ORIGINAL RESEARCH

Effect of Different Chemical Solvents on Bond Strength of Orthodontic Brackets: An *In Vitro* Study

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Abstract

Aim: The purpose of the present study was to evaluate the impact of various chemical solvents on bond strength of orthodontic brackets.

Materials and methods: One hundred healthy human premolars with undamaged buccal surfaces that were extracted for orthodontic purposes were gathered. Using 37% orthophosphoric acid, primer, and Transbond XT adhesive, ceramic 0.018″ × 0.022″ slot orthodontic brackets were adhered to the tooth surface. Following thermocycling, all samples were divided into four groups, with 25 samples in each group: group I: control; group II: application of ethanol; group III: application of acetone; and group IV: application of dimethyl sulfoxide (DMSO). Following the debonding tests, a double-ocular stereomicroscope was used to inspect the tooth surfaces. Additionally, adhesive remnant index (ARI) values were evaluated at 40× magnification. Data were recorded and statistically analyzed.

Results: The bond strength was lesser in acetone applied group (16.18 ± 3.64) followed by DMSO applied group (22.08 ± 2.86), ethanol applied group (24.36 ± 4.02), and control group (27.14 ± 3.68). There was a highly significant difference found between the chemical solvents group. The ARI score 3 was present in control (12%), ethanol (8%), and DMSO (4%), and it was absent in acetone applied group. The ARI score 0 was more in acetone applied group (24%).

Conclusion: The present study concluded that the reduced debonding force was found with the application of acetone solvent followed by DMSO, ethanol, and control groups. Applying acetone can be a substitute technique to help with ceramic bracket debonding.

Clinical significance: Orthodontic bracket debonding cannot occur without shear bond strength (SBS). The need for an ideal debonding technique for ceramic brackets without negative consequences arises from the risk of enamel damage that frequently follows the process. Acetone treatment prior to ceramic bracket debonding could be an alternate clinical technique to preventing enamel damage and facilitating debonding.

Keywords: Bond strength, Chemical solvents, Debonding, Orthodontic brackets.

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Introduction

The use of acid etching has been one of the most significant advances in orthodontics over the last 40 years. The enamel surface area is increased, and the adhesive can permeate the surface thanks to micropores created by acid etching using 85% phosphoric acid, a technique first presented by Buonocore in 1955. As a result, the bracket and tooth surface form a trustworthy mechanical bond.[1]

Orthodontic brackets must have a bond strength of at least 6–8 MPa and be able to withstand both mechanical and masticatory stresses for the duration of the treatment period. To avoid harming the tooth enamel during the debonding of the brackets, the ideal bond strength should not surpass 13.75 MPa, which is the cohesive internal strength of the enamel.[2]

Three decades ago, as the number of adult patients seeking orthodontic treatment with less apparent equipment increased, ceramic brackets were introduced into the field of orthodontics. Even while ceramic brackets look better than metal brackets, they had a stronger bond and a lesser fracture toughness, which made debonding difficult and caused fissures, tiny fractures, and tears in the enamel. Nevertheless, after the conclusion of orthodontic treatment, ceramic brackets cannot be removed by deforming because they lack the elasticity of stainless steel brackets to stretch.[3]

Depending on the circumstances, the ceramic bracket debonding process may cause the tooth enamel to become compromised, fragments of the bracket may stay on the tooth surface, and sometimes permanent damages such as enamel cracks and failures may occur as malpractice. Because residual composites and bracket remnants might result in uneven surfaces and increase the risk of poor oral hygiene during the debonding process, ceramic brackets are frequently not recommended for youngsters due to their lower treatment compliance and generally poor oral hygiene.[4]

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Various methods, including electrothermal, laser, and ultrasonic debonding, have been attempted to assist in the mechanical removal of the brackets in order to avoid such issues when removing ceramic brackets. It has become essential to investigate alternate approaches for ceramic bracket debonding because of the irreversible pulp damage and dangers of gingival irritation associated with these methods.[5] During the debonding stage, organic chemical solvent agents such acetone, ethanol, dimethyl sulfoxide (DMSO), peppermint oil, and hot water were considered to be used as alternatives to these methods. The concept was that by applying these chemical dissolving agents to the tooth surface prior to debonding, failure could be achieved with the least amount of effort and damage. To maximize the effect, the largest concentrations of these chemical dissolving agents were utilized.[6] Additionally, there are only few studies that compare various chemical solvents. Hence, the present study was conducted to assess the impact of three chemical solvents on bond strength of orthodontic brackets.

