The use of dental amalgam in pediatric dentistry: review of the literature

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Abstract

Dental amalgam is widely used as a restorative material even though it is not esthetic and there has been extensive anti-amalgam rhetoric. Although other materials have improved greatly, amalgam has the proven safety record and best cost-to-benefit ratio. Clinical evidence indicates that, in the posterior permanent dentition—where esthetics is not a primary concern—the small, minimally prepared, amalgam restoration, with its margins and any caries-susceptible fissures sealed with resin fissure sealant, is the restoration with the best survival. Amalgam also remains the best direct restorative option when larger restorations are required. In the primary dentition, the data indicates that resin-based composite and resin-modified glass-ionomer serve very well.(*Pediatr Dent.* 2002; 24:439-447)

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Dental amalgam is the most widely used material for the restoration of permanent teeth, although in the United States the ratio of amalgam to resin composite restorations placed in posterior teeth in clinical practice is near 50:50. In some regions, more resin composites than amalgam restorations are being placed in posterior teeth.[1] Amalgam has many positive properties that sustain its popularity, including its ease of manipulation, durability, lower cost, reduced microleakage with time and reduced technique sensitivity compared to other restorative materials. However, dental amalgam has drawbacks. First, and foremost, it is not esthetic.

Secondly, the mercury issue, even though there is overwhelming evidence of its safety, will always be controversial. From the standpoint of patient well being, amalgam is the most widely studied restorative material; however, relentless criticism in the press and the emotional response are difficult to dispel.

Thirdly, amalgam restorations are often prematurely removed because of "defects" noted by the practitioner.[1-4] Clinical practice surveys[5-8] indicate that recurrent caries around amalgam occur in up to 50% of amalgam restorations within 8 to 10 years after their placement. The routine removal of slightly defective amalgam restorations can best be described as an unnecessary practice and/or overtreatment.[2,3,9,10]

History

Dentistry's use of amalgam is entering its third century.[11] This material could be characterized as the first long-term restorative material. The early amalgams were, however, crude and poorly formulated, and, in many cases, did not serve patients well.[12,13] Poor quality restorations, misinformation and a lack of fundamental knowledge on the part of many early users of amalgam led to serious disputes over the use of the material. In fact, debates in the mid-1800s over the pros and cons of amalgam led to the formation of dental societies and to many dental publications.[14] In addition, the amalgam controversy was a leading factor in moving dental education from apprenticeship training to formal, school-based education programs.

It was not until the 1890s that Black came up with a successful formula for dental amalgam.[15] With his meticulous attention to detail, Black advised that precisely 52% mercury by weight should be used when mixing amalgam, and he discussed the spheroid nature of amalgam, later known as the mechanical property "creep."

Prior to the 1960s, existing amalgam formulations were subject to severe internal corrosion. The tin-mercury (Sn-Hg), or gamma-2, phase in dental amalgam matrix is weak, subject to rapid corrosion[16] and found in quantities up to 15% in the low-copper amalgams.[17] The corrosion of the Sn-Hg phase led to a highly porous amalgam that was easily fractured. Despite the problems of the gamma-2 phase, the clinical success of the low-copper amalgams was remarkable.[18]

During the 1965-1970 time period, a giant improvement in amalgam's clinical success was achieved by increasing the copper content in the basic formulation.[19,20] Clinical studies[21,22] showed the great improvement in performance brought about by this new formulation, and laboratory data explained the in vivo results.[23,24] In the simplest of terms, copper's affinity for tin was greater than mercury's affinity for tin. In high-copper amalgams, although mercury and tin may form a gamma-2 phase initially, sufficient copper quickly replaces the mercury in the Sn-Hg phase and forms a copper-tin (Cu-Sn) compound in the amalgam matrix. The high copper amalgams, because of the reduced amount or elimination of the Sn-Hg phase, were not as susceptible to the corrosion phenomenon and resulting porosity and, therefore, they maintained their strength. The profession and its patients gained a greatly improved clinical restorative material.[25-29]

