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The adhesive potential of dentin bonding systems assessed using cuspal deflection measurements and cervical microleakage scores

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ABSTRACT

Objectives. To assess the cuspal deflection and cervical microleakage of standardized mesio-occluso-distal (MOD) cavities restored with a dimethacrylate resin-based-composite (RBC) placed with one 3-step, one 2-step and three 1-step bonding systems and compared with the unbound condition.

Methods. Forty-eight sound maxillary premolar teeth with standardized MOD cavities were randomly allocated to six groups. Restoration was performed in eight oblique increments using a quartz-tungsten-halogen (QTH) light curing unit (LCU) with the bonding condition as the dependent variable. Buccal and palatal cuspal deflections were recorded post-irradiation using a twin channel deflection measuring gauge at 0, 30, 60 and 180 s. Following restoration, the teeth were thermocycled, immersed in a 0.2% basic fuchsin dye for 24 h, sectioned and examined for cervical microleakage assessment.

Results. The mean total cuspal deflection measurements with the one 3-step, one 2-step and three 1-step bonding systems were 11.26 (2.56), 10.95 (2.16), 10.03 (2.05) (Futurabond® DC SingleDose), 6.37 (1.37) (Adper™ Prompt™ L-Pop™), 8.98 (1.34) μm (All-Bond SE®), respectively when compared with the unbound condition (6.46 (1.88) μm) The one-way ANOVA of the total cuspal deflection measurements identified statistical differences ($p < 0.001$) between groups. Cervical microleakage scores significantly increased ($p < 0.001$) for the negative control (unbound condition) when compared with teeth restored with a bonding system although differences between the bonding systems were evident ($p < 0.001$).

Significance. The cuspal deflection and cervical microleakage protocol reported offers an opportunity to test the bonding technologies available to practitioners for RBCs. Poorly performing adhesives can be identified which indicated the technique may be useful as a screening tool for assessing existing and new bonding technologies which offers the potential to limit complications routinely encountered with Class II RBC restorations.

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1. Introduction

Today, *in vitro* bond strength measurements are performed in the laboratory 24 h post-light irradiation [1] using static techniques [2–5] or more laborious fatigue test methods [6–11]. However, none of these *in vitro* methods provides a reliable prediction of clinical bond adhesive performance *in vivo*. As with any *in vitro* experimental testing methodology there are significant disadvantages with those techniques that lack relevance to the clinical situation. Stress generation in resin-based composites (RBCs) that may compromise the adhesive margin of the restoration is not an intrinsic material property of the RBC but a multi-factorial phenomenon that relies upon the associated shrinkage [12,13] and the elastic modulus of the material [14]. Further considerations include the onset of gelation of the resin matrix [15], polymerization rate [16] and the ratio of bonded to non-bonded surface area (or 'configuration- (C-) factor') [17]. In many shrinkage stress experiments, it is the compliance of the test system and supporting constructs [18] that will significantly influence the results obtained [19].

The measurement of cuspal deflection using extracted teeth eliminates the problem of the compliance of the testing system and supporting constructs [18] and will better represent the 'real' stress distribution with relevant specimen geometry and boundary conditions. Although large cavities are required to produce a measurable deflection, the testing system represents equivalent compliance to that encountered *in vivo* and should reduce the conflicting stress data that currently exists in the literature [19,20]. Cuspal deflection using extracted teeth has been extensively investigated in the dental literature [21–28]. Cuspal deflection in conjunction with the cervical microleakage assessment approach has been used in extracted teeth with large Class II cavities to determine the efficacy of different LCUs [29–32], RBC placement protocols [33,34] and for assessing different RBC types [30,35]. Class II RBC restorations fail frequently due to marginal leakage [36] as the synergism at the tooth/RBC interface is compromised, allowing for the ingress of bacteria [1,15], ultimately leading to secondary caries [36–38]. Van Meerbeek et al. [1] stated that 'there is a definite need to test bond effectiveness of adhesives under more clinically relevant circumstances or upon aging of the specimen.' In line with this thinking [1], the cervical microleakage assessment employed used basic fuchsin dye as the tracer [39] and included an aging component, namely thermocycling for 500 cycles (as recommended by ISO TS 11405 [40,41]).

