

7 Dental Amalgam

Amalgam seems first to have been first used for the restoration of teeth in the early part of the 19th century in Europe. It was just one type of metallic restoration: others included hammered gold leaf or lead, the latter placed while molten. Right from the start, the use of amalgam was controversial. Mercury was known to be toxic and the technique of inserting amalgam seemed crude compared with the meticulous approach needed to place gold foil. Consequently the use of amalgam was considered unethical. In America, the dispute between those dentists who would use amalgam and those who would not became extremely polemical, leading to the so-called *amalgam wars*. In fact, there was an early professional body, the American Society of Dental Surgeons, whose express purpose was to unite ethical dentists (*i.e.* those refusing to use amalgam) against the 'unethical' ones. Later, many individuals were involved in helping to formulate safe and reliable amalgams for dental fillings.¹⁸⁷ One of the most notable was G.V. Black, whose *Manual of Operative Dentistry* published in 1896 established the mechanical principles for sound cavity design for use with these more satisfactory amalgams. Finally, in 1929, the American Dental Association adopted a specification for dental amalgam, which included the requirement that the material be tested under defined conditions. This was an important step in eliminating unsatisfactory products from the market.

To prepare dental amalgams, a powdered alloy consisting mainly of silver and tin is mixed with liquid mercury. The powder may be produced either by lathe cutting or by milling a cast ingot of the silver–tin alloy. The resulting particles are irregular in shape. Alternatively, the liquid alloy may be atomised and allowed to condense, a process which results in particles having an essentially spherical morphology. Alloys of both these types are used in clinical amalgams, as also are mixtures of lathe cut and spherical particles.¹⁸⁸

In clinical use, amalgam alloy is mixed with mercury in a process known as *trituration*. Although formerly done by hand, possibly in the hands themselves with a rolling action, modern dental surgeries tend to be equipped with vibratory mixers, and the unmixed amalgam is prepared by the manufacturers in two chambers of a small capsule. Immediately prior to mixing, the thin membrane that separates the alloy powder from the liquid mercury is broken, and the capsule inserted into the arm of the mechanical mixer and vibrated for the required length of time, typically 30 seconds, to bring about thorough mixing of powder and liquid. The freshly mixed amalgam, which has a plastic consistency, is then extruded from the capsule and into the cavity.

During the process of trituration, the surface layer of the silver–tin alloy dissolves in the liquid mercury, and there is a reaction that leads to the formation of new phases. These new phases are solid, and their formation causes the plastic amalgam paste to solidify. A number of metallurgical phases are involved in this transformation, details of which are given in Table 4.13.

The detailed metallurgy of the phases involved is complex, and changes in the silver content of the initial silver–tin alloy can lead to the formation of

Table 4.13 Phases involved in the setting of dental amalgam

Phase	Chemical formula
γ	Ag_3Sn
γ_1	Ag_2Hg_3
γ_2	Sn_{7-8}Hg
ϵ	Cu_3Sn
η	Cu_6Sn_5
Silver–copper eutectic	Ag–Cu

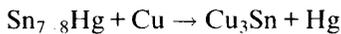
different phases which have correspondingly different physical properties. Silver–tin alloys anyway are brittle and difficult to grind uniformly unless a small amount of copper is included. This is limited to 4–5 wt%, since above this level the discrete compound Cu_3Sn is formed. Below this level, the presence of copper hardens and strengthens the Ag–Sn alloy.

Zinc may also be included in the alloy, typically at levels of around 1 wt%. The presence of zinc leads to amalgams that are less plastic than zinc-free amalgams, an important feature during finishing processes for fillings. The main purpose of adding the zinc, though, is for it to act as a scavenger for oxygen,¹⁸⁹ thereby reducing corrosion through minimising the occurrence of other metal oxides in the finished amalgam.

The main setting reaction of dental amalgam is as follows:¹⁹⁰



The final alloy also contains significant amounts of the unreacted γ phase, Ag_3Sn . Modern amalgams are formulated to include up to 30 wt% copper,¹⁹¹ and this leads to a subsequent reaction, as follows:



The elemental mercury that is formed in this reaction is then free to react with further silver–tin alloy, and form the desirable γ_1 phase. There are several advantages to these reactions occurring in the setting process of amalgams: resulting materials are less susceptible to creep and corrosion¹⁹² and they reach their final levels of strength quicker than so-called conventional amalgams.¹⁹³ The absence of corrosion is regarded as particularly advantageous, because it eliminates the main route by which mercury can be released from the filling and enter the patient *via* the gastro-intestinal tract. As a result, high-copper amalgams are now the material of choice for the clinical repair of cavities,¹⁹⁴ and in certain countries, *e.g.* Germany, high-copper is the only type of amalgam that is permitted for clinical use.

Dental amalgam is used within clinical dentistry for a variety of *permanent* restorations, *i.e.* those designed to last several years, rather than merely weeks or months.¹⁹⁵ The actual survival time varies considerably, depending on the

brand of material, condition being repaired, and patient factors such as age and quality of oral hygiene.¹⁹⁶ Amalgams are recommended for a range of cavities, including substantial ones needed to repair the molar teeth.

Amalgam itself has no adhesion to either dentine or enamel. This means that there is the potential for marginal leakage, especially with high-copper amalgams, which give rise to less corrosion product that might otherwise fill any marginal gap. Traditionally, cavity walls are coated with a layer of copal-ether varnish.¹⁹⁷ This results in a very thin layer of organic film, about 2 μm deep, which provides some modest sealing of the gap by flowing to fill any surface irregularities on the prepared wall.

