Comparison of Amalgam Dentin Bond Strength with Different Bonding Agents

Mohammad Javad Moghadasa, Marjaneh Ghavamnasirib, Homayoun Alaghemandc, Reza Gohariand, Taghi Salarie

Introduction: Recently, Adhesion of amalgam to dentin has been a common procedure. The aim of this study was to evaluate, the shear bond strength of amalgam to dentin using different adhesive systems.

Materials & Methods: In this experimental study, amalgam dentin bond strength was determined using a punch out method in sections of human molar dentin. There were 5 treatment groups (n=20) consisting of 4 experimental groups (dental adhesives: One Coat Bond, Scotchbond MP, Panavia 21 and PQ1) and 1 control group (copal varnish: Copalite) followed by restoration with a spherical high copper amalgam.

Results: The ANOVA and Duncan tests demonstrated a significant difference among groups (P<0.05). No significant difference in amalgam dentin bond strength was found among One Coat Bond (23.47MPa), Scotchbond MP (21.02MPa), and Panavia (20.06MPa), but there was a significant difference between the each of the mentioned groups with PQ1 and Copalite. The lowest bond strength was seen in PQ1 (13.15MPa) and Copalite (14.14MPa).

Conclusion: High filler content in PQ1 was an important factor for creating the lowest amalgam dentin bond strength.

Key words: Amalgam, bonding agent, dentin bond strength

A goal of amalgam bonding is to create a strong, durable bond strength tooth structure and amalgam. Traditional amalgam restorations are retained by preparation features that incorporate parallel or undercut walls, dovetails, box forms and retention grooves.1-6 According to Pagliarini,7 enamel and dentin adhesives were developed to increase the retention of a restoration, and to reduce the marginal gap at the tooth to restoration interface. An additional advantage of the adhesive techniques is increased bond strength for greater structural integrity of both tooth and restoration.8-10 In advent of adhesive materials capable of bonding to enamel, dentin and metallic surfaces have an intriguing effect after clinical approach to amalgam restorations.

In vitro studies of amalgam alloys bonded to various adhesives have shown increased retention and reduced microleakage compared to cavity varnishes.9,11-26 While amalgam bonding agents and dentin adhesives generally and significantly increase retention of amalgam to tooth structure, there are differences in retentive strength among the bonding agents.26 This in vitro study evaluated the bond strength of amalgam to dentin with the use of four different adhesives and then compared them with a cavity varnish.

Materials & Methods

In this investigation, the amalgam dentin bond strength of various adhesive systems was measured. The adhesives used in this study are listed in Table 1.

One hundred human molar teeth stored in normal saline were assigned random numbers of 20 for each group and were placed into five groups for bond strength testing. They were invested in clear auto polymerizing resin (Orthodontic resin, Dentsply, Caulk Co, Milford, DE 1993) with the apices down and inward within a section of a 1-inch diameter polyvinyl chloride pipe. The samples were wet ground with 600-grit silicon carbide sandpaper on both the occlusal and apical aspects until a cross section of tooth, approximately 30 mm in thickness, remained. Specimens were then stored in humidor (37°C and 100% humidity) for 24 hours.

A 3.3 mm diameter cylindrical cavity was prepared in the dentin perpendicular to the section plane. The cavity was prepared with a solid carbide broad point drill cooled with a constant stream of water in a drilling and milling machine (Model RF-20/25, Lincoln Crop, Taiwan). To assure parallelism of the cavity walls, a jig was used to position and support the dentin specimens during the procedure. The samples were rinsed of debris in tap water stored in a humidor for 24 hours.

Cavity surfaces were prepared with each adhesive system according to manufacturers instructions. For the control group, the dentin was rinsed; air dried, swabbed
with two coats of Copalite (Cooley & Cooley, Ltd, Houston, TX 77041) and allowed to air dry. Cavities were filled with a spherical high copper amalgam named Oralloy (Coltene/Whale Dent Inc, New York, NY, 10001). The amalgam was condensed with a hand instrument carved back to minimize flash and allowed to set for ten minutes. The opposing open end of the cavities was occluded by a glass slide.

