Fracture Resistance of Teeth Restored with the Bonded Amalgam Technique

GM Dias de Souza • GDS Pereira
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Clinical Relevance
Bonding amalgam technique in mesio-occlusal-distal (MOD) cavities within 2/3 the intercuspal distance width and 3/5 the height of the crown depth did not increase the fracture resistance of maxillary premolars.

SUMMARY
This study evaluated the fracture resistance of maxillary premolars with MOD Class II cavity preparations restored with silver amalgam (G1), Scotchbond Multi Purpose Plus and silver amalgam (G2) and Panavia F and silver amalgam (G3). After the restorations were made, the specimens were stored at 37°C for 24 hours at 100% humidity.

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and submitted to the compression test. Statistical analysis of the data (ANOVA and Tukey Test) revealed no significant differences among the three groups that were studied.

INTRODUCTION
Sound teeth rarely fracture during normal masticatory stress. However, cuspal fracture can frequently occur in teeth that have been weakened by caries, large cavity preparations (Jagadish & Yogesh, 1990; Mondelli & others, 1980) and reduced dental structure from erosion or abrasion (Eakle, Maxwell & Braly, 1986; Khers & others, 1990). Studies have shown that teeth with cavity preparations become weaker as the occlusal isthmus is widened, and they fracture more easily than intact teeth (Cavel, Kelsey & Blankenau, 1985; Eakle, 1986; Gelb, Barouch & Simonsen, 1986; Jagadish & Yogesh, 1990; Liberman & others, 1990). Therefore, it is important to preserve the integrity of the dental structure to maintain its resistance (Diefenderfer & Reinhardt, 1997; Eakle & others, 1986). When enamel is supported by dentin good clinical results can be obtained. However, there are cases in which the enamel walls have no support, resulting in a tendency to fracture (Espinosa, 1978; Franchi & others, 1994). In these situations, the unsupported enamel must be removed or a resilient material must be used to strengthen the weakened margins (Franchi & others, 1994).
Among direct restorative materials, silver amalgam has been clinically used for more than 160 years (Craig, 1971; Santos & Meiers, 1994; Staninec & Holt, 1988) due to its favorable mechanical properties and easy handling characteristics. Silver amalgam is also frequently chosen for posterior restorations since it resists masticatory stress (Gwinnett & others, 1994). However, its high modulus of elasticity (Skinner & Philips, 1993) does not allow it to reinforce weakened cusps (Boyer & Roth, 1994). This limits its use in cavities where the enamel is not supported by dentin (Glib & others, 1986; Santos & Meiers, 1994). In addition, lack of adhesiveness to dental structures requires cavity design with mechanical retention at the expense of healthy tooth structure, which increases fracture susceptibility (Bagley, Wakefield & Robbins, 1994; Gwinnett & others, 1994; Staninec & Holt, 1988).

With the development of adhesive systems, bonding of dental amalgam to tooth structure became possible (Staninec & Holt, 1988; Staninec, 1989; Gwinnett & others, 1994; Oliveira, Cochran & Moore, 1996). With this technique, the alloy is condensed against an adhesive resin before polymerization (Vargas, Dench & Ratananakin, 1994). This technique reduces the need for mechanical retention and allows more conservative cavity preparations (Bagley & others, 1994; Gwinnett & others, 1994; Staninec, 1989). Bonding alloy to enamel and dentin (Boyer & Roth, 1994; Staninec & Holt, 1988) may increase fracture resistance due to splinting of the anatomical crown (Gwinnett & others, 1994; Santos & Meiers, 1994).

Filled adhesive systems offer advantages in the bonded amalgam technique compared to unfilled agents (Bagley & others, 1994). Despite the progress made with this procedure, some limitations have been cited, such as increased chair time, increased cost and the practitioners’ learning curve for a new technique (Gwinnett & others, 1994; Christensen, 1994; Oliveira & others, 1996). It is, therefore, important to determine whether the proposed advantages of this technique offset the disadvantages.

This study evaluated two adhesive systems for the bonded amalgam technique—a dentin adhesive system and a resin cement—in terms of fracture resistance of maxillary premolars with standardized MOD cavities, and restored teeth with silver amalgam as a control group.

**METHODS AND MATERIALS**

Thirty unrestored, non-carious, extracted maxillary premolars were stored in 10% formalin solution (pH=7.0) at room temperature. After cleaning with periodontal curettes, the teeth were mounted in polystyrene resin cylinders, exposing 2 mm of root surface below the cementum-enamel junction. They were then stored in physiological saline.

The intercuspal distance on the occlusal surface and the distance from the buccal cusp tip to the cemento-enamel junction of each tooth were measured using a digital caliper to standardize the cavity preparations.

MOD cavities were prepared with parallel walls and no approximal boxes. A FG 3145 diamond bur was used in a high-speed water cooled handpiece that was fixed in a specially designed jig (Figure 1) that allowed their bucco-lingual (Figure 1A) and mesio-distal (Figure 1B) dimensions to be accurately prepared. The isthmus width was 2/5 the distance between the cusp tips, and the pulpal depth was 3/5 the height of the crown. The cavity preparation’s width was checked in the occlusal portion and the pulpal depth was measured with a digital caliper in relation to the buccal cusp tip. The preparations were finished with the same diamond bur in a low speed handpiece. The teeth were rinsed with an air-water spray, then randomly divided into three groups (n=10).