Use of amalgam in primary teeth

Dental amalgam has been used effectively for Class I and II restorations in primary teeth. However, clinical data[30,31] suggests that resin composites in the posterior primary dentition perform well in situations where amalgam would have been used routinely 30 years ago. Resin composite technology has improved, providing upgraded clinical handling characteristics as well as better clinical performance. Clinical studies have provided data concerning improvements in resin composite wear and bonding, as well as a greater understanding of clinical applications. This knowledge has provided pediatric dentists and general dentists with good information relative to placing successful resin composite restorations. Resin-modified glass-ionomer restoratives also have been reported to perform adequately in posterior primary teeth and it has been suggested they may be appropriate in the mouths of individuals at moderate risk for caries.[32-34] Although wear resistance of these materials is much reduced compared to resin composites, the relatively short time that restored primary teeth must serve makes long-term survival of the restoration less important.

A recent clinical study of primary teeth by Mjör and others[35] indicated that 9% of posterior restorations failed. Recurrent caries was responsible for approximately 50% of the restorations lost, and amalgam restorations were reported to last significantly longer than tooth-colored restorations (3 years vs 2 years) for the 9% failed restorations. The study demonstrated an impressive 91% success rate of restorations in the primary dentition, with a 9% failure rate of amalgam restoration, an 8% failure rate of traditional glass ionomer restorations and a 7% failure rate of resin-modified glass ionomer restorations.

Amalgam might be a more appropriate restorative material for posterior primary teeth in situations in which tooth isolation or patient cooperation is difficult to obtain.

Shift away from amalgam

Dentistry has experienced a paradigm shift over the last 20 years. Longevity of the restoration is no longer the primary factor in selecting a restorative material. Esthetics is now as important, if not more so. Coupled with the increasing rate of avoidance of dental amalgam because of its mercury content[36-38] and the excessive replacement of serviceable amalgam restorations,[2-4,9,10] amalgam has lost popularity as a restorative material. Those who continue its use may even feel pressure to stop. Yet, the concerns about safety of amalgam restorations have stimulated clinical research and evaluation[39-43] of amalgam and also several published reviews or the literature concerning the material.[44-46]

There have been multiple studies demonstrating the safety of amalgam,[39-50] reviews of clinical trials regarding reasons for replacement,[26,27,29] reassessment of the traditional teaching of the principle of "extension for prevention,"[51] and introduction of minimal intervention concepts.[52-54]

Caries management and permanent tooth restoration

Pediatric dentists currently make careful diagnoses, fully assess caries risk and design plans for management and/or prevention of caries as a disease prior to making the decision to restore a tooth.[52-56] Concepts concerning caries management and preservation of sound tooth structure have evolved based on evidence, and many ideas traditionally taught in schools are being replaced by new, evidence-supported concepts.[53-57] The use of very small rotary instruments, air abrasion and chemical removal of carious dentin are presently gaining recognition,[51-54] and the concept of minimal intervention has received widespread acknowledgement.[51,52]

Dentists were traditionally taught the concept of "extension for prevention" when preparing teeth.[58-60] Although the concept was progressive at its inception and led to improved patient care, it included the removal of a considerable amount of healthy tooth structure. "Extension for prevention" is currently being amended,[51-54] and preservation of non-carious tooth structure is becoming a priority. Black's first of 7 steps in cavity preparation called for obtaining "outline form."[61] This first step has been modified to provide for obtaining access to carious dentin and then using the extent of the carious dentin to determine the outline form.[51-53] In situations where dentinal involvement is unknown or minimal, that process of cavity preparation is slower and more meticulous. For fissure caries lesions, the tooth preparation may well be confined to the enamel or extend only minimally into dentin. For these situations, a resin composite with appropriate bonding is the preferred restorative technique.[62] If the carious lesion extends into dentin, unless esthetics is of primary importance to the patient, amalgam is an excellent choice for the restoration of posterior permanent teeth.

