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Repair Strength of Dental Amalgams

C Shen • J Speigel • IA Mjör

Clinical Relevance

The proper technique of condensing amalgam to the surface of an old amalgam is critical to establishing a bond between the new and old amalgams.

SUMMARY

This study tested the hypothesis that newly triturated amalgam condensed vertically on old amalgam was essential for establishing a bond between the new and old amalgams.

Twelve rectangular bars were prepared with Dispersalloy and Tytin to establish their baseline flexure strength values. An additional 12 specimens were made and separated into 24 equal halves. All fracture surfaces were abraded with a flat end fissure bur. Twelve surfaces were paired with the original amalgam, and the remaining 12 surfaces were repaired with a different amalgam. At first, freshly triturated amalgam was condensed vertically on the floor of the specimen mold (Group A). The majority of specimens repaired with Group A failed to establish bond at the repair interface. All repair surfaces were abraded again and prepared by a second method. A metal spacer was used to create a four-wall cavity to facilitate vertical condensation directly on the repair surface (Group B). The specimens were stored in ambient air for seven days prior to flexure testing.

The strength of specimens repaired with Group B ranged from 26% to 54% of the baseline specimens. ANOVA showed that amalgams repaired with a different amalgam yielded higher strength values than those repaired with the original amalgam, and the baseline specimens exhibited significantly higher strength values than all the repaired specimens.

*Chiayi Shen, PhD, associate professor, Department of Dental Biomaterials, College of Dentistry, Health Science Center, University of Florida, Gainesville, FL, USA

Jason Speigel, BS, senior dental student, College of Dentistry, Health Science Center, University of Florida, Gainesville, FL, USA

Ivar A Mjör, BDS, MSD, MS, Dr Odont, professor, Department of Operative Dentistry, College of Dentistry, Health Science Center, University of Florida, Gainesville, FL, USA

*Reprint request: PO Box 100446, Gainesville, FL, 32610-0446, USA; e-mail: cshen@dental.ufl.edu

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INTRODUCTION

Dental amalgam has been used successfully for more than a century. Although the use of tooth-color restorative materials has increased over the last decade, amalgam restorations are mostly used in some countries. The clinical diagnosis of secondary (recurrent) caries is the main reason for replacing amalgam restorations, with fracture being the second most common reason for amalgam restoration failure (Mjör, Moorhead & Dahl, 2000). When secondary caries is diagnosed, it inevitably results in replacement of the restoration, but an alternative treatment that removes part of the restoration to the full depth at the site of the defect is a recognized procedure that makes a firm diagnosis of the extent of the caries. Provided that the main part of the restoration is satisfactory, the part that is removed can then be filled with amalgam (Mjör & Gordan, 2002). Repair of an existing restoration has been considered to be a viable, cost-effective alternative to complete replacement (Mjör, 1993). A clinical study has indicated that repair of local defects in amalgam restorations is an effective alternative to total replacement, at least over a five-year period (Smales & Hawthorne, 2004).

An important factor related to the quality of amalgam repair is the interfacial bond between new and existing amalgam. The modes of measurement include tensile (Hadavi & others, 1992; Bagheri & Chan, 1993; Özer & others, 2002), shear (Gordon & others, 1987; Hadavi & others, 1991; Nuckles, Draughn & Smith, 1994; Diefenderfer, Reinhardt & Brown, 1997) and flexure strength values (Jørgensen & Saito, 1968; Hibler & others, 1988; Leelawat & others, 1992; Fruits, Duncanson & Coury, 1998; Jessup & others, 1998). Surface treatment of aged amalgam appears to be a major factor in achieving a high quality bond. Wetting the amalgam surface with mercury has been shown to result in a 98% recovery of the original strength (Jørgensen & Saito, 1968), which has apparently led to a protocol of using a mercury-rich amalgam made of one pallet of amalgam to three spills of mercury (Cowan, 1983). However, the need for using mercury-rich amalgam to enhance repair bond has also been questioned (Hibler & others, 1988) and, today, attention to mercury hygiene in dental practice prevents such use of mercury.

Other variables that were investigated include a clean, uncontaminated substrate, roughening the amalgam surface, additional undercut and using repair material that is different from the substrate. Recently, the use of bonding agents designed for metallic surfaces has also been suggested (Özer & others, 2002). Depending on the study design, the effect of surface treatment yielded mixed results. For example, the use of some bonding agents appeared to be superior when no mechanical roughening of the surface was performed, while other designs showed no benefit from using bonding agent if adequate roughening had been implemented.

