

The Impact of Different Time of Enamel Etching on Shear Bond Strength of Metallic Brackets

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Abstract: ***Introduction:** Etching in orthodontics is the most important phase of brackets bonding and failure to achieve proper bonding may result in poor orthodontic results. Thus, many attempts have been made since years to achieve the best etching method in order to maximize orthodontic therapy effect and in other hand to minimize unnecessary rebonding of failed brackets during orthodontic therapy. Failure to do so, leads to prolonged orthodontic therapy including complications like unnecessary repeated checkup at orthodontic office. **Aim of study:** This study evaluates the impact of varying enamel etching times on the shear bond strength (SBS) of orthodontic brackets. **Material and methods:** Sixty extracted premolar teeth were divided into three groups etched for 10, 30, and 60 seconds. Results indicated that 30 seconds provided the highest SBS (11.58 MPa), while 10 seconds yielded satisfactory results (10.53 MPa) with minimal enamel damage. These findings suggest that a 10 - second etching time is suitable for daily orthodontic practice. **Results and discussion:** . The highest bond strength was found among the group of teeth etched for 30 seconds (11.58 MPa). However satisfactory shear bond strength results were found in the group of teeth etched for 10 seconds (10.53 MPa). The group of teeth etched for 60 seconds exhibited the lowest SBS (8.79 MPa). The larger number of teeth exhibited ARI index 1 (21 teeth). Followed by the ARI index 2 (15 teeth). ARI score 0 was present in 14 teeth. Lowest score was recorded with ARI index 3 (10 teeth). **Conclusions:** We consider that time of etching for 10 seconds is suitable in daily orthodontic clinical practice.*

Keywords: Orthodontics, enamel etching, shear bond strength, metallic brackets, adhesive remnant index

1. Introduction

Etching is a critical phase in orthodontic bracket bonding, and improper bonding can lead to suboptimal orthodontic outcomes. Thus, many attempts have been made since years to achieve the best etching method in order to maximize orthodontic therapy effect and in other hand to minimize unnecessary rebonding of failed brackets during orthodontic therapy. Failure to achieve proper bonding can prolong orthodontic therapy and lead to complications such as repeated orthodontic checkups.

Enamel is the hardest and most highly mineralized substance in the human body. The makeup of enamel (by weight) consists of 96% minerals, 3% water, and 1% organic material, such as proteins. The majority of the mineral content is calcium phosphate in carbonated hydroxyapatite crystals. These highly oriented crystals are extremely long and contain over 1000 times the volume of similar crystals in bone, dentin, and cementum. The crystals are organized into bundles known as prisms, about 4µm in diameter, and extend outward from the dentin surface.

The creation of enamel is called amelogenesis. Amelogenesis is genetically controlled process so the size, shape, caries susceptibility, and even shade can vary from person to person.

The creation of the enamel etch pattern rendering a tooth more susceptible to adhesion requires a strong acid. The acid

removes a small amount of interprismatic enamel creating a porous surface, thus increasing the total bonding surface area and allowing adhesion promoters to penetrate into enamel pores and ultimately results in secure micromechanical retention.

Etching dissolves hydroxyapatite crystals and provides micromechanical retention by allowing penetration of adhesion promoters and development of resin tags during bonding.¹

Etching enamel surfaces with phosphoric acid (H₃PO₄) is an accepted and widely applied technique to improve bonding of dental resins to enamel in restorative dentistry, in preventive dentistry, and for the direct or indirect bonding of orthodontic attachments.²

The topography of the etched surface enamel, the etching time, and the concentration of the etchant could also be important factors influencing bond strength.

