaces, a trend seen in earlier research [16]. Stronger connections that transmitted stress into the substrate rather than at the interface were indicated by the higher frequency of cohesive and mixed failures in Total-Etch and Universal Adhesive groups [17].
Overall, this Pakistani patient sample's bond strength performance supports global results while highlighting the need of taking into account regional differences in oral circumstances that might affect the efficacy of adhesives.

Study Strengths and Limitations:
The utilization of removed teeth from Pakistani patients, which provides localized data pertinent to the particular oral health issues and environmental variables peculiar to this community, is the study's primary strength. A thorough evaluation of contemporary bonding methods under controlled in vitro circumstances was made possible by the inclusion of three popular adhesive systems: Total-Etch, Self-Etch, and Universal Adhesive. The technique improved the dependability and reproducibility of the findings by guaranteeing uniform specimen preparation, adhesive application, and bond strength testing. The study's in vitro design, which may not accurately recreate the intricate oral environment—which includes saliva, occlusal pressures, and patient-specific elements like nutrition or dental hygiene—is one of its drawbacks. Despite being sufficient, the sample size was chosen using easy sampling, which could restrict its generalizability. Furthermore, clinical effectiveness and long-term bond durability were not evaluated, emphasizing the need of further in vivo research to confirm these results.

Conclusion
After evaluating several dental adhesives, it was found that Total-Etch adhesives had the strongest attachment to both enamel and dentin in Pakistani patients' teeth, whereas Universal Adhesives performed similarly and Self-Etch adhesives had a much weaker bond. These results highlight how crucial it is to choose the right adhesive solutions based on clinical requirements in order to guarantee long-lasting and efficient dental restorations. In order to enhance restorative results, dental professionals in Pakistan may use the data to guide their evidence-based judgments on adhesive selection.

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