Mechanical Versus Chemical Retention for Restoring Complex Restorations: What Is the Evidence?

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Abstract: This article reports the findings from a study conducted to answer this research question: can adhesive resin liners provide retention that is the same as dentinal pins or pots and slots when restoring complex amalgam restorations? The study methodology consisted of two components: a review of the literature and a survey to assess methods and materials that general practitioners use in their clinical practice for restoring complex amalgam restorations. Even though a vast majority of the general practitioners surveyed reported using dentinal pins or pots and slots, the occurrence or frequency of use was under 50 percent. It was also reported from the survey that over half the respondents are using adhesive resin liners exclusively when restoring complex restorations. New and improved materials allow general practitioners to restore complex restorations without the risks associated with the placement of pins or pots and slots. A review of the available literature indicates that adhesive resin liners may be used as an alternative or adjunct to mechanical retention. Because of the improvements of bonding strength of adhesive resin liners, dentinal pins and pots and slots should not be the only methods considered when faculty assist students in the development of treatment plans for patients who need complex amalgam restorations.

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agents strengthen the restoration. Bonded amalgam restorations are amalgam restorations bonded to the tooth via a resin adhesive. This type of non-invasive method gives the restoration added retention and tooth reinforcement. This adhesive bonds to the enamel and dentin after the tooth is etched and primed, which is the same procedure that is used for composite restorations. It is believed that the bond formed between the resin and amalgam is a “micro-mechanical bond.” The alloy is condensed against the adhesive resin before polymerization, allowing the amalgam to surround the resin and “lock” into it as the alloy and the resin set.

Bonding resin to amalgam is entirely mechanical rather than chemical, which is different from that of bonding resin to resin-based composite. This mechanical attachment of amalgam to the resin is enhanced by the incorporation of filler particles into the bonding resin. A probable reason for this improvement in attachment is that the filled bonding resin is more viscous during condensation of the amalgam and this provides improved penetration of bonding resin into the amalgam for increased mechanical retention.

The increased emphasis on the use of dentin bonding agents has led to proposals of “bonding amalgam to tooth structure.” One material capable of doing this is Amalgambond (Parkell), which is a 4-methacryloxyethyl trimellitate anhydride (4-META)-based amalgam bonding system. Other companies have since developed amalgam bonding systems or have altered existing products to allow their use for amalgam bonding. Amalgambond is a self-cured dentin bonding agent capable of bonding amalgam and composite resins to dentin, enamel, and alloys. Shortly after Amalgambond was developed, the original formula was altered to include a High-Performance Additive (HPA). The HPA is a polymethyl methacrylate powder that may be added to the mixture of the base and catalyst for added retention and resistance. Amalgambond Plus is a hydrophilic universal bonding agent based on the 4-methacryloxyethyl trimellitate anhydride (4-META) system.

Methods

This study was conducted to answer this research question: can adhesive resin liners provide retention that is the same as dentinal pins or pots and slots when restoring complex amalgam restorations? The study methodology consisted of two components: a review of the literature and a survey to assess methods and materials that general practitioners use in their clinical practice for restoring complex amalgam restorations. The study protocol was reviewed and approved by the Institutional Review Board (IRB) at the University of Louisville in March 2005.

The review of the literature was conducted by searching the MEDLINE database and selecting English language articles published from 1966 to 2005 and was carried out in 2005. The search terms used to identify all relevant articles were dentinal pins, dentinal slots, complex amalgam restorations, retention, bonding agents, and dentin adhesive liners. Reports selected for further review included those published in peer-reviewed journals that involved laboratory and clinical testing of dental materials.

A survey titled “Alternatives to the Use of Dentinal Pins When Restoring Complex Restorations” was developed to assess whether general practitioners in Kentucky are using dentinal pins, pots and slots, or adhesive resin liners when restoring complex restorations. The survey was administered to general dentists at the 2005 Annual Kentucky Dental Association (KDA) Meeting in Louisville, Kentucky. During registration for the KDA meeting, any general dentist who was willing to participate in the study was given the survey and asked if he or she would complete and return it later that afternoon. All surveys were collected by KDA staff and returned to the University of Louisville School of Dentistry so that the data could be analyzed using SPSS. The survey instrument was comprised of nine questions that related to materials and techniques used when restoring complex restorations involving one or more missing cusps. However, only those questions pertaining to frequency of use will be analyzed and discussed in this article (highlighted in Figure 1).

