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Comparison of two test designs for evaluating the shear bond strength of resin composite cements

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ABSTRACT

Objective. To compare a shear bond strength test for resin composite cements developed in order to better consider the shrinkage stress (here termed "Swiss shear test") with the shear test design according to ISO 29022.
Method. Four restorative materials (VITA Enamic (VE), VITA Suprinity (VS), Vitablocs Mark II (VM) and VITA YZ T (YZ)) served as substrate. VE, VS and VM were polished or etched. YZ was polished, sandblasted or etched. Specimens were either bonded according to the Swiss or the ISO shear test. RelyX Unicem 2 Automix, Maxcem Elite and PermaFlo DC were used as cements. Shear bond strength (SBS) was measured. Failure modes (adhesive, cohesive or mixed) were evaluated by means of SEM.
Results. Mean SBS values obtained with the Swiss shear test were significantly lower than those obtained with the ISO shear test. VE and VM exhibited similar SBS, values of VS were significantly higher. On etched surfaces VM and VE exhibited primarily cohesive failures, VS primarily adhesive failures. On polished substrates significantly lower bond strength values and exclusively adhesive failures were observed. YZ exhibited solely adhesive failures. Compared to polished YZ, SBS significantly increased after sandblasting and even more after etching. Only for adhesively failed specimens mean SBS values of Swiss and ISO shear test were strongly correlated.
Significance. Both test designs showed the same ranking of test results. When adhesive failure occurred test results were strongly correlated. When cohesive failure was involved, both test designs did not provide reliable results.

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1. Introduction

All-ceramic restorations play one of the most important roles in today's dentistry. Available evidence indicates the effectiveness of many all-ceramic restorations for numerous clinical applications [1]. Biocompatibility, natural appearance and aesthetics in restorative dentistry are almost always associated with all-ceramic restorations. Furthermore, CAD/CAM allows the use of materials that cannot be used with conventional dental processing techniques [2].

Ceramic materials for the CAD/CAM technology can be divided into two groups, polycrystalline ceramics and glass-based ceramics [3]. Polycrystalline ceramics, based on alumina or zirconia, are stronger and tougher than glass-based ceramics, but translucency is significantly lower [4].

Based on the current evidence, glass-based all-ceramic restorations should be bonded with resin composite cements in order to increase their fracture resistance [5–7]. Because of various pre-treatments such as acid etching, silanization and bonding, the resin composite cements are more difficult to use and processing sensitive. The etching process creates a micro-roughness at the ceramic surface, thus providing retentions for a micromechanical interlocking and, due to an enlarged surface area increased bonding capabilities, which are necessary to improve the overall strength of all-ceramic restorations [8,9]. Silanization is required to establish a chemical bond between the hydrophilic ceramic surface and the hydrophobic resin composite cement [10].

Etching of zirconia as a polycrystalline ceramic may be done with highly concentrated hydrofluoric acid or with high temperature [11,12], which is too hazardous for chairside or labside application. Surface roughness therefore has to be created mechanically, preferably by sandblasting [13].

Bonding of resin composites to dentin requires three steps: etching, priming and bonding. In order to simplify these technically sensitive procedures, new self-adhesive cements have been developed, which bond to dentin without any pre-treatment [14]. A study has shown that the use of self-etch adhesives may be helpful in reducing postoperative sensitivity during 24 h after restoration placement [15]. Therefore, it is even suggested that the less experienced clinicians should better use the self-etching dentin bonding systems with reduced application steps to minimize the potential risk of complications [16].

In order to test the adhesion of resin composite cements, the following in-vitro test methods are commonly used: shear bond strength test (SBS), tensile bond strength test (TBS), micro tensile bond strength test (MBS), retentive bond strength of full crowns/crown pull-off test (RBS-C) and push out test (POT) [17,18]. SBS measures the force required to shear off the specimens from the substrate parallel to the bonding interface, TBS and MBS tests measure the force required to pull off the specimens perpendicular from the substrate, RBS-C and POT measure a mixture of both [19].

Correlations were found between different methods. One study showed that tests with different cements ranked the adhesives in the same order and the forces of displacement of crowns tend to be closer to shear than to tensile stresses [20]. SBS seems to yield higher bond strength values than TBS [21]. However, absolute numbers resulting from different test methods cannot directly be compared with each other.

The shear test according to ISO 29022 is assumed to be one of the most commonly used test designs for SBS due to the fact that it is applied for the regulatory approval of dental materials. Test setup and test procedure are simple. However, the shrinkage of resin composite cements, which occurs always during polymerization, is not considered in this test design. It is generally agreed that the shrinkage stress during polymerization is the weak point of resin composite cements due to the risk of poor marginal adaption and subsequent restoration debonding [22]. The stress is generated at the interface between tooth substance or intaglio surface of the restoration on one side and the cement on the other side as a result of inhomogeneous polymerization shrinkage in association with differing elastic moduli [23,24].

The push out test (POT) and the shear bond strength test by means of cementing a composite or metal cylinder are two tests, which take into account the polymerization shrinkage and polymerization stress [25,26]. Because the cement layer of these tests is sandwiched between the substrates, the debonding stress occurs at two rather than one interface. In order to take account of the shrinkage stress at one specific interface, a modified test design has been developed at the Universities of Bern and Zurich ("Swiss shear test" in the following) [14], and its efficiency was verified in several tests [14,27–29]. The test is characterized in that the adhesive cement is filled into a sleeve and pressed onto the surface with a screw fitting into the sleeve. A further characteristic of the test design is that loading of the cement at the interface is performed while the sleeve is still in place, thus distributing the shear stress to a larger area [28–30].

The aim of this in-vitro study was to compare the two test designs – Swiss shear test and ISO shear test – for the evaluation of SBS of adhesive resin composite cements by measuring the adhesion of different ceramic/cement combinations.

2. Materials and methods

Four types of ceramics (Table 1) and three adhesive resin cements (Table 2) were included in the study.

2.1. *Preparation of glass-based ceramic specimens*

Specimens of VITA Enamic (VE), VITA Suprinity (VS), and Vitablocs Mark II (VM) (all three VITA Zahnfabrik, Bad Säckingen, Germany) with dimensions of 15 mm × 15 mm × 10 mm ($n = 80$) were cut from ceramic blanks and embedded in acrylic cylinders, 25 mm in diameter and 20 mm in height (CaldoFix-2, Struers, Ballerup, Denmark). The specimens were divided into two main groups of 40 for each test method (Swiss shear test vs. ISO shear test). Each of the groups of 40 ceramic specimens was furthermore divided into four subgroups (three test groups and one control group) of 10 specimens each (Fig. 1).

The specimens of the test groups were ground with sandpaper (P#1200, Struers) and etched with 5% HF for 60 s (VITA Ceramics Etch, VITA). In order to exclusively test the chemical adhesion, the specimens of the control groups were polished (final step 3-μm diamond paste, Tegra Pol-25, Struers). All

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