ORIGINAL ARTICLE

Comparative Assessment of Total-Etch and Universal Dentin Bonding Agents on Marginal Adaptation and Fracture Resistance in Deep Margin Elevation: An *In Vitro* Study

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Abstract

Objectives: This study aimed to evaluate and compare the microleakage and fracture resistance of total-etch and universal dentin bonding agents applied to class II cavities with deep marginal elevations. **Materials and Methods:** Forty extracted mandibular molars with standardized class II cavities and deep margins were selected. The samples were divided into two groups: Group A1 was treated with a total-etch bonding agent (Ivoclar Vivadent Te-econom), whereas Group A2 received a universal bonding agent (Adper Single Bond Universal). Fracture strength testing was performed with a universal testing machine, and bonding failure modes were characterized microscopically with scanning electron microscopy (SEM). Data were analyzed with the independent *t*-test. **Results:** The total-etch bonding agent group (mean = 24.65) exhibited a higher fracture resistance than the universal bonding agent group (mean = 16.34), although the difference was not statistically significant ($P = 0.375$). The SEM analysis showed that the universal bonding agent group had large marginal gaps (17.89–21.04 µm), signifying poorer sealing ability and higher susceptibility to microleakage. Conversely, the groups treated with total-etch bonding agents had smaller marginal gaps, with the smallest recorded being 2.53 µm, which indicates better adaptation and sealing. **Conclusion:** Total-etch bonding agents presented better resistance to fracture and marginal sealing properties compared with universal bonding agents. While differences in fracture resistance were not statistically significant, better sealing through the total-etch bonding agents and reduced microleakage would indicate improved clinical performance and longevity in the treatment of deep margin cavities.

Key words: Class II cavities, dentin bonding, deep margin elevation, fracture resistance, microleakage, scanning electron microscopy, total-etch bonding agent, universal bonding agent

INTRODUCTION

Deep proximal restorations beyond the cement enamel junction toward subgingival space restoration involve a part of dentistry practice that continues to bother dental clinicians. It may be said that restorative dentistry had an ancient origin in Babylon (4500–4000 BC) and has since become a vibrant field engaged in impressive advancements in techniques, materials, and methodologies.[1] Longevities of deep sub gingival restorations remain a mystery under both functional and biological criteria. The solution to this problem was provided in 1998 by Dietschi and Spreafico with the introduction of the deep margin elevation (DME) technique.[2] DME is used to restore subgingival caries through the sagittal placement of indirect restorations. Likewise, it extends its applications to semi-direct and direct methods, which also embrace immediate dentin sealing (IDS).[4] DME serves as a viable alternative

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to surgical crown lengthening.[1,4] Integrating IDS with DME makes for better bond strength, fracture resistance, and increased performance of indirect restorations and the tooth structure. At the same time, marginal integrity alleviates hypersensitivity that can arise after cavity preparation, the teeth was decoronated [Figure 2].[5] In various literature, DME is often referred to by several other names, including cervical margin relocation, proximal box elevation, coronal margin relocation, and the open sandwich technique.[6]

Adhesive restorations depend on three important variables: The tooth status, the characteristics of the adhesive material, and the clinical technique. Most of these developments have recently been witnessed in clinical adhesive systems to enhance tooth structure bonding with the adhesives. Among these generations, the fifth-generation (total-etch) and seventh-generation (self-etching) systems seem to be the best recommended by many of them.[7] Based on the fact that the rinse-and-dry process removes smear layer or smear plug and exposes the collagen matrix, the total-etch technique application is then followed by a single bottle containing self-priming bonding agent, which combines primer and adhesive components.[7,8] The self-etch adhesive system comes in two main formats: A two-bottle system, which features one bottle containing both acid and primer and another for the bonding agent, and an all-in-one bottle system that combines all components.[8] Self-etch systems are preferred to total-etch systems as these reduce the risk of iatrogenic error due to acid conditioning, rinsing, and drying. Self-etch systems shorten the process by merging the two stages of etching and priming into one, while total-etch techniques all require rinsing, which may lead to complications such as over-etching or insufficient drying.[9] Self-etch system may fail to etch the enamel surface as efficiently as phosphoric acid, in achieving depth of penetration into the tubules.[10]

