

Reducing mercury release from dental amalgam fillings and improving patient acceptability

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Currently, the most common types of materials used for dental restorations are silver amalgam and composite resins. Unfortunately, both have disadvantages. Silver amalgam is favored for its ease of use, moderate cost and physical properties such as strength, durability and relative insensitivity to moisture. However, it lacks esthetic appeal. In addition, mercury is released from the filling during the initial setting of amalgam, which typically occurs during the first 24 hours. Following this period, trace amounts of mercury continue to be released throughout the lifespan of the filling. Composite resins provide good esthetics because they are tooth colored, but they deteriorate at a relatively faster rate and thus may require removal and replacement sooner than most amalgam restorations. Dentists and patients would benefit from restorations that are safe, durable and esthetically pleasing. We propose a novel dental concept of reducing mercury release with a previously documented technique. Preliminary experiments suggest that the favorable properties of both materials are retained and the issues regarding mercury release and poor esthetics are ameliorated.

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Background

SILVER AMALGAM RESTORATIONS or fillings, composed of approximately 50% mercury, have been used for at least 150 years in North America and are currently most commonly used by dentists worldwide (1). The success of amalgam is primarily due to its moderate cost, durability and ease of manipulation and placement. In most dental schools, it is taught as the material of choice for single or multi-

surface restorations in posterior teeth in both children and adults (2-5). After the dentist has drilled through the tooth and removed all decay, the silver amalgam is placed into the tooth to replace the missing portion. Since the filling forms a new surface on the molars, daily occlusal forces generated by chewing and grinding result in a constant low-level release of mercury from the restorations (6). This mercury release is the cause of much concern,

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especially in young children under the age of four, who are still neurologically developing, and in pregnant women, where mercury can affect the growth and development of the fetus. While some countries have an outright ban, others have advised at least limiting the amount of mercury to these groups by reducing the use of amalgam restorations, despite a lack of definitive scientific data (7-10). Another common complaint is that over time, the silver amalgam filling can tarnish and turn black. Given that patients generally choose the more cosmetic of treatment options, silver amalgam is increasingly the less popular choice (3, 11, 12). Nonetheless, silver amalgam is consistently more durable and less costly than other types of restorations.

Mercury release is the cause of much concern, especially in young children under the age of four, who are still neurologically developing, and in pregnant women.

In the 1980s, tooth-colored composite restorations were introduced and have evolved with continually improving properties. They are increasingly favored by patients and dentists because there are relatively few issues regarding their toxicity. Because they generally cannot be seen without close examination, they are considered more esthetically pleasing than amalgam restorations. However, although they are commonly used in the treatment of adults, composite resins generally have shorter functional periods than amalgam restorations (13). While composites are currently widely used by

dental practitioners, alternatives less susceptible to microfractures are constantly being called for and need to be developed.

Previous research showed that sealing restorations increases their longevity and clinical performance (14, 15). Sealants are already currently used in elementary school-based programs to prevent caries (cavities) formation in the pit and fissure surfaces of posterior teeth. Given that these sealants are responsible for reducing the occurrence of new decay by 60%, they will likely play a similar role with restorations (16). Therefore, we anticipate a layer of sealing composite resin will not only reduce mercury release, but also protect a restoration from physical forces, extend its lifespan, and reduce the risk of new caries formation.

Kinetics of mercury release from silver amalgams

Mercury release from silver amalgams is high over the first 24 hours immediately following placement of the restoration (17). Over time, the dissolution rate of mercury decreases exponentially (17). Recent studies show that even on the day the amalgam is placed, the daily amount of mercury released is around 0.35 μg and by 30 days, it is down to 0.05 μg

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(18). Both these quantities are significantly less than the daily amount likely to cause neurological damage, which is estimated to be 82.29 µg/day (18). Nevertheless, even these low levels are a concern due to the cumulative nature of mercury in the body that can be further exacerbated by food and other sources.

Statement of the problem

Silver amalgam is usually the more appropriate material for restorations because of its physical properties, but dentists and patients are reluctant to use it because of the aforementioned concerns. Composite resins are more popular esthetically, but lack the strength and durability associated with amalgam restorations. A novel technique that combines the advantages of both materials and minimizes their respective drawbacks would offer dentists and patients the option of a potentially superior course of treatment.

Hypothesis

This paper proposes the use of a sealing composite resin over a newly condensed silver amalgam restoration to reduce mercury release and improve esthetics.

