New/Modern Adhesive Systems in Orthodontics

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Summary

In this paper the bond strength of the bracket and tooth surface is defined with regard to suitability for clinical practice and different factors described which could have an effect on it. As moisture is the most frequent cause of debonding of the bracket, its effect is discussed on new adhesive systems: conventional, hydrophilic and self-etching. The bond strength of certain systems is compared in dry conditions and under the influence of water and saliva applied to the surface of the enamel during different phases of bracket bonding in in vitro *conditions. Their efficacy is then compared in clinical conditions. The specificity of contamination by saliva and blood and the effect of blood on bond strength when using different systems are pointed out.*

Key words: *bond strength, moisture, adhesive systems.*

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Introduction

The success of therapy with fixed orthodontic devices depends on several factors. Particularly important for its successful realisation, among other things, is adequate strength of adhesion of the brackets onto the surface of the tooth, and in this connection, their occasional debonding. Changing the debonded bracket with a new one often prolongs therapy and causes financial loss to the clinician due to the used material and time (1). Various investigations have indicated that bond strength of 2.8 Mpa-10 Mpa is suitable for clinical practice (2,3,4). However, the bond strength can be effected by different factors. Thus, Sharma-Sayal et al (5) point out that the appearance of the base of the bracket has a significant effect on bonding. Olsen et al (6) investigated the effect of enamel preparation prior to placing the bracket and determined that air abrasion compared with classical etching of the tooth surface with 37% phosphoric acid weakens the bond between the tooth and bracket. Consequently, they do not recommend this method in everyday clinical practice. In their investigation the duration of etching with acid did not appear to be an important factor. Namely, it was determined that it is clinically sufficient to etch for only 15 seconds, although clinicians are usually recommended 20 to 30 seconds. They also determined that even after 60 seconds of etching the bond between tooth and bracket is not significantly better (7, 8). Hobson et al (9) investigated the influence of different groups of teeth on this parameter. They started from the fact that the density of aprismatic enamel is different on different teeth, and showed that bond strength between the bracket and tooth is greatest on the first lower molar, and weakest on the first upper molar.

Different materials are available on the market, which are used for bonding brackets onto the surface of enamel. With the development of the etching technique new orthodontic devices with brackets, which are fixed with different composite res-

ins have many advantages over the former use of cement and rings on all teeth: greater comfort for the patient, no need for separation of teeth before placing the device, reduced gingival irritation, easier oral hygiene, improved aesthetics and shorter duration of the visit (10). Composite resins of older generations are hydrophobic and require dry and isolated working areas. The oral cavity often cannot fulfil such conditions, and the presence of moisture is considered one of the most frequent causes of debonding of the bracket. When the etched surface of the enamel is moist, the majority of the pores are blocked, which prevents penetration of the resin. The final result is an insufficient number and length of resin extensions? which enable bonding with the enamel by micromechanical retention, and consequently its reduced strength (11). As such a bond cannot withstand all the forces during treatment (mastication, forces of wire arches and active elements of the fixed apparatus, forces which occur due to patient negligence), breakage of some elements of the device occurs (13). A possible solution to the problem are self-etching systems which enable conditioning and penetration of resin at the same time. Such systems contain ester methacrylate phosphoric acid, which combine acid as the etching component and primer (14). It is considered that with these materials the bond strength of brackets on the surface of the tooth is clinically satisfactory (15). By reducing the number of procedures when bonding the bracket the total time for placement of the fixed orthodontic device is reduced and consequently the possibility of contamination of the working area with saliva is also reduced (14). Another possible solution is the development of primers which are resistant to moisture. They are produced on the basis of adhesive systems which are applied for bonding composites on dentine, and contain hydrophilic components such as hydroxyethyl methacrylate (HEMA) and maleic acid dissolved in acetone, which are effective in the presence of moisture (12).

Investigation *in vitro*

Cacciafest et al (11) investigated the effect of moisture on bond strength between the surface of the tooth and orthodontic brackets. They carried out an investigation on 315 extracted bovine incisors. Criteria for the selection of masticatory units was that the buccal surface was intact, without cracks caused by extraction and without caries. They were divided at random into 21 groups with 15 teeth each. Brackets were bonded by classic hydrophobia (Transbond XT), hydrophylic and self-etching primers and each combination of adhesive system tested on enamel in seven different conditions: 1. dry, 2. water applied to the enamel prior to the primer, 3. water applied to the surface after the primer, 4. water applied prior to and after the primer, 5. saliva applied to the enamel before the primer, 6. saliva applied to the surface after the primer, and 7. saliva applied before and after the primer.

