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SEMINARS

These papers, similiar to the Lectures to State Branches, are included in the Journal to avail others outside the State of origin of the material being presented to the particular teaching department. They have been segregated from the Lectures section because of their theoretical nature. The material is selected on the grounds that it is suitable background information for current clinical trends.

Another look at bonding .... where are we now?

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(Printed with the kind permission of Dr.V.C.West, Senior Lecturer in Orthodontics, University of Melbourne)

The direct bonding of orthodontic attachments to tooth structure was introduced as an alternative to circumferential banding in the early 1960's.

Since that time, improvements in technique, adhesive materials, and design and manufacture of attachments have contributed to a steady increase in the popularity of this technique. In fact, results of a survey published in 1979 by Gorelick indicated that, of 2000 respondents, 93% were currently using a direct bonding technique for securing orthodontic brackets. Russell et al (1985) found a similiar proportion for Australian orthodontists. As techniques and materials are further improved, it can be expected that this technique will be used more extensively, and not solely for the more obvious aesthetic advantages. Orthodontic bonding has a number of advantages over circumferential banding, the most commonly cited being as follows:-

1. Aesthetics are markedly superior.
2. Technique is quicker and simpler.
3. A more comfortable procedure for the patient...seating of bands and the need for separation are eliminated.
4. Arch length is not increased by band material.
5. Interproximal caries can be detected and access to restorations is facilitated.
6. Minimal size of orthodontic bracket and pad compared to a full band means less plaque retention and a better gingival response.
7. Bonds can be placed on fractured, surgically exposed or partly erupted teeth.
8. Lingual brackets are an aesthetic alternative.
9. Brackets can be placed with greater precision, especially to teeth of abnormal form.
10. Interproximal stripping may be carried out during appliance therapy.

This is not to say that bonded brackets are preferable in all instances...there are distinct disadvantages.

1. A bonded bracket is not as strongly attached as a well-fitted band.
2. The strength of bonding adhesives varies, and varies considerably when there is a departure from established ideal bonding techniques.
3. Oral hygiene is not necessarily better, and plaque can accumulate around the base, particularly around excess adhesive...a well fitted and cemented band can actually protect the tooth against caries.
4. If there is a need for headgear or auxiliaries a band is usually more suitable.
5. Debonding can be very time consuming, particularly where the adhesive is very hard, as with heavily filled composites.
6. There is a danger of enamel cracking or fracture if incorrect debonding techniques are followed.

Many workers have investigated and improved the bond strengths of various materials and a good deal of effort has been expended on this aspect of adhesion.

Adhesion — general principles

The adhesive joint

While it is difficult to explain the behaviour of an adhesive joint by theoretical considerations, it is possible to define the requirements of an adhesive joint as:

1. The establishment of an intimate contact between the liquid adhesive and the solid adherent (the enamel surface of the bracket base).
2. Stress concentrations at the interface should be as small as possible.
3. Suitable surface cleaning and preparation methods are needed to develop optimum wetting conditions on tooth surfaces — this also removes contaminant surface organic films and debris.
4. The adhesive must compete with and displace water for durable bonding.

The wetting process is thought to be of great importance if a good adhesive bond is to be achieved.

Adhesion is thought to be achieved by either mechanical interlocking into porosities created in the etched enamel surface or by interfacial bonding through molecular attraction. It could be that both mechanisms contribute to the strength of a bonded joint.

Adhesion via intermolecular attraction

For such bonding to occur, close intermolecular approximation is necessary — good wetting, and spreading of the adhesive over the solid surface to be bonded.

The bond may be due to secondary or van der Waal's forces, these being the intermolecular attractive forces of physical adsorption. These bonds are brought about by attraction between molecules possessing permanent or temporary dipoles. Although these forces are not as strong as hydrogen bonds or primary chemical bonds, they could theoretically exceed the cohesive strengths of many adhesives. These bonds break down under oral conditions due to the stronger affinity of water for the enamel surface. Primary chemical bonds are thus necessary if a durable bond is to be obtained.

Retention via mechanical interlocking

This is achieved by penetration of adhesive into microporosities and other surface irregularities in the conditioned enamel surface. The material then hardens and is retained in apposition to the tooth surface via this physical 'lock'. Many workers now feel that the relative importance of the physical bond is less than was originally thought, and that the ***adhesive bond is primarily physico-chemical rather than mechanical.***

Enhancing the physico-chemical bond

Modification of the adhesive to enhance physico-chemical bonding to a treated enamel surface and/or modification of the active surface layer of the enamel itself to enhance primary chemical bonding would have definite advantages.