Preliminary findings

A. Mercury release from sealed amalgams

A preliminary *in vitro* experiment was con-

ducted to determine mercury release from restorations. Third molars (n = 10) restored with silver amalgam were divided into control and experimental groups. Immediately after placement of the amalgam, all experimental teeth were etched with 37% phosphoric acid followed by a fourth generation primer, adhesive and a flowable composite resin (Revolution, Kerr, CA) that sealed the accessible portions of the amalgam surface, the occlusal margins of the restoration and adjacent portions of the tooth without encroaching on intact cusp tips.

Following restoration, both groups of teeth were stored in ultra-pure, mercury-free physiologic saline solutions in Teflon tubes. After 28 hours, the saline solutions were analyzed. Teeth were replaced into fresh saline solutions which were again analyzed at 64 hours. Release of mercury from these restorations into solution was assessed by a Varian Model Spectra 850 atomic absorption spectroscope equipped with Cold Vapor System VGA 77. Calibration was performed with diluted mercury stock solutions. The instrument sensitivity was 1 ppb. Each sample was measured in duplicate. Mercury detection was carried out as described previously (19).

Mercury release was analysed using two-way ANOVA with the two groups and time as

Restoration Type n=10/group	Mean Hg released at 28 Hours (ng)	Mean Hg released at 64 Hours (ng)
Unsealed	81.22 ± 4.6	12.8 ± 11.2
Sealed	31.50 ± 18.3	0.0 ± 0

Table 1 | Means and standard deviations of mercury (Hg) release from sealed and unsealed amalgam at 28 hours and 64 hours.

	Percentage of parents ranking factor as highly important	Mean scores of parent's responses
Child's health	87.2	4.71 + 0.87
Dentist's opinion	81.8	4.66 + 0.79
Esthetics	76.3	4.41 + 1.40
Tooth type	56.3	3.82 + 0.26

Table 2 | Mean score of parent's response regarding child's health, dentist's opinion, esthetics and tooth type and percentage of parents ranking factor as most important.

the two independent variables. It was determined that there was a significant decrease in mercury release from the sealed amalgam compared to the conventional restorations at each of the two time points measured, namely, 28 and 64 hours ($p < 0.01$; Table 1).

Given that the bulk of the mercury release occurs in the first 28 hours during the setting of the amalgam, these preliminary findings suggest sealed silver amalgam restorations may address concerns regarding mercury release.

B. Parental preference/acceptability of sealed amalgam restorations

Questionnaires were given to parents of children seeking dental treatment ($n = 55$) to assess parental acceptability of the proposed restoration technique. The questionnaires consisted of three parts: a description of types of restorations (composite, amalgam and sealed amalgam) for primary teeth, demographic data and several questions about acceptability and cost of the various restorations. The first question presented each parent with photographs of conventional and sealed amalgam restorations and asked which they preferred. Data were analyzed using summary statistics. 94.5% of the surveyed parents initially chose the sealed amalgam restoration for their child. The parent was then asked to rank on a Likert scale (lowest importance 1 – highest importance 5) the importance of the following aspects on their

choice of restoration material: type of teeth (primary or permanent), esthetics, child's health and dentist's opinion. The factors that did affect their decision were ranked: child's health, dentist's opinion, esthetics, and lastly, tooth type (Table 2).

Parents were also asked how concerned they were about the mercury released from amalgam. 58.1% considered it to be a great concern (mean score = 3.96). Among these, 41.2% of parents with a lower level of education (high school or less) and 88.2% of parents with higher levels of education marked mercury release as a great concern. These data suggest that the lower education group was not as concerned about mercury release as the higher education group. While there is lack of conclusive evidence linking Hg release from amalgams to detrimental effects, it appears the two groups interpret the same information differently. These differences in observed levels of concern could be due to the relative importance of the issue or the relative understanding of the issue.

The last question proposed fee quotations of the class I and II conventional and sealed amalgams, explained why the sealed amalgam was a more expensive technique and asked parents which of the two restorations they would choose after considering the fee. After being presented with the proposed fees, 92.7% of parents still chose the sealed amalgam restoration for their child. This suggests

parents respond positively to the proposed restoration technique. Thus, clinical studies should be conducted to further test efficacy and durability.

