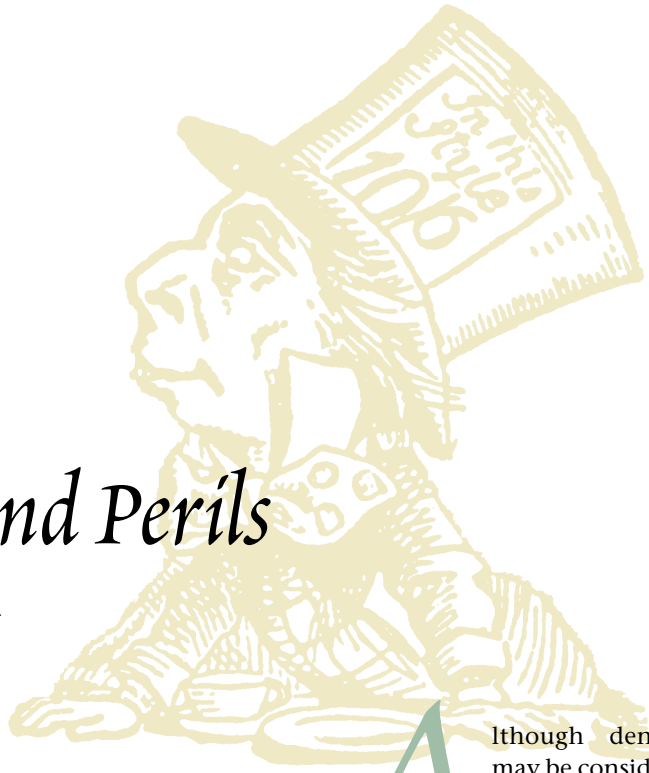

AMALGAM: *Its History and Perils*

J.M. Hyson, Jr., DDS, MS, MA

Abstract

The current amalgam issue is not new. In the 1840s, there was even an "amalgam war" between the dentists who advocated the use of gold as a restorative material and those who used silver amalgam as a filling material. There were complaints of the ill effects of mercury in the amalgam as a health problem. The split on this issue threatened to divide dentistry into two camps: those who used amalgam and those who condemned it. The first national dental society in the United States, the American Society of Dental Surgeons, had to disband because of the controversy. There was even a "New Departure" movement in the 1880s to eliminate gold as a restorative material in badly broken down teeth, which could be more readily salvaged by the use of material that did not require the force of condensation needed to pack a gold foil, then considered the ultimate restorative material. However, amalgam has proven to be an excellent restorative material with few side effects — amalgam saves teeth.

Although dental amalgam may be considered a relatively new material, compared to gold, in the dental armamentarium, it appeared in the Chinese materia medica of Su Kung back in 659 A.D. during the Tang Dynasty. In Europe, Johannes Stockerus, a municipal physician in Ulm, Germany, recommended amalgam as a filling material in 1528.[1]

Mercury, one of the key ingredients of dental amalgam, had first been described by Aristotle in 4th century B.C. as "liquid silver." Five centuries later, Dioscorides, a Greek physician, used it as an eye medicine, but warned it was dangerous if swallowed. In the 18th century, John Hill, an Englishman, described mercury as, "It penetrates the substance of all metals, and dissolves, and makes them brittle." Workers in the felt hat industry dipped furs into a mercuric nitrate solution to make them pliable, and in the process inhaled the mercury vapor. This process resulted in "tremors, loss of teeth, difficulty on walking, and mental disability." The mad hatter of Lewis Carroll's *Alice's Adventures in Wonderland* (**Figure 1**) was probably patterned after such a victim.[2]

In 1805, W.H. Pepys and Joseph Fox of England first introduced "fusible

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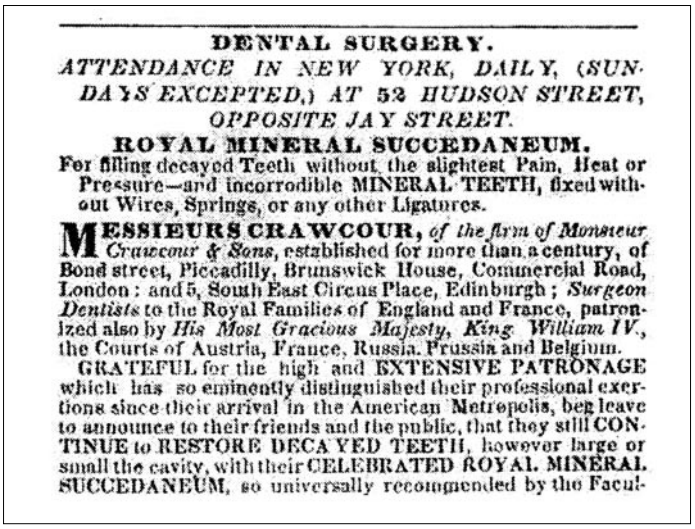
Figure 1. Mad Hatter from *Alice's Adventures in Wonderland* by Lewis Carroll (*courtesy of Bramhall House, Division of Clarkson N. Potter, Inc., N.Y.).*



DENTAL SURGERY.