Materials and Methods

Preparation of Samples

The present *in vitro* study was conducted in the Department of Orthodontics, Inderprastha Dental College and Hospital, India, during the year of 2022. Power and sample size computation software was used to determine the estimated sample size. A minimum of 25 teeth were needed per group at $\alpha = 0.05$ and a power of 0.95. One hundred intact buccal surfaces of sound human premolars that were extracted for orthodontic purposes were gathered. Teeth having hypoplastic lesions, fractures, carious lesions, or evident cracks were not included. Following a tap water cleaning, the teeth were placed in a 0.9% isotonic saline solution for storage. Using a rubber cup, non-fluoridated oil-free pumice, and water, the buccal surface of the teeth was polished. After that, they were rinsed and dried with an oil- and moisture-free air spray. Using 37% orthophosphoric acid, primer (Transbond XT, 3M Unitek, Monrovia, CA, USA), and adhesive (Transbond XT, 3M Unitek, Monrovia, CA, USA), ceramic 0.018" x 0.022" slot orthodontic brackets were adhered to the tooth surface. To make sure that the brackets were parallel to the tooth's long axis and in the middle of the one-third region in the mesiodistal and occlusogingival directions, guide labels were utilized. Heavy elastic measuring 61/2 ounces and 1/8 size was applied to the tooth in such a way as to encircle the bracket and the tooth's equatorial line, standardizing the applied force. New elastic was used for each sample and to prevent different forces that may occur due to the dimensional differences among the premolar teeth. A dynamometer was used to quantify the 200 g-force for each sample. After that, the adhesive was polymerized for 20 seconds using an light-emitting diode (LED) light source that emitted light with a wavelength of 430–480 nm.

Thermocycling Procedure

Following the bonding process, the model teeth were positioned vertically on the acrylic blocks, their roots in the acrylic and all of their crowns visible. After being kept in distilled water for 24 hours, all samples were exposed to 500 thermocycles in baths of distilled water with 30-second dwell duration. It took 5–10 seconds to switch between baths. All of the samples were then examined following a 24-hour water storage period and thermocycling.

Following thermocycling, all samples were divided into four groups, with 25 samples in each group.

Group I: Control

Group II: Application of ethanol (Ethanol Absolute, Maruti Pvt Ltd, India)

Group III: Application of acetone (Nice, Nice Chemicals Ltd, India)

Group IV: Application of dimethyl sulfoxide (Bio Balance DMSO, India)

Using a Pasteur pipette, the solutions were transferred into separate 150 mL beakers, one for each sample, with an inner diameter of 10 mm and a depth of 30 mm. In order to keep the tooth surface with the brackets in the solution, the samples were placed in glass beakers for 15 minutes.

Evaluation of Impact of Chemical Solvents on Bond Strength

The test equipment was configured to move its movable top plate at a speed of 1 mm/minute, to apply a maximum force of 500 N and to take measurements with an accuracy of 0.2 N. The force per unit area was expressed in MPa ($MPa = N/mm^2$) by dividing the measured forces (Newtons) by the brackets' base surface areas. After getting in touch with the manufacturer, the base surface area of the bracket was calculated and found to be 13.12 mm^2. Following the debonding tests, the tooth surfaces were inspected using a double-ocular stereomicroscope device at 15× and 25× magnification for the bracket bases, and the "Camera" computer program was used to record each image individually.

Assessment of Adhesive Remnant Index

After debonding, the fractured sample was inspected, and the adhesive remnant index (ARI) was calculated in accordance with Artun and Bergland.[7]

- Score 0—no adhesive remains on the tooth
- Score 1—<1/2 of the adhesive remains on the tooth
- Score 2—>1/2 of the adhesive remains on the tooth
- Score 3—all adhesive remains on the tooth, providing a clear visual of the bracket mesh

Statistical Analysis

Data were analyzed using SPSS Statistical Software, version 17 (SPSS, Chicago, USA). Two-way analysis of variance and Tukey's multiple comparison tests were used to compare the mean values of bond strength and their interaction. A value of 0.05 was chosen as the probability threshold for statistical significance. The Chi-square test was used to ascertain the difference in the ARI values.

Results

The impact of different chemical solvents on bond strength of orthodontic brackets is shown in Table 1. The bond strength was lesser in acetone applied group (16.18 ± 3.64) followed by DMSO applied group (22.08 ± 2.86), ethanol applied group (24.36 ± 4.02), and control group (27.14 ± 3.68). There was a highly significant difference found between the chemical solvents group.

Multiple comparisons of different chemical solvents on bond strength of orthodontic brackets using Tukey's *post hoc* test are depicted in Table 2. On pairwise comparison, there was a highly significant difference found between group I vs group III, group II vs group III, group III vs group IV, and group I vs group IV ($p < 0.001$).

Adhesive remnant index scores of different chemical solvents on bond strength of orthodontic brackets are depicted in Table 3. The ARI score 3 was present in control (12%), ethanol (8%), and

Table 1: Evaluation of the impact of different chemical solvents on bond strength of orthodontic brackets

Groups	*Mean ± SD*	*F value*	*p-value*	*Significance*
Group I: Control	27.14 ± 3.68			
Group II: Application of ethanol	24.36 ± 4.02			
Group III: Application of acetone	16.18 ± 3.64	29.328	0.001	HS
Group III: Application of DMSO	22.08 ± 2.86			

HS, highly significant

Table 2: Multiple comparisons of different chemical solvents on bond strength of orthodontic brackets using Tukey's *post hoc* test