Findings: Review of the Literature

Several in vitro studies have evaluated the adhesive and cavity-sealing capabilities of amalgam bonding materials and reported that bonding amalgam provides retention that is comparable to that of dentinal pins. In 1994, Vargas et al. conducted
a laboratory study that evaluated the bond strength of amalgam to dentin using five different bonding agents: Amalgambond Plus, Optibond, Imperva Dual, All-Bond 2, and Clearfil Liner Bond. Flat dentin surfaces obtained by grinding the occlusal portion of fifty human third molars were used for this study, and the teeth were randomly assigned to five test groups of ten samples each. To contain the amalgam on the tooth surface, plastic molds were placed on the dentin and secured with sticky wax; teeth were bonded and filled with amalgam. The samples were then thermocycled, and shear bond strengths were determined using an Instron Universal Testing machine. Analysis by one-way ANOVA indicated significant differences among the five groups (p<0.05). The bond strength of amalgam to dentin was significantly higher with Amalgambond Plus using the High-Performance Additive than with the other four bonding agents. The higher bond strengths for Amalgambond Plus may have resulted from the use of the High-Performance Additive, which contains the polymethylmethacrylate fibers discussed above.11

Other in vitro studies have since been conducted using Amalgambond Plus in conjunction with dentinal pins to determine if the two combined provided significantly greater resistance to fracture than Amalgambond Plus or pins alone. In 1997, Burgess et al.19 compared resistance form of complex amalgam restorations with Amalgambond Plus and four minim pins. They reported a higher bond strength with Amalgambond Plus (1,361 N) than with four minim pins (1,028 N). This particular study evaluated fracture resistance provided to complex amalgam restorations by adhesive and mechanical resistance features. The occlusal surfaces of thirty extracted teeth were ground flat to approximately 2 mm coronal to the CEJ, and the teeth were divided into three groups. Group one would receive four minim TMS pins and Copalite, group two would receive four minim pins and Amalgambond Plus, and group three would receive only Amalgambond Plus. After applying either Copalite or Amalgambond

1. What year did you graduate from dental school?
2. What dental school did you attend?
3. Gender
4. When restoring complex posterior restorations (involving one or more missing cusps) what material do you use? Alloy/Resin/Other
5. What percent of the time do you use dentinal pins when restoring complex restorations? Ranging from 0 to 100%
6. What percent of the time do you use dentinal pots or slots when restoring complex restorations? Ranging from 0 to 100%
7. What percent of the time do you use adhesive resin liners/bonding agents in conjunction with dentinal pins when restoring complex restorations? Ranging from 0 to 100%
8. Do you use adhesive resin liners only (no pins or slots) when restoring complex restorations that involve one or more missing cusps? Yes/No
9. If you answered “yes” to question # 8, what adhesive resin liner do you use?
Plus and amalgam, all teeth were stored at room temperature until being tested. Each specimen was loaded to failure in compression at 45 degrees in an Instron Testing Machine, and the data were analyzed using a one-factor ANOVA and a Tukey B post hoc test. Even though there was no statistical significance between Group 1 and Group 3, there was a higher bond strength when using Amalgambond Plus versus four minim pins.

Most in vitro studies have involved human extracted teeth that were ground flat, restored accordingly, and tested for fracture resistance. However, in 1999, Segura and Riggins conducted a study that compared the fracture resistance of four posterior restorations involving an entire cusp replacement. Four groups were established, each containing eight caries-free mandibular molars that were similar in size and anatomic form. A mesio-occlusal preparation including the lingual cusp was prepared in all teeth. Group A was restored with a pin-retained amalgam. Group B was restored with amalgam and meta adhesive. Group C was restored with a composite resin with a beta-glass quartz insert. Group D was restored with composite resin and a HEMA adhesive. All specimens were mounted in acrylic and stored in artificial saliva for thirty days. Each specimen was then loaded in compression at a 90 degree angle in an Instron Testing Machine. Results demonstrated the mean (SD) failure load in kilograms for each group to be as follows: A, 1155 N (388); B, 1232 N (436); C, 1345 N (375); D, 1595 N (373). Analysis of variance indicated no significant difference among groups at P<0.05.

Even though the groups were not statistically significant, there was an overall increase in the bond strength of amalgam and composite resin to tooth structure when an adhesive/bonding agent was used. When comparing the restorations that were bonded versus the ones that used dentinal pins alone, the resistance to fracture was slightly higher. The main advantage of bonding restorations is to conserve as much tooth structure as possible and decrease the likelihood of complications or risks that are involved with using dentinal pins.