ATTENDANCE IN NEW YORK, DAILY, (SUNDAYS EXCEPTED,) AT 52 HUDSON STREET, OPPOSITE JAY STREET.

ROYAL MINERAL SUCCEDANEUM.

For filling decayed Teeth without the slightest Pain, Heat or Pressure—and incorrodible MINERAL TEETH, fixed without Wires, Springs, or any other Ligatures.

MESSIEURS CRAWCOUR, *of the firm of Monsieur Crawcour & Sons*, established for more than a century, of Bond street, Piccadilly, Brunswick House, Commercial Road, London: and 5, South East Circus Place, Edinburgh; *Surgeon Dentists* to the Royal Families of England and France, patronized also by *His Most Gracious Majesty, King William IV.*, the Courts of Austria, France, Russia, Prussia and Belgium.

GRATEFUL for the high and EXTENSIVE PATRONAGE which has so eminently distinguished their professional exertions since their arrival in the American Metropolis, beg leave to announce to their friends and the public, that they still CONTINUE to RESTORE DECAYED TEETH, however large or small the cavity, with their CELEBRATED ROYAL MINERAL SUCCEDANEUM, so universally recommended by the Facul-

Figure 2. Crawcour's advertisement *(courtesy of the Samuel D. Harris National Museum of Dentistry).*

metals" for filling cavities; however, the heat required to melt the material was obviously objectionable. In 1818, Louis Nicolas Regnart, a Parisian physician who devoted himself to dentistry, overcame this problem by the addition of one-tenth by weight of mercury; and, in this manner, amalgam (an alloy of mercury with another metal or metals, from the French word amalgame, reportedly derived from the Latin malagma, meaning a "soft mass") was invented. In 1826, Auguste Taveau of Paris used a "silver paste" made from filings of five French franc pieces mixed with mercury. The silver coins also contained tin and a small amount of copper, which gave the mixture more plasticity and a quicker setting time. In 1837, J.L. Murphy of London stated he had used amalgam for 12 years.[3]

The Crawcour Brothers: Royal Mineral Succedaneum

The Crawcours were a family of five Polish dentists who acquired a "superficial knowledge" of dentistry in France before unleashing themselves on the English public in the 1780s. They advertised extensively, proclaiming their skill and claimed to be surgeon-dentists to the "royal family and patronized by the courts of Austria, France, Russia, Prussia, and Belgium."[4] In 1833, two of the Crawcour brothers invaded the United States with a cheap coin silver amalgam they called "royal mineral succedaneum" (**Figure 2**). The Crawcours set up lavish and elegant dental "parlours" in New York City and competed with the ethical dentists. With the "grace and mannerisms of the French," they catered to the wealthy and influential residents of the city. The patients reclined on sumptuous easy chairs, and their dentistry was painless since they merely sloped and thumbed a soft plastic mix of their impure material into cavities without removing the decay. They were out-and-out money-grabbing charlatans who exploited the public, charging exorbitant fees. As the Crawcours' business boomed, the conscientious practitioners, who were still working with gold and tin, lost patients. Later, as the brothers' fillings began to fall out, discolor the teeth, and cause tooth fracture because of the cheap amalgam's expansion, the public realized it had been cheated. With that, the brothers beat a hasty retreat in 1834 back to Europe, leaving "a long trail of victimized patients and exasperated dentists."[1] However, the damage had been done — amalgam now had a bad reputation, despite the fact that if used properly, it would later prove to be an excellent restorative material.[5]