<table>
<thead>
<tr>
<th>Bonding System</th>
<th>Materials</th>
<th>Bonding Procedure</th>
<th>Manufacturer</th>
</tr>
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<tbody>
<tr>
<td>Scotchbond Multipurpose</td>
<td>35% Phosphoric acid Primer, Adhesive</td>
<td>Etched for 15 seconds; rinsed; lightly dried to a moist surface; primer applied; lightly dried for five seconds; adhesive applied; light-cured for 10 seconds</td>
<td>3M Dental products; St. Paul, MN, 5544, USA</td>
</tr>
<tr>
<td>One Coat Bond</td>
<td>15% Phosphoric acid Adhesive</td>
<td>Etched for 15 seconds; rinsed; lightly dried to a moist surface; adhesive applied and massaged into dentin for 20 seconds; light-cured for 30 seconds</td>
<td>Coltene/Whaledent Mahwah; New Jersey 07430, USA</td>
</tr>
<tr>
<td>Panavia</td>
<td>---</td>
<td>The base and catalyst were mixed for 30 seconds, and applied to the dentin.</td>
<td>Kuraray Co, Ltd, 1-12-39 Umeda, Kita KU; Osaka, 530, Japan</td>
</tr>
<tr>
<td>PQI</td>
<td>35% Phosphoric acid adhesive</td>
<td>Etch for 15 seconds; rinsed; lightly dried to a moist surface; adhesive applied and rubbed into dentin for 15 seconds; adhesive air-thinned; and light-cured for 20 seconds.</td>
<td>Ultradent Products/Caulk, Inc; South Jordan, UT 84095 USA</td>
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</tbody>
</table>

**Bond strength testing**

The sample thickness was measured with a micrometer caliper (LS Starrete Co, Athol, MA, 01331) to allow later calculations of the dentin wall surface area. All samples were mounted in a metal jig that centered the restorations over a 4 mm hole with the remaining tooth structure supported by the metal samples holder. A steel probe 3 mm in diameter was centered over the restoration and used to apply force to the test specimen. Specimens were tested using a hydraulically activated materials test system (model 810, MTS Crop, St Paul, MN, 55101). The test model with a linear displacement mode had a linear displacement rate of 1 mm per minute. The force required dislodging. The bonded amalgam specimens was recorded in kilograms of force and converted to stress by the nominal interfacial area of the amalgam dentin interface.\(^2^7\) Data for each bonding system were analyzed by ANOVA and the Duncan Multiple range tests \(P<0.05\) to determine significant differences in shear bond strength value among the different adhesive systems.

**Results**

Shear bond strengths as measured by the push out test are shown in Table 2 and Fig 1.

**Table 2. Shear bond strength from push out tests**

<table>
<thead>
<tr>
<th>Adhesive</th>
<th>N</th>
<th>Mean (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PQI</td>
<td>20</td>
<td>13.15</td>
</tr>
<tr>
<td>Copalite</td>
<td>20</td>
<td>14.14</td>
</tr>
<tr>
<td>Panavia</td>
<td>21</td>
<td>20.06</td>
</tr>
<tr>
<td>Scotchbond MP</td>
<td>20</td>
<td>21.02</td>
</tr>
<tr>
<td>One coat bond</td>
<td>20</td>
<td>23.47</td>
</tr>
</tbody>
</table>

ANOVA revealed that there was statistically significant difference among dental adhesives \(P<0.05\). The Duncan test showed that the highest bond strength was found in One Coat Bond, Panavia 21, and Scotchbond MP \(P<0.05\). The Duncan test did not demonstrate a significant difference between the amalgam bond strength of PQ1 and Copalite and among the three bonding agents: One Coat Bond, Panavia 21, and Scotchbond MP \(P>0.05\).

**Discussion**

Application of adhesive resins between dental surfaces and amalgam restorations has become a common procedure.\(^2^6\)\(^,^2^8\) These applications represent the two main purposes for using adhesives in restorative dentistry which are marginal seal and retention.\(^9\) The aim of this in vitro study was to evaluate the amalgam dentin bond strength of two light-cured single
components (One Coat Bond and PQ1), 1 light-cured multi-component dentin-bonding agent (Scotchbond MP), and 1 self-cured resin Cement (Panavia 21) and to compare these groups with copal varnish (Copalite).