Group 1: teeth restored with silver amalgam, using alloy Permiste C (SDI, São Paulo, Brazil 05421-030) and a conventional restoration technique (Gwinnett & others, 1994). Group 2: dentin adhesive system Scotchbond Multi-Purpose Plus (3M Dental Products, Campinas, Brazil 13001-970) was applied before inserting amalgam. Group 3: the resin cement Panavia...
Table 1: Means and Standard Deviations

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<tr>
<td>G1</td>
<td>10</td>
<td>94.16 (± 19.3865)</td>
<td>a</td>
</tr>
<tr>
<td>G2</td>
<td>10</td>
<td>104.43 (± 24.8655)</td>
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</tr>
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<td>G3</td>
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The results of this study showed no statistically significant differences between the bonded amalgam techniques that used Scotchbond Multi-Purpose Plus or Panavia F and the conventional technique that only used amalgam. Such results suggest that using bonding agents associated with silver amalgam do not prevent cuspal fracture, which is contrary to other researchers' studies (Oliveira & others, 1996; Pilo & others, 1998). However, this study's findings can be explained by the cavity preparation size, with the isthmus width of 2/5 the distance between the cuspal tips, a pulp depth of 3/5 the height of the crown and parallel walls, in which a significant amount of dentin was still observed under the cusps. The dentin low modulus of elasticity might have supplied considerable flexure resistance to the remaining walls, resulting in statistically similar fracture resistance values. This study's findings agree with Santos & Meiers (1994) and Pilo & others (1998), who also found no significant differences among the groups restored with adhesive amalgam and the group restored with only amalgam. However, Pilo & others' (1998) comparison of the different dentin bonding systems found lower results for Scotchbond Multi-Purpose Plus, whose performance was justified by the absence of filler particles. According to Eakle (1986), reinforcement of dental structure is directly related to using an adhesive system since reinforcement was found only in the group in which the adhesive agent for enamel and dentin was applied. Therefore, Panavia F was expected to produce better results because, in addition to the presence of filler, the material adhesively bonds to enamel and dentin. However, this system uses an acidic primer that incorporates the smear layer instead of removing it. This produces a narrow hybrid layer and reduces the adhesion values (Nishida & others, 1993), which could explain the results of the Panavia F cement.

A one year clinical study (Mahler & others, 1996) found many technical problems and few benefits for the bonded amalgam technique. There were no statistical differences in post-operative sensitivity or marginal integrity.

The results of this research demonstrated high standard deviation values for the three groups studied. According to Jagadish & Yogesh (1990), individual variations in tooth morphology may occur, and the cusp's angulation, enamel thickness, inherent weaknesses and slight variations of the contact of the metal sphere with the cusp during testing may contribute to the large standard deviations. In addition, differences exist between fractures that occur clinically and those induced by a testing machine. Forces generated intraorally during function vary in magnitude, application speed and direction, whereas forces applied in vitro are at a constant direction and speed and continually increase until fracture occurs. Bell, Smith & de Pont

F (Kuraray Co, Osaka, Japan 1-12-39) was used before the teeth were restored with Permite C. The bonding agents' components used in the adhesive amalgam technique were applied according to the manufacturer's instructions.

The specimens were stored for 24 hours in 100% relative humidity at 37°C and the fracture test was conducted in an Instron testing machine (Instron Corp, Canton, England 02021-1089) with 500 Kgf load. A 4 mm diameter steel sphere contacted the buccal and lingual cusps of the tested teeth at a crosshead speed of 0.5mm/min until fracture occurred (Figure 2).

RESULTS

The values obtained in this study were subjected to Analysis of Variance (ANOVA), which revealed no significant differences among the experimental groups (p>0.05). The fracture resistance average for the experimental groups were: G1: 94.16 Kgf; G2: 104.43 Kgf; G3: 98.77 Kgf. To document these results, the Tukey test was applied (Table 1 and Figure 3).

DISCUSSION

Ideally, a restorative material should strengthen the tooth and protect against further fracture (Jagadish & Yogesh, 1990). Extensive cavity preparations weaken tooth walls and increase fracture susceptibility (Pilo, Brosh & Chweidan, 1998). Therefore, Eakle, Staninec & Lacy (1992) suggested that using an adhesive under amalgam restorations can increase the fracture resistance of restored teeth.
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**Figure 3. Box-Plot diagram of the fracture resistance test (AM=Amalgam; PN=Panavia F; SB=Scotchbond Multi-Purpose Plus; TRATAM=Treatment).**

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(1982), in their study of cuspal failures in teeth restored with MOD amalgams, concluded that cusp fracture occurs as a result of brittle tooth structure fatigue caused by the propagation of microcracks. In vivo, only 38% of the fractures occur on the functional lingual cusp (Cavel & others, 1985). In this study, where force was applied with constant direction and increasing load, fracture of the functional cusp occurred in 100% of the specimens.

It should be noted that the bonded amalgam technique is not only used to reinforce the remaining tooth structure. When amalgam is packed into the cavity against an unset resin, a mechanical interlocking of resin and amalgam occurs (Eakle & others, 1992). This interlocking is probably a significant factor in the retention of amalgam in the cavity (Lacy & others, 1989), reducing the need for additional retentive devices in already weakened teeth. Another advantage of the adhesive-amalgam technique is the significant reduction in marginal leakage (Gwinnett & others, 1994) due to better adaptation to the subgingival and the adhesive system (Diefenderfer & Reinhardt, 1997).

According to Christensen (1994), it is important that the adhesive amalgam technique be studied widely because, if amalgam restorations are improved by bonding, then the procedure should be routinely done. If not, this rather expensive and time-consuming task should not be used. According to the technique's limitations and the results found in this study, adhesive amalgam should not be commonly employed as a means of preventing dental fracture.

CONCLUSIONS

Study results indicate that when cavity preparations were restored with bonded amalgam techniques using Scotchbond Multi-Purpose Plus and Panavia F, no increase in fracture resistance was observed when compared to conventional amalgam restorations.

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