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# Proximal Contact Repair of Complex Amalgam Restorations

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### Clinical Relevance

The repair of an open proximal contact in an otherwise functional, intact existing complex amalgam restoration may be an acceptable alternative to replacement.

## SUMMARY

**The carving of a complex amalgam restoration may occasionally result in light proximal contact with the adjacent tooth. The purpose of this study was to investigate the strength of complex amalgam restorations repaired with a proximal slot amalgam preparation. Extracted human third molars of similar coronal size were sectioned 1 mm apical to the height of the contour using a saw and were randomly distributed into 9 groups of 10 teeth each. One pin was placed at each line angle of the flattened dentinal tooth surface. A metal matrix band was placed and an admixed alloy was condensed and carved to create a full crown contour but with a flat occlusal surface. A proximal slot was prepared with or without a retention groove and repaired using a single-composition spherical amalgam 15 minutes, 24 hours, one week, or six months after the initial crown condensation. The specimens were stored for 24 hours in 37°C water before fracture at the marginal ridge using a round-ended blade in a universal testing machine. The control group was not repaired. The mean maximum force in newtons and standard deviation were determined per group. Data were analyzed with a 2-way analysis of variance as well as Tukey and Dunnett tests ($\alpha$=0.05). Significant differences were found between groups based on type of slot preparation (*p*=0.017) but not on time (*p*=0.327), with no significant interaction (*p*=0.152). No significant difference in the strength of the marginal ridge was found between any repair group and the unrepaired control group (*p*>0.076). The proximal repair strength of a complex amalgam restoration was not significantly different from an unrepaired amalgam crown. Placing a retention groove in the proximal slot preparation resulted in significantly greater fracture strength than a slot with no retention grooves. Time of repair had no significant effect on the strength of the repair.**

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## INTRODUCTION

The repair rather than replacement of defective restorations is practiced more frequently today in dental practices. Complete replacement of restorations has the disadvantages of being time-consuming with unnecessary removal of healthy tooth structure, enlargement of the preparation, the risk of converting the restoration to an indirect restoration, the possibility of major injuries to the pulp tissues, and more expense for the patient. Even though the repair of a functional, intact section of an existing amalgam restoration has been accepted as a practical alternative, it requires sound judgment.

Multiple clinical studies have demonstrated that repairing an existing amalgam restoration is a viable alternative to replacement. Martin and others[1] supported through their five-year clinical study the concept that repair is as effective as total replacement of restorations with localized defects and reduces biological costs to the patient. Minimally invasive treatments of defective amalgam restorations presented similar results to the restorations that were replaced.[1] A clinical study by Smales and others[2] also indicated that repair of local defects in amalgam restorations is an effective alternative to total replacement, at least over a five-year period. A recent prospective, blind, randomized clinical study[3] showed similar results between repaired and replaced Class I and II amalgam restorations after 10 years.

Roggenkamp and others[4] suggested that freshly mixed amalgam added to existing amalgam restorations as a means of repair may be expected to join at nearly the original strength with sufficient condensation time (one and a half seconds) and heavy pressure (four pounds). Under the condensation pressure used in their study, the addition of new amalgam to smooth previously set amalgam surfaces (up to seven years) resulted in shear-bond forces not statistically different from the intact control.[4] Virtually all (94%) of the bonds tested resulted in cohesive rather than adhesive failures. Condensation was done with a consistent force of 22.5 MPa, which is approximately 4 times the force a dental practitioner would apply clinically when condensing an amalgam restoration when deliberately trying to use extra force.[4]

The proper technique of condensing amalgam to the surface of an old amalgam is critical in establishing a bond between a new amalgam and old amalgam restoration. Shen and others[5] showed condensation pressure should be applied vertically to the repair surface whenever possible, or the size of the condenser should be smaller than the repair site in order to exert maximum pressure on the repair surface. Their study[5] also concluded that when repair of an amalgam restoration is carried out, an amalgam material of different composition should be used to achieve greater repair strength. Reducing the dimension of the amalgam repair site has also been shown to improve repair strength.[6] As the diameter of the condenser decreases along the width of the repair site, the axial condensation pressure exerted on the freshly triturated repair amalgam increases. Ogura and others[7] recommend that a spherical alloy should be selected as the repair material due to its high plasticity, which could facilitate the adaptation between new and old amalgam. The modes of measurement of the interfacial bond between new and existing amalgam include tensile,[8] shear,[9-12] and flexural strength values.[13,14] All of these studies, however, have reported that the bond strength of the repaired amalgam was significantly less than that of the intact specimen (less than 50%). If high condensation forces had been used, the strength of the repaired amalgam may not have been significantly less than that of an intact specimen. In addition, the use of heavy pressure upon condensation may infuse the available mercury in the fresh amalgam into the substrate amalgam, potentially precluding the use of spherical alloy.[4]

