Alternatives to Dental Amalgam: A Review

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Abstract: Worldwide publicity of the amalgam controversy has intensified the growing concerns on its utilization and safety. This controversy has grown beyond the confines of the dental profession itself and has become an emotional public health issue. Amalgam has been the material of choice for restoring posterior teeth for more than 100 years. Presently, there has been a shift toward resin composite and other alternative materials because of concern about the esthetics and biocompatibility of dental amalgam. Other materials such as glass ionomer cements, ceramic inlays and onlays, and gold alloys have been used as alternatives to amalgam. Cast gold restorations are excellent but extremely expensive and difficult to place. For most people, who have limited financial resources, amalgam remains the only feasible choice. Moreover, those who oppose amalgam for possible health reasons should remember that other substances have not received extensive scrutiny in this regard. This article will review recent studies on the longevity and biocompatibility of these alternatives to dental amalgam.

Keywords: Amalgam, Composite resins, Longevity, Biocompatibility, Cytotoxicity.

Introduction

Dental amalgam is an alloy composed of a mixture of approximately equal parts of elemental liquid mercury and an alloy powder, containing powdered metals like silver, copper, zinc, and tin. For the last 150 years, it has been the most popular and effective restorative material used in dentistry. This popularity of amalgam mainly arises from its excellent long term performance, ease of use and low cost. However despite the long history and popularity of dental amalgam as a restorative material, one of its major components, mercury, is of particular concern due to its potential adverse effects on humans and the environment (1-3). This controversy surrounding the use of dental amalgam as a restorative material has increased over the past 25 years and there has been much research into the health effects of amalgam over this time.

Human beings are constantly exposed to mercury from a multitude of sources as a result of both natural emissions and human pollution. It is recognized that mercury in general does constitute a toxicological hazard, with reasonably well defined characteristics for the major forms of exposure, involving elemental mercury, organic and inorganic mercury compounds. It is accepted that the reduction in use of mercury in human activity would be beneficial both for decreasing indirect human exposure and environmental considerations (4).

Some local adverse effects occasionally seen with dental amalgam fillings include allergic reactions and an association with clinical features characteristic of lichen planus. The incidence of these is however low and normally readily managed. Also many systemic adverse effects have been claimed to be caused by amalgam including Alzheimer’s, Parkinson’s disease, Multiple Sclerosis and kidney disease. However, several major epidemiological studies have failed to reveal such effects (5). Utilization of amalgam is expected to diminish as a result of public pressure and concerns over the potential risk of amalgam. While the environmental hazards of amalgam still stand to
the cosmetic issue related to amalgam is another major issue. The past three decades have witnessed significant advances in restorative materials themselves towards more esthetic materials and also in the bonding techniques for retaining a restoration in the prepared tooth. As a result, there has been a shift toward these alternative materials because of concerns about the esthetics and biocompatibility of dental amalgam. Many alternatives to amalgam are available, each with their own advantages and disadvantages. Most of these materials are not new, although significant improvements have been made within the last several years in their composition, techniques for placement and finishing, and/or agents for bonding them. Issues to consider when looking at alternative restorative materials include longevity and durability, sensitivity, allergenicity and cost effectiveness. Hence, the ultimate decision with regard to material selection should be based on the following factors.

- Cosmetic/Esthetic concerns of the patient
- Clinical performance of the restoration
- Biocompatibility & safety issues
- Cost effectiveness

The three most commonly used and most popular direct dental restorative materials are amalgam, and now amongst its alternatives, composites and glass ionomers. In addition, newer advancements in composites like compomers, ormocers are being explored. Each of these materials has different qualities and uses, which need to be properly assessed before deciding on their indication. This article will review recent studies on these aspects for both amalgam and its alternative direct restorative materials.

Cosmetic issues:

One of the main reasons for the need of alternatives to amalgam was the unesthetic appearance of this filling material. Silver amalgam due to its dark colour is contraindicated in anterior teeth. It is mainly used for restoring posterior teeth. Glass ionomer cement is aesthetically better than amalgam as it is a tooth colored restorative material but due to its surface roughness and decreased translucency, it is inferior to composites. Composites due to their good surface finish, translucency and better shade matching, provide best esthetic results. Clearly, posterior composites when properly placed can provide excellent restorations because of their conservative and adhesive nature. These qualities make composites a logical choice, in particular, for the restoration of small incipient carious lesions in the anterior region.

