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Review Article

Profile of Amalgam and Non-Amalgam Restorations: A Review of Literature

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Abstract

The practice of restorative dentistry dates back to the 1st century AD. These restorations are done to restore form, function and esthetics. In current restorative practice, the materials to choose from are dental amalgam, composite resin (and its modifications) and glass ionomer cements (and its modifications). Dental amalgam was the material of choice for nearly two centuries. This was because it has such properties as durability, ease of placement, high compressive strength and it was cheap. It however was not esthetic and there was concern of its use due to its mercury content. Composite resin was initially only restricted to the anterior portion of the mouth and for small Class I cavities this was because though it was esthetic, it lacked strength, but with modifications, new research now shows it can be a good substitute for dental amalgam. Glass ionomer cement bonds to both enamel and dentine, it also has sustained release of fluoride which helps to remineralize tooth structure as well as prevent future caries occurrence. It can now also serve as a definitive restoration in the posterior stress bearing portion of the mouth. Although dental amalgam has been the material of choice almost two centuries, there is now a paradigm shift towards non-amalgam restorative materials. This paradigm shift has been occasioned by the need to restore tooth with materials that best match the tooth in terms of function and esthetics. The biomimetics are in as they fulfil the conditions and conserve tooth tissue.

Key words: Dental amalgam, composite resin, glass ionomer cement.

INTRODUCTION

Restorations in dentistry are used to cover tooth defects, they restore form and function. These defects could be as a result of dental caries, tooth surface loss/tooth wear lesions, congenital defects and fractures. The choice of restorative material to be used is dependent on certain factors such as the location of the tooth in the mouth, (anterior or posterior region), site of the lesion on the tooth (occlusal, incisal, cervical or the root surface), competence of the operator and extent of tooth loss.

The practice of restorative dentistry dates back to the 1st century AD [1]. In ancient civilizations like Babylon, Egypt and Assyria, materials such as ivory, waxes, lead, and gold were used for restoration of teeth [1]. In more recent history; gold foil was introduced in 1795, but is now obsolete [1]. Amalgam, an alloy of mercury and silver was introduced in 1826 and this marked a turning point for dentistry [1]. It had good compressive strength and thus could withstand the forces of mastication [2]. This made it a good restorative material for teeth in the posterior region of the mouth [2].

In 1848, gutta-percha was introduced as a temporary filling material. Silicate cement, the first aesthetic restorative material was introduced in the late 19th and early 20th century [1]. The great advantage of this material is the release of fluoride [1], which acts to re-enforce the tooth, making it more resistant to bacterial acid attack [1]. While G V Black [1, 3] was the first person to clearly classify/define the cavities of dental caries and with this classification came the type of restorative cavity to prepare, the principle of cavity preparation here included extension of the cavity margin to prevent the development of secondary caries. However, this no more applies because of research which has yielded better understanding of the carious process as well as innovations which led to the development of better restorative materials such as composite resin invented by R. L. Bowen in 1962 [1] This led to the era of dentine and enamel bonding as well as better aesthetics restorations [1, 2]. With further improvement and modification, there are now a variety of composites each with its unique applications e.g. microfilled, hybrid, microhybrid, packable, flowable [1, 2]. Glass ionomer cement (GIC) was invented in 1968 and like silicate its precursor, has the ability to release fluoride [3]. Modifications of GIC now incorporate resin (Compomer) [3] or metal (amalgomer) [3].

This is not a comprehensive list of all the restorative materials past and present. Some have been discontinued e.g. alum, ground mastic, powdered pearl [1] while amalgam because of its mercury content is being phased down and would eventually be eliminated [4].

An overview of the restorative materials

Dental amalgam: This is an alloy of mercury and silver [5]. Introduced in 1826 and was material of choice for dental restorations because it was cheap, durable, and able to withstand the occlusal forces especially in the posterior part of the mouth where it is used [5]. It however lacked aesthetic [5], making it confined to the posterior region of the mouth [5].

There are concerns of mercury toxicity with the use of dental amalgam. Mercury use for dental amalgam represents about 10% of global mercury consumption [6-8].

Mercury, an essential component of dental amalgam functions to make the amalgam plastic and soft, a quality needed during insertion and condensation in the cavity. It binds the particles of the alloy together and is necessary for the setting reaction of amalgam and hardening of the alloy [9, 10].

While some authors opine that mercury is firmly bonded to the alloy, others postulate that mercury is released from the dental filling throughout life [6-8].