The Amalgam War: 1841-1855

The so-called "Amalgam War" raged from 1840 to 1855, "broke up friendships and, even threatened to disrupt the profession."[1] In 1841, the American Society of Dental Surgeons, which had been founded the year before as the first national dental society in the United States (it gave the first honorary doctor of dental surgery degree), appointed a committee to study the amalgam problem. The committee, consisting of Drs. Eleazar Parmly, Elisha Baker, Solyman Brown, Chapin A. Harris, and Jahiel Parmly, reported that all filling materials, in which mercury was an ingredient, were "hurtful both to the teeth and every part of the mouth, and that there was no tooth in which caries in it could be arrested, and the organ rendered serviceable by being filled, in which gold could not be employed."[6] Two years later, without even testing silver amalgam, their derogatory report resulted in the society's blanket state-

ment that "the use of amalgam constitutes malpractice."[2] On the other hand, Dr. Christopher S. Brewster of Paris thought that to condemn the use of amalgam in all cases merely because its use was abused by some "unprincipled quacks" was unwise. He felt that "much good has been and may be done by a judicious use of this composition."[7] In 1842, Harris warned that there were few cases in which the "filling of teeth with an amalgam of mercury and silver, is justifiable." He believed that amalgam exerted "a vitiating influence upon the fluids of the mouth and given rise to an unhealthy action in the gums."[8]

The same year, a case of "ptyalism" following the insertion of amalgam filling in several large cavities was reported. The patient's gums began to "inflame and swell," followed by an "increased flow of saliva, inflammation of the mucous membrane," "soreness and loosening" of the teeth, and "fetor of the breath, anorexy, and all the other symptoms attendant upon a mercurial diathesis of the system."[9] On 1844, Dr. Amos Westcott of Syracuse, N.Y., published a lengthy report on amalgam for the *American Journal of Dental Science*. He stated that "salivation" was a common complaint, the "oxyd" formed on the outer surface of the fillings was "easily carried into the stomach," and that amalgam was "destructive to gold fillings and plate." He concluded that the bad effects of mercury precluded its use by the dental practitioner in all cases.[10] In 1844, Parmly of New York stated that "gold is the only substance known that can be permanently relied upon."[11] Even in 1844, some dentists advocated removing amalgam fillings and replacing them with gold. Dr. S. M. Shepherd of Petersburg, Va., reported finding decay under one patient's amalgam fillings and even though there were no symptoms, he replaced them with gold.[12]

In 1844, the society's members were warned that they were to sign a pledge never to use amalgam or they would risk being expelled from the membership. Many members resigned; and by 1847, only five of New York's 200 dentists remained in the society, which Dr. Charles C. Allen said had "gold" for its motto.[3]

Another incident in 1847 cast an unfavorable light on amalgam with the death of a Massachusetts man, a Mr. Ames, reportedly, according to the newspapers, "killed by bad dentistry." In 1840, Ames was reported by his Parisian physicians as "thoroughly salivated, and without doubt from the

Figure 3. J. Foster Flagg *(courtesy of the American Dental Association).*

cement in his teeth." Before his death later in 1847, his American physicians disclaimed amalgam's role (it had been removed earlier) by stating that it had "no agency in causing his disease."[13]

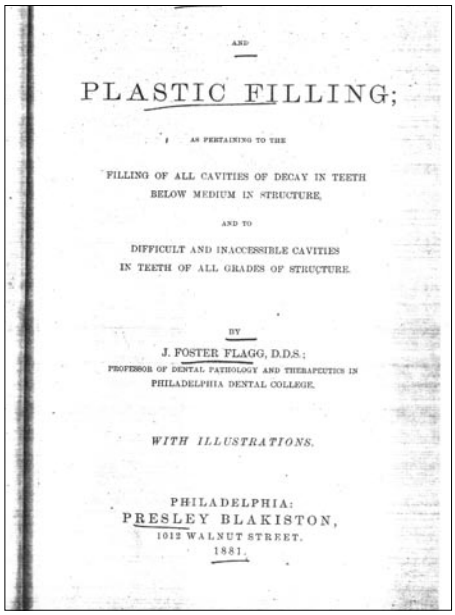
Many dentists felt that the mercury in amalgam was a poison capable of "producing grave and lasting disturbances of health."[14] On the other hand, Dr. Elisha Townsend reported in 1855 that two amalgam fillings he had inserted in 1834 were still "as good as when filled." Although he did not think it would ever supersede gold, he felt that some cases it was in the best interest of the patient to save the tooth using amalgam rather than gold, which required "heavy pressure for consolidation." Townsend even gave his personal directions for preparing the amalgam, known as "Townsend's Amalgam."[15] In a special meeting of the Pennsylvania Association of Dental Surgeons held in October 1855, Townsend, the association's president, reiterated his views on amalgam that "a plastic material" was invaluable. He stated, "I am not a prodigy, and I do often see teeth my patient will thank me for saving, even if for a few months, which I have not the skill to fill with gold."[16] Townsend said that he had seen hundreds of amalgam fillings and had never seen "any injurious systemic effect."[17] In 1858, Townsend reversed his stance on amalgam and recommended removal of teeth that could not be saved by gold.[18]