One of their biggest challenges is to produce a reliable bond between varied dental surfaces, which include enamel and different types of dentin, sound, carious, or sclerotic.[11] If anything has changed in dentistry, it has most recently been through the generation of different types of bonding agents. With time, he has introduced progressively more comprehensive versatile adhesive systems to match differing clinical preferences and techniques, which can be termed "universal" or "multi-mode" adhesives as they allow the clinician to apply an adhesive-all self-etch on etch-and-rinse, thus providing much more flexibility, which is advancement in adhesive technology.[12,13] An adhesive designed for multiple application methods allows dentists to choose the bonding technique that best suits the specific needs of each cavity.[13] Adopting such approach would allow the correct adaptation of the bonding process to fit the condition of the tooth and what is required clinically, by enabling self-etch, etch-and-rinse, or selective-etch methods. Hence, these adhesives achieve better treatment results for patients.[14] This study aimed at comparing the performance of self-etch and universal dentin bonding agents in DME cases for two of the most relevant microleakage and fracture resistance attributes.

MATERIALS AND METHODS

Sample selection and preparation

Multirooted mandibular were selected. These teeth specimens were kept in a tightly sealed plastic container containing a 1:10 bleach solution. Before use, clean them thoroughly by scrubbing with soap and water or using an ultrasonic cleaner. Sterilization of the teeth through autoclaving was done to ensure they are safe for use. Mandibular molars with class 2 cavities and deep margins are selected from extracted teeth. These teeth are carefully cleaned, sterilized, and examined to ensure uniformity in cavity size, depth, and location. Then these samples were mounted in acrylic block, as shown in Figure 1. Class 2 cavities are prepared using standard dimensions with appropriate dental instruments.

Grouping

The samples are divided into two groups:

- Group A1: Ivoclar Vivadent Te-Econom dentin bonding agent
- Group A2: Adper single bond universal dentin bonding agent.

Sample size determination was done using G*Power software. Equal numbers of specimens are allocated to each group to maintain statistical validity.

Application of bonding agents

The bonding agents are applied following the manufacturers' instructions. Proper etching, priming, and bonding techniques are employed for each group to maintain consistency.

Thermo cycling

The samples were exposed to 1,000 thermocycling cycles to mimic the thermal changes that occur in the oral environment. This method simulates temperature fluctuations experienced in the mouth and helps assess the durability of bonding agents, offering realistic insights into microleakage and fracture resistance in DME cases.

Figure 1: Sample collection

Table 1 : Statistical analysis for fracture resistance

Groups	Mean	Standard deviation	Mean difference	t	95% Confidence interval		*P*-value
					Lower	Upper	
Maximum force							
Universal	16.3440	13.28060	−8.30400	−0.940	−28.67978	12.07178	0.375
Total-ETCH	24.6480	14.62865					

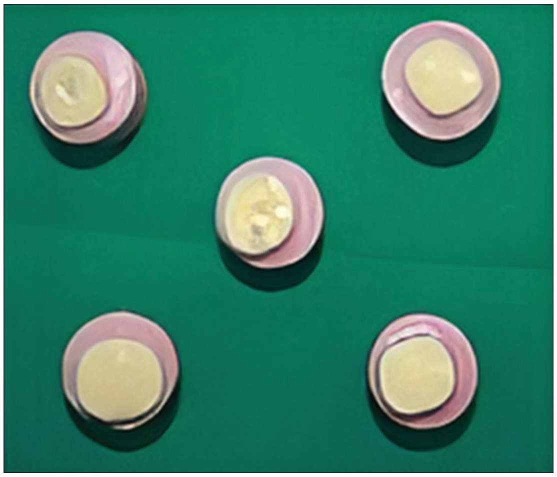


Figure 2: Decoronation of teeth

Figure 3: Dentin strips (5 mm × 1 mm × 1 mm)