This release of mercury from dental amalgam is said to occur when patients with amalgam filling undertake such action as chewing of food [7, 8], toothbrushing [8] and grinding of teeth [7, 8] which is a parafunctional habit. Even the chewing of gum is said to release mercury from amalgam fillings [7, 8].

In the dental clinic, mercury is released from amalgam during such actions as the use of high-speed drill to remove an already existing amalgam filling, polishing of amalgam surface, use of hydrogen peroxide in tooth whitening and use of ultrasonic scalers on amalgam surfaces [11].

This suggests that both at home and in the dental clinic, mercury can be released from amalgam restorations [7-9, 11, 12].

The toxicity of mercury affects all systems in the body [13, 14] and in the oral cavity bleeding gums, alveolar bone loss, loosening of teeth, excessive salivation, foul breath, metallic taste, burning sensation with tingling of lips and face, tissue pigmentation (amalgam tattoo of oral soft tissues), stomatitis, ulceration of gingiva, palate, tongue occur [15].

Other components of amalgam and their function

Silver is a major element in the alloy, improves the colour of the alloy by whitening it; increases strength of the mixture, increases setting expansion and decreases the flow of the amalgam [9, 10].

Zinc acts as a scavenger by removing unwanted oxides and other impurities [9, 10]. It can be omitted from the mixture if the alloy is manufactured in an O_2 free environment; it delays the expansion if the amalgam is contaminated with moisture during manipulation [9, 10]. It also helps in workability and cleanliness of the amalgam [9, 10].

Copper increases strength and hardness of the alloy, decreases flow and promotes setting [9, 10]. An increase in the copper content helps eliminate the gamma 2 phase (the Tin-Mercury phase) in the setting reaction [9, 10]. This increase allows for corrosion to occur but not to the level of a breakdown of the amalgam restoration [9, 10, 16, 17]. Tin decreases expansion and help in amalgamation [9, 10].

Shape of the particles

There is the spherical amalgam which contains small round alloy particles which allows for easy condensation with minimal pressure [9, 10]. It has high early strength and can be used for very large or complex amalgam restorations [9, 10]. The Lathe cut imparts resistance to the alloy during condensation [9, 10]. The admixed amalgam however has irregularly shaped and sized particles; it would therefore require more condensation pressure [9, 10]. The advantage of this is that it makes recreation of the contact point easier [9, 10].

Some properties of amalgam

They are metallic, have good thermal conduction and would require a liner to protect the pulp [9, 10, 17]. They are also brittle thus having low edge strength, therefore sufficient depth or bulk is required for placement of the amalgam [9, 10, 17].

The prepared cavity should have a minimum thickness for strength, a butt-joint form i.e. a 90^0 angle at the margin [9, 10, 17]. It should have features that aid mechanical retention such as undercut, grooves, slot [9, 10, 17]. The placement of amalgam is less technique sensitive when compared to composite or GIC [9, 10, 15].

While dental amalgam is easy to place, has high compressive strength; it also has very good wear resistance, excellent durability and is cheap [9]. However, it is contraindicated in areas where esthetics are important such as the anterior portion of the mouth as well as patients who are allergic to the component parts of the amalgam alloy [9, 17].

Bonded amalgam

The retention here is by bonding. This is done with dentine bonding agents and the adhesion generated is minimal and should be used as added retention [10, 16, 17, 19]. So there is still the need to still prepare a proper cavity based on the principles of cavity preparation [10, 19]. The cavity is prepared, etched, primed and the adhesive placed and light cured [10, 19].

This may provide such advantages as decreased microleakage, decrease post-operative sensitivity, pulpal inflammation and the incidence of recurrent caries [16, 17, 19]. Bonding has also been said to provide support to weakened tooth tissue making the cavities more conservative (though not as conservative as the non-amalgams), and increasing the fracture resistance of the tooth [16, 17, 19].

Other modifications

Incorporation of fluoride

At a point, fluoride was incorporated into amalgam to aid with remineralization of the surrounding decayed tooth tissue but the release of fluoride was not sustained long enough to produce the desired result [15].

Substitution of mercury

In an attempt to eliminate mercury, gallium, which is also a liquid when alloyed with indium and tin at room temperature, has been considered as a substitute. It did not perform as well as amalgam [9, 10, 17].

