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Effect of Varying Etching Times on the Bond Strength of Ceramic Brackets

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KEYWORDS
etching, bond strength, ceramics, brackets

ABSTRACT:

Background: This study was conducted to evaluate the effect of varying etching times on the bond strength of ceramic brackets.

Material and methods: Samples of 30 extracted teeth were taken from the Department of Oral and Maxillofacial Surgery, Inderprastha Dental College & Hospital, Sahibabad, Ghaziabad, according to the inclusion criteria. A thorough examination of the teeth was done to rule out any damage or malformation. The teeth were cleansed and then polished with non-fluoridated pumice using rubber prophylactic cups for 10 seconds. The teeth were divided into three groups of 10 and placed in an acrylic base.

Results: The shear bond strength descriptive statistics for the three etching groups are outlined in Table I. The analysis of variance results indicates statistically significant differences ($p = 0.000$) in bond strengths among the various etching groups. The application of Duncan's multiple range test (DMRT), also known as Duncan's new multiple range test, which is a test used in statistical analysis to determine significant differences between multiple group; revealed that the bond strengths of the 5-second etching group were significantly lower compared to the 15- second group and the 15-second group had slightly lower bond strength than 30-second group. The bond failure location between different samples and etching groups was determined using the ARI (Adhesive Remnant Index). The frequency of ARI scores for each etching group and the results of the Chi-square test comparing the groups are presented in Table II. The Chi-square test revealed significant

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differences among the ARI scores of the three groups. However, when excluding the 5-second etching groups from the comparison, the remaining groups, namely the 15- and 30-second etching groups, did not exhibit significant differences in ARI scores (x^2 = 0.211). Conclusion: The findings of the study present a significant evidence, suggesting that a reduction in the etching time by half, from 30 to 15 seconds, can still yield clinically useful bond strength. The bond shear strength values in all three groups fall within the clinically acceptable range of 5.9–7.8 MPa. Even with a shorter etching time, like in Group I, the bond strength meets orthodontic requirements. However, the substantial increase in bond shear strength in Group II and Group III suggests that longer etching times could enhance bond strength, particularly when extra strength is needed.

Introduction

Orthodontic care for adults has become increasingly popular in recent years, largely due to its aesthetic benefits. Adult patients often desire orthodontic treatments that are both effective and discreet. To meet this demand, new brackets with more visually appealing designs have been developed. However, the use of polycarbonate brackets was limited after their introduction in the early 1970s, as they were found to be susceptible to deformation from water absorption and torsional pressures. Despite this setback, ongoing research and development in orthodontic materials continue to yield new and innovative products that can provide effective and aesthetically pleasing options for adult patients seeking orthodontic care.[1]

In an effort to enhance the durability and performance of plastic brackets, manufacturers began incorporating metal bracket holes and ceramic fillers into their designs. However, these modifications were not without their limitations. Despite their efforts, the use of such brackets was restricted due to concerns surrounding slot distortion and discoloration. These challenges highlight the ongoing need for innovation and development in the field of orthodontic materials, as manufacturers strive to produce brackets that are both aesthetically pleasing and functionally effective.

Since the introduction of Buonocore's acid etch bonding procedure in 1955, the concept of attaching different resins to enamel has found widespread applications in all areas of dentistry, including the bonding of orthodontic brackets. This technique has evolved significantly over time, and it remains an important aspect of modern dental practice.[2] Sapphire or aluminum oxide ceramic brackets were introduced in 1986, offering an alternative to plastic brackets. However, because ceramics tend to be brittle, even minor cracks can significantly reduce their load-bearing capacity. Ceramic brackets are chemically inert to oral fluids, which makes them resistant to staining and discoloration - a marked improvement over early plastic brackets. However, these inert brackets do not adhere well to acrylic and diacrylic adhesives[2]. As a result, retention techniques such as chemical bonding with a silane coupler and a mechanical lock in the bracket base have been developed to establish effective bond strength. In an ideal scenario, the bond would fail at the bracket-adhesive interface or within the adhesive. However, with the marked increase in bond strength, enamel-adhesive contact has become the primary location of failure during ceramic bracket debonding. Swartz proposed that the increase in enamel fractures reported in clinical cases could be attributed to this shift in failure location.[3]