Before application of Transbond XT and hydrophilic primer the teeth were etched with 37% phosphoric acid in gel. The strength of the bond was measured by a universal testing machine (Model 4301, Instron, Canton, Mass). The following results were obtained: the uncontaminated surface of the enamel showed the highest values of bond strength, regardless of the system used. Hydrophilic and conventional primers showed the same bond strength when the surface of the enamel had earlier been contaminated with saliva. Webster et al obtained the same result (16). In the majority of cases of enamel contamination, bond strength was greatest when using self-etching primers. Water and saliva least effected such adhesive systems, except in cases where moisture was applied after the recommended drying with compressed air for 3 seconds.

Similar investigations in laboratory conditions have been conducted on extracted human teeth. Littlewood et al (17) examined the difference in bond strength of the bracket and tooth when using conventional and hydrophilic primer. They used extracted healthy premolars of patients under 18 years of age. Hydrophilic primer 3M Unitek and conventional adhesive primer (Transbond) were used. Each adhesive system was tested on 30 masticatory units. The force needed to debond the bracket from the tooth surface was measured by a conventional machine (Lloyd Instruments, Fareham, U.K.: NAMAS certified No. 980108). Bond strength was then calculated by dividing that force with the surface of the bonded bracket on the tooth. Although the hydrophilic system was made with the object of being insensitive to moisture, instructions for use indicate the need to

dry the tooth surface prior to bonding the bracket. Thus, this investigation, because of comparison with conventional adhesive systems, was carried out in dry conditions. The brackets placed by using hydrophilic primer showed less bond strength compared to the conventional adhesive system.

Rajagopal et al (12) carried out a similar investigation, although differences in bond strength of the examined primers were not only compared in dry conditions. Namely, they were also compared during contamination with saliva. The primers used were: conventional - Transbond XT, primer insensitive to moisture - Transbond MIP and self-etching - Transbond plus. The sample of teeth for the investigation consisted of 120 upper human premolars extracted for orthodontic reasons with intact buccal enamel. The teeth were divided into 6 groups: groups 1, 2 and 3 were tested without saliva contamination, and groups 4, 5 and 6 with saliva contamination. Bond strength was measured by a Lloyd Universal testing machine (model No. LR 100K). In the case of dry conditions the self-etching primer showed greatest strength, conventional slightly less and the primer insensitive to moisture the least. In the contaminated conditions the situation was different. The primer insensitive to moisture achieved the greatest bond strength. The self-etching primer produced slightly less strength and the conventional the least.

Clinical investigations

Although laboratory investigations give guidelines for the use of certain adhesive systems in everyday practice, it should be kept in mind that they are used in conditions which are different from everyday clinical conditions. Namely, complete isolation from moisture, which can be achieved in *in vitro* conditions is frequently impossible in the patient's mouth. It has always been presumed that clinical investigations lead to results similar to those obtained in such investigations (18). However, with no apparent reason, systems for placing brackets without statistically significant differences in the strength of their bonding to the tooth in *in vitro* conditions, show different frequency of debonding from the enamel surface *in vivo*. On the other hand, different adhesive systems, with mutually significant differences in bond strength, do not necessarily show the same clinical differences (13). It is possible that composites, as a consequence of the effect of the oral environment, are exposed to greater wear *in vivo* than in *in vitro* conditions, which could have an influence on the different results (19).

Littlewood et al (2) examined the difference between conventional Transbond and hydrophilic primer (3M) in *in vivo* conditions. The investigation was performed on 33 subjects younger than 18 years. In each patient a fixed apparatus was placed on one side of the oral cavity by conventional primer, and on the other side by hydrophilic primer. The patients were monitored for 6 months, during which debonding of brackets was registered in the following way: the tooth on which the debonding occurred, the type of primer used and the time passed since placement of the apparatus. Brackets which were placed by using hydrophilic primer more frequently debonded than those placed by conventional primer. As the brackets placed by using the hydrophilic primer debonded twice as frequently compared with the conventional primer, the authors do not recommend it in clinical practice.