The mean age of the parent was 39 years with a slightly higher response rate from mothers than fathers. However, the parent's gender did not seem to influence the choice of material ($p = 0.45$). Similarly, level of education also did not influence the selection ($p > 0.05$). Parents of both high and low levels of education consistently chose sealed over conventional amalgam treatments. Almost all surveyed families were covered by dental insurance.

This paper proposed the use of a sealing composite resin over a newly condensed silver amalgam restoration to reduce mercury release and improve esthetics. The data presented supports this hypothesis.

Proposed clinical procedure

Restorative procedures are carried out under

rubber dam isolation. Immediately after a carious tooth has been filled with silver amalgam and carved, the restoration should be etched with phosphoric acid. Primer and bonding agent should then be applied to the etched surface, followed by a thin layer (less than 0.5 millimeter) of flowable composite resin to all accessible surfaces. The sealing composite resin will reduce mercury release both in the first 24 hours, when the amalgam is setting, and beyond. In addition, the composite layer will give the restoration a tooth-colored finish, which addresses the esthetic concerns (Figure 1).

Limitations and future directions

Restorations for young children always require careful consideration on the part of the dentist and parent, as to the most appropriate material. While it may be advantageous to use non-amalgam restorations for children under four, those prone to more cavities are likely to benefit from an amalgam restoration. The bacteriostatic effects and durability of

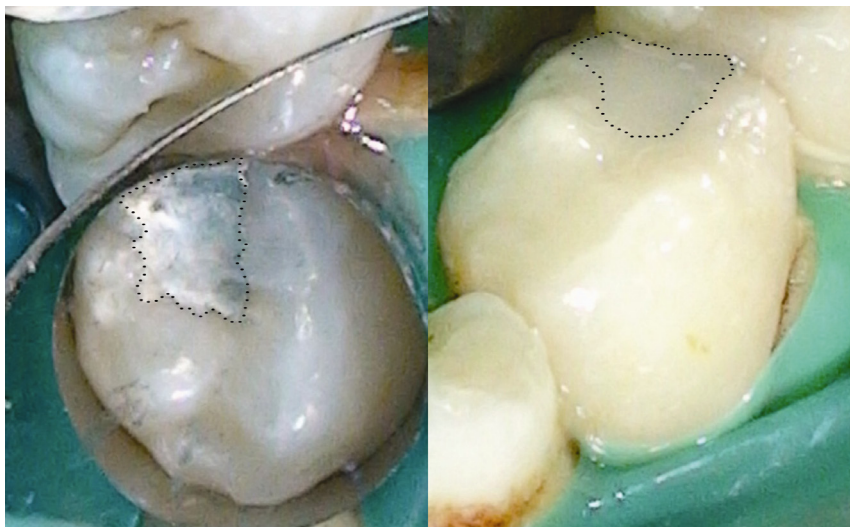


Figure 1 | Amalgam restoration immediately following condensation (left panel) and following sealing with a flowable composite resin (right panel). The amalgam restorations are outlined. Note that the sealed amalgam is barely visible.

amalgams are superior to composite resins, which actually contain components that encourage micro-organism growth (20).

The proposed sealed amalgam technique combines the benefits of traditional silver amalgam and composite restorations. Preliminary *in vitro* experiments show the sealant markedly reduces the mercury released over time. The composite layer greatly improves esthetics and will likely be more favored than silver fillings. Previous studies have suggested that sealants applied over restorations will improve longevity of the filling (14, 15). Since the layer of sealant is hardened immediately after application, it is also anticipated to protect the restoration and reduce the number of fractured amalgams, which are common occurrences in young children in the initial 24 hours after placement. Since the restoration itself is silver amalgam, the desired physical properties are still provided. Parents who responded to our survey consistently chose a sealed restoration over a conventional amalgam restoration for their child. Although our experiments focused mainly on primary dentition because of arguments about mercury release into young children who are still neurologically developing, these findings and benefits are also applicable to adult dentition.

The experiments conducted in this study will benefit from additional experiments that subject the sealed and control teeth to mechanical stresses from occlusal forces and thermal changes in the oral cavity. These experiments could also be repeated using different types of adhesives and flowable composite resins to improve bonding to the amalgam and enhancing esthetics. Further validation of this restoration technique should include a randomized, controlled clinical trial to verify

the observed decrease in mercury release and the proposed increase in longevity. Additionally, materials more suited to adhering to amalgam restorations should be developed. Patients should then be presented with the findings and asked to choose among: i) conventional amalgams, ii) composite resins and iii) sealed amalgam restorations.

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