In both resin composite and amalgam restorations, any non-carious, caries-susceptible fissures should be cleaned etched, rinsed and dried, and a resin sealant material should be placed over the margins of the restoration and in the fissures.[51,52] Fissures with walls that are heavily stained or demineralized may be slightly opened with a small bur or air abrasion prior to etching for sealant placement.[63,64] This minimal intervention approach not only preserves healthy tooth structure, but also minimizes the amount of restorative material used.[52,53]

In a 10-year study[65] comparing traditional amalgam restorations with extension through occlusal fissures to resin composite restorations placed over carious dentin, the traditional amalgam restorations performed as well as the resin composite restorations. But when these traditional amalgam restorations and the resin composite restorations were compared with amalgam restorations that had been placed only where carious dentin and overlying, unsupported enamel had been removed, then remaining fissures sealed (minimal intervention), the latter type of restoration performed much better (2% failure rate in 10 years, compared to 17% failure of traditional amalgam restorations and 14% failure of resin composite restorations).[65] This classic clinical trial provides valuable evidence and strong support for minimal intervention in the restorative treatment of fissure caries. Other clinical and in vitro studies[66-68] have reinforced the advantage of small, narrow amalgam preparations.

For lesions in posterior proximal surfaces of permanent teeth, a minimal intervention approach is also advocated.[51-53] Tooth preparation is performed simply to gain access to carious dentin, and the resultant cavosurface margins are finished to remove fragile, unsupported enamel. This type of Class II preparation is referred to as a “slot” preparation. Care is taken to examine the remaining enamel for demineralization, and, if enamel demineralization is minimally present, the preparation is slightly extended to remove it. However, if there is more extensive enamel surface demineralization, a remineralization protocol should be considered.

For the slot preparation, carious dentin is removed and proximal retention form is obtained. The preparation is extended only into occlusal grooves if there are carious fissures adjacent to the slot. For proximal slot restorations, retention grooves in the dentin of the facial and lingual walls should extend to the occlusal DEJ and then through the enamel to the occlusal surface.[69] The retentive undercuts can be made with the tip of a #169 bur or with a #1/8 bur. If the preparation extends into the occlusal surface, retention grooves or points in the dentin of the proximal walls may be minimized or eliminated.[70,71]

As with occlusal restorations, caries-susceptible fissures are sealed with resin. The clinical success of this slot-type restoration has been demonstrated.[72] In addition, we have observed 50-year-old, slot-type amalgam restorations placed by Markley in the 1930s and 1940s.

For a proximal restoration in which the caries lesion has extended past (gingival to) the cementoenamel junction (CEJ) and tooth isolation is difficult, amalgam may be preferred because of its marginal adaptation and sealing potential over time.

Amalgam safety

Dental amalgam is the most researched, from the standpoint of safety, of all restorative materials. Amalgam safety has been examined by many studies and reports,[38-50,74-86] and dentists are encouraged to read some of the reviews listed at the end of this paper. In this manuscript, the review of amalgam safety will be minimal.

The topic of mercury toxicity from dental amalgam has been an issue since the beginning of amalgam use almost 200 years ago.[11,87,88] There have been several “amalgam wars” over the past two centuries,[11] with the most recent controversy beginning almost 20 years ago.[36-38,46] Accordingly, a small group of anti-amalgamists has been very vocal and quite passionate. Anecdotal information has been made readily available by this group, especially to the press, which has been ready to sensationalize the reports. These groups also post much of their non-scientific information on the Internet, where peer-review guidelines have yet to be developed.

Indisputably, mercury is released from amalgam restorations, and the rate and levels of mercury release have been the subject of several studies.[40,50,77,78,81,83] One study[40] indicated that for every 12 amalgam restorations in a mouth, the rate of release of mercury from those restorations is approximately 1.7 μg per day; this rate of release has been collaborated by others.[50,78,81] This reported amount of mercury release would represent only 10% of daily intake of mercury from all sources, including air, water and diet.[89,90] At this rate, it would take 10,000 years to release all the mercury in an amalgam restoration. Since the normal intake of mercury from amalgam restorations is less than 0.2% of a toxic level, for even the most susceptible person, it is highly unlikely that an individual could receive a toxic dose of mercury from amalgam restorations.[91]

Additionally, release of mercury during removal of amalgam restorations has been shown to be greater than the daily dose and causes a transient increase in patient blood-mercury levels.[82-85] However, biochemical assays in these cases have indicated no negative effect to an organ system.[82-85] Interestingly, in one study,[84] 12 patients went to the extreme of having an average of 18 amalgam restorations removed in one session. There was a transient (up to 3.5 months) increase in blood-mercury level, but again no loss or deterioration of organ function was found.