Similarly, Mvropoulos et al (21) investigated the possibility of clinical application of two different hydrophilic systems: Unite and Transbond primer resistant to moisture, and Assure - photopolymerising compomer resistant to moisture, which releases fluor. The investigation was performed on 25 patients, aged from 10 to 17 years. Brackets were bonded in such a way so as to enable equal distribution of adhesive on the teeth of the left and right side of the dental arches. Molars and teeth with caries on the enamel surface, fillings or gingival hyperplasia were excluded. The patients were monitored for 9 months, during which time debonding of brackets was monitored. Forty-six were recorded, of which 16 (7.3%) were placed by using Unite and Transbond primer, and 30 (13.8%) by using Assure. In a parallel investigation (22) carried out by the same authors, in the same clinic and under the same conditions, 5.1% debonded brackets were recorded which had been placed by standard composite resin (System 1+, Ormco, Orange, California, USA). As no standardised protocol exists for such a clinical investigation, comparison should be done with an element of caution. Nevertheless, debonding of the

bond between the bracket and tooth of up to 10% is considered acceptable, and thus the authors concluded that Unite and Transbond primer resistant to moisture could be used as useful substitutes for conventional orthodontic adhesives.

Influence of saliva on adhesive systems

When placing a fixed orthodontic apparatus, the presence of moisture in the work area can usually be prevented by various methods of control. Orthodontists, however, are very often confronted with situations in which there is increased danger of contamination by saliva (23). This can be extremely marked when placing an apparatus on partially erupted premolars, particularly in the lower jaw, where debonding of the bracket most frequently occurs. The problem arises because of the presence of gingival sulcus and cervical fluid, complex occlusal and masticatory loading and the crowns of the teeth themselves, which vary with regard to shape (24). Even very short exposure of the tooth surface to saliva has an effect on bond strength. In the first few seconds of exposure saliva deposits an adhering organic layer, which cannot be removed by rinsing with water (25). As saliva influences the bond strength of conventional composite resins for placement of a fixed orthodontic apparatus, and new products have appeared on the market which manufacturers claim are less sensitive to moisture, the earlier cited *in vitro* and *in vivo* investigations were carried out. The results were varied. On the basis of their investigations some authors (20) concluded that hydrophilic primers are unsuitable for everyday clinical practice, while others (12,21) consider that they could be a good alternative to conventional systems. However, some other authors concentrated on investigating self-etching primers with the aim of solving this problem. Thus Bishara et al (26) consider that self-etching primers can successfully be used in conditions of slight contamination with saliva.

Influence of blood on adhesive systems

It is frequently difficult to obtain ideal conditions for work when it is necessary to place a non-erupted tooth in an appropriate position in the dental arch. Possible therapeutic options are surgical exposure of the tooth or surgical exposure of the tooth with placement of a device for orthodontic extrusion (27). Postponement of placement of the bracket until healing results in slight risk of contamination by blood or moisture (28). In any case the soft tissue covering the tooth must be removed or repositioned in order to expose the crown, which can lead to poor gingival edge (29,30). In such situations the only possibility is to place the bracket on the tooth during the operation. Nevertheless, even minimal exposure of the enamel surface to saliva or blood leads to weaker bonding of the bracket. Hydrophilic systems could also be an adequate solution in such cases. In their investigation Cacciafesta et al (27) compared the bond strength of conventional and hydrophilic primers after contamination with blood. They showed that after contamination both primers showed poorer bonding than without contamination. Although hydrophilic primer demonstrated better properties the difference is not enough to show that it would be better in clinical practice.

Oonsombat et al (31) and Sfondrini et al (32) carried out similar investigations with self-etching primers. In the case of blood contamination the self-etching primers also showed reduced bond strength. Contamination by blood after application of the primer showed poorer results compared to that of the opposite order. A possible explanation could be that application of self-etching primer helped by partially cleaning or hydrolysing the contaminating blood (31).

Conclusion

Investigations which were performed in order to define factors which effect bond strength of the bracket and tooth show the following results:

- Bond strength of 2.8-10 Mpa is adequate for clinical practice.
- Air abrasion is not an appropriate method for preparing the enamel compared to classical etching with 37% orthophosphoric acid, because the brackets frequently debond easier.
- Duration of etching between 15 and 60 seconds did not show significant difference in bond strength of the bracket and tooth, and thus preparation of the enamel by etching for 15 seconds is sufficient.

- Bond strength is greatest on the first lower and weakest on the first upper molar.
- Moisture has different effects on bond strength of the bracket and tooth, depending on the adhesive system used:
  - Uncontaminated surface of the tooth showed the highest values of bond strength, regardless of the system used.
  - In dry conditions use of hydrophilic primer lead to decreased bond strength compared with conventional adhesive system, and self-etching primer enabled the strongest bond.
  - In the majority of cases of contamination self-etching primer showed greatest bond strength.
  - In contaminated conditions Rajagopal et al achieved greatest bond strength with primer resistant to moisture, and least with conventional primer.
  - In clinical conditions brackets placed by using hydrophilic primer more frequently debonded compared to those placed with conventional type primer.