©Operative Dentistry, 2010, **35-2,** 137-138

Editorial

Decades of Bond Strength

The development of dental adhesives over the last several decades has relied upon the measurement of bond strength as one indicator of effectiveness. For many years, bond strength and microleakage testing have been the frontline *in vitro* methods for evaluating success of the adhesive interface. Attempts to measure adhesive bond strength to teeth dates to at least 1965.[1] Today, much of this work has moved into micro-bond strength testing and nanoleakage evaluations. I will leave a look at leakage testing for another time. As I write this on February 5, 2010, a *PubMed* search on bond strength with limits set for dental journals provided 4,603 references. Does all of this bond strength testing really make sense?

When bond strength values are reported, it is an inappropriate assumption to believe that the actual strength of the adhesive has been determined. That is not what has actually been done. When achieving dental adhesion, an adhesive is being used to create a bond between a material and tooth structure. The provided values are dependent upon many factors other than the adhesive. How the specimens are shaped and prepared, the presence and geometry of flaws within the interface and the speed and direction of the applied load all impact the values reported in this test. In addition, the material properties of each of the components (including Poisson's ratio and the modulus of elasticity) influence the results. The components involved include: the restorative material; the interphase between the restorative material and the adhesive; the adhesive; the interphase between the adhesive and the tooth structure (for example, the hybrid layer) and the tooth structure itself.[2] Clearly, reported values from these tests are showing results from a complex system. Because of this complexity, interpreting the data has proven to be challenging.

Last fall, the Academy of Dental Materials brought together many of the international leaders in the area of dental adhesion. Three days of presentations and dialogue left a distinct impression that much of the bond strength literature published over the last 40 years may be of limited value. Critical evaluations of the literature, which struggled to find definite conclusions, were presented. Much of that struggle was related to the minimal information and test description that is commonly reported in these manuscripts. A specific appeal was made to editors and reviewers to help make these manuscripts more useful. To the extent possible, a comprehensive description of the materials and methods used in the test must be included. This is something that all researchers, editors and reviewers know should be done. Certainly, it is appropriate to reference published work that describes a given method. But, sometimes I fear that minor changes in a previously published method do not get included in the methods description, which complicates any evaluation of the body of evidence, that is, the many bond strength manuscripts. There are a couple of specific areas that I would like to encourage our authors to consider before submitting bond strength manuscripts to *Operative Dentistry*, and for our readers to understand as they continue to see published bond strength studies.

It is imperative to evaluate specimens after testing to explore the mode of failure. Failure is commonly reported as: adhesive within the interface; cohesive within one of the substrates or as a mixed combination. If the intent of a study is to investigate the adhesive capability of a particular formulation, the specimens that fail adhesively, without cohesive failure of one of the substrates, are the ones that provide the most reliable insight into that pursuit. It has often been argued that cohesive failures in tooth structure indicate that the adhesive has done all that can be expected of it. However, if the tooth structure is compromised through storage techniques or if specimen alignment and load application were not appropriate, the result may not be indicative of adequate clinical performance at all. Because of this, cohesive failures should be viewed with some degree of caution. If they are included, it is imperative for authors to understand what they represent as they present their work. When

included, the reported data only gives an indication of failure somewhere within the bonded system, and any attempt to compare adhesives should be undertaken with extreme caution.

A second area of consideration specifically targets micro-bond strength testing. Because of smaller specimen sizes, the number of flaws within a specimen adhesive interface will be less than with a macro-bond strength specimen. This decreases the chance that a relatively large flaw will be present and tends to increase measured bond strengths. Another purported benefit has been that multiple specimens can be obtained from a single tooth, resulting in a decreased need for extracted teeth. Often, each of these multiple specimens is treated as an independent specimen statistically. As a result, it has been common to see a one-way ANOVA used to evaluate statistically significant differences between experimental groups using specimens from as few as two or three teeth. Unless the differences are very large, something no longer common in this field, an overstatement of significance may result from this approach.[3] Usually, multiple specimens from a single tooth are best not reported as independent specimens. There is more than one statistical method available to deal with this kind of data. But, whichever one is used, it is strongly encouraged that it takes into account that these are dependent specimens.

There are many other issues that impact results in these tests; issues about which much debate can, and will, be had. But, it is clear that, if there is sense to be made from this growing body of manuscripts, that it needs to reflect an increased quality in the information they provide.

Jeffrey A Platt, Editor

References

1. Bowen RL (1965) Adhesive bonding of various materials to hard tooth tissues. I. Method of determining bond strength *Journal of Dental Research* **44** 690-695.
2. Armstrong S, Geraldeli S, Maia R, Raposo LH, Soares CJ & Yamagawa J (2010) Adhesion to tooth structure: A critical review of "micro" bond strength test methods *Dental Materials* **26(2)** e50-62.
3. Eckert GJ & Platt JA (2007) A statistical evaluation of microtensile bond strength methodology for dental adhesives *Dental Materials* **23(3)** 385-391.