Both cylindrical and rectangular specimens have been used in the study of amalgam repair strength. For the cylindrical specimen, the repair surface is vertical to the direction of condensation. In the case of rectangular specimens, the repair surface is often parallel to the direction of condensation. Regarding the condensation process, the literature is not specific as to whether the investigator should try to condense new amalgam laterally towards the repair surface or to condense it, like building a large amalgam restoration.

This study investigated how the mode of condensation, in terms of applying pressures directly on or parallel to the repair surface and the repair material, would affect repair strength. Two commonly available amalgams were used as substrates and repair materials in this study. The hypothesis was that, newly triturated amalgam condensed vertically to the old amalgam, was essential for establishing repair bonding, and repairs using a different material should yield higher repair strength than repairs with the same material.

METHODS AND MATERIALS

Six split molds (Figure 1) for making amalgam specimens (3 x 2 x 12 mm) were used. Twelve rectangular specimens were made from an admix amalgam (Dispersalloy) and a spherical high-copper amalgam (Tytin). The specimens were removed from the split mold 24 hours later, stored in ambient air for seven days and subjected to the three-point bending test with a 10-mm span using a Universal Testing Machine with a crosshead speed of 0.5 mm/minute. The actual width and thickness of the specimen near the fracture surface were measured using electronic calipers.

Another 12 specimens were prepared from the two amalgams for the repair study. During the initial setting stage, a groove was made with the carver at the midline of the specimens. The specimens were removed 24 hours later, stored in ambient air for seven days and broken into two halves with finger pressure. For each of the two amalgams, the procedure resulted in 24 repair substrates that were divided randomly into two subgroups of 12 substrates. The first specimen subgroup was repaired with the same amalgam and the second subgroup with the other amalgam.

The fractured surface of the substrate being repaired was abraded with a flat end fissure bur and fit into the split mold with the abraded surface in the middle of the mold. To ensure that the abraded surface remained perpendicular to the long axis of the substrate, two Vee-blocks and a laboratory jack were used. The repair

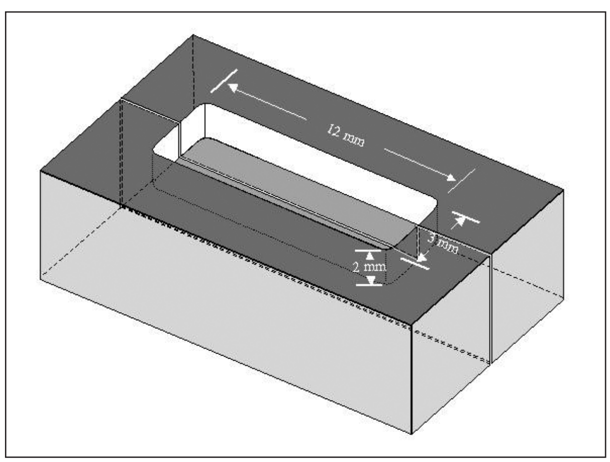

Figure 1. *Schematic illustration of the split mold for fabricating specimens.*

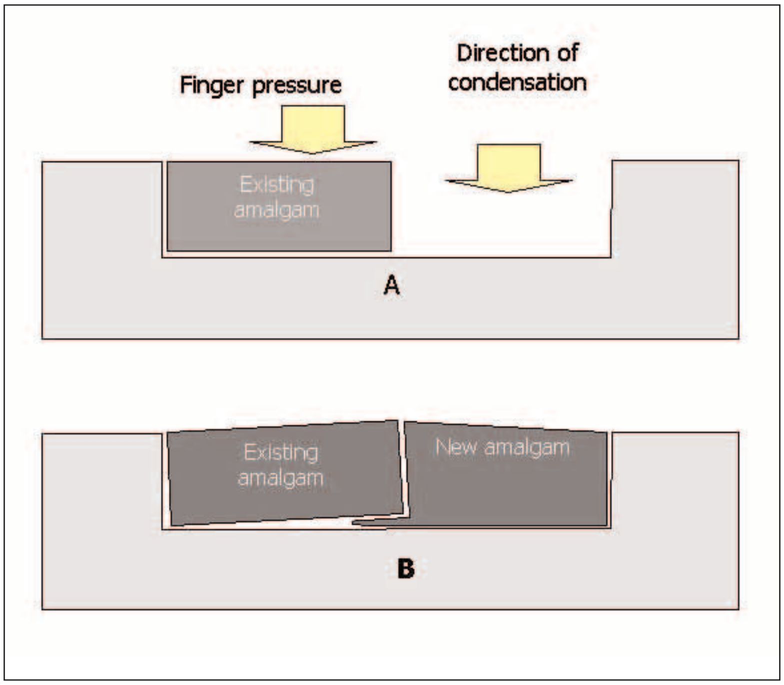

Figure 2. *Schematic illustration of holding the existing amalgam with finger pressure and condensing new amalgam parallel to the repair surface (A) that often resulted in new amalgam oozing underneath the existing amalgam (B).*