Some disadvantages of note are that tooth preparation is technical [9, 10], there may be initial marginal leakage before the corrosion products sets in [9, 10]. It is not esthetic neither is its cavity preparation conservative of tooth tissue [9, 10]. Another disadvantage is the two visits for required for amalgam restoration [9]. The first is for the placement of the amalgam and the second for its polishing at least 24 hours after insertion [9].

Failure of amalgam restorations

Failure of amalgam restoration may be experienced in patients with high caries rate, in cases of marginal breakdown of the restoration especially when the principles of cavity preparation are not strictly adhered to [9, 10]. Sometimes there can be bulk fracture especially at the isthmus and this could be due to low tensile strength [9].

The Non-Amalgams

The new approach was a search for restorative materials which would be biomimetic [20]. That means the materials should closely mimic the natural tooth in such functions as esthetic and function [20]. Composite resin and GIC are such materials [20]. The composite require minimal cavity preparation, reduces the chances of pulpal involvement, and records less tooth fractures of the restored tooth [20]. GIC on the other hand are biomimetics because its properties are similar to dentine [20]; it adheres to tooth structures and has the ability to release fluoride release [20].

Composite resin was introduced in 1962 [1]. It is composed of an organic matrix in which the inorganic filler is dispensed [21, 23]. It also has a coupling agent which enhances the bond between the inorganic matrix and the inorganic fillers [18, 23].

The organic matrix may be bisphenol A-glycidyl methacrylate or polyurethene dimethacrylate [22, 23]. There are filler particles which may be quartz, borosilicate or other ceramics [22, 23]. They reduce the polymerization shrinkage [21, 23]. Recently modifications were done by adding fibre like polymers nano-fibres or glass fibres [22, 23]. These were aimed to improve the properties of composite. Calcium and phosphate have also been added to composite resin with a view to increase its remineralization potential [22, 23]. The coupling agent is a saline group [22, 23] and the setting reaction is a polymerization reaction [22, 23].

For chemically cured composite aromatic tertiary amines are the activators while the light cured has a photoactivator which is camphoroquin one (a diketone) [22, 23]. Newer light units have curing modes that are used to pulse, or step up the light intensity [22], they ultimately control polymerization shrinkage [22].

Composite resin can be used for all types and sizes of restorations [21-23]. The cavity preparation here leads to minimal tooth structure loss unlike that done for amalgam [21, 23]. Improvement of the composite resin bond to tooth results in better seal [21, 23]**.** However all composites exhibit some degree of polymerization shrinkage [21, 23].

Types of Composites

Macrofill or Conventional Composites are the first generation of composites [21-23] but are no longer in use in clinical practice [21, 23]. They contained large filler particles leading to rough surface texture [22] making it difficult to polish, so it did not exhibit excellent esthetics [21]. It was also prone to discoloration and had high surface wear rate [21].

Microfill has filler particles that are not as large as those in macrofill [21-23], the surface was smoother, making it easier to polish and finish [21-23]. They have higher wear resistance [21], low fracture strength, good flexural properties which make them good as Class V, Class III restorations [21-23].

Hybrid was developed to combine the favourable properties of macrofill and the smooth surface of the microfill [21, 23]. Newer version of the hybrid contains smaller nanofillers and is known as nanohybrid [21, 23], they however have superior characteristics [21]. Such as improved wear resistance, fracture strength as well as improved polishability [22, 23].

Microhybrid [21, 22] has a smooth surface, good strength, so it can be used in both posterior stress bearing areas and in anterior for esthetics.

Nanofill has extremely small filler particles [21, 23]. The physical properties and esthetics are improved offering improved optical properties [21-23].The resultant restoration has high polishability [20, 21, 23]. They have high versatility thus they are universal in usage [21-23].

Packable Composite is more viscous and can be inserted in bulk resulting in handling properties like that of amalgam and easier restructuring the proximal contact [21-23]. However, the viscosity makes it difficult to flow into all the margins [21]. It may then be advisable to first flow in a small amount of flowable composite to help with the marginal adaptation [21]. They were to be used as amalgam substitute [22]. One drawback with its use was that interproximal contacts were not readily reproduced [22].

Flowable Composites have lower amount of filler particles resulting in lower wear resistance, lower strength, and higher polymerization shrinkage [21-23]. They are best used as sealants and for marginal repairs [21-23].

Compomers (Polyacid Modified Composites) are composites with some added GIC [10, 23]. Their properties are better than both Conventional GIC and Resin Modified GIC but are inferior to composite [21].