The same year, a case of amalgam fillings being blamed for "an affliction of the eyes" was reported in the *American Dental Review*. The patient's vision cleared up upon the removal of two silver fillings.[19] In addition, amalgam was blamed for a patient's tendency to catch cold, an "eczematous" facial eruption, and facial neuralgia.[20] However, so much bitterness was created over the amalgam issue that eventually the society rescinded the amalgam pledge, but the damage had been done, and the organization folded in 1856, all because of the amalgam controversy.[3]

J. Foster Flagg: Amalgam Advocate

In 1855, Dr. J. Foster Flagg (1828-1903), professor of dental pathology and therapeutics at the Philadelphia College of Dental Surgery (**Figure 3**), began testing different amalgam formulas for posterior restorations. Flagg modified the popular formula of 60 percent tin to 40 percent silver by reversing it to 60 percent silver and 40 percent tin, and added combinations of other metals, e.g. copper, zinc, antimony, gold, cadmium, and platinum.[11,21] In 1861, he presented his findings to the Pennsylvania Association of Dental Surgeons. In 1881, he published his book, *Plastic and Plastic Fillings* (**Figure 4**), as amalgam fillings were then popularly referred to as "plastic fillings." The inevitable result of this affair was that silver amalgam was proven to be "an excellent filling material" and expanded dentistry's "ability to save teeth."[2]

Meanwhile, in 1859, M. Gershrine developed a new copper amalgam, which was rendered soft by heating to about 675 degrees, then triturating in an iron mortar, and heated to 225 degrees until it became soft.[22] Although copper amalgam was used up until the



AND

PLASTIC FILLING;

AS PERTAINING TO THE

FILLING OF ALL CAVITIES OF DECAY IN TEETH BELOW MEDIUM IN STRUCTURE,

AND TO

DIFFICULT AND INACCESSIBLE CAVITIES IN TEETH OF ALL GRADES OF STRUCTURE.

BY

J. FOSTER FLAGG, D.D.S.;

PROFESSOR OF DENTAL PATHOLOGY AND THERAPEUTICS IN PHILADELPHIA DENTAL COLLEGE.

WITH ILLUSTRATIONS.

PHILADELPHIA:
PRESLEY BLAKISTON,
1012 WALNUT STREET.
1881.

Figure 4. *Plastics and Plastic Fillings* (1881) by J. Foster Flagg *(courtesy of the Dr. Samuel D. Harris National Museum of Dentistry).*

1950s for pediatric restorations, by the 1970s, dentists were advised to avoid heating it.[23]

Amalgam in the 1860s: St. Louis Odontological Society

During the American Civil War, the debate on the merits of amalgam continued. In 1861, Dr. John Tomes and his son, Charles, in England studied and conducted important experiments testing the expansion and contraction of the various amalgam products.[24] In April 1861, at the meeting of the Pennsylvania Association of Dental Surgeons, the subject of "amalgam" was the first topic on the agenda. It was argued that "the fault was not in the material but in the manipulation." Flagg stated that "the mission of the true dentist is not merely to be able to put in a solid gold filling, regardless of consequences, but to operate in such a manner as would best subserve the interest of the patient." He did not use amalgam in anterior teeth as he believed "the preservation of their beauty" was as essential as preserving

them for mastication. Flagg also noted that his friend, Dr. James E. Garretson (father of oral surgery), had suggested adding zinc chloride to the mixture and then washing with water.[25] At the Brooklyn Dental Association's meeting in October 1864, it was recorded: "Some men's amalgam is good universally, and some men's gold is bad universally; the difference lies in the preparation of the tooth and in the plug (filling)"; however, the "slovenly manner of preparing and using the material" was condemned in unqualified terms.[26] Many amalgam failures were blamed on them having been "put in over the decay."[27] Then too was the fact that the medical profession was against the use of mercury in restorations.[28] Finally, as early as 1867, the St. Louis Odontological Society unanimously adopted a resolution to the effect that amalgam was "injurious and detrimental to health" and that its members would discontinue its use.[29] The same year, a 15-year-old girl, who suffered from "inflamed eyes," had three teeth filled with amalgam extracted on the orders of her oculist, "They must come out." However, the disease was neither "palliated nor cured."[30]

Amalgam in the 1870s: "The New Departure"

In August 1871, at the 11th annual meeting of the American Dental Association held at Niagara Falls, N.Y., Dr. E.A. Bogue gave a report on operative dentistry, which discussed the expansion and contraction of amalgam. Bogue urged the dental profession to know the composition of any remedies it employed, whether it be "patent medicine or amalgam fillings."[31] The same year, the mercury in amalgam was blamed for causing a "rash breaking out" on a patient's face when she ate oysters.[32] The following year, 1872, an amalgam filling was reported as the cause of death of a Nebraska middle-aged man. His physicians thought, "The filling had salivated the unfortunate man, and as the inside of his mouth, throat and windpipe swelled, respiration was hindered, and it finally ceased altogether."[33]