For this study, the light-cured and self-cured adhesive systems were selected because a previous study claimed that the mode of curing did not seem to affect the amalgam bonding.26

For evaluation of bond strength, the push out test was selected, because this unique shear test could take a variety of stresses into consideration and it can better simulate the bonded dental restoration model than the flat-bonded specimens in the planner interface shear test. Frictional forces between the restorative material and substrate, and the requirement of parallelism of the preparation walls, were two perplexing variables associated with this method.29,30 The development of a uniform shear stress without the presence of tensile component is an important advantage of the push out test methodology.30

Smith and Cooper31 described a punch out shear test in which a cylindrical specimen of material was pushed through a substrate. Mahler and Nelson28 also described a push out method to measure the force required to remove simulated class I restoration from cavity molds. The push out test in the present study is similar to Smith and Cooper.31

Scotchbond Multi-Purpose was chosen for this study because it is a water based adhesive and bonds reasonably well to dentin and fresh amalgam.23,32 It consists of a single component dentin primer followed by a light-cured adhesive resin.30 A bond strength of 17-25 MPa has been reported for Scotchbond MP.33,34 In this present study, Scotchbond MP's amalgam bond strength was 21.02 MPa, which was in the range of previous studies.

Panavia 21 is self-cured resin cement which is commonly applied as an amalgam bonding agent. It is thought that Panavia 21 bonds poorly to dentin, but reasonably well to fresh amalgam.23,55,56 As reported previously, Panavia was viscous and sticky to handle.18,37 Therefore it was to create a thick layer adhesive. It has been recognized that this amalgam bonding agent significantly increased retention of amalgam to tooth structure.26 The mechanism for bonding between the amalgam and the resin liner was by a mechanical intermingling of amalgam with the setting resin liner during condensation of amalgam.38,39

A high film thickness36 and the interlocking of amalgam, Panavia and dentin could be the reasons for higher amalgam dentin bond strength. One Coat Bond is a water-based single component multi-purpose adhesive system which can create a thicker layer than Scotchbond MP.40 This is because of 5% filler content and the combination of primer and adhesive in a single bottle, but there is no statistically significant difference between One Coat Bond and Scotchbond MP in their bond strengths. This is probably due to two reasons: 1) Scotchbond MP is a multi-step dentin bonding system; meaning that the primer infiltrates the etched dentin prior to resin application which promotes adhesion of resin to dentin.40 The monomers in the adhesive diffuse into the dentin, forming a hybrid layer.41 This hybrid layer formation plays an important role in achieving maximum bond strength.39 2) One Coat Bond is a single step process with 5% filler content. It is more viscous than Scotchbond MP and cannot penetrate into the etched dentin. In contrast, one previous study showed that filler content in new adhesive systems were able to create greater dentin bond strength than dentin bonding systems without fillers, because of the reinforcement of the hybrid zone.42 Therefore, filler loading in One Coat Bond could compensate for its high thickness and consequently amalgam dentin bond strength between these two adhesives had no significant difference.

PQ1 is also a viscous single component multi-purpose adhesive resin system. Its solvent is ethyl alcohol and it has 40% filler loading. This adhesive can create a thick layer, perhaps even more than One Coat Bond because of its higher filler content. PQ1 and One Coat Bond are single components with thick layers of over-etched dentin. The higher thickness of dentin bonding layer over the dentin could have a thicker air-inhibited layer of resin.28 An oxygen-inhibited layer plays an active and significant role in adhesion,43 because it is softer than the other parts of the resin and at the time of condensation of amalgam it would interlock with resin and high bond strength could be created. Adhesion to amalgam by the resinous adhesive layer is mainly formed by inter-digitations and mechanical interlocking.43 But it was observed that the amalgam bond strength of PQ1 was statistically less than the One Coat Bond, and is probably due to higher filler loading of PQ1. Increased filler loading increased viscosity of the bonding system and might reduce its flow. The addition of high filler content prevented the adhesive from adapting optimally to the etched dentin surface and the exposed collagen fibers. However, a suitable hybrid layer may not form44 It appears that the threshold of filler loading into the dentin-bonding agent is an important factor for forming suitable bond strength. In this study, it was recognized that the highest bond strength was seen in One Coat Bond, Scotchbond MP, and Panavia 21.

In the future, clinical evaluation of the amalgam bond strength in conservative cavity preparation is necessary.

Acknowledgments
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References