Clinical Issues:

The clinical performance of these materials can be judged according to the following parameters:

- Restoration Longevity
- Wear
- Proximal contacts
- Post operative sensitivity/ polymerisation shrinkage
- Secondary caries

i) Restoration Longevity:

When comparing restoration choices, the issue of restoration longevity is of utmost importance. Not only is it an important clinical issue but it also has economic consequences. Factors influencing the success of a restoration and the duration for which it remains in the mouth, can be related to the patient, dentist and material factors. Patient factors include cooperation at time of placement, personal oral hygiene, prevention practices and oral habits. Professional factors include awareness of possibilities and alternatives, experience and clinical skills of dentist. Probably the most important is the material factor which includes complexity of the restoration, wear, strength, durability of the material and its technique sensitivity when placed, as well as the choice of restorative materials available to us.

Amalgam:

Amalgam so far has served exceptionally well in terms of its durability especially in stress bearing areas. High strength and low wear have allowed this success. Recent research shows that amalgam restorations last longer than was previously thought. Several clinical studies have demonstrated that high-copper amalgams can provide satisfactory performance for more than 12 years (6-10). This appears to be true even for large restorations that replace cusps (11).

Composites:

Most studies have shown that resin composite restorations do not last as long as amalgam restorations. A study by Forss H et al (2001) showed the median age of over 1,800 failed amalgam
restorations was nearly 12 years but slightly less than five years for 1,500 failed resin composite restorations (12). Mjör IA et al (2000) found that the median age of replaced amalgam restoration was 10 years, but that of composite was only eight years, with amalgam outlasting composite for Class 1, 2, 3, 4, and 5 restorations (13). A study of more than 9,000 restorations by Burke et al (1999) showed that amalgam outlasted resin composite for Class 1, 2, and 5 restorations (14). Mjör IA et al (1998) found the median age of a replaced amalgam restoration was 15 years versus only eight years for a replaced resin composite (15). Hickel and Manhart, in a 2001 comprehensive review article on longevity of posterior restorations, described annual failure rates of 0 to 7 percent for amalgam restorations, 0 to 9 percent for direct composites (16). Amalgam shows excellent longevity data with studies up to 20 years, whereas with posterior composites the study duration is much shorter, up to 10 years.

A group of researchers in 2002 used an insurance claims database to study more than 207,000 replaced amalgam and more than 93,000 replaced composite restorations and found that resin composite restorations were significantly more likely to fail than amalgam restorations, but observed that composite faired almost as well as amalgam (17). Composite resin has been accepted by thousands of clinicians as adequate for restoration of small- and medium-sized intracoronal restorations. A recent research by Da Rosa et al evaluated composite restorations after a period of 17 years, they concluded that most restorations were clinically acceptable except that probability of failure was more in posterior teeth and large restorations especially class 2. Composite faired very well for class 1 and small restorations (18). Most clinical performance studies show that, in general, there is a linear correlation between the size of restoration, observation period and the number of failures, which supports the recommendation that posterior composites should be used in conservative, selected cases (19). Efforts are being made at reducing wear and increasing the strength of this material which may further improve its durability.

Glass ionomers:

Glass ionomer cements lack the physical properties needed for large restorations and they are susceptible to fracture under high shearing stresses. This material is suitable only in minimally stress bearing areas as it is a brittle material. It is adequate as a filling material in primary dentition. In the permanent dentition GIC can be used to replace dentine using sandwich technique and also in tunnel preparations where the occlusal opening is small (20-22). In so-called “cermet” cements, metal powders improve abrasion resistance, but fracture resistance remains low. However, even improved glass ionomers do not last as long as amalgam (20, 22-25). Current research suggests that resin modified glass ionomer cements have comparable durability to amalgams for occlusal and moderate sized class II cavities in primary molars (15, 26).

Compomers:

Compomers (Polyacid- modified composite resins) were first introduced in 1991 as an extension in the development of glass ionomer cements (27). When compared to conventional and resin-modified glass ionomer cements, compomers exhibit significantly higher strength and they behave more like composite resins than glass ionomers (28, 29). Only short term data is available regarding its clinical performance & longevity. The quality & longevity in cervical restoration is good (30-32).