Since the involved tooth was a mandibular second molar, it is more likely that the patient died from diffuse submaxillary cellulites or as it is more popularly called, "Ludwig's Angina," rather than mercury poisoning.[34] Another case of "pytalism" causing headache, fever, rapid pulse, metallic taste, loss of appetite, and generalized malaise was reported in 1872 in a female patient following the insertion of eight amalgam fillings. However, the examining dentist said that the fillings had washed away, and that upon probing, the metal crumbled away into fragments. He removed them all with an explorer in three minutes; therefore, the workmanship was shoddy and could have explained the patient's symptoms.[35]

One of the most frequently asked questions was whether amalgam should be washed and dried before insertion into the cavity.

One of the earliest dentists to speak out against the use of amalgam in 1874, and probably the most radical, was Dr. J. Payne, who claimed the dental profession was poisoning "thousands of people all over the world from corrosive sublimate generated in the mouth from amalgam plugs in the teeth." He claimed the "quick-silver in the plugs is driven off by the heat in the mouth in very minute particles, and, combining with the chlorine in the fluids of the mouth, or any saline substance, such as our food, passed into the stomach, and produces slow poisoning." Payne wanted Congress to pass an act "making it a penitentiary offense to place any poisonous substance in teeth that will injure the people."[36]

In rebuttal, *Dental Cosmos* commented that although it was true that temperatures of 300 degrees to 400 degrees a combination of chlorine and volatilized mercury could produce corrosive sublimate, it was highly unlikely it happened in the mouth.[37] However, one dentist, W.R. Hayes of Dyersburg, Tenn., apparently took Payne's advice to heart and announced he was removing all the amalgam fillings in his patients' mouths and replacing them with gold. He thought the "golden gain" motivated the amalgam users.[38] One of the most frequently asked questions was whether amalgam should be washed and dried before insertion into the cavity. Dr. Thomas Burgh recommended washing it with soap and water, followed by plunging it into alcohol, and then expressing the excess mercury.[39] However in 1874, E.A. Bogue, MD, who had conducted experiments on amalgam, at a special meeting of the New York Odontological Society, stated, "It will be seen that, if almost any amalgam is used intelligently, teeth can be filled so as not only to preserve them, but to do so without danger to the general health, from any element of the filling, unless it be copper."[40]

In the late 1870s, a new trend called the "new departure" came into popularity, which signified "total abstinence from the use of gold."[41] Flagg was given credit for the creed because of a paper he read at the meeting of the Odontological Society of New York on Nov. 20, 1877.[42] The "new departure" considered gold the "worst material" and amalgam an "excellent filling material." Furthermore, "the use of 'plastic' filling material tends to lower that dentistry, which has for its standard of excellence 'ability' to make good gold fillings, but very much extends the sphere of usefulness of that dentistry, which has for its standard of excellence 'ability to save teeth'."[43] Dr. Henry S. Chase of St. Louis endorsed Flagg's conclusions that gutta-percha, tin, and amalgam fillings were superior to gold.[44]

However, there was still reluctance by some dentists to endorse amalgam as safe. In 1878, the *Canada Lancet* said,

Figure 5. Greene Vardiman Black *(courtesy of Mrs. Elizabeth Hubert Malott).*

"The constitutional effects of mercury are too well known to require mention, and there can be no good reason for its use at all aside from its facility of introduction. The introduction of so virulent a poison into the system, even in any form, renders it possible for it to be absorbed in the slow way above indicated, is radically wrong, and should not be ventured upon if the patient's welfare is to be considered."[45] This was very strong language for the time.