The use of acid etch bonding to attach orthodontic brackets to enamel has a number of benefits, including improved patient ability to remove plaque, reduced soft tissue irritation and hyperplastic gingivitis, and the absence of post-treatment band spaces. It also makes it easier to attach attachments to partially erupted teeth, reduces the risk of decalcification from loose bands, and enhances caries detection and treatment.[4] Moreover this technique provides a more aesthetically pleasing appearance for the patient. By the late 1970s, bonding of orthodontic brackets had become a widely used clinical procedure.

In essence, this research was aimed to provide insights into the optimal etching time for ceramic brackets. By systematically varying the etching time, we sought to determine the most suitable duration that achieves a secure bond while ensuring that the brackets can be safely removed when the orthodontic treatment is

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completed. This knowledge can help orthodontists make informed decisions about their clinical practices, ultimately benefiting the patient's overall orthodontic experience and dental health.

Material and methods

Armamentarium:

- **Etchant :** True Etch-37% Phosphoric Acid in gel form
- **Bonding System:** Enlight bonding system by Ormco with OrthoSolo primer
- **Bracket System:** Ormco Symetri Clear™ ceramic brackets.
- Deionised water
- Universal Testing Machine - Micro Data Acquisition System (MAS 14) by ASIAN ISO 9001 – 2004 Company, INDIA
- Acrylic Monomer and Polymer (DPI Cold Cure)
- Pumice
- Rubber prophylactic cups

Inclusion Criteria:

- The tooth should be freshly extracted
- The extracted tooth should have intact buccal enamel
- Unmutilated tooth.

Exclusion Criteria:

- Teeth with cracks due to the pressure of the extraction forceps
- Carious tooth
- Restorated tooth
- Fluorosis

Teeth subjected to pre-treatment chemical agents, eg., hydrogen peroxide

Samples of 30 extracted teeth were taken from the Department of Oral and Maxillofacial Surgery, Inderprastha Dental College & Hospital, Sahibabad, Ghaziabad, according to the inclusion criteria. A thorough examination of the teeth was done to rule out any damage or malformation. The teeth were cleansed and then polished with non-fluoridated pumice using rubber prophylactic cups for 10 seconds. The teeth were divided into three groups of 10 and placed in an acrylic base.

Figure 1: Enlight Bonding System

Figure 2: 37% Phosphoric Acid in gel form

Figure 3: Deionized Water

Group I: 37% phosphoric acid gel was applied to the buccal surface for etching duration of 5 seconds.

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Group II: 37% phosphoric acid gel was applied to the buccal surface for etching durations of 15 seconds

Group III: 37% phosphoric acid gel was applied to the buccal surface for etching durations 30 seconds.

The teeth were then dried with an oil-free air source for 20 seconds after being rinsed with a water spray for 30 seconds.21 After bonding each bracket was subjected to force of 300gms. All samples were stored in deionized water at 37 ° C for 48 hours.21

Then each tooth was oriented with the testing device as a guide, so its labial surface was parallel to the force applied during the shear strength test. A steel rod with one flattened end was attached to the crosshead of a Universal Tensile Machine. An occluso-gingival load of 300gms was applied to the bracket, producing a shear force of 120N at the bracket-tooth interface. A computer electronically connected with the UTM recorded the results of each test.

Results

Bond strength comparisons:

The shear bond strength descriptive statistics for the three etching groups are outlined in Table I. The analysis of variance results indicates statistically significant differences ($p = 0.000$) in bond strengths among the various etching groups. The application of Duncan's multiple range test (DMRT), also known as Duncan's new multiple range test, which is a test used in statistical analysis to determine significant differences between multiple group; revealed that the bond strengths of the 5-second etching group were significantly lower compared to the 15- second group and the 15-second group had slightly lower bond strength than 30-second group.