Figure 4: Longitudinal sectioning was done of the teeth sample

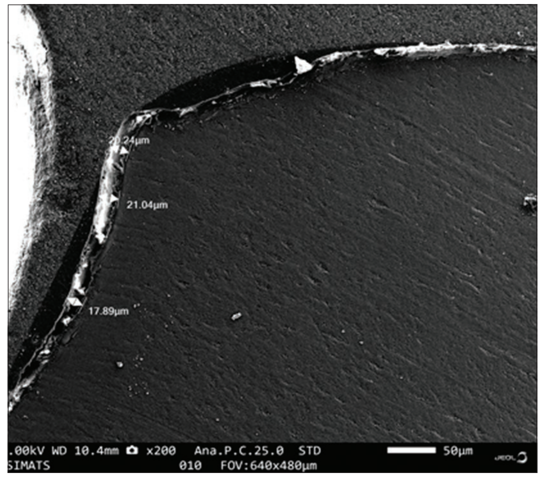


Figure 5: Scanning electron microscopy analysis for universal bonding agent

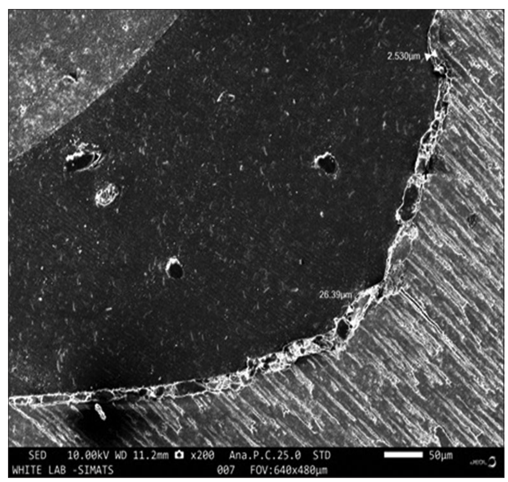


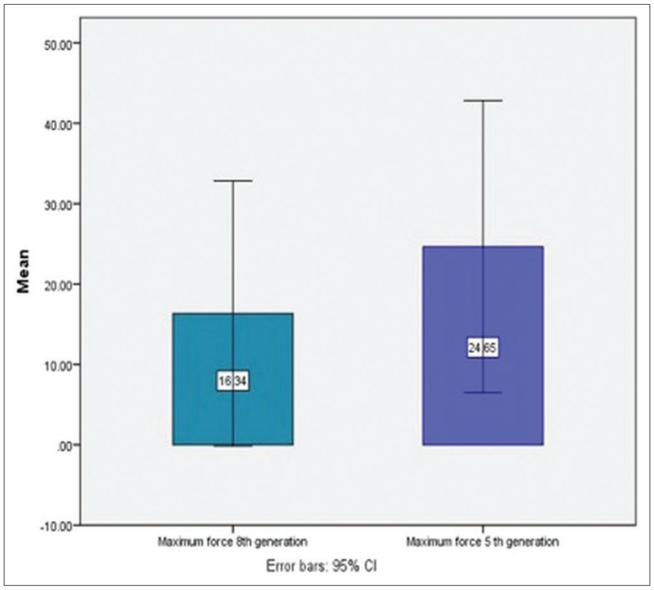
Figure 6: Scanning electron microscopy analysis for total-etch bonding agent

Fracture resistance testing

An Instron 9400 universal testing machine is used to apply controlled compressive forces to the restored teeth. The force required to cause fracture is recorded for each specimen in both groups. Multiple tests are conducted for accuracy and reliability.

Marginal adaptation

Following fracture resistance testing, the bonding interface is examined using either a stereomicroscope or SEM. The



Graph 1: Comparative results for fracture resistance

type of bonding failure (adhesive, cohesive, or mixed) is identified for each specimen in both groups [Figures 5 and 6]. The distribution of bonding failures is carefully documented and analyzed.

RESULTS

Fracture resistance

When evaluating fracture resistance between the universal bonding agent and the total-etch bonding agent, the following observations were made-

The universal bonding agent had a mean maximum force of 16.3440 N with a standard deviation of 13.28060 N, while the total-etch bonding agent showed a higher mean force of 24.6480 N with a standard deviation of 14.62865 N. The mean difference of −8.30400 N suggests that the total-etch bonding agent could demonstrate higher fracture resistance [Table 1]. The 95% confidence interval for this difference, ranging from −28.67978 N to 12.07178 N, reveals considerable variability in the data, making it unclear if one bonding agent truly outperforms the other in terms of marginal adaptation. $P = 0.375$ indicates that the differences in fracture resistance between the two bonding agents are not statistically significant, implying that these variations could be due to chance.

A graph comparison shows that the total-etch bonding agent group exhibited a wider range and higher median force, possibly reflecting better fracture resistance [Graph 1]. However, overlapping error bars (95% confidence intervals) suggest no substantial difference between the two bonding agents in this aspect.

Marginal adaptation

The scanning electron microscopy (SEM) analysis reveals notable differences in the marginal adaptation between the bonding agents.

