Building stronger bonds
Dr Julian Caplan discusses how to achieve the best adhesion to enamel and dentine for maximum bond strength

If you believe the success rates of the leading cosmetic dentists for their indirect adhesive restorations you may go along with this. If you have had adhesive failures, you most probably do not. Is it down to luck, better technique or good case selection?

At dental school, we all learned about MG Buoncore in the 1950s discovering he could bond acrylic to enamel if he treated the enamel surface with 37 per cent phosphoric acid.1 By etching the enamel, he removed the biofilm, increased the surface energy, produced a microrretentive surface and managed to achieve bond strength in the region of 30MPa. It was a small step to extrapolate this to bonding BisGMA resins to enamel. But what actually happens. What is required to bond two materials together?

The two key issues in dental bonding are:
• Can a mechanical lock be produced?
• Can we get the intermolecular forces to produce true adhesion?

Under an SEM image, it is apparent that contact between two surfaces is not as intimate as it first appears with the naked eye. In fact, they only touch in sporadic places along their surfaces when viewed on an SEM image.

This means in order to get mechanical interlocking or to allow the intermolecular forces, such as the Van Der Waal forces, to work to achieve adhesion we have to use something to fill in the many gaps to give us the necessary intimacy. A fluid material is needed that will easily coat the two surfaces. For good wet ability, the contact angle of the intermediary material needs to be very shallow.

The intermediary material must ‘like’ the surface we want it to get close too. In dentistry, the surfaces to be bonded to can be divided into:
• Surfaces that can be dried (as with enamel)
or
• Surfaces that can not be dried (as with dentine)

The intermediary material can also be divided into whether it is:
• Hydrophobic
or
• Hydrophilic.

As would seem obvious a hydrophilic material works best on enamel and a hydrophilic material is required for bonding to dentine.

Dentine bonding systems for bonding a BisGMA material have three elements present – an etchant, a primer and a bond.

The etchant is used to remove the smear layer, to demineralise the dentine to expose a network of collagen fibres and to remove some hydroxyapatite from the intertubular dentine. The dentine is kept moist to maintain the for-
1. Etching.
   - Over-etching can lead to a deep layer of exposed collagen fibres that are too deep to be penetrated completely by the primer. This leads to an area bereft of primer and causes nanoleakage - unprimed collagen. Nanoleakage is much less extensive than micro-leakage and has probably no short-term clinical relevance. However, the long-term stability of the adhesive bond between dentin and the restorative material might be adversely affected.

2. Prime.
   - The primer must penetrate to full depth of the exposed collagen. Over-etching may produce nanoleakage as discussed above.
   - The primer is a hydrophilic monomer (for example, Hydroxethyl methacrylate-HEMA). This may attract water after bonding causing ‘water trees’ to develop at the dentine adhesive interface. There is a possibility that this may cause long-term degradation of the dental adhesive.¹³

5. Bond resin
   - This is a hydrophobic material that is designed to separate from the hydrophilic primer if left to stand. In systems that have primer and bond co-packed in the same bottle, as in fifth-generation bonding systems, they must be vigorously shaken to recombine the solutions prior to use.
   - Over-etched root surfaces will leave the bond strength compromised.
   - Some bonds contain filler particles at a level that makes them relatively thick. It is paramount that the hybridised layer is set prior to seating of the restoration to prevent the collagen matrix from collapsing with the pressure from the luting cement. This is where most of the bond strength is developed from. However, this thick layer can prevent the correct seating of indirect restorations. To try and overcome this, the idea of immediate dentine bonding has been proposed. In this technique the dentine is etched, primed and bond applied and set immediately after the preparation has been completed. The enamel is cleaned with a finishing bur to expose fresh, unbounded enamel. The impression is now taken after the oxygen inhibition layer has been removed with alcohol from the bonded dentine. This prevents this unset bond on the bond surface from reacting with the impression material and affecting its setting.
   - The working model produced from this impression has the thickness of the bond on the dentine recorded on the working dies. At the seating appointment the enamel is etched and bond applied. The bond on the dentine is roughened with air abrasion using 50 micro aluminium oxide particles, the enamel etched in the usual way and bond applied. The restoration is silanated, dried and bond applied to the fitting surface. Luting cement is placed and the bond set. Following excess cement removal the luting cement and the bond are set with a suitable light-curing unit. As the bond is set after the restoration is seated an intimate fit is achieved. Some research shows that the bond strengths produced are as good as or better than conventional delayed dentine bonding techniques.