Amalgam in the 1880-90s: G.V. Black's Formula

In 1883, Dr. Alton H. Thompson commented before the Kansas State Dental Association, "The presence of amalgam with us is a tremendous fact which we must accept, and accepting, must study. It is a great factor in the dental economy of the day, which cannot be ignored, and we are utterly unable to prohibit its use, even were it as pernicious as some would have us believe … Amalgam saves more teeth in this country than gold, and is more generally useful."[46] In 1883, the *Independent Practitioner* reported the death of a Buffalo druggist from swallowing a "large amalgam filling"; however, an autopsy failed to show the filling.[47] The same year, amalgam fillings were blamed for deafness. Reportedly, the hearing improved after the restorations were replaced with gold.[48] In the dental profession, the general feeling was that the charges against amalgam "must be proven by its accusers"; "amalgam has the field."[49] Also, some dentists complained of "partial paralysis" caused by mixing amalgam in the palm of their hand. However, an 1887 article recommended never mixing the alloy in the hand because of the "film of dermal secretions that will be spread over the surface of the mercury." The mix should be made in a "clean rubber or vitrified mortar with a rubber or glass pestle," and compressed on a "piece of washed and dried buckskin."[50] One dentist said he developed a "dull pain extending from the fingers to the shoulder."[51] Despite the research on amalgam, it was not until 1895 that Dr. Greene V. Black (**Figure 5**) laid the foundation for a "scientifically balanced alloy." His formula of silver and tin would "neither shrink nor expand in setting" at ordinary room temperature, and did not discolor.[21] He also found that copper (as much as 5 percent) was beneficial. After Black reported his work in 1895-1896, several dental manufactures sent representatives to his laboratory for instructions in making alloy.[52]

The Homeopaths: The First Anti-Amalgamists

In 1899, James Youngs Tuthill, MD, of Brooklyn, N.Y., read a paper titled, "Mercurial Necrosis Resulting from Amalgam Fillings," at the Medical Society of Kings County. He blamed amalgam fillings for mercurial poisoning, which affected the "nerve centers, impairs locomotion by heaviness of limb and stiffness of joint, gives rise to obstinate diseases of the skin, and makes a mental wreck of its victim."[53] He cited his own personal experience and five cases he treated, all benefiting from the removal of their amalgam fillings. However, when the paper was discussed, the dentists present, Drs. R. C. Brewster, E.A. Bogue, E.H. Babcock, and A.C. Brush, all challenged his findings. They felt that amalgam made a good restorative material from which "no mercury can be removed so long as it remains in the mouth."[48] The same year, Richard Grady, MD, DDS, also refuted Tuthill's premise at the meeting of the Maryland State Dental Association. He hoped to "call attention to and record a protest against the views promulgated, in the hope of preventing serious consequences which may follow such teachings."[54] It seems the homoeopathic physicians were the main opponents of amalgam by claiming the absorbed mercury threw the "system out of balance" and caused "derangement of the spleen, stomach, liver, kidneys, nerves, mucous membranes, the skin, etc."[55] Black reported that at the time of the Civil War, "A little quarrel occurred between dentists in St. Louis regarding the use of amalgam, and very promptly a homeopathic physician took the matter up, and made the contention that the mercury in the amalgam used in filling teeth had a deleterious action upon the system, and that passed into pretty much all the books of the homeopathic creed. Ever since, the homeopaths have objected to the use of amalgam as fillings, notwithstanding the wide observation of dentists that persons with amalgam fillings in their teeth, are just as healthy as any other persons."[56]

Amalgam in the 1900s was recognized as the "great tooth saver" in the hands of the average operator.[57] In 1908, Dr. E. Bumgardner of Lawrence, Kan., in a paper before the Kansas State Dental Association, stated, "I think that amal-

gam is the best filling material in the world for the place in which it should be put: In a cavity that is properly selected and properly prepared, when the amalgam is properly mixed with a proper alloy, and properly inserted, you have the best filling material in the world."[58]

Amalgam in the 1920s: Professor Alfred Stock

The 1920s began with the report of an incident in the dental literature of an amalgam filling becoming lodged in the lungs and being successfully removed by bronchoscopy.[59]

In 1926, a report came from Germany of Alfred Stock, professor, at the Kaiser Wilhelm Institute of Chemistry, who contracted a chronic case of mercurial poisoning from working in a laboratory for 25 years. The air in the lab "contained from 0.001 to 0.01 mg of mercury to 1 cubic meter of air." The professor recommended removal of amalgam fillings if "neurasthenic or catarrhal conditions develop for which the physician can find no cause."[60] In rebuttal, Dr. F. Flury stated that mercury poisoning was not possible with the "complex mixtures" currently used.[61] Finally in 1931, in response to reports of mercury poisoning in primarily foreign medical literature, the National Bureau of Standards in Washington, D.C., conducted tests on amalgam, which concluded that the "claims for mercury poisoning, either as a vapor or as a solution from the standard amalgams passing into the body through the air or food taken into the mouth, are not justified."[62] The same year the ADA adopted specifications for the purity of mercury, ADA Specification No. 6.[63]