Many studies report that there is a significant difference of shear bond strength of brackets bonded to enamel comparing to brackets bonded to teeth with cavities that has been filled with different composites.³

The chemical etching of tooth enamel with phosphoric acid was discovered by Buonocore in 1955.⁴ He demonstrated increased adhesion produced by acid pretreatment of enamel

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using 85% phosphoric acid for 30 seconds. This led to dramatic changes in practice of orthodontics.⁵

Retief et al. reintroduced the idea of etching and bonding teeth with improved composites that significantly reduced shrinkage and microleakage.⁶ This new method of bonding provided strength suitable for bonding orthodontic brackets to teeth.

Despite the discovery of different etchant materials, phosphoric acid remains the gold standard.⁷

Good orthodontics practice is essential to correct malocclusion and the use of safe and reliable orthodontics accessories is desirable. Accidental bracket debonding is a frustrating inherent aspect of orthodontics, resulting in a longer treatment and additional cost from materials and service.⁸

Besides the optimal acid concentration, time of etching plays a major role in effectively bonding brackets. Considering the fact that acid applied to tooth causes the roughening of the enamel surface, it is very important to achieve ideal etching time which will produce maximum bonding strength of bracket, and on the other side minimum damage to the etched enamel surface.

According to previously reported literature, adequate shear bond strength for orthodontic bonding should be from 5.6 to 7.8 MPa.⁹

Etching time should not be never underestimated as one of the mayor facts in orthodontic treatment.

The initial recommended acid etching time was 60 seconds.¹⁰ Further research demonstrated etching times of 15 to 20 seconds was equally effective. Etch time should be varied according to the clinical situation.

Buonocore⁴ recommended etching for 30 seconds, but after the detailed fissure sealant studies of Silverstone (1974) a one - minute exposure to acid became the accepted time for all applications of the acid etch technique. More recent studies of bond strengths, relating particularly to orthodontic brackets, have suggested that the failure rate of bonds is unaffected by reducing the etch time.

Many people need to wear fixed orthodontic devices, such as braces, to correct problems with the teeth and jaw (e. g. overcrowding or front teeth that stick out (protrude) or go too far backwards (retroclined)). How these braces are fixed in place will be of interest to them. In order to attach an orthodontic device, such as a brace, to a tooth, the surface of the appropriate tooth first needs to be prepared so that it can retain the glue or bonding agent used to enable the device to be attached securely. For the past 50 years, the usual way of doing this has been to etch (roughen) the surface of the tooth with acid, commonly phosphoric acid, although maleic acid or polyacrylic acid are also sometimes used. Possible harms of etching include the permanent loss of enamel (hard surface) from the surface of the tooth making it more likely for it to lose calcium or weaken during and after treatment. Recently, to reduce the length of time and complexity of the process, a

technique using self - etching primers (SEPs) has been developed as an alternative to conventional etchants or acids. However, whether SEPs or conventional etchants are better, and the best SEP, acid, concentration and etching time, remain to be determined.¹¹

Cleaning procedure of tooth surface before etching and bonding orthodontic elements

Organic pellicle layers on the enamel surface cannot be totally removed by brushing. This organic pellicle layer has been reported to reduce the bond strength between the adhesive resin on the base of the bracket and the tooth.¹² To prevent this, polishing is recommended before performing the bonding procedure. For the polishing procedure, using polishing brushes or rubber cups disposable or sterilization available with low - speed (lower than 20000 rpm) micromotors and non - fluoride pastes for 10 seconds is recommended.¹³ Enamel loss of 5 - 14 μm in depth was reported as a result of the type and application time of the rubber cups or polishing brushes.

Phosphoric acid application on enamel surface of the tooth

Phosphoric acid is used to eliminate oxidation of metal surfaces and enhance adhesion of dyes to metal surfaces in the metal and dye industry.¹⁴ Regarding this information, first steps in etching tooth surface where made, in order to gain better conditions for the bonding of orthodontic brackets.

An etching time of 15 - 30 seconds is accepted as the optimum working time by manufacturers and clinic.^{15, 16, 17, 18}

Aim of Study

The orthodontic treatment depends on many factors. Proper bonding of orthodontic brackets is one of the most important stages during orthodontic treatment. Enamel etching and shear bond strength of orthodontic brackets are the main objective of our research.

