An Analysis of Incisive-Bracket Bond Resistance in Orthodontics

II. Operating in moderate aggressive media

MADALINA MATEI, SORIN CIORTAN, ADRIAN CIRCIUMARU*
Dunarea de Jos University, 47 Domneasca Str., 800008, Galati, Romania

During the daily activity the orthodontic systems are suffering various loadings which together with saliva lead to a depreciation of bonding material which is used to fix the brackets on the dental surfaces. For this study human incisive shaped bovine bone were used to simulate mastication in a media consisting in a mixture of sesame, poppy and sunflower seeds and water. The aim is to compare the shear resistance of the bond with the one evaluated for fresh mounted brackets. Also a qualitative analysis is aimed based on micro photos took before and after bracket debonding. There are not rare the cases when patients are returning to doctor immediately after orthodontic system installation despite the medical advice because it is almost impossible to inhibit natural habits developed. In the first period after the installation of the orthodontic systems the reflex of biting the food is present in all the cases and that produces the detachment of the incisive bonded brackets. However during the mastication components of the food are interacting with the brackets generating local loads over the brackets themselves and also over the bonding material which can be a polymer or a composite. These loadings together with the ones meant by the doctor are producing in time small fractures and cracks at the bonding level with consequences on shear resistance of brackets on the tooth.

Keywords: orthodontics, adhesive, bracket, shear strength

In fixed orthodontic treatment, brackets were used for transferring orthodontic forces to the teeth. At first, to attach the brackets to the tooth, orthodontic bands were used and after welding brackets to bands, they were cemented to the tooth. The direct bonding of orthodontic brackets technique was developed rapidly due to its simplicity, efficacy and providing more esthetic qualities. For achieving successful bonding, the bonding agent must penetrate to the enamel surface have easy clinical use, dimensional stability and enough bond strength. The bond strength of orthodontic brackets should be enough to not cause bonding failure and delay in treatment and it also should have adequate resistance against chewing forces and stresses from archwires. According to few stages for bonding of orthodontic brackets and related problems in the conventional system, other techniques such as application of self-etch primers or laser irradiation was suggested to simplify the bonding procedure [1]

The bond strength and the clinical behaviour of orthodontic brackets are important to achieve a satisfying orthodontic treatment. Several materials have been used for the production of orthodontic brackets including stainless steel, titanium, plastic, and ceramics. Titanium has been introduced as an alternative material for the production of orthodontic brackets due to its proven biocompatibility, lack of allergenicity, and increased corrosion resistance. Ceramic brackets were introduced to orthodontics to meet the increasing demand for more esthetic appliances.

In recent years, the number of adults seeking orthodontic treatment has increased, and the need for more esthetic appliances has led manufacturers to design various types of ceramic brackets. However, enamel fractures and cracks have been reported during debonding procedures as ceramic materials are very rigid and brittle materials. *In vitro* testing of orthodontic bond strength provides a guide to the selection of bracket-adhesive combinations. Measurements of shear and tensile bond strength tests are the most commonly used laboratory assessment to determine the performance of orthodontic bonding systems. Nevertheless, the large distribution of results and the lack of standardization of bond strength testing protocols often prevent confident conclusions from being drawn [2].

The study and evaluation of the adhesive potential of a specific bonding system are complicated, as there are multiple variables that can influence the survival or longevity of the bracket-enamel interphase. The two primary tests used for evaluating the strength of the orthodontic adhesives measure shear and tensile bond strengths. In the shear test, the force is directed parallel to the long axis of the tooth and as closely as possible to the bracket-tooth interface [3].

There are many factors that can cause bond failure of orthodontic brackets, including the multifactorial nature of the oral environment which causes *p*H fluctuations, as well as the complex cyclic loading of chewing, alcohol-containing fluids, temperature variations, and food consistency, all of which make it difficult to specifically determine the reasons for failure. When considering each of these factors, the true effectiveness and performance of any particular bracket-bonding system in vitro studies become questionable when different studies are compared [3].

In vitro tests should take into account these factors and somehow to allow the analysis of their effect on the integrity of the tooth-bracket system. From mechanical point of view that means to study the fatigue of bonding agent (polymer or composite) under the controlled variation of external factors and there are many attempts on this way [4-14].