Universal bonding agent

Marginal gaps are noticeable, with sizes of 20.24 µm, 21.04 µm, and 17.89 µm at various sections. The overall adaptation indicates some visible micro-gaps, suggesting that the Universal Bonding Agent may not have fully sealed the interface between the restoration and the tooth, potentially leading to microleakage.

Total-etch bonding agent

Smaller gaps are observed, with measurements of 2.53 µm and 26.39 µm. The smaller gap of 2.53 µm suggests a better seal in some areas. However, variations in gap sizes indicate that the bonding may still be uneven, although the total-etch bonding agent appears to have achieved a tighter adaptation in certain regions compared to the universal bonding agent.

DISCUSSION

The present study evaluated the performance of total-etch and universal bonding agents by examining fracture resistance and marginal adaptation in DME cases. The findings indicated that the total-etch bonding agent generally provided superior results in terms of fracture resistance and marginal adaptation when compared to the Universal Bonding Agent in case with DME. The dentin/adhesive interface is the most vulnerable aspect of adhesive restorations. In bonding procedures, the aim is to mimic the dentin-enamel junction and achieve minimum microtensile bond strength of 51 MPa. However, this bond strength tends to deteriorate over time.[6,15,16] As a result, IDS is a critical component of indirect bonded restorations and should be utilized in DME techniques. IDS effectively reduces bacterial microleakage and dentin hypersensitivity while enhancing bond strength. For optimal results, three-step total-etch and two-step self-etch systems are preferred for IDS, as they offer better durability and bond strength compared to single-step systems.[6,17-20]The bonding strength of dentin adhesives diminishes as dentin depth increases. Pegado *et al*. investigated the microtensile bond strength of various bonding agents in both deep and superficial permanent dentin. They found that the bond strength in superficial dentin was significantly greater for all adhesive systems examined than that in deep dentin.[21]

Gwinnett demonstrated that the bond strength to dentin covered by a smear layer is approximately 50% lower than that of dentin without a smear layer. This implies that the smear plug prevents monomer penetration into the tubules, prohibiting the formation of resin tags.[22] Moreover, the mineralization of intertubular dentin might prevent the forming of a hybrid layer. Thus, the total-etch technique will remain crucial because it effectively removes the smear layer, allowing for monomer penetration and hybrid layer formation [Figures 2-4]. Bouillaguet *et al*. claimed that self-etching adhesive systems would be another way to minimize the chances of defective hybridization since they allow acidic resins to penetrate the smear-covered surface, etching, and priming dentin. This process removes essential steps like rinsing the etchant and priming the hydrated collagen fibers, thereby minimizing the chances of incomplete resin penetration into the demineralized dentin.[9] However, Sano *et al*. stated that it remains uncertain whether these materials can consistently establish strong and durable bonds when applied to dentin.[23] Additional research is needed to determine their effectiveness in ensuring reliable bonding in various clinical contexts.

A systematic review of earlier clinical trials indicated that a greater proportion of restorations met the ADA provisional acceptance criteria (6 months), with two-bottle total-etch materials achieving 91% and self-etch materials achieving 82%.[24-26] Scotchbond Universal contains HEMA, but it exhibits greater hydrophobicity than previous simplified adhesives. This enhanced hydrophobic nature is partly due to MDP, a molecule that is inherently hydrophobic. The retention rates observed over a 24-month period were 87.6% for Scotchbond multi-purpose, 94.9% for Scotchbond Universal in self-etch mode, and 100% for Scotchbond Universal in total-etch mode.[26] The hydrophobicity of the universal adhesive could contribute to its better performance compared to the two-bottle total-etch material in laboratory tests performed in the present study. The present study carries limitations concerning sample size and laboratory conditions that might not accurately simulate the complexities of the oral environment. Even findings about immediate results and two kinds of bonding agents may not be broadly applicable. Moreover, differences in operator technique and the exclusion from consideration of esthetic factors and patient preference may dampen clinical relevance.

CONCLUSION

The total-etch bonding agent exhibited better fracture resistance and marginal adaptation than the universal bonding agent. SEM analysis revealed fewer and smaller micro-gaps in the total-etch group, indicating a more effective marginal seal. Therefore, total-etch systems appear to provide higher clinical reliability in cases that require durability and marginal integrity.

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AUTHOR CONTRIBUTIONS

Shreshtha Muskan: Intellectual content, investigation, and manuscript writing. Manish Ranjan: Concept design and intellectual content, investigation, and manuscript writing. Anjali Rathi: investigation, and manuscript writing.

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