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Research paper

Bond strength of five dental adhesives using a fracture mechanics approach☆

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ABSTRACT

Objectives: The adhesion tests utilized in dentistry are unable to separate the effects of adhesive composition, substrate properties, joint geometry and type of loading on the measured bond strength. This makes it difficult for the clinician to identify the most suitable adhesive for a given procedure and for the adhesive manufacturer to optimize its composition. Thus, an adhesion test protocol based on the fracture mechanics has been proposed to generate data for which separation of the effect of composition from that of the joint geometry on the shear (τ_a) and tensile (σ_a) bond strengths was possible for five commercial dental adhesives.

Methods: Planar $40 \times 5 \times 5$ mm^3 sections of *bovine femur* were used as model adherends. The adhesive thickness (h) was varied from 15 to 500 μm. Commercial adhesives with fracture toughness (K_{IC}) ranging from 0.3 to 1.6 MPa m$^{1/2}$ were used. Double lap joint (DLJ) and modified compact tension (MCT) specimens were conditioned for 24 h in 37 °C distilled water, then dried in a vacuum oven at 37 °C for 24 h prior to testing. The thickness dependence of σ_a and τ_a was measured at constant strain rate and analyzed using the interface corner stress intensity factor model.

Results: Both τ_a and σ_a increased with increasing adhesive thickness, exhibiting a maximum bond strength at the optimum thickness (h^{opt}). For $h < h^{opt}$, both τ_a and σ_a were proportional to h, and, above h^{opt}, both τ_a and σ_a decreased with $h^{-4/10}$ in agreement with the fracture mechanics predictions. Hence, two geometry-independent material parameters, Ψ and (H_c/Q), were found to characterize τ_a and σ_a over the entire thickness interval.

Significance: The adhesion tests currently used in dentistry provide the geometry-dependent bond strength, and such data cannot be used either for prediction of clinical reliability of commercial dental adhesives or for development of new ones. The proposed test protocol allowed us to determine two composition-only dependent parameters determining τ_a and σ_a. A simple proposed procedure can then be used to estimate the weakest point in clinically relevant joints always exhibiting varying adhesive thickness and, thus, to predict the locus of failure initiation. Moreover, this approach can also be used to analyze the clinical relevance of the fatigue tests of adhesive joints.

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