Glass Ionomer Cements: The powder is a calcium-fluoro-alumino silicate glass and the liquid is an aqueous solution of polymers and copolymers of acrylic acid [21-23]. Other acids like itaconic acid, polymaleic acid, tartaric acid [3, 21-23]. It undergoes an acid base setting reaction [21-23]. The acidic liquid solution dissolves portions of the periphery of the silicate glass particles releasing calcium, aluminium, fluoride, sodium and other ions [21-23]. This is the initial set and takes place within 5mins [21-23]. During the next 24-72 hours, the calcium ions are replaced by more slowly releasing aluminium ions to produce a more highly cross-linked matrix that is now mechanically stronger [21-23]. Water initially serves as the medium but later it slowly hydrates the matrix adding strength to the cement [21-23]. This is the maturation process [21-23].

The conventional GIC was developed in 1972 [21, 23]. One very good characteristic is its ability to release fluoride to the surrounding tooth tissue [3, 21, 23]. This made it material of choice in patients with high caries risk or activity [21, 23]. It however has low wear resistance and low strength so it was not recommended for use in posterior teeth [21, 23].

Resin Modified GIC**:** Resin was added to GIC to improve its physical properties as well as its esthetics [21]. And this makes it possible for them to be cured by light source [21-23], though they still undergo the acid base setting reaction [21].

Although their properties such as strength, wear resistance, esthetics and ease of use are better than that of Conventional GIC, they are still inferior to those of composite [21]. The modification means they can be light cured, self-cured or both [21].

Arguments for Non- Amalgam restorations

The principle being applied here is that of biomimetics and the search is for materials whose properties closely mimic that of the natural tooth in terms of esthetics and function [24]. Both composite resin and GIC have been identified as such [24]. Composite because it encourages minimal cavity preparation, decrease pulpal involvement and reduce the chances that the restored tooth would fracture [24]. GIC is termed a biomimetic because it has properties similar to dentine; it adheres to tooth structure, and its ability to release fluoride [24, 25].

Research has observed that the performance of newer composite is at par with amalgam in terms of compressive strength and longevity [26], even in multi-surfaced restorations. For instance, Non-amalgam cavities are more conservative of tooth structure and this impact positively on the longevity of the tooth [22, 27-31]. Still on longevity some other studies have demonstrated no statistically significant difference in terms of performance between amalgam and non-amalgams [29, 32-36]. Even the European Commission's Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) agrees that there are improvements in terms of quality and durability of non-amalgam restorative materials [29]. Thus dental restorations can be effectively done with the non-amalgam restorative material [29].

The overall goal should be to preserve the tooth for as long as possible without endangering the overall health of the patient or the environment [27, 36-42].When preparing amalgam cavity for instance, implementing the principles of cavity preparation results in sacrificing ,some sound tissue [27, 36-42]. While the non-amalgams because of its adhesive properties, can adapt to all cavities leads to less sound tissue loss [27, 36-42]. This means that the non-amalgams unlike amalgam are compatible with the concept of minimal intervention dentistry [27, 36-42]. Biomimetic approach aims to create a restorative that is compatible with such properties of the tooth as biological, mechanical and optical and not just considering strength of the material [27, 36-42].

With the advent of these newer non-amalgam materials came such restorative technique as Minimal Intervention [40]. This allows for conservative tooth preparation, localized repair, making it possible to avoid the consequences of total restoration replacement (as would happen with amalgam) which are increasing the depth and width of the cavity each time the previous restoration has to be removed [40]. Localised repair is easy to do, it saves time, cost and ultimately preserves tooth integrity [22, 39, 43]. World Health Organization in its report noted that resin based composites perform as well as amalgam and that it is easier to repair a composite than an amalgam restoration [37]. The result is that there is increased longevity of the filling, longevity of the tooth, as well as reduce costs. Another author [43] found that composite can be repaired more successfully than amalgam; their study also found that the cause of restoration failure which could be due to fracture or recurrent caries impacts on the prognosis of the repaired restoration [43]. For instance, tooth fracture, which is seen more in large amalgam restorations, has a worse prognosis than repaired restorations due to recurrent caries [43].