Amalgam: Mercury Allergy

Reports of true allergy to mercury are scarce in the dental literature; the earliest reports of mercury stomatitis in the 1930s resulting from the use of mercurials in the treatment of syphilis, in which the teeth become "blackened, fragile, blunt and eroded."[64] Patients were advised to use sodium bicarbonate as a dentifrice on a soft toothbrush.[65] As the use of heavy metal therapy has been replaced by the antibiotics, references in the literature have been confined to occupational contact with mercury.[66] However, in 1943, Dr. Bass, a New York pediatrician, reported two cases of "idiosyncrasy" to amalgam fillings in children, and Markow reported a case of mercury allergy in a 41-year-old nurse.[67,68] The same year, a case of mercurial poisoning was reported in a man who had been prescribed calo-

mel (mercurous chloride) by his physician for "trench mouth" after a severe cold.[69] In 1951, a case of true allergy to mercury was reported in the *Journal of the American Dental Association*. A 4-year-old girl developed allergic symptoms on two occasions following insertion of amalgam fillings. A patch test was positive for mercury alone, but not amalgam.[70] Johnson et al. reported the case of a 32-year-old veteran treated at the Dermatological Service, Crile VA Hospital, for sensitivity to his amalgam fillings. A patch test confirmed the diagnosis, and the six teeth with amalgam fillings were extracted.[71] In 1962, the *British Dental Journal* reported a case of mercury allergy in a 33-year-old woman in Stockholm.[72] In 1963, Engelman reported a case of a 27-year-old woman who had been allergic to mercury since the age of 2.

Two amalgam restorations were placed and the patient developed a "generalized, weeping vesicular eruption, accompanied by an itching sensation," which was relieved by an antihistaminic. A patch test confirmed the mercury allergy.[65] In 1969, Frykholm et al. first reported a link between amalgam and lichen planus. A 45-year-old Scandinavian woman had developed the disease on her oral mucosa and tongue. Allergy to the copper in her amalgam fillings was demonstrated by positive skin tests. The replacement of her fillings with copper-free materials resulted in a cure.[73] Silver was even blamed for an allergic reaction in a 52-year old female patient.[74] Wright, in 1971, reported a case of a positive mercury allergy in a 9-year-old girl. She had been sensitized to mercury at the age of 13 months by an ointment applied to her lower lip.[75] The *British Dental Journal* reported a case in 1982 of a Greek Cypriot who had a positive reaction to amalgam powder when tested. Twenty years earlier, after the insertion of amalgam fillings, he had immediately developed "swollen itching fingers and lips." The next day, the fillings were removed and the problem resolved.[76] In 1983, the ADA reiterated its stance that there was "no reason to remove amalgam restorations from a patient or prohibit the use of dental amalgam in restorative dentistry except in those cases of proved sensitivity of the patient to mercury."[77] However, true allergy is rare and may spring from the "unfounded fear that the amalgam may be poisonous."[78]

Amalgam in the 1960-70s: Mercury Vapor

As early as 1935, McGeorge, in his article on mercurial stomatitis, mentioned that mercury may be inhaled "in the form of mercury vapor."[79] Giese warned dentists in 1948 that mercury vapor was toxic and that famous scientists, such as Michael Faraday and Blaise Pascal, were victims of "chronic mercury poisoning."[80] Grossman and Dannenberg in 1949 published their study on mercury vapor in dental offices and laboratories, using a portable General Electric mercury-vapor detector of the instantaneous type. They studied 50 dental offices and concluded that the concentrations of mercury were not toxic to dental personnel; however, they were directly proportional to the "amount of mercury used by the individual dentist."[81]

Giese warned dentists in 1948 that mercury vapor was toxic and that famous scientists, such as Michael Faraday and Blaise Pascal, were victims of "chronic mercury poisoning."

In 1960, air analyses were conducted in the Helsinki dental school to evaluate the mercury vapor content during the mixing of amalgam. The mercury values were considered below what is a safe margin for dental personnel. The investigators recommended adequate size rooms and proper ventilation.[82] In 1962, Krykholm and, in 1963, Knapp warned that when the concentration of mercury in the air in the dental office exceeded 1:100,000,000, it could pose a health hazard to the dental staff.[83] Griffith in 1963 reviewed the literature and concluded that the amount of mercury exposure to dental personnel was "not expected to cause any detectable harm at any time during life."[84] Joselow et al. in their 1968 study of dental offices showed 14 percent had mercury concentrations in excess of what was considered "good hygienic practice." Absorption of mercury was evidenced by higher than normal urinary mercury levels.[85] However, the 1960s ended with the death of a 42-year-old dental assistant with a 20-year history of exposure to mercury in England. She had developed a "rapidly fatal nephritic syndrome," from mulling amalgam in the palm of her hand.[86]

The concern about mercury vapor extended into the 1970s when squeeze cloths were still being used to express the excess mercury. Then, too, the 1970 Occupational Safety and Health Act created a legal responsibility for the employer-dentist to protect their employees.[87]