Reports[36,37] implicating amalgam implication as an etiological agent in diseases such as Alzheimer’s, Multiple Sclerosis, ALS, cancer and heart disease have been described as lacking credibility in the medical community.[91-99] Intuitively, if mercury vapor was indeed a health hazard at the reported level patients receive, it would seem logical that health problems would be widespread among dentists. Dentists are exposed to this mercury vapor on a routine basis. Yet, studies[100-104] have demonstrated that no mercury-related illnesses are identified within the profession. In fact, dental personnel lead healthier lives than most professions.[103] Dentists even live longer than their physician colleagues, and physicians are not exposed to mercury as are dentists.[104]

There have also been several multidisciplinary medical/dental studies[42,74,75,77,105-114] of individuals who are suffering from "amalgam illness" or the illnesses they believe to be caused by amalgam restorations. When one examines several studies psychologically profiling these individuals, the common psychological patterns are noteworthy.[86] Individuals with "amalgam illness" show more anxiety, psychosomatic disorders, depression, panic disorder and/or an inability to perceive and understand threatening situations.[42,74,75,77,105-114] Usually, these individuals have real medical problems and are looking for something to blame for these problems. In many cases, the real illness is too frightening to accept, and many continue to seek help with different providers until someone agrees with their own appraisal of the cause.[74,86,105,106]

Care provided without scientific basis or without accurately-diagnosed pathosis can be dangerous if proper treatment for a serious underlying medical condition is delayed or if the individuals are suffering from serious mental disorders.[42] The level of mercury found in patients in multidisciplinary studies[42,74,75,77-85,105-110] was never abnormally high in any individual with or without "amalgam illness". In fact, some reports[74,105] showed that patients with "amalgam illness" had average mercury levels lower than "normal" counterparts. Although children of these patients may not suffer from "amalgam illness," the parents may pass their treatment belief idiosyncrasies to the child.

Routine removal of amalgam restorations

Perhaps the most dangerous time for an amalgam restoration is when a dentist, especially a patient's new dentist, examines it.[1,3,9,10,115] Studies strongly indicate that, because of a lack of patient longitudinal data, more dentistry is done for a patient who is new to a practice than at any other time.[1,10,115] Surveys of dental practices[5-8,116] consistently indicate that amalgam restorations are replaced because of recurrent caries more than all other reasons combined. Yet, long-term clinical trials of amalgam restorations[26-29] clearly indicate that the recurrent caries rate is less than 1% in 10 years.

One of the arguments put forth, by those who doubt these studies, to explain the low incidence of the recurrent caries, is that these clinical investigations are largely conducted in dental school environments. Their further rationale for this huge disparity between what is perceived in clinical practice and what has been demonstrated in clinical trials is that (1) dental students are used as patients, and (2) researcher-dentists take greater time and care in placing restorations.

In fact, dental students are rarely used as subjects in clinical trials that require reevaluation of restoration performance over several years, because they graduate and are unavailable for follow-up evaluation.[18] And academic dentists, although using enough time to place the restorations well, take the same amount of time in their private practices.