Giomers:

Giomers are a relatively new type of restorative material. The name "Giomer" is a hybrid of the words "Glass ionomer" and "Composite", which pretty well describes what a giomer is claimed to be. Giomers are distinguished by the fact that, while they are resin-based, they contain pre-reacted glass-ionomer (PRG) particles. The particles are made of fluorosilicate glass that has been reacted with polyacrylic acid prior to being incorporated into the resin. Little published research is available on the properties or performance of giomers. A three-year clinical study comparing the performance of a giomer with that of a microfill resin composite in Class V erosion/abrasion/abfraction lesions has also been done. After measuring eight performance characteristics, no significant differences between the two materials were found (33). Another study evaluated two-year clinical performance of giomers in occlusal (Class I) and cervical (Class V) cavities. The success rate for cervical restorations after two years was 71-80% and occlusal restorations had a 100% success rate (34). But these are only short term studies and information on long term success is lacking.

Ormocers:

Ormocers, consisting of a silicon-based polymer, have been developed recently as a tooth-colored restorative material. Ormocers (organically modified
ceramics) consist of organic-inorganic copolymers and inorganic silanated filler particles. Mahmoud SH et al (2008) evaluated and compared 2-year clinical performance of an ormocer, a nanohybrid, and a nanofill resin composite with that of a microhybrid composite in restorations of small occlusal cavities made in posterior teeth. After 2 years, the ormocer, nanohybrid, and nanofill composites showed acceptable clinical performance similar to that of the microhybrid resin composite (35). In another study Bottonberg et al (2009) evaluated the performance of two small-particle hybrid ormocer based restorative systems and one small-particle hybrid bis-GMA-based composite restorative system in 128 class II cavities and concluded that there was no significant difference in failures after 5 years between ormocer based and bis-GMA based restorative systems (36).

Siloranes:

Silorane, a recently developed composite material, is derived from the combination of siloxane and oxirane and has a compact ring structure. The advantage of this material is that it has reduced polymerization shrinkage (less than 1%) and improved esthetic stability (37). These properties may ultimately affect the longevity of restoration. One-year clinical testing has found good clinical performance using this new material compared to other posterior composite material (38). Since this is a new material, ongoing research may give us more information regarding the desirable physical properties.

Ceramics/composites inlays and onlays:

In 1998, Fuzzi and Rappelli published the results of a 10-year longitudinal study on 183 Class 1 and 2 ceramic inlays and found a survival rate of 97 percent (39). In 2000, Reiss and Walther published a 12-year study of more than 1,000 computer-generated Class 1 and 2 ceramic inlays and found an 85 percent survival, with inlay fracture or cusp fracture the most common causes of failure (40). In 1999, Donly et al reported a 75 percent survival rate of 36 composite inlays and onlays after seven years, with the main reasons for failure being secondary caries and fracture (41). These studies shows that in term of longevity, ceramic inlays are better than composite inlays.

Gold restorations:

Although limited, the data available shows that gold restorations can yield excellent longevity, even more so than amalgam. Mjör and Medina (1993) reported a median age of 18.5 years for 111 failed cast and direct gold restorations and median ages of at least 15 and 17 years for 1,689 gold castings and 875 direct gold restorations in situ. The most common causes of failure were enamel fracture and recurrent caries (42). In 1999, Stoll et al. studied 1,839 cast gold inlays placed over a 30-year period and found a 10-year survival rate of 76 percent for class I inlays and 83 percent to 88 percent for Class 2 inlays. The most common causes of failure were recurrent caries and lack of retention (43). A similar study by Erpenstein H et al (2001) also showed similar results (44). Though survival rates of gold restorations are excellent, the esthetic concerns and patient’s preference does not allow gold restorations to be frequently used in modern times.

ii) Wear:

Amalgam has served exceptionally well for restoration of posterior teeth defects, ranging from tiny carious lesions to complex amalgam restorations. High strength and good wear resistance have allowed this success. In the past, posterior composite materials were plagued by much lower wear resistance than amalgam (45), but improvements in these composite materials have led to clinically acceptable wear resistance (46-48). However, with some of the newest composite materials, greater wear than amalgam is apparent after two years (49). Among different resin composite and resin based materials (ormocer, hybrid, giomer, packable), the ranking of wear resistance from least to most is as follows: Ormocer < Hybrid < Giomer < Packable (50). In the posterior area ormocers exhibit increased wear and marginal deterioration (51). So an ormocer should not be a material of choice in high stress bearing areas. The wear resistance of Silorane was found to be similar to resin composites (52, 53).

