

EVALUATION OF ENAMEL SURFACE AND BOND STRENGTH DEPENDING ON THE ETCHING DURATION - an in vitro study

ЕВАЛУАЦИЈА НА ПРОМЕНИТЕ НА ПОВРШИНАТА НА ЕМАЈЛОТ И ЈАЧИНАТА НА ВРСКАТА ПОМЕЃУ ЕМАЈЛОТ И МЕТАЛНИОТ БРЕКЕТ ВО ЗАВИСНОСТ ОД ВРЕМЕТРАЕЊЕТО НА СРЕДСТВОТО ЗА НАГРИЗУВАЊЕ НА ЕМАЈЛОТ – ин витро студија

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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, for many years, many attempts have been made to achieve the best etching method in order to maximize orthodontic therapy effect, and on the other hand, to minimize unnecessary re-bonding of failed brackets during orthodontic therapy. Failure to do so leads to prolonged orthodontic therapy including complications like unnecessary checkups at orthodontic office. **Aim of the study:** The impact of different etching duration on enamel surface; the evaluation of bond strength regarding different etching duration; the optimal etching duration for bond strength. Establishing laboratory evidence of the minimum etching duration of enamel to provide effective retention of orthodontic brackets. **Material and methods:** Thirty sound premolar teeth (extracted for orthodontic reasons) were divided into three groups. Each group of teeth was etched for 10, 30 and 60 seconds. Shear bond strength and ARI Index were evaluated. **Results and discussion:** The highest bond strength was found among the group of teeth etched for 30 seconds (9.89 MPa). However similar results were found in the group of teeth etched for 10 seconds (9.44 MPa). The group of teeth etched for 60 seconds exhibited the lowest SBS (8.16 MPa). The larger number of teeth exhibited ARI index 1 (10 teeth). Followed by the equal number of teeth belonging to ARI index 0 and 2. (7 each). Lowest score was recorded with ARI index 3. **Conclusions:** We consider that 10 seconds of etching is suitable in daily orthodontic clinical practice.

Апстракт

Вовед: Нагризувањето на емајловата површина е многу значајна фаза во поставувањето на брекетите од фиксниот ортодонтски апарат, и може да биде причина за неуспех во ортодонтскиот третман поради воспоставување на слаба врска меѓу забот и брекетот и да влијае на јачината на силата. Затоа низа години наназад се прават обиди да се постигне најдобриот метод за нагризување со цел да се подобри ефектот од нагризувањето и да се минимизира непотребното повторување на постапката за врзување на брекетот со емајлот на забот со што се успорува и компромитира текот на ортодонтскиот третман, што вклучува и дополнителни прегледи и пролонгирање на времетраењето на третманот. **Цел:** Да се испита влијанието на различно време на нагризување на емајлот, да се изврши проценка на јачината на врската меѓу брекетот и емајлот на забот во зависност од различното време на нагризување и да се утврди оптималното време на нагризување, преку лабораториски докази за минимално потребно време од нагризување на емајлот како би се обезбедила ефикасна врска помеѓу брекетот и емајлот на забот. **Материјал и метод:** Испитувањето е извршено на 30 здрави премолари (екстрахирани од ортодонтски причини, во цел екстракциона ортодонтска терапија) поделени во три групи. Кај секоја група беше изведено нагризување во траење од 10, 30 и 60 секунди. Извршена е проценка на трите различни времетраења на нагризување на емајлот врз јачината на врската на емајлот и брекетот и беше одреден ARI индексот. **Резултати и дискусија:** Најјака врска помеѓу емајлот на забот и брекетот е пронајдена кај втората група на заби нагризувани со киселина 30 секунди (9,89 MPa). Сепак слични резултати најдовме кај првата група заби нагризувани 10 секунди (9,44 MPa). Групата заби нагризувани 60 секунди покажа најнизок степен на јачина на врската (8,16 MPa). Кај поголемиот број на заби ARI индексот беше 1 (10 заби). Проследено со ARI индекс од 0 до 2 по 7 заби. Најмал број на заби покажаа резултат на индексот ARI 3. **Заклучоци:** Според добиените резултати најдобро и оптимално време на нагризување е 10 секунди кое е истовремено и најсоодветно за примена во секојдневната ортодонтска пракса.

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, for many years many attempts have been made to achieve the best etching method in order to maximize orthodontic therapy effect and in other hand to minimize unnecessary re-bonding of failed brackets during orthodontic therapy. Failure to do so leads to prolonged orthodontic therapy including complications like unnecessary checkups at orthodontic office.

The 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 process of creating enamel is called amelogenesis. Amelogenesis is genetically controlled process, therefore 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 bonding¹.

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 direct or indirect bonding of orthodontic attachments².

The topography of the etched surface enamel, the etching duration, 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 have been filled with different composites³.

The chemical etching of tooth enamel with phosphoric acid was discovered by Buonocore in 1955⁴. He demonstrated increased adhesion produced by acid pretreatment

of enamel using 85% phosphoric acid for 30 seconds. This led to dramatic changes in the practice of orthodontics⁵.

In 1973, Retief reintroduced the idea of etching and bonding teeth with improved composites that significantly reduced shrinkage and microleakage⁶. 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 standard⁷.

Good orthodontic practice is essential to correct malocclusion and the use of safe and reliable orthodontic accessories are desirable. Accidental bracket debonding is a frustrating inherent aspect of orthodontics, resulting in a longer treatment and additional cost for materials and service⁸.

Besides the optimal acid concentration, etching duration plays a major role in effectively bonding brackets. Considering the fact that the acid applied to tooth causes the roughening of the enamel surface, it is very important to achieve ideal etching duration which will produce maximum bonding strength of bracket and, on the other hand, cause 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 MPa⁹.

