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Relationship between bond strength tests and other in vitro phenomena

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ABSTRACT

Objectives. The objective of this manuscript is to outline the relationship between bond strength tests of adhesive materials and other in vitro phenomena by reviewing the literature generated over the thirty years.

Methods. Information was gathered from nearly 30 published articles appearing in dental literature. Studies were predominantly identified through a search of the PubMED database with a few additional studies published in Japanese domestic journals.

Results. Studies were included that provided evidence for the relationship between results of evaluations of the bond strengths and other in vitro phenomena such as micro-leakage, nanoleakage, structural of bonding interface and mechanical properties of bonding interface. An attempt was made to select articles that spanned the timeframe from approximately 1980 to today to try to ensure that the classic literature as well as the latest information was included.

Conclusions. Previous studies have indicated bond strength did not correlate with the results of micro-leakage tests nor gap formation at the cavity margin. The nanoleakage test and morphological and chemical characteristics of the bonding interface had potential to predict the dentin bond durability.

Significance. Bond strength test results and other in vitro phenomena was not evenly correlated. According to the development of the materials, the most appropriate bond test and analysis of the in vitro phenomena should be also developed.

1. Introduction

Adhesive restorations are widely distributed as the routine procedures in operative and restorative treatments. The bonding performance of the adhesive materials is evaluated by means of the bond test to enamel and dentin. In general, tensile bond test and shear bond test have been applied. Because of the improvement of the bonding performance of the materials, the micro-tensile bond test [1] and micro-shear bond test [2] are becoming more commonly applied for testing the recent adhesive materials. The main purpose of bond tests is recognized as the comparative evaluation of the bonding performance of materials.

Micro-leakage tests at the margins of restorations have been widely performed, since the micro-leakage of the restoration had been believed to be the significant factor to cause post-operative tooth sensitivity, marginal discoloration and

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recurrent caries. In the micro-leakage tests, various cavity designs and filling techniques have been evaluated. The separation of restoration from cavity walls occurs as the result of contraction stress of composite resin during polymerization, which is higher than that of the bond strength.

However, even when micro-leakage is not observed at the interface between bonding material and dentin, a channel that accepts the penetration of water and other solutions was found at the bonding interface. This nano-sized space is now recognized as the nanoleakage space [3]. The nanoleakage test is often applied in recent papers to compare the dentin bonding performance of materials.

Morphological analysis of the bonding interface is also performed in most of the papers on dentin bonding. These micro-structural studies are sometimes combined with acidic and/or basic treatment. Through the studies on microstructure of dentin bonding interface, the so-called hybrid layer was pointed out [4].

The evaluation of adhesive materials is carried out by the methods described above in most of the recent studies. The recent materials are proven to exhibit extremely high bond strengths when they are tested after 24 h of bonding. However, the durability of bonding, especially dentin bonding, remains a major issue for most of the adhesive materials. The bonding interface consisted of multiple structures such as bonding resin, hybrid layer and dentin substrate. The characteristics of these components are becoming more important for predicting the future degradation of bonding.

The above-mentioned phenomenon should be discussed with association to each other. The bond strength of the materials, particularly dentin bonding, is discussed in the present paper particularly correlating it with the other in vitro phenomenon.

2. Micro-leakage

Micro-leakage has been evaluated using dye solutions to detect the space between the restoration and cavity walls and contraction gaps have been evaluated as the gap width at the cavity margin [5,6]. Though the methods are not the same, these two phenomenon cannot be differentiated from each other. The gap and the micro-leakage space are the results of the separation between the restoration and cavity wall. And the separation occurs when the bond strength to the cavity wall is lower than the contraction stress of the restoration.

When the mechanism for debonding at cavity walls is taken into account, bond strength and micro-leakage are considered to be correlated. Actually, the gap width was reported to be correlated with the shear bond strength [5,6]. In these studies, the cavity was prepared in human dentin, and its depth and diameter were 1.5 mm and 3 mm, respectively. In contrast, a correlation between bond strength and marginal adaptation could not be demonstrated when class V cavities were filled with various bonding materials, procedures, and filling materials [7]. In this study, the gap was evaluated as the fraction of sample numbers showing a cervical gap, not by the gap width. Even when the same adhesive procedure was applied, correlation was found between the gap test and shear bond strengths at 5 min or 24 h after bonding. The fraction of samples showing a cervical gap correlated inversely with the Young's module values of the restoratives used to fill the cavities. Also, the application of an intermediate unfilled resin layer improved the quality of marginal adaptation.

Other studies have shown that the mechanical properties of dental composites were highly correlated with bond strengths to dentin or enamel [8–11]. On the other hand, the bond strength at the dentin cavity floor with a stiffer composite was reported to be more affected by the cavity configuration than that of a less stiff composite [11]. The stiffness of composites is considered to influence differently bond tests and micro-leakage tests.

Thus, the results of micro-leakage tests are influenced by cavity size and shape, bonding procedures, filling procedures and materials. The bond strength and micro-leakage should be discussed separately, since the bond strength does not directly result in the micro-leakage score. However, the evaluations of the micro-leakage and gap are beneficial for the evaluation of the restoration procedures including the adhesive materials and procedures, and filling materials and procedures, simulating the clinical application.

3. Nanoleakage

The recent adhesive materials provide excellent bonding to both enamel and dentin. Especially dentin bonding has been extremely improved and the bonding interface is observed by SEM to be perfectly sealed. The dentin hybridization was reported to be very important for bonding. However, the hybrid layer is not uniformly created, leaving the demineralized dentin without the impregnation of adhesive resin materials. This area is thought to accept the penetration of substances that are smaller than the space in the hybrid layer. Nanoleakage may be recognized as a phenomenon, which provides the space or defect at the bonding interface to accept the penetration of solutions, ions and enzymes.

Durability of dentin bonding is often discussed with the recent materials, however, dentin bonding has been the most significant issue for any adhesive material. Kiyomura [12] reported the drastic decrease of the dentin bonding of Super Bond after 3 months, 2 years, and 4 years. The initial bonding after 24 h was 18 MPa, however, the bond strengths decreased to 8 MPa at 3 months, and 4 MPa at 2 years and 5 years after bonding. The degradation of the bonding material, which was the MMA with 4-META activated by TBBO catalyst, was considered to be the main cause of the decrease of bond strength. The drastic decrease of the bond after 2 years and 5 years was considered to be caused by the degradation of the hybrid layer as well as the interface between the hybrid layer and underlying dentin. Regarding the adhesive with self-etching primer, comparatively more stable bond durability was confirmed than that with the adhesive system using the more aggressive acid etching [13]. The fracture tended to occur at the bottom of the hybrid layer with the bonding system using the acid etching after 1 year storage, however, the fracture surface was covered by the bonding resin throughout the whole time period with the self-etching system.