A Microshear Test to Measure the Adhesion of Dental Composites to Tooth Structure

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Introduction: Mechanical property tests such as the diametral tensile, uniaxial tensile and transverse strength tests are commonly used in studying the interfacial properties of dental composites and of the bond between dental composites and dental substrates such as dentin and enamel. These tests, while providing useful information, can be difficult to interpret because of the interaction of many competing failure modes that accompany failure. With these challenges in mind, a microshear test has been developed in an effort to reduce the complexity of events that can confound the analysis at the interface. In the case of enamel, adhesion occurs primarily by micro-mechanical interlocking resulting from the penetration of the unpolymerized resin into a superficial porous zone to form polymeric resin tags. Because of the structural anisotropy of enamel, it is thought that variation in enamel bonding sites might influence the bonding strength of direct restorative systems to this substrate. The purpose of this study was to study how regional tooth structure variation and the effect of enamel rod orientation affects the bonding ability of a non-priming adhesive system. This paper presents some of the opportunities that the microshear bond strength test offers in designing dental composites and adhesive systems with enhanced strength and durability.

Materials and Methods*: The most important elements of the microshear test come with the design of the test. As seen in the figure, cylinders of cured resin are bonded onto a prepared substrate, sheared off at a specified rate, and the bond strengths calculated. Tooth slices were taken from human molars and the selected enamel region was then sectioned transversely, obliquely, and parallel (longitudinal) to the enamel prism. Each slice was approximately 1.0 mm thick. The enamel slices were bonded to aluminum tabs by first air abrading the aluminum with 50 μm aluminum oxide powder and then bonding with a cyanoacrylate adhesive. The exposed tooth surface was then resurfaced under water with 320 grit SiC paper. A phosphoric acid gel (K-etchant gel, Kuraray) was then applied to the resurfaced enamel for 30 s, the surface was rinsed and dried, and an adhesive applied. An iris was cut from micro-bore Tygon tubing with an internal diameter of approximately 0.7 mm was affixed to the enamel surface, and then the resin composite was injected into the iris. The resin was photo-irradiated for 60 s. After curing, the iris was removed and the specimens were stored in distilled water at 37 °C for 24 h. The cylindrical specimens were tested in shear at a rate of 0.5 mm/min. The change in load as a function of time was recorded and the shear strength was calculated from the equation $\tau = F/(\pi r^2)$, where τ is the estimated interfacial shear strength, F is the load at failure, and r is the radius of the resin cylinder.

Results and Discussion: Seven specimens were tested and the mean shear strength and standard deviation for the specimens whose rods were sectioned transversely was (31.12 ± 3.38) MPa. The result for five specimens that were sectioned obliquely was (27.78 ± 2.17) MPa. The result for eight specimens that were cut parallel to or longitudinally along the prisms was (13.90 ± 3.11) MPa. The results of this particular study showed that the surface parallel to the enamel prism rods was significantly weaker than were the surfaces cut transversely or obliquely. One-way analysis of variance was done ($F = 60.8$; $df = 5, 34$; $p < 0.05$). When the uncertainties in this test method were considered, the calculated results were interesting. When the microscope attached to the testing apparatus was used to measure the specimen diameter, the combined standard uncertainty in calculating the interfacial shear strength was 2.4 MPa. When the diameters were remeasured using a microscope with greater precision, the combined standard uncertainty due to the area measurement in the interfacial shear strength was reduced to 0.3 MPa. Hence, a source of uncertainty other than that caused by the measurement of the diameter is present. Identifying this source may allow researchers to improve the specimen preparation process and, thus, identify the sources of other components of uncertainty.

Conclusions: A microshear test has been developed that allows one to study adhesion to very small areas (0.4 mm^2) that are not accessible to conventional macroshear testing. Thus, the researcher can now map interfacial adhesion at different areas and depths of tooth structure. Furthermore, this method requires significantly fewer extracted teeth for studies.

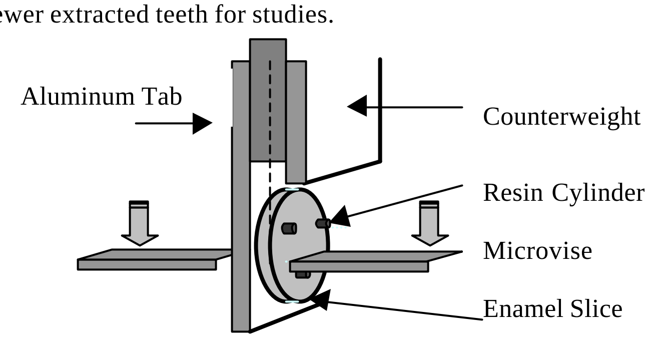

Figure 1: Schematic of the microshear test.

*Materials and equipment are identified only for describing experimental procedure and do not imply recommendation or endorsement.

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