Fruits and others[15] also concluded the strength of the repaired amalgam was about 40% of that of unrepaired amalgam. Leelawat and others[16] revealed similar results when testing the shear and flexural strengths of the repaired amalgam. There were higher shear bond and flexural strength values when Amalgambond (Parkell, Edgewood, NY, USA) was applied to the prepared surface of the existing amalgam. Even with this treatment, however, the strength values were less than 50% of those of the amalgam control group.[16]

Hadavi and others[8] concluded that fractures in the repaired amalgam always occurred at the junction between old and new amalgam. The repaired amalgam exhibited a reduced tensile strength when compared with intact restorations. The authors[8] also suggested that when an amalgam repair is anticipated, precise mechanical retention must be prepared in the tooth and in the remaining amalgam restoration to complement the union between old and new amalgam alloys. Where the amalgam repair is in functional occlusion, the additional retention is critical to the longevity of the restoration.[8]

All of these studies have compared old amalgam repaired with new amalgam. However, very little investigation has been done to compare the repair of the newly condensed amalgam with newly triturated amalgam. The repair of new amalgam with new amalgam may become necessary when the clinician discovers a defect after the removal of the matrix band or an open contact is discovered after condensing a full cuspal-coverage amalgam. Bagheri and others[17] revealed when new amalgam was repaired, the samples that were repaired five minutes after the initial condensation had 84% of the tensile strength of the controls. The 15-minute samples had 59% of the tensile strength of the controls, whereas the 30-minute, 60-minute, and 24-hour samples had tensile strength that was less than 50% of the controls. The study concluded that in the repair of the newly condensed (beyond 15 minutes) amalgam restorations, precise mechanical retention must be added.[17] However, in a study by Roggenkamp and others,[4] the *in vitro* shear bond strength at 15 minutes was not statistically different from the unrepaired control using Valiant PhD amalgam under heavy pressure and a one-and-a-half–second condensation time. Fifteen minutes is in the range of immediate chairside repairing of an amalgam accomplished at the same appointment.

No research has evaluated the strength of a complex amalgam after repair of a proximal contact using a slot preparation in human teeth. The purpose of this study was to investigate the strength of complex amalgam restorations repaired with newly triturated amalgam and added mechanical retention. The site of repair was the proximal contact area of a full cuspal-coverage amalgam restoration, and the mechanical retention was achieved through a slot preparation with or without retention grooves. The first null hypothesis to be tested was that there would be no difference in marginal ridge strength between the repaired marginal ridge and the unrepaired control group. The second and third null hypotheses were that there would be no difference in marginal ridge strength based on time of repair or type of slot preparation, respectively.

## METHODS AND MATERIALS

Human third molar teeth were collected, stored in 0.5% chloramine-T, and used within six months of extraction. A total of 90 caries-free maxillary and mandibular third molars of similar coronal size were collected. The groups that were tested are shown in Table 1.

A diamond saw (Isomet, Buhler, Lake Bluff, IL, USA) was used to section the crowns of the teeth to a level of 1 mm below the height of contour. A uniform smear layer was created on the flat dentin surfaces using 10 passes on 600-grit carbide paper. One retentive regular TMS pin (Coltene, Cuyahoga Falls, OH, USA) was placed at each line angle of the flat, sectioned dentinal tooth surface about 1 mm from the dentinoenamel junction. The pinhole was prepared using a slow-speed handpiece (Midwest, Shorty, Dentsply, Milford, DE, USA) by aligning the drill parallel to the external surface of the tooth. The teeth were mounted in the posterior sextant of a ModuPRO Endo (Acadental Inc, Mission, KS, USA) typodont next to a dentoform tooth that was part of the typodont using a heavy vinyl polysiloxane material (Regisil PB, Dentsply). The ModuPRO Endo is a typodont system with a socket area that allows the placement of an extracted tooth. The dentoform tooth served to provide a proximal contour during the condensation of amalgam as well as a point of reference for the height of the complex amalgam restoration. A No. 1 adult matrix band (Henry Schein, Melville, NY, USA) was placed and secured with a Tofflemire matrix retainer (Henry Schein). A wedge was used to separate the teeth (see Figure 1).