The main limitation of the glass ionomer cements is their relative low resistance to abrasion and wear and they should not be subjected to undue occlusal load unless they are well supported by surrounding tooth structure. However, metal reinforced GICs have highest wear resistance than other types of GICs (54), but it is still lower than resin composites (55).

On the other hand Gold alloys and porcelain exhibit considerably reduced wear when compared with composite resins (56) and hence can be recommended in areas of high occlusal stresses.

iii) Proximal contacts:
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One challenge with posterior composites as compared to amalgam has been the operator’s ability to achieve acceptable proximal contacts in Class 2 cavity preparations. Because composites are plastic, noncondensable materials, generating tight proximal contacts with composites is a challenge. Proper selection and placement of matrix systems for Class II posterior composites is important. For most clinical applications, the use of a sectional, precontoured metallic matrix is preferred. Two recent studies demonstrated that posterior composite restorations placed with sectional matrices and separation rings resulted in a stronger proximal contact than when a circumferential matrix system was used (18, 57). The types of composite like packable composites have been proven to have no influence on proximal contact strength (58, 59). As far as composite and ceramic inlays/onlays are concerned, due to their indirect technique of fabrication, acceptable proximal contacts are achievable.

iv) Post operative sensitivity/polymerisation shrinkage:

Initial postoperative sensitivity seems to be a problem with resin-based materials (60). Studies generally have found that postoperative sensitivity diminishes during the first few weeks after the restoration is placed, but it may persist for a longer period (61, 62). Post operative sensitivity that may occur with composite restorations could be caused by high shrinkage of the composite occurring during polymerisation that set up stresses at the tooth-resin interface (63). Christensen described several methods to prevent such sensitivity, including perfect use of the total-etch technique, tooth desensitizing solutions, flowable resins, high-viscosity bonding agents, resin reinforced glass ionomer liners, and using multiple layers of bonding agent. He stated that the introduction of self-etching primers, which do not remove the smear layer, has virtually eliminated the problem of postoperative sensitivity (64). Two recent clinical studies that examined whether self etching adhesives result in less postoperative sensitivity than total-etch adhesives, were not able to demonstrate a difference between the two methodologies. Both studies found virtually no postoperative sensitivity with either technique, so if postoperative sensitivity is observed more often clinically with total-etch adhesives, it may be attributable to their greater technique sensitivity (65,66).

Pollington S, van Noort R (2008) compared the clinical performance of a resin composite and a compomer in non-carious cervical lesions and found no postoperative sensitivity problems with both materials (67). In another study, Ermiş RB (2002) found no significant difference in post-operative sensitivity between compomers and resin modified glass ionomers (68). No statistically significant difference was found in post operative sensitivity after 2 years of clinical service among Ormocers and resin composites (69). Gordon et al (2007) observed no postoperative sensitivity with giomers after eight years of clinical service (70).

Silorane has been found to reduce polymerization shrinkage and associated stresses (71), which would also reduce microleakage and postoperative hypersensitivity (72, 73) but this needs to be substantiated by further research.

Hence, all the above data indicates a very low prevalence of post operative sensitivity among alternative materials which may be transient in nature. However, post operative sensitivity is a practical problem experienced by most of the clinicians at some or other time in their clinical practice. This may be attributed to the preoperative pulp status, tooth preparation techniques and most importantly, inadequate management of polymerisation shrinkage stresses. This can be minimized by following the recommended clinical protocols and manufacturer’s instructions.

v) Secondary caries:

A possible adverse effect of using composite resin is marginal leakage, resulting in invasion of microorganisms causing pulp reactions and secondary caries. Secondary caries is the major reason for failure of composite restorations (74-76). Mjor IA et al (1993) demonstrated a higher incidence of secondary caries in Class 2 composite restorations than in Class 2 amalgam restorations after five years (77). This may possibly be due to composite resin components that contribute to plaque formation and the levels of cariogenic bacteria at the margins of composite restorations have also been shown to be higher as compared to amalgam restorations (78, 79).

Although glass ionomer cements offer greater ease of placement than composites and have been advocated in caries-prone patients because of their fluoride-release, they have not been considered to possess adequate mechanical properties to function as long-term definitive restorations (80).
Paradoxically, in spite of the fluoride release which occurs from glass ionomer restorations, studies have shown that the leading cause of failure of glass-ionomer restorations has been secondary caries. Studies conducted in 1997, 1999, 2000 and 2001 have also confirmed this fact (81-84).