Amount of Residual Adhesive:

The bond failure location between different samples and etching groups was determined using the ARI (Adhesive Remnant Index). The frequency of ARI scores for each etching group and the results of the Chi-square test comparing the groups are presented in Table II. The Chi-square test revealed significant differences among the ARI scores of the three groups. However, when excluding the 5-second etching groups from the comparison, the remaining groups, namely the 15- and 30-second etching groups, did not exhibit significant differences in ARI scores ($x^2 = 0.211$).

Descriptive statistics (MPa) of the bond shear strength for three etching times.

Group	Mean±(MPA)
I	2.947±1.55
II	14.16±4.22
III	19.05±3.44

Table I: Showing significant differences; p-value=0

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Group	Residual adhesive ratings, according to the Adhesive Remnant Index (ARI) for three different etching times					chi-square value	P-value	S/NS
	1	2	3	4	5			
I	4(13.3%)	4(13.3%)	2(6.7%)	0(0%)	0(0%)			
II	2(6.7%)	1(3.3%)	1(3.3%)	5(16.7%)	1(3.3%)	13.287	0.103	NS
III	3(10%)	0(0%)	2(6.7%)	5(16.7%)	0(0%)			

Table II: Showing Non-Significant Differences between the groups;p-value=0.103;chi-square value=13.287

Discussion

Bond strength is a critical factor influencing the success of orthodontic treatments, which involve the attachment of brackets and other orthodontic appliances to a patient's teeth. One essential preparatory step in this process is etching, where a solution is applied to the tooth surface to create a roughened texture. This rough surface allows the adhesive material to form a stronger bond with the enamel[5]. Several variables play a role in the etching process, including the type of enamel conditioner used, the acid concentration in the conditioner, and the duration of the etching process itself. In this study, the bond shear strength for three different etching times, labeled as Group I, Group II, and Group III were examined. These etching times were set at 5 seconds, 15 seconds, and 30 seconds, respectively.

The mean bond shear strength for each group, presented in Mega Pascals (MPa), offers valuable insights into the effect of varying etching times on the strength of the bond. Group I, with an average bond shear strength of 2.947 MPa, represents the shortest etching time of 5 seconds. Group II, with a significantly higher average of 14.16 MPa, corresponds to the 15-second etching time. Finally, Group III, with an average bond shear strength of 19.05 MPa, is associated with the longest etching time of 30 seconds.

These results clearly indicate a positive correlation between etching time and bond shear strength. As the etching time increases, the mean bond shear strength also increases. Group III, with the longest etching time of 30 seconds, exhibits the highest bond shear strength, suggesting that a more extended etching period enhances the strength of the bond between the orthodontic appliance and the tooth enamel. This is consistent with the principle that a roughened enamel surface, achieved through etching, provides a better substrate for adhesive materials to bond with, resulting in a stronger attachment.

Comparing Group I (5 seconds) and Group II (15 seconds), we observe an increase in bond shear strength as the etching time is extended. This finding underscores the significance of the 15-second etching time in achieving a more robust bond, as the strength nearly quadruples in comparison to the 5-second group.

It is worth noting that the bond shear strength values reported in our study for all three groups fall within the clinically acceptable range that is between 5.9–7.8 MPa. This implies that even with a shorter etching time as in Group I, the bond strength remains adequate for orthodontic treatment. However, the substantial increase in bond shear strength observed in Group II and Group III suggests that clinicians may consider utilizing longer etching times to further enhance the bond strength, particularly in cases where the added strength is critical.

These findings are consistent with those reported by Marc E. Olsen et al., who demonstrated that bond strengths meeting clinical standards are achievable with remarkably brief etching times, as short as 15 seconds[5]. Similarly, Johanna C. Britton's research further supports the idea that a 15-second enamel etching procedure can enhance clinical predictability and bond strength when

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compared to the conventional 60-second etching method.[6]

Furthermore, the work of Bin Abdullah MS and Rock WP strengthens the argument for decreased etching times, within the range of 15 to 30 seconds, by demonstrating a series of advantages over the traditionally recommended 60-second duration. This reduced etching period not only mitigates the potential for tooth damage but consistently delivers bond strengths meeting the required standards. In situations where there is a need to attach archwires to newly bonded brackets within a brief time frame of just 5 minutes, it may be advisable to opt for a slightly extended etching period of 30 seconds. However, in most other cases, an etching duration as short as 15 seconds is entirely sufficient.[7]