Adhesive bonding classification systems include 'etch and rinse' adhesives where the three-steps involved include a separate etch with acid and rinse (conditioning) step, a priming step followed by the application of the adhesive resin [1] or alternatively simplified two-step 'etch and rinse' adhesives which combine the primer and adhesive resin [42]. 'Self-etch' adhesives which eliminate the rinsing phase are user-friendly although their effectiveness has been questioned [42,43]. In 2005, reviews suggested that simplification of the application procedure with 'self-etch' adhesives reduced bond effectiveness [42,43], although more recent studies show these systems to be improved, albeit product dependently [44].

The aims were to assess the cuspal deflection of standardized large mesio-occluso-distal (MOD) cavities, incrementally filled with a conventional dimethacrylate RBC used in conjunction with one 3-step, one 2-step and three 1-step bonding systems and compared with the unbound condition using a twin channel deflection measuring gauge. The cervical microleakage of the restored teeth was assessed, following thermocycling, to determine bond integrity. The hypothesis proposed was that the choice of dentin bonding system would significantly impact the cuspal deflection measurements recorded and the associated cervical microleakage scores when restored with a single RBC, light irradiated in eight oblique individual increments using a QTH LCU.

2. Materials and methods

The maximum bucco-palatal-width (BPW) of maxillary premolar teeth, extracted for orthodontic reasons, were measured with a digital micrometer gauge (Mitutoyo, Kawasaki, Japan) with a tolerance of 10 μm. The teeth were selected only when their mean BPW was within 9.2–9.6 mm, such that the variance of the mean (9.4 mm) was less than 5% [29–35]. Following selection, 48 maxillary premolars free from caries, hypoplastic defects or cracks on visual examination were subjected to calculus deposit removal using a hand-scaler and distributed into six groups ($n = 8$). The maxillary premolars were fixed into a cubic stainless steel mold using a chemically activated orthodontic resin (Meadway Rapid Repair, MR Dental Supplies Ltd., Surrey, UK) such that the orthodontic resin extended to within 2 mm below the amelocemental junction (ACJ) [29–35]. The teeth were fixed with the crown uppermost and the long axis vertical. They were then stored in 0.5% chloramine solution at 23 ± 1 °C until required for the extensive cavity preparation.

Large standardized MOD cavities were prepared under copious water irrigation in accordance with the established protocol [29–35]. The width of the approximal box was two-thirds the BPW of the maxillary premolar, the occlusal isthmus was prepared to half the BPW and the cavity at the occlusal isthmus was standardized to a depth of 3.5 mm from the tip of the palatal cusp. The approximal boxes were extended to 1 mm above the ACJ. The cavosurface margins were all prepared at 90° and all internal line angles were rounded. Following MOD cavity preparation, the maxillary premolar teeth were stored in high purity double distilled water at 23 ± 1 °C unless moisture isolation was required for aspects of the experimentation.

Following cavity preparation the teeth in Group A were prepared for bonding with the 3-step adhesive (All-Bond 2® Dual-Cured Universal Adhesive System, Bisco Inc., Schaumburg, IL, USA) [45]. Firstly, the MOD cavity preparation was air-dried for 30 s, prior to the application of a 32% phosphoric acid etching gel (Uni-Etch®). The acid was applied for 15 s without agitation and rinsed with water. Following a light drying with an air-syringe for 1 s, five consecutive coats of the primer (a mixture of All-Bond 2® Universal Dental Adhesive System Primer A (Ref B-2511, Lot 1000007217) and Primer B (Ref B-2512, Lot 1000007218)) was applied with a saturated brush tip until the surface appeared glossy. The primer