More recently, amalgam restorations have been bonded in place using a bonding agent especially designed for the purpose. Using such materials, quite high experimental bond strengths have been recorded between bovine dentine and amalgam; it is, however, too soon to have demonstrated whether such bonding agents improve the longevity and clinical performance of amalgam restorations when used in human teeth.

Briefly, amalgam has the following advantages:

- (i) It is inexpensive;
- (ii) It is strong and durable in the oral environment, and shows excellent (*i.e.* minimal) wear;
- (iii) Its use is relatively insensitive to clinical technique;
- (iv) It has a proven track record of over 150 years of clinical service.

On the other hand, it has the following disadvantages:

- (i) Lack of adhesion, which may lead to marginal leakage (see above);
- (ii) It has to be retained mechanically, which in turn means it is not conservative of tooth structure (healthy tooth tissue has to be removed to create the necessary undercut cavity in order to retain the hardened material);
- (iii) Its aesthetics are poor;
- (iv) There is patient concern over toxicity.

Dental amalgam is a space filler, and its placement in the tooth causes a weakening effect. Consequently, techniques that are highly conservative of tooth tissue are generally employed by dentists and cavities are cut so as to avoid sharp angles because they also weaken the tooth by causing stresses to be concentrated at the corners.

Amalgam is prepared and placed under the driest possible conditions because if an unset amalgam comes into contact with a wet liquid, *i.e.* saliva or blood, the cavity margins become difficult to finish properly, and the adaptation is poor. In amalgams containing zinc, there is also the possibility of reaction of the metallic zinc with water to yield zinc oxide and hydrogen:



The latter causes bubbling and expansion of the filling which, in severe cases, will result in pulpal pain and cuspal fracture.

When used properly, amalgams have extremely good properties as restorative materials being durable and showing little in the way of recurrent caries. Modern high-copper zinc-containing amalgams have been shown to have extremely good survival rates, typically being shown in one study to have over 90% surviving for at least 12 years.¹⁹⁸ The overall conclusion from studies of durability is that the lifetime of an amalgam restoration depends on three sets of factors:

- (i) the material (brand, composition, quality of mixing *etc.*);
- (ii) the dentist (cavity design, condensation, moisture control *etc.*); and
- (iii) the patient (oral health and hygiene, diet, occlusal forces applied, including possible tooth grinding during sleep, behaviour known clinically as bruxism).

The first two influence performance during the early part of the restoration's lifetime, whereas the latter emerge as important as the restoration ages.

Dental Amalgams and Health

Mercury is a toxic element, both as the free metal and in chemical combination.¹⁹⁹ Elemental mercury is relatively soluble in lipids, and is readily absorbed at the lung surface, where it is oxidised to Hg^{2+} . It is transported from the lungs by the red blood cells to other tissues, including the central nervous system. Mercury is readily methylated in the environment and, as methylmercury, easily crosses the blood-brain barrier and also the placenta into the foetus. Consequently, it may accumulate in the brain, and may also affect the unborn child. Inorganic and metallic mercury, by contrast, does not cross the blood-brain barrier, and hence from amalgam fillings in these forms it does not pose a threat to the brain.

Corrosion of dental amalgam fillings may occur under the conditions found in the mouth.^{200,201} There is some inhibition of corrosion by the strong passivating layer of SnO on the γ_1 phase which, though soluble in acid solutions, is not under the relatively mild acidic conditions of active caries, *i.e.* about 4.9.²⁰² Despite this inhibition, some corrosion may occur, and this causes mercury to be released as ions which pass into the gastro-intestinal tract. However, the amount is limited, and there is no evidence that it is sufficient to cause any adverse effects.

There are many studies which show mercury to have negligible effect on the health and well-being of patients. For example, in a study in Sweden,²⁰³ the possible effects of amalgam fillings were examined by evaluating the health of patients drawn from the ongoing Swedish Adoption/Twin Study of Ageing. The mean age of the subjects was 66, and the authors concluded that no negative effects on physical or mental health could be found from dental amalgam, even after controlling for age, gender, education and number of remaining teeth.

There have been numerous attempts to link the presence of dental amalgam with the disease multiple sclerosis, MS. There are difficulties in that MS is characterised by bouts of spontaneous but temporary remission, so that anecdotal accounts of improvements in health following removal of amalgam fillings are of no value in determining whether there is any relationship. In fact, what evidence there is shows there to be no relationship. Clausen²⁰⁴ analysed the mercury content of brains from those who had suffered from MS in their lifetimes and compared the results with those from the brains of deceased non-sufferers. The overall levels showed no significant differences, but the lipid-soluble mercury levels were significantly *lower* in the MS sufferers. This was explained in terms of changes in both the blood-brain barrier and in vitamin B₁₂ metabolism in those affected by MS. Whatever the explanation, it is clear that MS is not connected with increased levels of mercury in the brain, and any suggestion of a connection between dental amalgams and the disease seems to have no basis in fact.

Dentists and their assistants have a much higher level of exposure to mercury in the form of vapour than do patients,²⁰⁵ yet studies have shown that there are no significant differences in health, mortality and morbidity compared with the general population. In fact, the only known and scientifically confirmed problem with mercury is the very rare instances of mercury hypersensitivity.²⁰⁶ Studies have also been conducted on the health of children born to dental personnel, and again there appear to be no risks of abnormalities in neonates in this group.²⁰⁷ In conclusion, the scientific evidence suggests that the use of amalgam fillings poses no threat to the health of the dental personnel carrying out treatment and that, once placed and set, there is similarly no evidence that amalgam poses a threat to the health of patients.

8 References

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