Table 1: *Groups Based on Time of Repair and Type of Preparation*

| Group | Repair Time | Preparation Type |
|---|---|---|
| 1 | No repair (control) | None |
| 2 | 15 min | Slot |
| 3 | 15 min | Grooved slot |
| 4 | 24 h | Slot |
| 5 | 24 h | Grooved slot |
| 6 | 1 wk | Slot |
| 7 | 1 wk | Grooved slot |
| 8 | 6 mo | Slot |
| 9 | 6 mo | Grooved slot |

An admixed amalgam (Dispersalloy, Dentsply) was triturated per the manufacturer's instructions and incrementally placed and condensed with a Densco Condensaire (WaterPik Inc, Ft Collins, CO, USA). The matrix was removed and the amalgam was carved to contour with a flat occlusal surface to a height of 5 mm. The tooth specimen was removed from the ModuPRO (Acadental Inc). Each group consisted of 10 specimens. All specimens were stored in a lab incubator in 100% humidity at 37°C for 15 minutes, 24 hours, one week, or six months after condensation and carved before the proximal surface was prepared with a box and repaired with new amalgam.

The slot preparation was created at the proximal contact either with or without retention grooves. The slot was prepared using a No. 330 bur in a high-speed handpiece (Starbright, Star Dental, Lancaster, PA, USA). The occluso-gingival height of the proximal slot was 4 mm. The proximal preparation

Figure 1. *A flattened tooth with 4 pins was mounted into a typodont. A matrix band and wedge was placed and an admixed alloy was condensed and carved to create a full crown but with a flat occlusal surface.*

had a mesiodistal dimension of 2 mm and a buccolingual dimension of 3 mm at the occlusal surface and 4 mm at the gingival floor. The gingival floor was flat and perpendicular to the long axis of the tooth. The lingual and facial walls converged to the occlusal. The slot preparations were measured with a digital micrometer. For the grooved-slot preparations, the retention grooves were 0.5 mm in diameter and opposed each other to form a dovetail effect. The grooves were placed at the axio-pulpal line angles with a No. 169L bur using the high-speed handpiece. The grooves extended from the gingival floor to the occlusal surface and were prepared to be parallel buccolingually to each other (see Figure 2).

After the slot preparations were created, the tooth specimens were placed back into ModuPRO (Acadental Inc). A No. 1 adult matrix band was placed and secured with a Tofflemire matrix retainer (Henry Schein) and a wedge. A single-composition spherical amalgam (Tytin, Sybron Kerr, Orange, CA, USA) was triturated per the manufacturer's instructions, incrementally placed and condensed with hand condensation, and carved to contour in the slot preparation. The specimen was removed from the ModuPRO (Acadental Inc) and mounted in polyvinyl chloride pipe with dental stone and bis-acryl resin (Integrity, Dentsply). The tooth specimens were stored in a lab incubator in 100% humidity at 37°C. Twenty-four hours after repair, each specimen was removed from storage. A No. 6 round bur in a high-speed handpiece was used to produce a small flat area of consistent size and depth in the middle of the marginal ridge. The flat area was created to allow the stabilization of a smooth, round-ended blade. The blade was attached to the upper member of a universal testing machine (Instron 5943, Instron, Norwood, MA, USA), and the tip was lowered onto the flattened area of the marginal ridge. A compressive force was applied parallel to the specimens' long axis using a crosshead speed of 5 mm/min (see Figure 3).

Failure strengths of the restorations were recorded in newtons. A mean and standard deviation was determined per group. Data were analyzed with a 2-way analysis of variance (ANOVA) with Tukey *post hoc* tests to evaluate the marginal ridge strength of

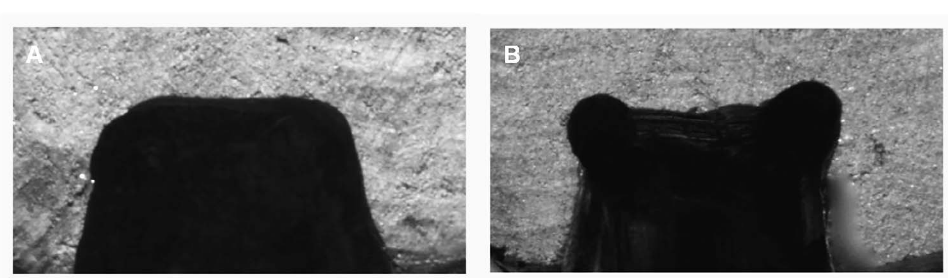


Figure 2. *After 15 minutes, 24 hours, one week, or six months after the initial crown condensation, slot preparations were made in the amalgam crowns with (A) or without (B) retention grooves. The specimens were placed back into the typodont, a matrix band and wedge were placed, and the slot preparations were restored with spherical amalgam.*