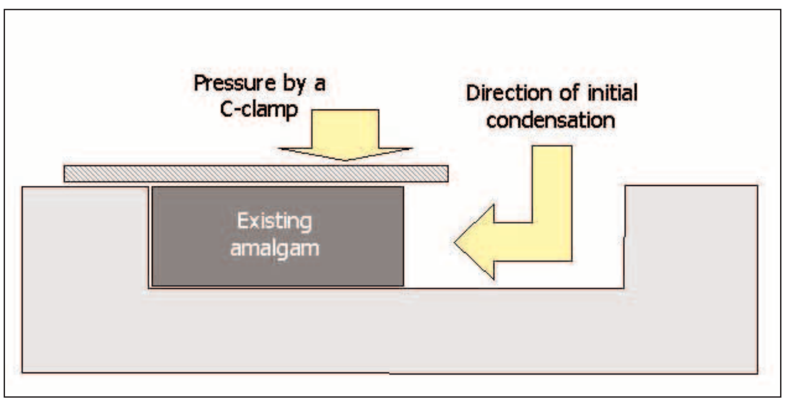

Figure 3. *Schematic illustration of holding the existing amalgam with finger pressure and condensing new amalgam parallel to the repair surface (A) that often resulted in new amalgam oozing underneath the existing amalgam (B).*

substrate was secured on one block. A straight handpiece with a flat end fissure bur was secured on the second block, which was resting on the laboratory jack. Both blocks were aligned perpendicular to each other. By raising and lowering the laboratory jack, a surface ready for bonding on the repair side of the substrate was generated.

Two condensation methods were used. The direction of condensation used in the first method (Group A) was parallel to the repair surface. Fresh amalgam was triturated and condensed into the empty half of the mold beginning at the repair surface, similar to filling an amalgam restoration. During condensation, the specimen was held down with finger pressure (Figure 2A) to keep it from elevating by way of the new amalgam being pushed under the set amalgam (Figure 2B). During the procedure, finger pressure was found to be adequate for holding down the specimen. The procedure was expected to yield 4 subgroups of 12-specimens. However, a majority of the specimens (>83%) separated at the repair interface when removed from the split mold 24 hours later. Those specimens that did not separate were found to have new amalgam pushed under the old amalgam (Figure 2B) and could be separated with finger pressure. Apparently, bonding did not occur at the repair interface of the Group A specimens.

Since the specimens prepared in Group A were not subjected to any flexure test, the repair surface of the substrates were abraded again as described earlier and used in preparation for the second method. The direction of amalgam condensation used in the second method (Group B) was vertical to the repair surface (Figure 3). The specimen was placed against one end of the mold, with the repair surface in the middle. A flat metal piece was placed on top of the repair substrate and extended approximately 2 mm over the empty half of the specimen mold (Figure 3). A C-clamp was used to stabilize the flat metal

Table 1. *Mean Flexure Strength Values, Standard Deviations and Percent of Recovery or Repair Specimens with Respect to Non-repair Controls*

Group	Substrate Material	Repair Material	Number of Specimens	Mean Flexure Strength (SD), MPa	Percent of Recovery
Baseline	Tytin	none	12	116.6 (14.6)^{A}	-
	Dispersalloy	none	12	104.2 (13.4)^{A}	-
B	Dispersalloy	Tytin	12	55.8 (20.3)^{B}	54%
	Tytin	Dispersalloy	12	44.5 (17.5)^{B,C}	38%
	Tytin	Tytin	11	32.2 (13.7)^{C}	28%
	Dispersalloy	Dispersalloy	10	26.7 (10.2)^{C}	26%

Note: 1. The majority of specimens prepared for Group A failed during removal from the mold; the group was treated as having no bond strength and not included in this table and statistical analysis.

2. The values of mean flexure strength with the same superscript are not significantly different by Tukey's HSD test at α=0.05.

spacer. This preparation protocol served two purposes: it secured the substrate and formed a box that allowed the operator to condense the new amalgam vertically on the repair surface, then on the floor of the mold. All 48 specimens were removed from the split mold 24 hours later, stored in ambient air for seven days and subjected to a three-point bending test. No specimen separated during removal.

The flexure strength values were calculated by the following equation, $FS = 3P \cdot l/(w \cdot h^2)$, where P is the load to fracture, l is half-length of the span, w is the width and h is the thickness of the specimen. Analysis of variance (ANOVA) was used to determine statistical differences in strength values among the subgroups, including baseline specimens.