* email: acirciumaru@ugal.ro; tel.; (+40) 0730290022

Experimental part

Materilas and methods

For this study metal brackets Avex MX Opal from Opal Orthodontics by Ultradent had been used and Transbond™ Plus Self Etching Primer and Transbond™ PLUS Color Change Adhesive from 3M Unitek to ensure the brackets positioning on teeth. Transbond™ PLUS Colour Change Adhesive is a moisture tolerant light cure bonding system with the convenience of delivery on demand. Transbond PLUS adhesive provides excellent bond strength with metal and ceramic brackets along with the special features of colour change and fluoride release [15] it is a photo curable polymer composite allowing a more accurate operation during the bracket installation and its pink colour disappear after the photo cure. Transbond™ Plus Self Etching Primer is the all in one bonding solution. It is one-step primer features unique chemistry and an exclusive delivery system which together allows user to etch, prime and bond enamel in one simple and cost-effective step, in just seconds [16]. Avex MX stainless steel brackets offer accuracy and predictable treatment results. They allow for an extremely low-profile design to enhance patient comfort without sacrificing bracket strength. Precise right angles create parallel slots, resulting in more control and reduced wire bending. True torque in the base delivers proper positioning with minimal occlusal interference [17].

Bovine rib bones were human incisive shaped after conditioning and the brackets were installed on them such as the obtained systems can be easily gripped on the universal testing machine. The use of bovine bones allows repeated use of the same system including cases of wrong positioning, insufficient etching, various quantities of composite and other difficulties that might occur in practice. The presented shape of analyzed system ensures the facile manipulation of samples during tests and during their reconditioning avoiding the necessity of fixing the human teeth on cements or polymer slots in order to be used for different types of tests.

As is an usual practice for orthodontists to re-install the detached brackets this study is carried out by re-installing the brackets used already in a study regarding shear resistance of the bond on the same systems. The remains of the adhesive were removed both from the bone surface and from the bracket surface and then the installation procedure was executed. Using the same human incisive shaped bones it is expected that this time some consistent amount of the bone porosity to be covered.

The use of the mixture of poppy, sesame and sunflower seeds ensure a moderate abrasive media for the incisive with bracket and water was added to ensure the compaction of the seeds. The dimensions of the seeds and their hardness allow the interaction direct to interface (poppy and sesame) or with the system components tooth or bracket (sesame and sunflower) generating at those levels some loadings which may produce reduction of the strength of the bond.

The twenty tooth simulators were divided into five groups (samples 1 to 4, samples 5 to 8, samples 9 to 12, samples 13 to 16 and samples 17 to 20) and for each group a number of simulated bites were performed on the universal testing machine from CTR. Because of the natural curvature of the bovine rib bone the penetration of the tooth in the seeds mixture was accompanied by a soft rotation as in the case of human superior incisive during chewing. The bite was simulated by an oscillatory like movement with a cycle formed of descending part when the tooth enter into the moist mixture and the components of orthodontic system interact with the seeds and an ascending part during the components of the moist mixture are sliding along the elements of the orthodontic system.

For the first group 1000 cycles were produced, for the second group 2000 cycles, for the third 3000 and so on. If there are effects of the seeds mixture and water on the orthodontic system (tooth, composite, bracket) they must be observable in reducing of the necessary force which produce the detachment of the bracket and on the aspect of tooth surface, broken area of the adhesive and brackets elements observable by microscope.

Results and discussions

Preliminary tests were run in order to point out elemental conditions of the experiment. Six of the simulated teeth had simulated bites in a dry mixture of seeds (poppy, sesame and sunflower) for one hundred, two hundred, three hundred and so on bites. The microscope analysis (executed on an Olympus SZX 10) did not reveal any modifications of the tooth surface, bracket surface, any signs of wear on the wire or on the silicon ring figure 1. Also the shear resistance was measured and the mean value was of about 20N (the same value as the one measured for the set of 20 fresh installed brackets).

For this study twenty tooth simulators were gripped on an universal testing machine from CTR (fig. 2. and fig. 3.) and the machine was set to execute the oscillatory movement.