The European Commission report concluded, that the longevity of non-amalgam fillings should no longer be a factor with significant effect on the overall cost difference between dental amalgam and composite or glass ionomer restorations [44]. Reasons they gave for this include the ease of repair or replacement of the non-amalgams, there is negligible treatment time difference between amalgam and the non-amalgams as well as the deleterious health and environmental impact of the amalgam restorations [44]. The amount of tooth structure removed when preparing for an amalgam cavity is more than that removed when preparing the same tooth for a composite or GIC restoration [45, 46].

The amount of remaining tooth structure is a major factor in determining the prognosis of the tooth on the long term [36, 45, 46]. Minimally invasive adhesive restorative dentistry is the way to go if we want to preserve tooth structure [45, 46].

To safeguard human health and the environment while doing amalgam restorations, we would need among others the installation of amalgam separators, these would make amalgam filling actually cost more than the non-amalgams [47].

Amalgam has environmental consequences even after death of a patient with restorations; there may be emissions to air, soil, and water if the patient is cremated or buried with amalgam restorations [47]. The non-amalgam restorations are environmentally friendly [48, 49].

The consensus is that the non-amalgams are safe to use without risk of adverse effect in the vulnerable group (children and pregnant women) [50-55]. The release of Bisphenol A (BPA) is said to occur minimally, and only within the first 24 hours in composite resin with an ester linkage (Bisphenol A dimethyiacrylate) and not from the ether linkage resin (Bisphenol A glycidyl mathacrylate) [50-55].

Some government agencies agree that non-amalgam fillings are safe for health and the environment [56, 57]. Berge et al. [58] in a comparative study of over 90,000 women demonstrated no adverse birth outcome in those who had composite restorations done during pregnancy when compared with those who did not even visit the dentist during pregnancy.

In another study, Vieira et al. [59] noted that using lower cost to justify the continued use of amalgam is no more tenable because the broader picture is that the added costly of eliminating its health and environmental impact would make it the more expensive option. The improved performance of the non-amalgams makes it a good alternative to amalgam [59]. It can replace amalgam [59]. Their study also demonstrated statistically significant lower failure rate of posterior composite resin when compared to amalgam restorations in 5 years follow-up period [59].

Although composite resin restorations are technique sensitive, with more practise and experience the dentist is able to eliminate the time difference between its placement and that of amalgam [60].

Interestingly, in the 1980s Hendriks et al. [61] found that the treatment time for amalgam restorations is equal to the treatment time of composite restorations and this was a time when dentists were not as well versed in the use of composite. They found that the dentists got faster and better the more they placed composite restorations [61].

Moreover, innovations like the development of the sectional matrix system (which made recreation of the contact point easier) and the bulk fill composites (which made the placement of composite easier) was a major turning point in posterior restorative dentistry [62]. These made for faster, more efficient and economical placement technique [62].

GIC release fluoride and this has been demonstrated to aid in caries prevention [21-23, 63, 64]. Studies have demonstrated that GIC fillings using atraumatic restorative technique were completed more quickly than amalgam or composite restorations [21-23, 65, 66]. This may be because there was no need for cavity preparation [21-23, 65, 66], this is also cost effective [65], and can be carried out in the dental clinics [66]. Survival rates of 10 years and above has been reported with this technique, demonstrating that the fillings were intact and still effective [67, 68]. Even composites resins can incorporate preventive measures when used as sealant for adjacent pits and fissures [67].

The high viscosity GIC [69, 70]: This consist of high viscosity packable GIC and a nanofilled light-cured resin surface coating. The material has higher fluoride release, higher flexural strength, and higher acid and wear resistances than other GICs. There is no restriction of its use in class I and II cavities.

With the advent of non-amalgams like Glass ionomer cements and composites which are aesthetic, bind to dental tissue, therefore requiring less removal of tooth tissue than amalgam to gain retention there is reduced risk of tooth fracture because of the remaining bulk of tooth tissue [28, 37]. So the patient gets to keep their tooth longer. They are good alternatives for amalgam [71].

Dental amalgam was considered an inferior restorative comparatively when three of its characteristics namely its being non-aesthetic, being non-adhesive and that larger cavities have to be prepared leading to excessive tooth tissue removal were considered [46].

CONCLUSION

Dental amalgam as a restorative tool in dentistry has been around for almost two centuries. In more recent times however, there has been a paradigm shift towards non-amalgam restorative materials. This paradigm shift has been occasioned by the need to restore tooth with materials that best match the tooth in terms of function and esthetics. The biomimetics are in as they fulfil the conditions and conserve tooth tissue.

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