

Problems in Standardization of Orthodontic Shear Bond Strength Tests; A Brief Review

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Abstract:

Bonding brackets to the enamel surface has gained much popularity today. New adhesive systems have been introduced and marketed and a considerable increase in research regarding bond strength has been published. A considerable amount of these studies deal with shear bond strength of adhesives designed for orthodontic purpose. Previous studies have used variety of test designs. This diversity in test design is due to the fact that there is no standard method for evaluating shear bond strength in orthodontics. Therefore comparison of data obtained from different study is almost impossible.

This article tries to briefly discuss the developments occurred in the process of shear bond strength measurement of orthodontic adhesives with an emphasis on the type of test set up and load application.

Although the test designs for measuring shear bond strength in orthodontics are still far from ideal, attempts must be made to standardize these tests especially in order to make comparison of different data easier. It is recommended that test designs be set up in such a manner that better matches with the purpose of the study.

Key Words: Orthodontic bond strength; Shear bond strength; Standardization

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INTRODUCTION

The introduction of the acid etch bonding technique in 1955 by Buonocore has found applications in all fields of dentistry, including orthodontics [1-3]. Bonding brackets to the enamel surface has gained such popularity that most orthodontists bond attachments either directly or indirectly to the teeth today [4].

It can be stated that bonding in orthodontics has an age comparable to bonding in other fields of dentistry. The first attempts of bonding attachments goes way back to 1965, when Newman tested an epoxy resin as an adhesive [5]. Since then, many adhesive

systems have been introduced and marketed and a considerable increase in research regarding their bond strength has been published. The development of adhesives has been so rapid that clinicians can hardly keep up with all the developments. A considerable amount of these studies deal with measuring bond strength of adhesives and the shear bond strength being the most common factor to be tested [6]. Reviewing previous studies revealed that there are considerable variety of test designs [6,7]. Such diversity is due to the fact that there is no standard method for evaluating shear bond strength in orthodontics

[8]. Therefore comparison of data obtained from different study is almost impossible [9].

This article tries to briefly discuss the developments occurred in process of shear bond strength testing methods of orthodontic adhesives with an emphasis on the type of tests' set up and load application.

Bond strength tests

Eliades et al have categorized bond strength testing methods according to the study environment into three different types [7]:

- **Ex vivo:** This group consists of procedures like finite element modeling (FEM). This method is a computer based study in which the loading circumstances are simulated. Many efforts have been made in this field to improve the method and in order to include more details to achieve more accurate simulation. However, still many parameters are missing and have to be studied.

- **In vivo:** this category includes analyses of rate and site of failure in brackets during the course of treatment. Although it may seem that this group is the most appropriate category for studying the clinical behavior of bond strength, a full control of the study environment is not completely possible.

- **In vitro:** This group of tests can be performed using a mechanical testing machine or using debonding devices (pliers, wrenches, etc.). The former method is actually performed to evaluate the mechanical properties of adhesives to simulate clinical conditions which might lead to bond failure. This group of tests can also use to compare adhesives with each other. The main disadvantage of this category might be that complete replication of in vivo conditions has not been possible yet.

Despite all limitations, most bond strength studies fit into the last category because performing this group of tests is much easier and there is also reasonably good control on the study design [7].

Extreme variety of bond strength test setups: Some variables that may cause

inconsistency of bond strength test results include:

Teeth: Extreme variety exists in the type of tooth selected for bond strength testing, from human teeth (including molars, incisors, and premolars) to animal (bovine and monkey) teeth. Synthetic materials also have been introduced as a substitute for natural teeth in order to have better sample unification and test standardization [6,10], however, no consensus has been achieved on the concept of tooth selection. Although in theory human teeth should be the most suitable specimen, one of problems with human teeth is to collect healthy and intact human teeth [10]. Most healthy teeth which have been extracted are mainly first premolars due to orthodontic treatment. On the other hand, premolars are said to have the most variety in morphology [10]. As another problem, collecting healthy human teeth requires much more time and it is highly probable that this time factor shall end up in bias [10]. It has been reported that bovine teeth can be used as a substitutes to human teeth in orthodontic bond strength studies [10].