Belcher and Stewart conducted a clinical trial that supports the laboratory data showing that amalgam adhesives do provide an alternative to pins for retention of complex amalgam restorations. In addition to providing adequate retention, amalgam adhesives conserve tooth structure. Patients selected for the Belcher and Stewart study had been treatment planned at the School of Dental Medicine, Southern Illinois University. Vital molars and premolars that were to receive complex amalgam restorations were selected for the study, particularly those that would require pin retention. All teeth selected had occlusal contacts with opposing natural dentition or a prosthesis. All restorations were placed on teeth in which the amalgam would be the final restoration. Forty-five patients were selected and assigned to one of three treatment groups: Group A, restoration with conventional preparation with pin retention; Group B, restoration with an adhesive (without powder); and Group C, restoration with an adhesive (with powder).

Teeth in Group A were restored with amalgam and dentinal pins as the main source of retention. All compromised tooth structure and unsupported enamel were removed. The dental students placed retention pins at the rate of one pin per missing line angle. Group B teeth were restored with amalgam and adhesive without powder as the main source of retention. No additional slots, locks, or boxes were made to aid in retention. Group C teeth were restored with amalgam in the same manner as Group B except that adhesive with powder was used as the main source of retention.

Restorations were then evaluated one and two years after placement using the modified Cvar and Ryge criteria for bonded restorations. This system was developed by Cvar and Ryge and is used as criteria for the clinical evaluation of dental restorative materials. At one-year and two-year recall, clinical examination was performed by the principal investigator, and photographic documentation was done at each recall. A visual examination was performed to check for any areas of the restoration or tooth structures that were missing. Retention of the amalgam was noted, and any areas that were unsupported or compromised were documented. An explorer was also used to examine the cavosurface margins for marginal adaptation and areas of recurrent decay. The investigator also asked patients about any sensitivity that they were experiencing.

All groups had fifteen patients each at the beginning of the study. At the end of two years, Group A had thirteen patients available for recall, Group B had fourteen patients, and Group C had eleven patients. Those patients who did not complete the study had either relocated from the area or moved and left no forwarding address. At the end of one and two years, all teeth that were available at the recall appointments received Alfa ratings (Cvar and Ryge criteria) on the four parameters being evaluated (retention and...
reinforcement, sensitivity, marginal adaptation, and recurrent caries).

For purposes of this article, findings that involve the first parameter—retention and reinforcement—will be discussed. Using the evaluation criteria based on Cvar and Ryge, an Alpha rating for retention and reinforcement can be interpreted as “amalgam restoration and remaining tooth structure are intact as originally restored.” Bravo and Charlie ratings would have been assigned if small or large portions of the amalgam restoration or tooth structure were missing at the recall appointment; however, this was not the case in this clinical study.

The outcomes of the clinical study conducted by Belcher and Stewart support the laboratory data showing that amalgam adhesives do provide an alternative to pins for retention of complex amalgam restorations. The investigators concluded that “effectively bonding amalgam to tooth structure enables us to place a complex restoration with adequate retention without risking pulp exposure from trying to place additional mechanical retention into an already large preparation, or penetrating the pulp when drilling a pin hole.”

Summit et al. conducted a clinical trial that compared the clinical performance of complex amalgam restorations that were either mechanically retained with self-threading pins or bonded with a filled, 4-methacyrloxyethyl trimellitate anhydride, or 4-META-based resin. The authors placed sixty amalgam restorations (twenty-eight pin-retained and thirty-two bonded), each restoration replacing at least one cusp. For both groups, the authors left in place any retention form remaining after removal of an old restoration. Patients selected for the study had a posterior tooth or teeth requiring restoration that included at least one proximal surface and replacement of one or more cusps. Teeth to be restored also had at least one proximal contact and occluded with natural or restored teeth. A coin toss determined which tooth or teeth received bonded restoration(s) and which received pin-retained restoration(s).

Once the patients and teeth were selected, five operators, all faculty members and experienced clinicians, placed the restorations. All operators were calibrated to the guidelines concerning resistance features and the use of the bonding system. The guideline for pin placement stated that one vertical pin was used for each missing cusp, with a maximum of four vertical pins in any single restoration. Rubber dam isolation was used during the cavity preparation, amalgam placement, and initial carving of all restorations.

The operators used no added mechanical retention form for the resin-bonded restoration group; instead, they used the Amalgambond Plus (Parkell) bonding system. The instructions for Amalgambond Plus state that it may be used either with or without incorporation of a polymethylmethacrylate filler powder. In all bonded restorations in this study, operators used the HPA powder following the manufacturer’s instructions to achieve extra retention. After either pin placement or bonding agent was applied, the operators hand-condensed amalgam. Restorations were then shaped and carved until achieving proper anatomical form and occlusion was adjusted to provide contact in maximum intercuspation.