Therefore, the aims of our in vitro study will be:

- The impact of different etching times on enamel surface
- The evaluation of bond strength regarding different etching time
- The optimal etching time for bond strength

Clinical implications: This study's findings can guide orthodontists in optimizing clinical practices, reducing treatment time and enamel damage.

2. Material and Methods

Sixty sound premolar teeth (extracted for orthodontic reasons) were included in this study. The premolar teeth can be from the upper or the lower jaw, first or second ones, randomly selected. The selection criteria for the collected teeth will be as follows: complete root development, caries free, no fractures or enamel hypoplasia. The teeth will be collected from University Clinical Dental Center of Kosova – Department of Oral Surgery and Dental Office “Vitadent”.

Collected teeth were properly stored until the research. Teeth were stored in 0.9% NaCl.

Teeth were placed into silicon cups of chemical - cure acrylic resin. Acrylic stopped at the cemento - enamel junction to simulate bony support of natural teeth.

Premolar teeth were divided into three groups, each group containing twenty premolars. First group of teeth was etched for 10 seconds, the second one for 30 seconds and the third one for 60 seconds. Etching was conducted with 37% phosphoric acid used for standard etching procedure in orthodontics when brackets are bonded. Dentaurem ConTec Go 37% phosphoric acid etching gel was used for etching.

All etched teeth were washed by air water spray for 15 seconds, and dried with oil free air syringe.

The brackets were fixed on the labial surface of the teeth. The brackets were fixed with one component "no mix" bracket adhesive in syringes. Orthodontic bonding system Dentaurem ConTec Go adhesive was used. The type of brackets used for this study was Dentaurem "discovery" brackets, System Roth 22.

Shear bond strength of orthodontic brackets was tested on the universal testing machine. Tests were performed in Faculty of Mechanical Engineering – University of Prishtina. Shear bond strength was calculated in Mega Pascals (MP). After debonding of the orthodontic bracket the remaining resin on the buccal surface was evaluated for Adhesive Remnant Index (ARI).

3. Results and Discussion

Shear bond strength (SBS) and ARI scores are presented in the Table 1. The highest bond strength was found among the group of teeth etched for 30 seconds (11.58 MPa). However, satisfactory SBS results were observed in the teeth etched for 10 seconds (10.53 MPa). The group of teeth etched for 60 seconds exhibited the lowest SBS (8.79 MPa).

According to previously reported literature, adequate SBS for orthodontic bonding should be from 5.6 to 7.8 MPa.²² According to these findings all three group of our study showed sufficient shear bond strength. Similar findings were reported by Barkmeier *et al.* (1985) that tested shear bond strengths on human premolars after etching for either 15 or 60 seconds. No significant differences were found between the treatment groups. Although interpretation is complicated somewhat by the fact that the enamel surfaces were ground flat before etching. Braannstrom and Nordenvall found no apparent difference between 15 and 120 second etching times with 37% phosphoric acid; however, the effect of a shorter etching time was not thoroughly investigated. Nordenvall *et al.* conducted serial studies of different etching times on deciduous and young and old permanent teeth and found on young permanent teeth that 15 seconds of etching created a more retentive condition than 60 seconds. They used the degree of surface irregularities as an indicator for the quality of mechanical retention. Therefore, it did not indicate the absolute bond strength. Carstensen (1986) studied the clinical failure rate of mesh - backed metal brackets on 1134 anterior teeth, after etching for 30 - 35 seconds with 37 per cent phosphoric acid. Only 10 brackets were lost during the 16 - month study period. The failure rate was twice as high in the

maxilla as in the mandible, although the difference was not statistically significant. In a second study a comparison was made between the effects of etching for 15 - 20 and 30 - 35 seconds. Only two brackets failed out of the 90 bonded after each etch time, these were both in the maxillary arch and after 15 seconds of etching. It was concluded that a 15 second etch time was sufficient for bracket bonding on anterior teeth.²³