The real difference is between the final objective of a clinical trial and that of a private practice.[4] In a clinical trial the objective is to see how long the restorations will last and to determine failure type and reason.[17,18,25,26-29] Factors other than longevity and cause of failure are also often assessed in clinical trials[26,31,66,67,117,118] These include operator variation, effect of personal preventive measures, size and location of the restorations, and time and cost efficiency. It is understandable that objectives of the private practitioner differ from those of the clinical investigator. To further complicate the issue, as Bader and Shugars[9] have demonstrated, the likelihood of 2 dentists coming up with the same diagnosis on an individual tooth is almost zero. Additionally, the diagnosis of recurrent caries is directly related to the dentist's perception of the marginal breakdown of the amalgam restoration.[3,10,119-126]

Our inability to examine tooth structure under amalgam restorations only makes the diagnosis process more difficult. One study[127] showed that polishing old amalgam restorations will reduce the rate of restoration replacement, and other data[123] indicates that a 90% reduction in amalgam replacement occurs when, after the old restoration is polished, 2 dentists agree that the restoration requires replacement.

Marginal fracture is not in itself an indicator of recurrent caries.[2,3,10,119-126] Kidd[119] has shown that recurrent caries lesions under amalgam restorations are not only difficult to detect, but are not likely to be present. As Markley so aptly stated, "Amalgams always look worse than they are, and castings always look better than they are."[129] Routine removal of amalgam restorations needs a serious reevaluation by dental schools and by each practitioner.

Tooth fracture

Amalgam does not cause teeth to fracture.[130] The contention that amalgam causes teeth to fracture has been made so often that it has been regarded by many as accurate, However, no clinical evidence of a relationship of amalgam dimensional change and tooth fracture has been demonstrated,[116,130-132] and long-term clinical trials[18,26-29] indicate that this is not a prominent phenomenon. Large, wide preparations can accelerate tooth fracture, because too little sound tooth structure is left to resist occlusal forces.[10,66-68] The creep mechanism of amalgam[133] causes the amalgam to deform out of the cavity; the amalgam itself will not create the pressure needed to split a tooth.

Zinc in amalgam

Zinc-containing amalgam alloys give the best clinical service,[26,29,134] yet many dentists will not use them for fear of "delayed expansion." Studies by Eames[135] and Yamada and Fusyama[136] have clearly shown that zinc-containing, high-copper amalgams do not show excessive delayed expansion due to moisture contamination[137,138] that was observed in low-copper alloys in the 1940s.[139-143] In fact, a report[138] has shown that, after 2 years, Dispersalloy (with 0.9% zinc) did not display more expansion when contaminated with water than water-contaminated Tytin (no zinc). This lack of "delayed expansion," the 200-400 m expansion that begins approximately 4 days after placement of water-contaminated amalgam,[144] is probably related to the low creep of the high copper amalgams.

Cavity size upon removal of a restoration

One study[145] has indicated that when an amalgam restoration is removed, the resultant cavity is the same size or only slightly larger than the original preparation. The color contrast between enamel/dentin and amalgam is marked. In contrast, removal of a resin composite restoration has been shown to greatly increase the size of the resultant cavity,[146] largely due to operator inability to discern the composite-tooth interface.

Summary

Dental amalgam is an effective direct restorative material for primary and permanent posterior teeth when caries involves dentin. Careful preparation to remove minimal amounts of sound tooth structure is advantageous for best clinical service of tooth and restoration. Use of sealants over amalgam to prevent the extension of preparations into non-carious fissures is strongly advocated. Clinical data indicate that the small, sealed amalgam restoration in a posterior permanent tooth gives the best clinical service as compared to the more traditional amalgam restoration that extended through all occlusal fissures. Therefore, conservative, sealed, amalgam restorations or preventive resin restorations would be appropriate for the management of occlusal caries.

Amalgam, resin-based composite and resin-modified glass ionomer cement have all been shown to be effective restorative materials for Class I and conservative Class II restorations in primary teeth. In larger preparations, amalgam provides the longest clinical service. Dental amalgam does release mercury, but the quantities are so low that it is highly unlikely to cause toxicity in humans. Zinc-containing amalgam alloys perform better than non-zinc-containing amalgam and do not show excessive delayed expansion when contaminated. Removal of an amalgam restoration does not significantly increase the size of the cavity, whereas resin composites are difficult to discern at the composite-tooth interface, and their removal is more likely to increase cavity size.

Disclaimer

Any opinions expressed represent those of the authors only and do not reflect the official policy or opinion of the US Air Force, the Department of Defense or the US Government.

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