Before patients returned for follow-up, the evaluators were calibrated in the use of an explorer to detect marginal discrepancies and in the criteria and methods that were to be assessed (tooth sensitivity, tooth vitality, marginal discoloration, marginal adaptation, and secondary caries). The restorations were classified as having failed when they had to be replaced, required major repair, or the tooth needed endodontic treatment or extraction. Patients returned for a baseline evaluation as close to one week postoperatively as possible and after that were recalled for evaluation at six months, one year, two years, three years, four years, five years, and finally six years. Results of the study are summarized as follows. At four years, six restorations had failed. At five years, of the forty restorations available for evaluation, three had failed, for a total of nine failed restorations; seven of those were pin-retained and two were bonded. Using the Fisher’s exact test to compare the groups at five years, the authors found no significant difference in failure rate, marginal adaptation, marginal discoloration, secondary caries, tooth sensitivity, or tooth vitality. At the six-year recall, twenty-seven of the original sixty restorations were available for evaluation. Twelve were pin-retained, and fifteen were bonded. Nine restorations had failed prior to the six-year recall and had been eliminated from further evaluation. Twenty-five of the twenty-seven restorations evaluated at six years were performing satisfactorily (eleven pin-retained and fourteen bonded). Fisher’s exact test was again used to compare the failure rate of the two groups, bonded and pin-retained. There was no significant difference in failure rate (p=0.05) at six years.
Findings: Practitioner Survey

The data contained in the returned questionnaires were analyzed using SPSS. There were 1,305 dentists who attended the meeting; however, this number includes general practitioners as well as specialists. Of those in attendance, eighty-three actually completed the survey. Nearly 76 percent of the eighty-three respondents reported using dentinal pins at least some of the time when restoring complex restorations (Table 1). However, those practitioners who indicated using pins only reported doing so in less than 31 percent of the patients needing a complex restoration (Table 2). Nearly 81 percent of the respondents reported using pots and slots at least some of the time when restoring complex restorations (Table 1). However, those practitioners who indicated using pots and slots when restoring complex restorations reported doing so only in less than 41 percent of the patients needing a complex restoration (Table 2). This was a slightly higher frequency of use than was reported for dentinal pins. Fifty-three percent of the seventy-seven respondents reported using adhesive resin liners exclusively when restoring complex restorations.

Discussion

There are non-invasive methods that general practitioners can use when restoring complex restorations without all the risks involved with the placement of dentinal pins and pots and slots. These data suggest that adhesive resin liners may be used as an alternative or adjunct to mechanical retention. Even though the laboratory and clinical studies reviewed did not demonstrate a statistical significance between adhesive resin liners and placement of dentinal pins and pots and slots, investigators still found an overall increase in the bond strength of amalgam and composite resin to tooth structure when an adhesive/bonding agent was used. When comparing the restorations that were bonded versus the ones that used dentinal pins alone, the resistance to fracture was slightly higher.

Even though a vast majority of the general practitioners who were surveyed reported using dentinal pins and pots and slots, the frequency of use was under 50 percent. More than half of the respondents reported using adhesive resin liners exclusively when restoring complex restorations. This slight increase in the use of adhesive resin liners is the result of new and improved bonding agents. The survey findings, although obtained from a small, convenience sample of meeting participants, suggest that general practitioners are relying more on adhesive resin liners as the primary source of retention and are able to restore complex restorations without the risks associated with the placement of dentinal pins or pots and slots.

Conclusion

The findings of this study have implications for the dental school curriculum. Because of the improvements in the bonding strength of adhesive resin liners, dentinal pins and pots and slots should not be the only methods considered when faculty assist students in the development of treatment plans for patients who need complex amalgam restorations. Many studies have demonstrated improved retention with the use of adhesive resin liners, suggesting that adhesive resin liners may be used as an alternative or adjunct to mechanical retention. There is still need for further investigation and testing of bonding agents that are to be used for retaining complex restorations. Long-term studies are still needed to assess longevity and failures of complex restorations that rely solely on chemical retention. General practitioners and dental educators need to be cognizant of current evidence-based research regarding adhesive resin liners.

Table 1. Methods and materials used by general practitioners to restore complex amalgam restorations (n=83)

<table>
<thead>
<tr>
<th></th>
<th>% Yes</th>
<th>% No</th>
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<tbody>
<tr>
<td>Pins</td>
<td>75.9</td>
<td>24.1</td>
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<tr>
<td>Pots and slots</td>
<td>80.7</td>
<td>19.3</td>
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<tr>
<td>Adhesives</td>
<td>53.2</td>
<td>46.1</td>
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Table 2. Practitioners using pins or pots and slots only

<table>
<thead>
<tr>
<th></th>
<th>% Pins (mean)</th>
<th>% Pots and slots (mean)</th>
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<tbody>
<tr>
<td>Pins</td>
<td>30.62</td>
<td>40.78</td>
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