Etching time should never be underestimated as one of the major facts in orthodontic treatment.

The initial recommended acid etching duration was 60 seconds¹⁰. Further research demonstrated etching duration of 15 to 20 seconds was equally effective. Etching duration should vary according to the clinical situation.

Buonocore (1955) recommended etching for 30 seconds, but after the detailed fissure sealant studies of Silverstone, (1974) a one-minute exposure to acid became the accepted duration for all applications of acid etching technique. More recent studies of bond strengths, particularly in relation to orthodontic brackets, have suggested that the failure rate of bonds is unaffected by reducing the etching time.

Barkmeier et al. found neither qualitative differences in the enamel surface structure nor differences in the bond strength after etching for 15 or 60 seconds with a 50% phosphoric acid. However, the study did not use wide range of etching duration nor did it count the percentage of bond failure interface distributions.

Many people need to wear fixed orthodontic devices, such as braces, to correct problems with teeth and jaw (e.g. overcrowding or front teeth that stick out (protrude) or go too far backwards (retroclined)). The manner in which 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 bond-

ing agent used to for safely attaching the device. For the past 50 years, the usual manner of doing this was etching (roughening) the surface of the tooth with acid, commonly phosphoric acid, although maleic acid or polyacrylic acid are also used sometimes. Possible harms of etching include 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, it remains to be determined whether SEPs or conventional etchants are better, and which is the best SEP, acid, concentration and etching duration¹¹.

Cleaning procedure of tooth surface before etching and bonding orthodontic elements

Organic pellicle layers on the enamel surface cannot be completely 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 tooth¹². To prevent this, polishing is recommended before performing the bonding procedure. For the polishing procedure, using polishing brushes, disposable rubber cups or sterilization available with low-speed (lower than 20000 rpm) micromotors and non-fluoride pastes for 10 seconds, is recommended¹³. 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 the enamel surface of the tooth

Phosphoric acid is used to eliminate oxidation of metal surfaces and enhance adhesion of dyes to metal surfaces in metal and dye industry¹⁴. Regarding this information, the first steps in etching tooth surface where made, in order to gain better conditions for bonding of orthodontic brackets.

Etching for 15-30 seconds is accepted as the optimum working time by manufacturers and clinic^{15,16,17,18,19,20,21}.

Aim of the 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 duration on enamel surface
- The evaluation of bond strength regarding different etching duration
- The optimal etching duration for bond strength

Material and methods

Thirty 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. The container was filled with acrylic up to the cemento-enamel junction to simulate bony support of natural teeth.

Premolar teeth were divided into three groups, each group containing ten 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 universal testing machine. The tests were performed at the Faculty of Mechanical Engineering – University of Prishtina. Shear bond strength was calculated in Mega Pascals (MP). After debonding the orthodontic bracket, the remaining resin on the buccal surface was evaluated for Adhesive Remnant Index (ARI).

Results and discussion

Shear bond strength (SBS) and ARI scores are presented in Table 1. The highest bond strength was found

among the group of teeth etched for 30 seconds (9.89 MPa). However similar results were found in the group of teeth etched for 10 seconds (9.44 MPa). The group of teeth etched for 60 seconds exhibited the lowest SBS (8.16 MPa).

According to previously reported literature, adequate SBS for orthodontic bonding should be from 5.6 to 7.8 MPa²². According to these findings, all three groups 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 being 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 duration 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 duration on deciduous and young, and old permanent teeth, and found that 15 seconds of etching created a more retentive condition than 60 seconds in young permanent teeth. They used the degree of surface irregularities as an indicator for the quality of mechanical retention. Therefore, it did not indicate the absolute bonding 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% 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 etching time, these were both in the maxillary arch and after 15 seconds of etching. It was concluded that a 15-second etching time was sufficient for bracket bonding on anterior teeth²³.

It has been previously reported that etching of less than 10 seconds and more than 60 seconds do not produce enough shear bond strength^{24,25}. Ten seconds of etching does not produce enough tagged areas on the enamel, and etching of 60 seconds or more than 60 seconds impairs 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^{26,27,28}. These results does not match our findings, since in our study 10 seconds of etching provided sufficient bond strength.

However, it is well known fact that the longer etching duration, the higher enamel damage is recorded. This means that the most favorable etching duration in our study was the shortest time of etching (10 seconds) since it provided suitable SBS (9.44 MPa) with minimum enamel damage. According to literature, reports regarding

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

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
X	9.44		9.89		8.16	
Range	8.0-10.4		7.7-12.1		6.9-9.2	

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 treatment²⁹.

Regarding ARI score findings in Table 1 among groups of teeth with different etching duration, results revealed that there was a correlation between SBS and ARI score. This means that the highest ARI scores were recorded in teeth with 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 surface³⁰.

Table 2 represents ARI (Adhesive Remnant Index) according to different etching duration. The larger number of teeth exhibited ARI index of 1 (10 teeth). Followed by the equal number of teeth belonging to ARI index of 0 and 2. (7 each). Lowest score was recorded with ARI index of 3.

Similar reports with findings of 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 due to the risk of damaging the enamel surface, no damage in teeth was observed after debonding³¹.

Table 2. ARI scores according to different etching duration (10 sec, 30 sec, 60 sec)

ARI	10 sec	30 sec	60 sec	Total
0	2	0	5	7
1	4	3	3	10
2	2	3	2	7
3	2	4	0	6

Conclusion

Sufficient shear bond strength was found among the group of teeth etched for 10 seconds only. Also, the lowest ARI Index was recorded at the same group of teeth. Therefore, we consider that etching for 10 seconds is suitable in daily orthodontic clinical practice.

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