The Development of Dental Amalgam

Cavity fillings were not developed until the early middle ages. Before that, tooth extraction as practiced in ancient Greece and elsewhere was the only treatment available for toothache.

In the early middle ages, dental fillings were made from resin, wax, or gum. By the late middle ages, lead and gold leaf metals came into use. In the mid-1850s, a new and very effective technique was developed: gold foil was first heated in an alcohol flame to free it of surface contaminants and make it weld to itself, and then layers of the metal were inserted into a prepared cavity. The layers were then cold welded and hardened by strong compression. The compression process was carried out with a slightly blunt hand-held tool. The physical strength of the practitioner was important, and blows struck with specially designed mallets were used to aid in the process of compacting the gold filling. When electricity came into use, electric-powered mallets were devised.

By the end of the 19th century, a dental student was expected to learn a great deal of practical metallurgy. *American System of Dentistry*, a textbook by W. F. Litch dating from the 1890s, includes a lengthy illustrated chapter on the preparation and use of gold foils, and included passages such as ``Purity of gold imparts to the foil the extreme softness it should possess and gives it the facility of being easily adapted to the surfaces of the cavity...any [metal impurity]... impairs its ductility [malleability] and also causes it to harden more quickly by the application of instruments upon it than if it were absolutely pure.'' The author also speculated about the possible atomic-scale mechanisms by which heating improved the cohesiveness of gold foil.

Amalgams are alloys of mercury. Dental amalgam, an alloy of silver and tin and sometimes other metals with mercury, was first introduced as an alternative to gold foil fillings in the 1820s, but its use was not accepted into dental practice until much later. Amalgam is prepared by mixing fine particles of silver/tin alloy with liquid mercury at room temperature. This pasty mixture is quickly inserted into the cavity where it then hardens rapidly.

Many nineteenth-century dentists were concerned that mercury might leach from an amalgam filling over time and cause poisoning. The earliest practitioners to use dental amalgam were written off as quacks by the dental profession, partly because the technique was taken up by itinerant charlatans who sometimes prepared the material by scraping shavings from coins. Improperly prepared amalgam generally led to a high frequency of failure. If the composition and preparation of the alloy were not carefully controlled, the resulting filling might swell upon setting and cause extreme postoperative pain.

The controversy over the use of amalgam among the members of the American Society of Dental Surgeons became so intense that the society actually divided and disbanded in the 1850s. Up to that time, opinions on the matter were formed solely on the basis of each clinician's own personal experience. Finally, starting in the 1870s, systematic laboratory investigations were begun on the effectiveness of amalgam. In 1873, Ambrose Lawrence of Boston began using small iron tubes as simulated cavities and filled them with amalgam, then tested the strength of these fillings by applying pressure with a pump. He demonstrated that moisture in the cavity could lead to leaky fillings. More systematic studies followed; and in 1895, G. V. Black of Illinois published a pivotal work on the preparation and efficacy of dental amalgam. By the early 20th century its use was accepted as part of standard dental practice.

However, commercially available alloy powders were uneven in quality. The exact composition and properties of the material varied tremendously from one brand to the next, and from one batch to another even from the same producer. After World War I, dentists from the U.S. Army Dental Corps appealed to scientists at the National Bureau of Standards (NBS) for help in writing a bid request for amalgam that would be based on standard physical property measurements.

Wilmer Souder, a physicist from the NBS Section on Thermal Expansion, took up the problem. Using interferometry to measure small changes in physical dimensions, Souder established that amalgam of different compositions differed significantly in expansion upon setting, compressive strength, and flow characteristics. He also measured the thermal expansion of amalgam and of teeth for temperatures normally enountered in the mouth; if the thermal expansion is not well matched between tooth and filling, stresses can build up when heat or cold is applied, possibly causing the filling to leak or fail. This work led to formulation of federal standards for amalgam alloy powders that were later expanded and adopted by the American Dental Association.

In the 1940s, dental researchers at NBS discovered that the common practice of mixing amalgam in the bare palm of the practitioner's hand was responsible for much of the difficulty with excessive expansion of amalgam fillings after setting. Water and salt absorbed from the skin reacted with zinc, which was a common addition to amalgam alloys. The water decomposed into hydrogen, which was entrapped and caused swelling, and oxygen, which produced severe corrosion of the metal. Immediately after the publication of this finding, dentists were directed to wear rubber gloves when preparing amalgam. This measure not only improved the quality of amalgam fillings but also served to reduce dentists' exposure to poisonous liquid mercury.

Dental amalgam is still used for the majority of fillings, particularly for use in back teeth, where amalgam's superior strength and durability are needed, and where they are less visible. Composite materials are commonly used for fillings in front teeth and are cosmetically superior but are not as durable as metals. In the 1960s, workers at NBS invented an amalgam which required a significantly lower mercury content. The powder particles of this so-called "spherical alloy" are round, and are produced by atomizing the molten metal into droplets which are quickly cooled. Most recently, research has begun on the development of metal alloy powders that can be made into fillings without mercury or any other liquid sintering agent. The powder particles are washed in acid to remove any oxide layer, inserted in the cavity, and then cold-welded by compression alone just like the gold foil that amalgams have replaced.

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FOR FURTHER READING: G.C. Paffenbarger, J.A. Tesk, and W.M. Brown, *Journal of the American Dental Association* **111**, (1985) p. 83; R.W. McCluggage,``A History of the American Dental Association: A Century of Health Service,'' (American Dental Association, Chicago, 1959); and R. W. Phillips,``Science of Dental Materials,'' (W.B. Saunders Co., Philadelphia, 1982).

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