Despite the observation that glass ionomer appears to exert an anticariogenic effect in laboratory studies, Papagiannoulis et al (2002) found that no preventive effect was exerted in vivo from the glass-ionomer to protect the adjacent enamel wall from secondary caries attack (85). Hence it seems that there is little or no advantage in sacrificing the esthetics of resin composites for GICs. In all these studies where restoration longevity was analyzed, the median age of failed resin composite exceeded that of failed glass ionomer. Manhart et al (2002) stated, “Glass ionomers can be considered only as long-term provisional restorations in stress-bearing posterior cavities” (86).

Biocompatibility issues:

Estrogenicity:

The “estrogenicity issue” for resin composites and sealants was first raised in 1996 by Olea et al (87). Estrogenicity of resin composites and sealants is related to Bisphenol- A (BPA) that leaches from resin containing materials. Other compounds besides bisphenol-A that leach from dental resins have also been found to be estrogenic (88-90). Even bis-GMA itself has been shown to exhibit modest estrogenic activity in an animal study (91). Wada et al. examined the estrogenicity of 24 resin composites, and they found that six products were estrogenic. They also found that three of 18 different resin composite constituents exhibited estrogenicity (90). The implication was that bisphenol A may be continually released after the initial dental work (92) although others have reasoned that this would be unlikely (93, 94). The persistence of leaching of BPA from dental resins has been examined in two clinical studies, which found that BPA release declined to levels below detection limits in a short period (one to three hours) (95,96). Hence the minute concentration in resin based amalgam alternatives is not considered to be a problem.

Cytotoxicity:

Cytotoxicity of resin based materials is mainly due to leaching of unbound monomers or additives. An in vitro evaluation of the cytotoxicity of 35 dental resin composite monomers and additives indicated moderate to severe cytotoxic effects (97). The completeness of the polymerisation process is reflected by the degree of conversion. According to Ferracane (1994), 15% to 50% of the methacrylate groups may remain un-reacted (98). Improvements in the material formulations has resulted in increasingly superior degrees of conversion in recent years and currently only 1.5 to 5% of groups should remain un-reacted. However, this may be enough to contribute to major cytotoxic effects in vitro (99). It has also been shown that the surface of composite resins exposed to oxygen during curing, produces a non-polymerized surface layer rich in formaldehyde, which by itself is an additional factor of cell toxicity (100).

The cytotoxicity and genotoxicity of substances leached from resin based materials and metallic elements have been the subject of extensive studies using cell culture techniques and bacterial mutation test (Ames test). Substances such as TEGDMA and HEMA cause gene mutations in vitro. Studies on the intracellular biochemical mechanisms have clarified various effects such as cell membrane damage, inhibition of enzyme activities, protein or nucleic acid synthesis etc. (101).

At present, the clinical relevance of these in vitro studies is uncertain. It is generally accepted that the amount of potentially toxic substances absorbed from alternatives to amalgam is too small to cause systemic reactions. However, this statement does not deny that adverse reactions may occur, elicited by minute quantities of released substances, including allergies and genotoxicity. Of these, dermatological ailments particularly contact dermatitis has been confirmed in dental professionals and patients.

HEMA appears to be a common sensitizer, although a small minority of dental personnel may have positive patch-tests to BisGMA and/or TEGDMA (102). It is relevant that relatively low molecular weight resin monomers, including HEMA and TEGDMA take only a few minutes to diffuse through latex gloves of the type worn by dental personnel, while higher molecular weight monomers, such as BisGMA, take a little longer to pass through the relatively thin latex of treatment gloves (103,104). These findings emphasize the importance of a “no-touch” technique when handling resin-based restorative materials, even when wearing gloves. This approach to the handling of resin-based restorative materials is highlighted in manufacturers’ directions for use.
Ceramic and gold restorations can be potential alternatives to amalgam but these are quite expensive than a similar sized amalgam restoration.

Before deciding which material would be best suited for a particular clinical condition, factors such as physical/mechanical properties, occlusal forces, patient’s considerations and esthetic demands should be kept in mind.

One cannot assume that non-mercury containing alternatives are free from any concerns about adverse effects, as allergies to alternative materials have been reported in patients and dental personnel. However, these materials have been in use since last 30 years and there is lack of long term data with regard to toxicological hazards.

Decision making with regard to choice of materials should be made taking into considerations the best alternative for a particular clinical condition and risks and benefits of the material.

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