Figure 3. *The specimens were removed from the typodont and mounted in polyvinyl chloride pipe. After 24 hours of storage, the specimens were mounted in a universal testing machine. A round-ended blade was lowered onto the marginal ridge. The mean maximum force in newtons and standard deviation were determined per group (n=10).*

repaired complex amalgam restorations based on time of repair (4 levels) or type of preparation (2 levels) ($\alpha$=0.05). Data ware also analyzed with the Dunnett test to compare differences between the control and the other eight groups ($\alpha$=0.05). Fracture patterns were observed under 10× magnification using a stereomicroscope (SMB-1B, Nikon, Melville, NY, USA) . Four fracture patterns of the amalgam restoration were recorded among the groups: internal fracture; partial amalgam fracture of marginal ridge; complete amalgam fracture of marginal ridge; and bulk amalgam crown fracture.

## RESULTS

The 2-way ANOVA found significant differences between the groups based on type of slot preparation ($p$=0.017) but not on time ($p$=0.327), with no significant interaction ($p$=0.152). Placing a retention groove in the proximal slot preparation resulted in significantly greater fracture strength than a slot with no retention grooves. The Dunnett test found no significant difference between any repair group and the unrepaired control ($p$>0.076; see Table 2). Four fracture patterns were observed among groups (see Figure 4). The control group was associated with more bulk amalgam crown fractures, and the prepared groups were associated with a mix of internal, partial, and complete amalgam fractures of the marginal ridge (see Figure 5).

Table 2: *Mean Fracture Strength in Newtons (n=10)*

| Time | Mean Fracture Strength, N (Standard Deviation) | |
|---|---|---|
| | Slot | Grooved Slot |
| 15 min | 1323.8 (292.8) | 1805.4 (481.2) |
| 24 h | 1278.3 (463.2) | 1697.6 (273.8) |
| 1 wk | 1486.1 (572.5) | 1433.1 (405.0) |
| 6 mo | 1646.2 (303.7) | 1735.4 (520.5) |
| Control (unrepaired) | 1324.6 (389.4) | |

## DISCUSSION

Minimal-intervention dentistry, such as repair of localized defects of restorations, could increase the longevity of amalgam restorations and reduce patient stress regarding treatment time and cost.[1-3] Most previous laboratory studies observed the repair of old amalgam with newly triturated amalgam. In some clinical situations, the repair of the newly condensed amalgam restoration may become necessary. However, a study by Bagheri and others[17] determined that when newly condensed amalgam was repaired after 15 minutes or later, precise mechanical retention must be prepared in the newly condensed amalgam restorations to compensate for diminished tensile strength of the repaired amalgam. If an open contact is discovered in a full cuspal-coverage amalgam restoration, should the clinician replace the restoration or should a slot-type box be prepared and repaired with newly triturated amalgam? This study demonstrated that the marginal ridge strength of a repaired proximal contact is not significantly different from the strength of an intact complex amalgam crown. Also, time of repair did not have a significant effect on marginal ridge strength. Therefore, the first and second null hypotheses were not rejected. However, the repaired amalgam with a grooved-slot preparation had significantly higher fracture strength than the repaired amalgam with only a slot preparation. Therefore, the third null hypothesis was rejected. This study supports the concept that when an amalgam repair is planned,

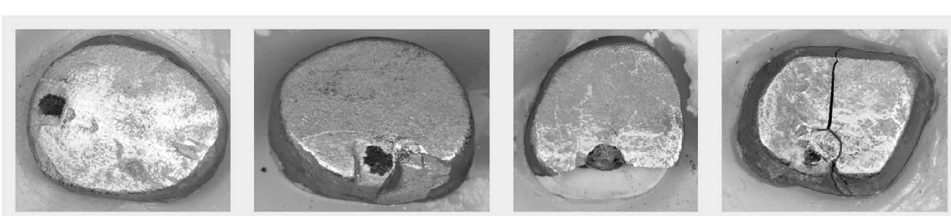

Figure 4. *Fracture patterns were recorded (left to right): internal amalgam fracture; partial amalgam fracture of marginal ridge; complete amalgam fracture of marginal ridge; amalgam crown fracture.*