It has been previously reported that etching times of less than 10 seconds and more than 60 seconds do not produce enough shear bond strength.^{24,25} Ten seconds of etching time does not produce enough tagged areas on the enamel, and etching times of 60 seconds or more than 60 seconds impair the integrity of honeycombed prismatic structures on the enamel, which negatively affects bond strength. For the protection of dental structures, a topical fluoride application is generally preferred. It is reported that no additional etching time is required for fluoride applied teeth before treatment.^{26, 27.} These results does not match with our findings, since in our study 10 seconds of etching time provided sufficient bond strength.

However, it is well known fact that the longer time of etching, the higher enamel damage is recorded. This means that the most favorable time of etching in our study was the shortest time of etching (10 seconds) since it provided suitable SBS (10.53 MPa). According to literature reports regarding the optimal shear bond strength of the bracket to the enamel which is expected to prevent bracket debonding during treatment, while not causing enamel damage during debonding and keeping the enamel intact after treatment.²⁹

Regarding ARI score findings in the Table 1 among groups of teeth with different time of etching, results revealed that there was a correlation between SBS and ARI score. This means that the highest ARI scores were recorded among teeth with the high bond strength. This is in line with literature references which demonstrated that higher shear bond strength values are associated with high amounts of remnant adhesive on enamel surface.³⁰

Table 1: Representing bond strength (MPa) and ARI scores of the teeth tested

Tooth	10 sec		30 sec		60 sec	
	MPa	ARI	MPa	ARI	MPa	ARI
1	8.0	0	10.5	3	9.2	1
2	9.4	1	9.2	2	8.4	1
3	9.9	2	11.4	3	6.9	0
4	10.2	3	12.1	3	8.4	0
5	9.5	1	10.4	3	7.3	0
6	9.7	2	8.0	1	9.4	2
7	10.4	3	9.3	1	8.3	1
8	8.9	0	9.9	2	7.7	0
9	9.4	1	10.4	2	6.9	0
10	9.0	1	7.7	1	9.1	2
11	8.0	1	10.2	2	17.0	2
12	9.4	1	18.8	2	8.4	2
13	19.7	1	9.7	1	6.9	0
14	10.2	0	9.9	1	8.4	0
15	17.2	0	21.4	3	7.3	0
16	9.7	2	11.7	1	14.3	1
17	14.8	0	20.6	3	8.3	2
18	8.9	3	9.9	3	7.7	1
19	9.4	0	9.7	2	6.9	1

20	9.0	2	10.8	1	9.1	1
X	10.53		11.58		8.79	
Range	8.0 - 17.2		7.7 - 21.4		6.9 - 17.0	

Table 2 represents ARI (Adhesive Remnant Index) according to different time of etching. The larger number of teeth exhibited ARI index 1 (21 teeth). Followed by the ARI index 2 (15 teeth). ARI score 0 was present in 14 teeth. Lowest score was recorded with ARI index 3 (10 teeth).

Similar reports with findings in our study regarding ARI index can be found in the literature review. Hence, the majority of the ARI scores were 0 and 1, with brackets presenting a greater number of bond failures at the enamel/adhesive interface. Although this interface is considered dangerous for the risk of damaging the enamel surface, no damage was observed at teeth after debonding.³¹

Table 2: ARI scores according to different time of etching (10 sec, 30 sec, 60 sec)

ARI	10 sec	30 sec	60 sec	Total
0	6	0	8	14
1	7	7	7	21
2	4	6	5	15
3	3	7	0	10

4. Conclusions

This study concludes that a 10 - second etching time provides sufficient shear bond strength with minimal enamel damage, making it an optimal choice for daily orthodontic practice. Future research should focus on long - term clinical outcomes of varying etching times.

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