An orthodontic bracket adhesive has a maximum desirable adhesive bond strength. It should not approach or exceed the tensile or shear bond strength of the tooth enamel, if the danger of enamel fracture or cracking on debonding or under unexpectedly heavy occlusal forces is to be kept low. It is also desirable that clean-up of adhesive be relatively easy. If the physico-chemical adhesion of an adhesive is high, it should then be possible to reduce the extent of enamel damage caused by the etching process, i.e. by producing a milder etch, a clinically satisfactory adhesive bond strength could still be achieved.

It has recently been shown (Nakabayashi et al, 1982) that the addition of molecules of specific polarity to methyl methacrylate will enhance the bond of the adhesive to the highly polar acid phosphate groups on the etched enamel surface. These molecules contribute reactive hydrophilic and hydrophobic components, such as

phosphate, sulphate and carboxyl ions, and are thought to *increase the surface free energy* and so allow enhanced penetration of the adhesive into the etched enamel surface and provide a bond which will resist disruption via water penetration, polymerization shrinkage, expansion and contraction brought about by temperature change, and other adverse effects of the oral environment.

Assessing an adhesive

In order to assess an adhesive, in relation to other adhesives, a combination of laboratory tests are required.

Practically, tensile and shear bond strength tests after subjecting the bond to simulated oral conditions might be all that is required, but this will give no indication of the nature of the bond, so does not assist in furthering knowledge of the reactivity of various materials nor assist in the devising of improved techniques of enamel surface conditioning and improving adhesive chemistry.

The microscopic structure of the etched enamel surface varies depending upon the etchant used and the etching technique. Many workers have examined the penetration of resin into these areas — the so-called 'tags' of resin. In fact, the morphology of a resin penetrating a phosphoric acid etched surface often has the *appearance of a tube* on Scanning Electron Microscopy, the resin penetrating the etched periphery of enamel prisms. Great care is needed in preparing a specimen which will show this structure, however, as the tags quickly become very brittle as they extend into the etched area around the enamel prisms. When the prism is dissolved away to expose the tag, the loss of enamel support can result in collapse of the tube. It is quite possible however to observe 'tubes' of up to 20μm in length and 'tags' of up to 50μm. The fragility of the resin where it penetrates deeper into the enamel would indicate that this resin is not contributing significantly to the adhesive bond to enamel, but deeper penetration is indicative of high surface reactivity between the etched surface and the adhesive. Hopefully, study of this aspect of adhesion will result in a clinically useful technique, where a satisfactory bond can be obtained using an adhesive which will bond well to a minimally etched surface such that enamel damage from the procedure is only slight.

The site of failure of the adhesive is of great significance. If, for example, the failure is at the bracket mesh, an increased adhesion at the enamel interface will not improve bracket adhesion, as failure will still occur at the mesh. Incorporation of more filler particles in the material will not necessarily increase its tensile strength, but it should increase its shear strength, including that at the mesh area. *Filler particles do have disadvantages* however. If they are coarse, they will increase the resin viscosity, so affecting the ability to closely appose the bracket base to the tooth and also exhibit a *type of 'rebound' phenomenon* if the bracket is not held hard against the tooth until a set occurs. This is a tiresome procedure, so a compromise needs to be met, via the use of lightly filled adhesive of finer grain size or unfilled resins which have been modified to improve their affinity for the acid-etched surface. It should be emphasized that the increased shear strength obtained by using very fine particles (in the 0.2-0.5μm range) or fine particles mixed with coarser particles, is potentially hazardous. The fine particles can penetrate the etched circumference of the enamel prisms and markedly increase the shear strength in this area. If too heavy a shearing force is applied in the debonding procedure, or if a heavy shear force is produced during mastication, enamel can be torn from the tooth along with the resin.

Adhesives of the improved reactive acrylic (notably the 4 — meta type in Orthomite 'Superbond') and the lightly filled composite resins which are in common use in orthodontic practice nearly all tend to fail at the adhesive/mesh interface, providing care is taken to prevent contamination of the etched surface and thorough washing and drying is performed. Although work could then be directed towards increasing the bond at the adhesive/mesh interface, it could well be preferable to have failure at this point, using a lightly filled or unfilled adhesive that will clean up easily and not pose a threat to the enamel surface.

With the materials currently available, and proper attention to the appropriate enamel conditioning technique, clinically satisfactory bonds should be achievable in a consistently high percentage of cases. Further improvement may be directed towards improving the bond at the mesh/adhesive interface.

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