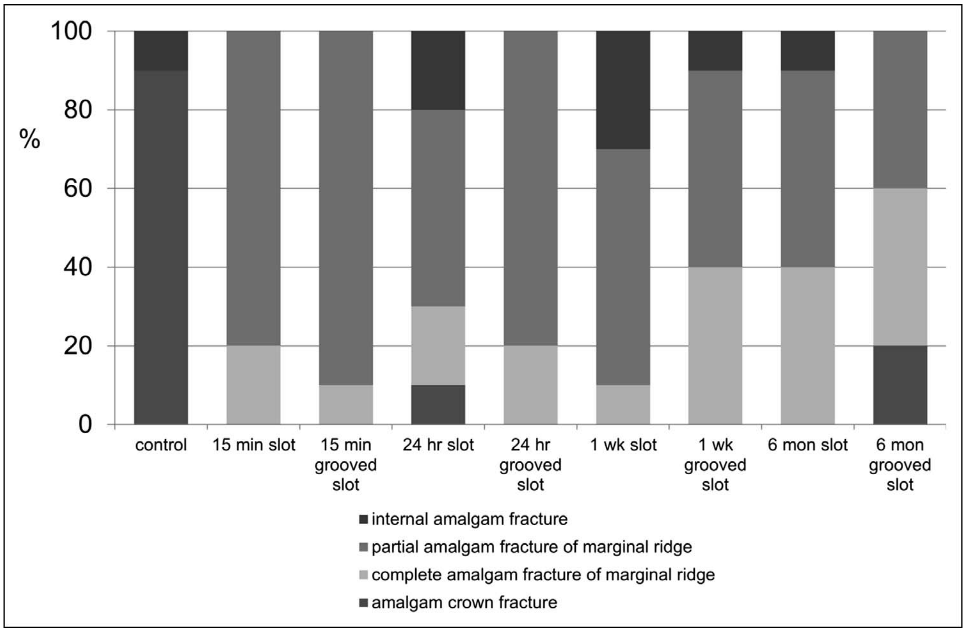


Figure 5. *Fracture pattern percentage per group.*

greater retentive features should be accomplished in the preparation to complement the union of the new and old amalgam.[8] However, heavy forces of condensation during the repair procedure may reduce the need for retentive features.[4]

The present study did not show a biological risk for the teeth: There were no catastrophic tooth fractures in any of the groups. The prepared groups were associated with a mix of internal, partial, and complete amalgam fractures of the repaired marginal ridge. However, the control group was associated with more bulk amalgam crown fractures and no fractures of the marginal ridge. Hadavi and others[8] also observed that fractures in the repaired amalgam always occurred at the junction between old and new amalgam. This finding could be related to the fact that the interface between the newer and older amalgam at the marginal ridge is the weakest point of the amalgam crown. However, the newer-to-older amalgam interface may not have been the weakest point of the amalgam crown if heavy forces were used during condensation, as found in the study by Roggenkamp and others.[4]

Although not statistically different, it was observed that the repairs completed with Tytin amalgam (spherical alloy) in the grooved-slot preparation displayed higher fracture strength than the amalgam crown control group, which was completed using Dispersalloy (Dentsply) amalgam (admixed alloy). The trend toward greater fracture strength could have been due to the higher mechanical properties of the spherical alloy compared with the admixed alloy and increased surface area with the retention grooves[18]; although, Shen and others[6] attributed the higher repair strength of a spherical alloy to the fact that the spherical amalgam is more plastic than admixed amalgam immediately after trituration. The extra plasticity may result in better wetting of the repair surface and higher repair-strength values.[6]

The carving of a complex amalgam restoration may occasionally result in light proximal contact with the adjacent tooth. Complete replacement of restorations has the disadvantages of being time-consuming with unnecessary removal of healthy tooth structure, enlargement of the preparation, the risk of converting the restoration to an indirect restoration, the possibility of major injuries to the pulp tissues, and more expense for the patient. This is the first study to evaluate the fracture strength of the marginal ridge of a repaired complex amalgam restoration. This investigation found no significant difference in fracture strength between repaired and unrepaired amalgam and suggests that the repair of a light proximal contact in an otherwise functional, intact, existing complex amalgam restoration may be an acceptable alternative to replacement.

## CONCLUSIONS

The proximal repair strength of a complex amalgam restoration was not significantly different from that of an unrepaired amalgam crown. Placing a retention groove in the proximal slot preparation resulted in significantly greater fracture strength than a slot with no retention grooves. Time of repair had no significant effect on the strength of the repair.

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**Regulatory Statement**

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of the Wilford Hall Ambulatory Surgical Center Institutional Review Board. The approval code for this study is FWH20140034N.

**Conflict of Interest**

The views expressed in this article are those of the authors and do not reflect the official policy of the United States Air Force, the Department of Defense, or the United States Government. The authors do not have any financial interest in the companies whose materials are discussed in this article.

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