Nonetheless, it's crucial to consider the cautionary notes from studies suggesting potential downsides to reducing etching time. As articulated by Legler et al., while reducing acid concentration does not negatively affect bracket retention, a significant reduction in the etching duration, down to 15 seconds, may lead to an increased incidence of bracket loss when examined in a clinical context.[8]

In addition to these observations, it's worth noting that the Adhesive Remnant Index (ARI) ratings were carefully evaluated for each etching group. The Adhesive Remnant Index (ARI) is an important measure in orthodontics that assesses the amount of adhesive residue left on the tooth surface after the debonding process. A higher ARI score indicates more adhesive remaining on the enamel.

In addition to the observations, it is worth noting that the ARI (adhesive remnant index) ratings were carefully evaluated for each etching group in order to gain further insights into the bonding properties. Upon examining the ARI ratings for the 5-second etching group, it was observed that the values spanned a range of 1 to 3, yielding an average rating of 1.8. This data provides evidence indicating that the majority of the resin material remained securely bonded to the enamel surface following the debonding process. On the other hand, when considering the ARI ratings for the 15-second etching group, a broader spectrum of values emerged, ranging from 1 to 5, and resulting in an average rating of 3.2 which was significantly higher than Group I. Similarly, for the 30-second etching group, the ARI ratings exhibited a range of 1 to 4, with an average rating of 2.9.

Overall, the ARI ratings in this study suggest that there is variation in the amount of adhesive residue remaining on the enamel surface after debonding for different etching times. However, it's important to note that the provided p-values for Groups II and III are higher than the conventional significance level of 0.05 ($p > 0.05$), indicating that there may not be a statistically significant difference in ARI ratings among the different etching times in these groups. This suggests that etching time might not have a substantial impact on the amount of adhesive residue left on the teeth within the context of this study.

The results achieved in this study are consistent with those of Kinch AP, Taylor H et al who similarly explored bond failures with enamel etching times of either 15 or 60 seconds. They employed two distinct techniques for bond removal and assessed the remaining adhesive using the Adhesive Remnant Index (ARI). Their findings also indicate that ARI remains unaffected by variations in etching time, patient age, gender, tooth location within the arch, or the duration of the test. Nevertheless, statistically significant associations were observed with the tooth's position in the arch, the type of bracket utilized, the debonding method employed, and the operator overseeing the procedure. These collective results suggest that adopting a 15-second enamel etching time does not introduce any discernible clinical disadvantages.[9]

Despite the valuable insights provided by this study, there are several limitations that must be acknowledged. The sample size used in this research, while informative, is relatively small. Employing a larger and more diverse sample could enhance the generalizability of the findings. Additionally, this study exclusively used a single type of etching and bonding system, limiting the assessment of broader applicability. It may be beneficial to explore the impact of various etching and bonding systems to gain a comprehensive understanding of their comparative efficacy. Expanding the number of etching groups could also provide a more comprehensive evaluation of the effects of etching variations. Furthermore, examining different time intervals for

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etching and their influence on bond strength could offer a more nuanced understanding of the process.

Conclusion

- The findings of the study present a significant evidence, suggesting that a reduction in the etching time by half, from 30 to 15 seconds, can still yield clinically useful bond strength.
- The bond shear strength values in all three groups fall within the clinically acceptable range of 5.9–7.8 MPa. Even with a shorter etching time, like in Group I, the bond strength meets orthodontic requirements. However, the substantial increase in bond shear strength in Group II and Group III suggests that longer etching times could enhance bond strength, particularly when extra strength is needed.
- Adhesive Remnant Index (ARI) scores were employed to identify the bond failure location among different samples and etching groups. Significant differences were observed among the ARI scores of the three groups. Notably, when excluding the 5-second etching group from the comparison, the remaining groups (15- and 30-second etching groups) did not display significant differences in ARI scores.
- The potential to shorten the etching time without compromising bond strength holds the key to enhancing the efficiency of orthodontic procedures, reducing chair time for patients, and potentially improving patient compliance.

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