Both for descending part and the ascending part of the cycle representing the bite the speed of the orthodontic system was of 50mm/s and the amplitude of the movement was of 15mm, This values are fitting the values which are obtained in the case of natural processes of biting and chewing. Also as it had been mentioned above the natural curvature of the bovine bone contributes to the complexity of the simulation by introducing a soft rotation, proper to the natural movement during the bite.

After all the incisive-bracket systems supported the planned number of bites they were tested for shear resistance according to the first part of this study and the result can be analyzed in table 1. Interesting is that for sample numbered 11 practically any loading was not necessary denoting a poor bond between tooth and bracket. An explanation could be connected with the fact that during the test a large amount water dispersed milled substance was transferred between composite and bracket as can be easily observed in figure 4.

The debonding mode according to ARI (adhesive remnant index) by means of qualitative analysis of microscope [18] shows for all the samples variations

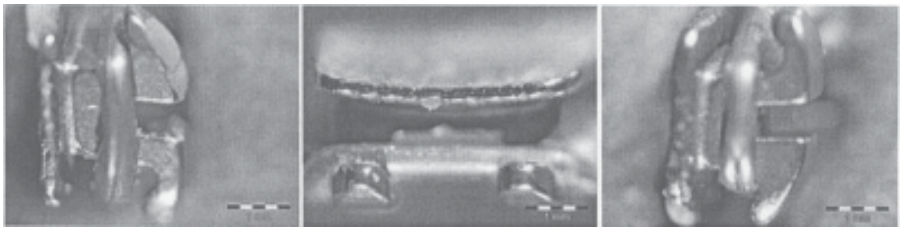

Fig. 1. Microscope photos of the detached bracket from the orthodontic system which simulated 500 bites on a dry mixture of seeds. Any sings of wear cannot be observed

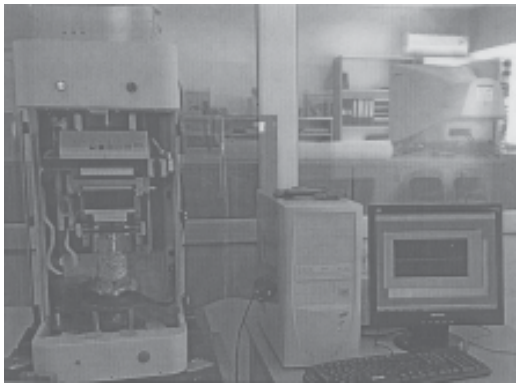

Fig.. 2. Universal testing machine from CTR

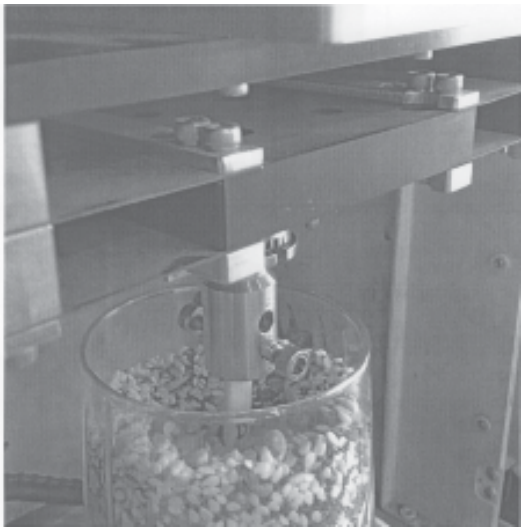

Fig. 3. Bite simulation on a dry mixture of poppy, sesame and sunflower seeds

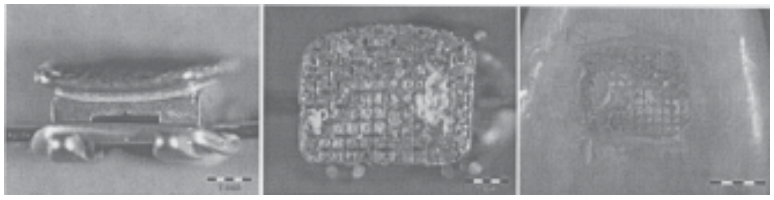

Fig. 4. Sample no.11. It might be noticed the transfer of milled substance on the composite surfaces signifying that the bond was poor