RESULTS

Group A was considered to have zero strength values and was excluded from data analysis. For specimens prepared with Group B, one specimen from Tytin, repaired with Tytin subgroup, and two specimens from Dispersalloy, repaired with Dispersalloy subgroup, had new amalgam covering one side of the old amalgam. They were excluded from the statistical analysis.

One-way ANOVA showed that there was a statistically significant difference ($p<0.0001$) among the remaining six subgroups of specimens (Table 1). The Tukey's HSD test indicated that the non-repair subgroups exhibit higher mean strength values than the four repaired subgroups, and the percentage of repair strength ranged between 26% and 54% of the non-repair strength values. Amalgam substrates repaired with a different amalgam yielded higher repair strength than the substrates repaired with the same amalgam.

Examination of the fracture surface of all 45 specimens of Group B with an optical stereomicroscope showed that there were adhesive failures in all the specimens examined and no signs of cohesive fractures. All fracture surfaces showed some degree of porosity. The specimen with a higher degree of porosity often exhibited lower repair strength.

DISCUSSION

Repairs of non-roughened amalgam surfaces have been frequently known to yield no bond strength (Özer & others, 2002). Therefore, the surfaces to be bonded should be roughened and free of loose debris, and the new amalgam should wet the surfaces to establish adhesion between the two surfaces. All set amalgams contain significant amounts of unreacted amalgam alloy particles, and a significant amount of mercury in freshly triturated amalgams is in free form during initial setting. As long as the roughening procedure exposes the unreacted particles and the mercury in freshly triturated amalgam wets the roughened surface, the condition of bonding is established.

While the literature has repeatedly shown that proper roughening of the repair surface is essential for achieving some degree of repair strength, it does not seem to treat condensation procedure, which is a major variable, equally. Perhaps it has been taken for granted that the same vigor involved with condensing new amalgams will be used in the repair of existing amalgams. This study showed that the mode of condensing amalgam played an important role in final repair strength. Freshly triturated amalgam is near a solid mass that does not flow like free-mercury. To assure wetting on the repair surface, it is critical to press the mass of freshly triturated amalgam directly against the repair surface. If the size of the mold to be filled with new amalgam is greater than the diameter of the condenser head, it will allow for the new amalgam to flow around the condenser head with minimal resistance (Ogura, Hadavi & Asgar, 1983). The result may be adequate for restoring the repair interface but not sufficient for pressure to establish a desirable bonding.

Clinically, the size of the repair is small; that is, if the width is about the diameter of a condenser head, the physical constrain of the repair site would minimize the up flow of amalgam and result in higher pressure exerting itself on the existing amalgam. However, if the size of the repair is great in area or volume, a certain strategy is needed to ensure bonding to the existing amalgam, for example, placement of new amalgam should start by condensing vertically on the repair surface.

Hibler and others (1988) reported that the repair should only be done by the clinician who placed the original restoration to ensure repair with the same material. When a high-copper amalgam was used to repair a conventional amalgam, it was shown that the repair strength was lower than when the old amalgam was also a high-copper amalgam (Hadavi & others, 1992). The mean repair shear strength of Tytin repaired by Contour, a high-copper admix amalgam, was higher than Tytin repaired with Tytin or Contour repaired with Contour (Nuckles & others, 1994). The current study confirmed that repair with different materials yielded higher repair strength values.

Nuckles and others (1994) suggested that a spherical alloy be used for all amalgam restoration repairs. Spherical high-copper amalgam is known to be more plastic than admix amalgam immediately after trituration. This extra plasticity should help wet the repair surface better and result in higher repair strength values. However, when admix amalgam was used to repair old spherical amalgam (Table 1), less improvement in strength was also observed. It appears that, in addition to the plasticity of amalgams, some interaction between admix and spherical might have occurred. Therefore, if the type of the old amalgam is known to the clinician, then another material should be used for repair. If the information is not available, then a spherical alloy should be used.

The use of different amalgams for repair would undoubtedly raise the potential for corrosion between the two amalgams. A 16-month study showed that there was no evidence of corrosion or adverse effect when a high-copper amalgam was bonded to a conventional amalgam (Cowan, 1983). Since the composition of Tytin and Dispersalloy is metallurgically much closer than either amalgam to a conventional amalgam, the potential for corrosion between Tytin and Dispersalloy would be minimal.

CONCLUSIONS

Within the limitations of this study, the following conclusions can be drawn:

1. Condensation pressure should be applied vertically to the repair surface whenever possible, or the size of the condenser should only be slightly smaller than the repair site in order to exert maximum pressure on the repair surface.
2. When repair of an amalgam restoration is carried out, a material of a different composition should be used to achieve greater repair strength.

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