Brackets: The use of different types of brackets is another parameter causing diversity in shear bond strength results. Among differences, the composition of the bracket is worth mentioning. Brackets may be basically made from plastic, metal or ceramics. Guan et al [11] have shown that the filler content of plastic brackets can cause a difference in shear bond strength results. The shear bond strength increases as the filler content of brackets increases.

Storage media: Various storage media like water, saline, chloramine, formaldehyde, ethanol, thymol, sodium azide and artificial saliva have been recommended and utilized as storage media [6, 7]. This variety also may be a factor which can influence the results of bond strength studies. Except for a few materials, the use of different media does not

seem to play a strong role however further investigation might be needed [7].

Crosshead speed: The moving crosshead of the testing machine is the component that applies the required force to the specimens. It has been recommended to minimize the crosshead speed of the testing machine as low as possible [6]. Fox has recommended a 0.1 mm/min speed [6]. The fundamental concept may be that a lower crosshead speed results in more accuracy. However such slow and precise force application rarely occurs in the oral environment. This means that using slow crosshead speeds might not be suitable for simulation of the forces acting in the oral cavity. Most bond failures are caused by a much higher velocity. Versluis et al also have demonstrated that when higher crosshead speeds are used, the incidence of cohesive failures in the tooth substrate decreases significantly [12]. Some studies have recommended upper limits for bond strength of adhesives. This recommendation is for preventing damage to the tooth structure. It is better to have a repeatable bond failure rather than an irreversible enamel tear or crack. It can be concluded from Versluis et al that higher "upper limits" can be achieved for adhesives if higher crosshead speeds are used. That is because less enamel destruction could be observed in these circumstances. Therefore, it might not be necessary or desirable to use very slow crosshead speeds. This also could be a subject for further investigation.

Mode of force application: One of the most common and oldest methods of shear force application is by a loop of wire. Newman was one of the first to engage a loop of wire under Plexiglas, polycarbonate and acrylic blocks [5] since the direct bonding of orthodontic attachments to tooth structure had not been introduced. After the appreciation of direct bonding of metal brackets, these attachments were used thereafter. In this method, a loop of wire was formed and engaged under the

bracket tie-wings. A pulling force on the wire causes stress on the adhesive interface and breakage occurs. As the direction of force is fairly parallel to the adhesive interface, the stress is considered to be of a shearing nature. After a review and comparison of previous studies, Fox et al mentioned the problem of "play" of round wire under the tie-wings and therefore introduced their method of force application by using a rectangular wire engaged under the bracket tie-wings; an improved design of the "wire loop" method [6].

One of common method for shear force application was schematized by Brantley and Eliades [8]. In this method the force applied to an area near the base of the bracket or at the bracket-adhesive interface via a blade or rod attached to the crosshead of a testing machine [8]. The idea of using this design came from the concept of basic material properties (explained in next section) and attempting to produce a "pure shear" force vector, and eliminating other undesirable force components.

Another mode of force application is by means of a chisel shaped blade, but this design actually creates wedge opening forces which neither simulate clinical conditions nor describe basic material properties [13, 14].

Standardization of bond strength test protocols. Unfortunately the topic of bond strength tests contains more criticism than attempts to standardize them [6,7]. Few studies are reported that show such enthusiasm in them [16]. Fox et al have taken the first step for bond strength standardization in orthodontics by introducing their rectangular wire loop design [6]. This method has served as a reference to many bond strength studies. Another step has been taken by Guan et al [11]. Although their main idea was not standardizing, they tried to use the method introduced and defined in the ISO TR 11405 technical report [15]. One limitation of this protocol is that it is designed for cylindrical

specimens and the blade cannot be adjusted to brackets, which have a square outline, and therefore modifications have to be made in the blade design.

A main step towards standardization has been taken by Littlewood and Redhead [16]. These investigators constructed and used a jig for mounting specimens and using a specially designed blade for the application of shear bond strength. In their study, the technique has been compared to the recommended protocol of Fox et al. The results showed a superior control on the test when using jigs. In a controlled study with adequate number of samples, dispersion of results in one group could be an indicator of poor force control [19]. This is evidently seen in Littlewood and Redheads study, where using jigs showed even less dispersion of results than when using a wire loop as recommended by Fox et al [6]. It is highly probable that the dispersion might be caused by the play of the wire under the bracket tie wings [16].