Sample	1	2	3	4	5	6	7	8	9	10
Force [N]	12,38	13,04	17,63	13,40	13,94	16,71	13,52	11,87	14,7	11,19

Sample	11	12	13	14	15	16	17	18	19	20
Force [N]	0	14,81	15,90	8,69	16,27	16,85	12,34	17,84	10,98	16,42

Table 1
SHEAR RESISTANCE VALUES

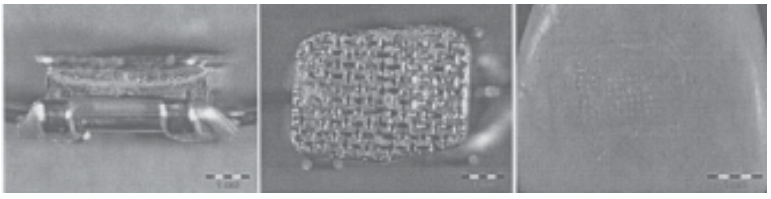

Fig. 5. Sample no. 4 scoring 3 in ARI (more than 90% of the adhesive remained on the tooth surface)

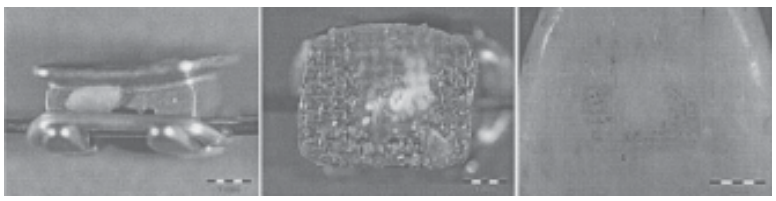

Fig. 6. Sample no. 20 scoring 1 in ARI (less than 50% of the adhesive remained on the tooth)

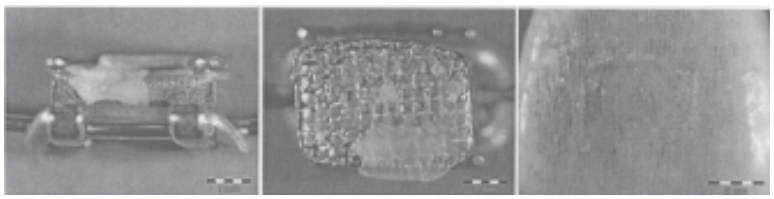

Fig. 7. Sample no. 17 scoring 2 in ARI (more than 50% of the adhesive remained on the tooth)

between sample no. 4 (fig. 5.) and sample no. 20 (fig. 6.) for example sample no. 17 (fig. 7.).

Regarding the shear resistance it is easily to observe that the values are smaller than the mean value evaluated for fresh installed brackets. Since the used materials (excepting the bovine bone) are for orthodontic applications the diminishing of resistance cannot be explained by water absorption at the composite level neither by water absorption at the bone level (in this case it should exist many samples scoring 0 in ARI – less than 10% of adhesive remained on the tooth). The only explanation is based on the interaction between the orthodontic system and moist

mixture of seeds with consequences at microscopic level (micro fractures and cracks) which are leading to a decrease of shear resistance.

Conclusions

Using bovine bone as replacement for human teeth the accidental debonding of orthodontic brackets was studied by measuring the force which produces the detachment of the bracket from the composite which is keeping it on the tooth. The incisive-bracket samples were supposed to repeated bites in a moist mixture of seeds with moderate hardness in order to point out the effect of quasi-normal use of orthodontic system.

According to the physiologists [19] a mean value of one hundred bites per day was evaluated for a normal adult. The orthodontic practice recommends the tuning of the orthodontic system of a patient between 20 and 40 days, in this conditions the tested samples were for 10, 20, 30, 40 and 50 days of normal life.

An interesting aspect concerning the results is that for all the groups the mean value is almost the same which means that the system is affected during de first 1000 bites and after that the influence is absent. Further studies have to cover these first 1000 bites to point out the turning point.

In order to use the bovine bones it is necessary to develop a protocol of bracket installation such as to ensure the reproduction of the test results.

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