Classification of bonding systems

There are two main ways to classify the present bonding systems. They can be classified chronologically by using the fourth to eighth generation systems or sometimes by the number of bottles and whether the etch is rinsed off or not. For simplification the chronological classification will be described:

- Fourth generation. These are three bottle systems comprising of separate etch, prime and...
bond. They consistently produce good long term bond strength. For example, Optibond FL, Allbond 2.

- **Fifth generation.** These also have a separate etch that is rinsed off but the prime and bond are combined in one bottle. For example, Brime and Bond NT, Excelite.

- **Sixth generation.** These have a combined etch and primer with a separate bond. The etch is not rinsed off. For example, Contax, Clearfil SE Bond. Many studies have shown these to provide bond strengths closest to those achieved by fourth-generation systems. The bond strengths are increased if tungsten carbide burs are used to prepare the dentine rather than diamond burs.

- **Seventh generation.** These are single bottle systems where all three constituents are in one bottle. For example, I-bond, Xeno IV. Although initial short-term bond strengths seemed reasonable, there is now some doubt regarding long-term bond strengths.

- **Eighth generation.** This is the newest of the generations. For example, Surpass. There are three bottles, with each solution applied to the preparation separately but cured together at the end. They are claimed to combine the convenience of a pre-etch bonding system with the bond strength of the fourth-generation bonding systems. There is limited independent research on these materials at the moment.

Shear bond strengths to dentine in the region of 30MPa for indirect restorations would be considered to be at a good level according to the research available. Many systems show these levels at short term testing but some products show a worrying decrease over time. There is also a concern for the systems that do not have a separate etch and wash stage as the etch present in these materials do not etch enamel sufficiently. The sixth and eighth-generation bonding material manufacturers recommend that their first solution, which contains the etching component, is agitated on application which may increase the etching potential of these materials. At this time if a sixth, seventh or eighth system is being used (or self etching bonding cement) it would seem prudent to pre-etch the enamel or air abrade the enamel prior to applying these materials.

**Conclusion**

Unfortunately there are few studies that compare all the different generation systems. For example one study when looking at microleakage compares different bonding systems (etch and rinse and self etch systems) and concludes that etch and rinse systems produce less microleakage. However, sixth-generation systems are not included. Another study compares sixth and seventh-generation systems and concludes the sixth-generation bonding systems appear to have the least amount of microleakage after six months. However, fourth and fifth-generation bonding systems are not included.

Looking at a number of recent studies it would appear that fourth-generation bonding systems are still the gold standard but, following close behind, sixth-generation bonding systems are giving clinically acceptable good long term bond strengths.

References are available on request.

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Dr Julian Caplan qualified from Sheffield University in 1988. He is a Director on the board of the BACD, a senior instructor for the Larry Rossenthal Aesthetic Continuum course and lectures internationally on CAD/CAM dentistry, specifically Cerec. He has completed all levels of occlusion courses run by Peter Dawson in Florida, USA. He owns Aviva Cosmetic Dentistry, a dental practice aimed at providing high-end cosmetic and functional dentistry in Hertfordshire. For further information about becoming a member of the BACD or to register for the 2009 BACD Conference ‘The Future of Dentistry’ please call Suzy Rowlands on 020 8241 8526 or visit [www.bacd.com](http://www.bacd.com).