In vitro shear bond strength tests have been highly criticized [12, 17]. Bond strength tests in orthodontics lend itself well to the pioneer works of researchers in the field of restorative dentistry and dental materials.

Van Noort et al used a finite element model to show that stress concentration is not uniformly distributed at the adhesive interface [17]. They have shown that shear stress is not uniformly distributed over the entire bonded surface.

Versluis et al pointed to the fact that "shear" bond strength is actually a basic material property that is independent of geometry [12]. On the other hand, simulation of clinical performance is a totally different approach, and the two issues should not be confused with each other. It appears that there has been a misunderstanding in describing "shear bond strength" in dentistry, especially in orthodontics. Probably it would be more appropriate not to use the term "shear" in orthodontic tests and use a more general terms like "occlusal

force resistance". Many studies have used the term "shear" or "peel" for describing similar conditions [6, 16, 18]. The diversity in results obtained from different shear bond strength test method indicates that orthodontic bond strength tests are not representative of a basic material property.

Versluis et al stated that standardization cannot fix deficiencies in the basic mechanics of the test set up. However another problem is that lack of a standard procedure eventually makes the comparison of results obtained from different studies almost impossible [9].

In order to show the differences in the results obtained by different test setups, a study was conducted to compare the two most common methods for measuring shear bond strength in orthodontics [19]. The results showed a significant difference between the results obtained from two methods. Specimens tested using a shearing blade showed the shear bond strength approximately one and a half times higher than when wire loops were used.

CONCLUSION:

Although bond strength tests are still far from ideal, attempts should be made to standardize these tests at least in order to make comparisons easier.

Before using any method, it would be necessary to be ascertained that for what purposes the study is being performed.

Is this to see how the adhesive is going to withstand occlusal forces or other stresses available in the oral cavity? In this case we are dealing with a more complex force pattern. Exact simulation of this situation may not be possible at but efforts should to be made to unify these tests therefore, a better agreement and conclusions could be drawn

On the other hand, one might be planning to evaluate circumstances and enamel surface changes that occur at the end of a proposed orthodontic treatment or exploring the surface characteristics of enamel after a debonding

procedure therefore, simulation of that circumstance would be more appropriate. It has been argued that such methods of force application has a more tensile behavior and not shear [20]. Designs and setups using debonding pliers have been introduced which could be suitable for quantitative and qualitatively evaluations [20].

A study of basic material properties is a totally different scenario, which should not be mixed up with clinical issues in orthodontics.

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مروری بر مشکلات استاندارد نمودن آزمونهای تعیین استحکام باند برشی در ارتودنسی

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چکیده

با توجه به گسترش روزافزون درمانهای ارتودنسی ثابت، مسأله اتصال براکت به سطح مینا اهمیت بسزایی یافته است. سیستم‌های ادهزیو بسیاری معرفی و وارد بازار شده‌اند و به موازات آن تحقیقات بیشتری نیز در زمینه باندینگ انجام شده است. درصد قابل توجهی از این تحقیقات در زمینه ارتودنسی است. در مطالعات قبلی روشهای مختلفی جهت تعیین استحکام باند به کار گرفته شد. استفاده از روشهای مختلف به این دلیل است که روش استاندارد برای تعیین استحکام باند در ارتودنسی وجود ندارد؛ بنابراین مقایسه نتایج حاصل از مطالعات مختلف غیر ممکن می‌نماید. مطالعه حاضر به طور مختصر به پیشرفتهایی که در زمینه اندازه‌گیری میزان استحکام باند برشی ادهزیوهای ارتودنتیک به وجود آمده با عنایت به نحوه تنظیم تست و نیروی وارده می‌پردازد. گرچه طراحی‌های مختلف که به منظور ارزیابی میزان استحکام باند در ارتودنسی به کار می‌رود، هنوز دور از ایده‌آل به نظر می‌رسد، تلاشهایی باید در زمینه استانداردسازی این آزمونها صورت گیرد تا امکان مقایسه راحت‌تر آنها فراهم شود. باید گفت تنظیم و طراحی آزمون، باید به گونه‌ای باشد که بهتر با اهداف مطالعه انطباق یابد.

واژه‌های کلیدی: استحکام باند ارتودنتیک؛ استحکام باند برشی؛ استانداردسازی

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