Groups	*Compared with*	*Mean difference*	*Significance*
Group I	Group II	2.78	0.072
	Group III	10.96	**0.001**
	Group IV	5.06	**0.001**
Group II	Group I	−2.78	0.072
	Group III	8.18	**0.001**
	Group IV	2.28	0.826
Group III	Group I	−10.96	**0.001**
	Group II	−8.18	**0.001**
	Group IV	−5.9	**0.001**
Group IV	Group I	−5.06	**0.001**
	Group II	−2.28	0.826
	Group III	5.9	**0.001**

Bold values indicate statistically significant

Table 3: Adhesive remnant index scores of different chemical solvents on bond strength of orthodontic brackets

Groups	*n*	*Score 0*	*Score 1*	*Score 2*	*Score 3*
Group I	25	2 (8%)	8 (32%)	12 (48%)	3 (12%)
Group II	25	3 (12%)	10 (40%)	10 (40%)	2 (8%)
Group III	25	6 (24%)	14 (56%)	5 (20%)	0
Group IV	25	2 (8%)	12 (48%)	10 (40%)	1 (4%)
Chi-square = 12.66; $p = 0.018$					

DMSO (4%), and it was absent in acetone applied group. The ARI score 0 was more in acetone applied group (24%). The Chi-square test showed that there was a statistically significant difference. This proved as the adhesive material remaining on the tooth was less on acetone applied group compared with other groups.

Discussion

The ability of an adhesive system to adhere to the substrate is the most therapeutically significant characteristic since it dictates the clinical longevity of the bonded attachments. The pursuit of sufficient bond strength to endure masticatory forces and effortless removal following treatment has resulted in numerous inventive orthodontic material designs. Adhesive and attachment bond strengths should be strong enough to resist mastication forces, activated archwire stresses, extreme temperature and pH fluctuations, and patient abuse and allow for control of tooth movement in all three planes of space.[8]

The bond strength should also be such that bracket debonding can occur without endangering the enamel's surface. Numerous factors, such as the adhesive's composition, the debonding technique, the enamel conditioning procedure, and the bracket retention mechanism, affect the forces used during bracket debonding.[9] Three distinct chemical solvents were utilized in the current investigation to measure the bond strength during the debonding process in an effort to reduce the variables that could affect the debonding characteristics.

Bracket removal may result in bond failure within the adhesive, at the adhesive–bracket contact, or at the adhesive-enamel interface. Bond failure moves in the direction of the adhesive–enamel contact with an increase in bond strength. At the adhesive–enamel interface, enamel is lost as a result of adhesive failure in the micromechanical bond that holds the adhesive agent and the acid-etched enamel together.[10]

Transbond XTs were employed as the adhesive material in this study. This is comparable to research by Pickett et al.[11] and Arnold et al.[12] found that Transbond XT had a mean shear bond strength (SBS) of 9.7 MPa. The Transbond XT had the highest mean SBS of approximately 19.0 MPa, according to a study by Vilchis et al.[13]

In the present study, all samples were applied at each chemical solvent for 15 minutes in which acetone was found to be statistically significant with other chemical solvents. Therefore, the results are consistent with the theory that chemical solutions work better when applied for 15 minutes. Comparably, Uzunçıbuk and Öztaş[14] discovered that acetone was the solution with the greatest softening impact on the composite, as evidenced by the statistically significant difference in SBS reduction between acetone groups and other chemical solution groups. The current study's results indicate that employing acetone prior to ceramic bracket debonding can lower the SBS and provide a different, less-damaging technique for the enamel surface.

According to Santana et al.,[15] the use of ethanol and acetone in addition to the ultrasonic debonding approach did not result in a decrease in the SBS; the SBS might have impacted by the ultrasonic tip's angulation. In the study of Cruickshank and Chadwick,[16] ethanol, polyacrylic acid, acetone, and acetic acid were applied to anterior restorations for 3 minutes, but the hypothesis that chemical solvents soften the composite was not accepted; this could be because polymers with more crosslinks are more difficult to soften than polymers with a linear structure.

By measuring the amount of adhesive that remained, ARI analysis was used. According to the study's findings, the group that applied acetone had less adhesive material left on their teeth than the other groups, and the microstructure of their enamel had not changed much. Higher ARI scores, once more, clearly indicate a decrease in enamel damage.[17]

It was postulated that failure with the least amount of damage and force might be achieved by applying these chemical dissolving agents to the tooth surface prior to debonding. Dimethyl sulfoxide applied group performed better in the current investigation than both the ethanol applied group and the control group. This is comparable to a study by Larmour et al.,[6] which found that DMSO exhibited analgesic, antibacterial, and anti-inflammatory properties in addition to being able to dissolve a variety of compounds more effectively than water.

There were certain limitations in the present study such as only examining the effects of various chemical solvents on a single type of adhesive substance and lacking accurate models of oral circumstances, such as salivary pH and biofilm presence. Prior to clinical application, it is advised to conduct studies with larger sample sizes and clinical trials while taking these considerations into account.

Conclusion

Within the limitation, the present study concluded that the reduced debonding force was found with the application of acetone solvent followed by DMSO, ethanol, and control groups. Applying acetone can be a substitute technique to help with ceramic bracket debonding. The strategies and procedures needed to make these chemical solutions clinically useful, however, need to be investigated further.

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