In 1970, Gronka and his associates found mercury contamination in one in seven dental offices.[88] In 1973, Lenihan, Smith, and Harvey surveyed 62 dental practices for mercury hazards. They studied the mercury levels in head and body hair, fingernails and toenails from 183 dentists, dental assistants, and office managers. They concluded that although there was "no evidence that the amount of mercury absorbed is harmful to the patient, there should be "monitoring programmes to assess individual contamination by mercury" for the dental staff.[89] The American Conference of Governmental Industrial Hygienists recommended a mercury threshold limit of 50 µg/m for a 40-hour workweek.[90]

Finally, in 1973, the ADA House of Delegates adopted a resolution on the biological levels of mercury for the dental team. The guidelines were published in February 1974.[91] Atmospheric mercury is

the primary concern for the dental team. There were many reasons for undetected mercury lying in the dental suite: loose fitting amalgam capsules, accidental spillage, and inhalation of amalgam particles during removal of an old restoration. The ADA recommended personal monitoring of team members rather than area monitoring.[92] In addition, the council recommended periodic urine analysis by the Hatch and Ott flameless atomic absorption procedure.[93] Mercury accumulation in the central nervous system interferes with nerve conduction by "tampering with electric potential across the nerve cell membranes." The symptoms include a psychic aberration known as erthism, which manifests itself as "self-consciousness, embarrassment without justification, disproportionate anxiety, indecision, poor concentration, depression, irrational resentment of criticism, and irritability."

Tremors of the hands can occur along with a brownish-yellow discoloration of the eye lens. Severe cases affect the oral cavity with inflamed and edematous gingival, bleeding gums, and a blue line at the gingival margin. At the terminal stage, the teeth may loosen.[94] Historically, it was known that hatters in England who used mercury in the felt hat industry developed mental instability and tremors; thus the expression "mad as a hatter."[95]

In 1974, the Department of Health Science, California State University, and the Occupational Health Section, California State Department of Health, reported on an environmental survey of 19 dental offices with 284 dental personnel for mercury vapor. They recommended education on handling mercury for all personnel, proper storage of mercury, proper disposal of waste mercury and amalgam, use of rubber dam for amalgam fillings, suitable amalgam waste traps on cuspidors, proper ventilation in the operatory, wearing oral-nasal dust masks when removing amalgam fillings, vinyl floor covering in operatories rather than carpeting, scrubbing with soap and water after contact with amalgam products, and periodic urine testing for those handling mercury and amalgam. They concluded that "environmental contamination of dental offices by mercury does not seem to pose an acute health hazard for personnel." However, "dental assistants who handle mercury have the greatest risk of absorption of mercury vapor."[96] Johnson pointed out that "dentists have a moral and legal responsibility to protect themselves and their employees from high amounts of mercury vapor in the dental office."[97]

Mercury accumulation in the central nervous system interferes with nerve conduction by "tampering with electric potential across the nerve cell membranes."

The U.S. Navy Dental Corps in 1973 investigated the use of a Harold Kruger (Model 24) mercury vapor meter to measure the mercury vapor generated at the evacuation system exhaust, the amalgam preparation cabinet, and the floor of seven operatories at the regional dental center in Norfolk, Va. They recommended a "vigorous program of mercury control, as well as a continuing education program for the hygienic handling of mercury," and a commercial solution known as HgX, or "mercury X," to decontaminate scrap amalgam. In addition, they installed mercury vapor filters (MSA Mersorb cartridges) on the evacuation outlets.[98] The ADA's House of Delegates in 1975 directed the Council on Dental Materials and Devices to revise the standards for amalgamators, capsules, and proportioners to minimize mercury spillage.[99] To emphasize the importance of staff education, in 1976, the *British Dental Journal* reported a case of contamination of a dental operatory by a temporary assistant who spilled mercury in the operatory and did not report the accident to her employer.

Subsequently, the regular dental staff all developed symptoms of mercury poisoning. The dentist and his regular assistant experienced severe headaches, nausea, irritability, fatigue, and insomnia. They were treated with N-acetyl-D-penicillamine. Fortunately, there were no fatalities, although there was a prolonged recovery.[100] The same year, a dental office was vandalized and 20 pounds of mercury spilled. Vacuuming the heavily contaminated rugs exacerbated the problem and the carpeting had to be discarded.[101]

Battistone and his associates at the U.S. Army Institute of Dental Research tested the blood of 1,555 dentists for mercury levels and found the mean for all dentists was 8.2 ng Hg/ml blood (U.S. population 0 to 5 ng Hg/ml). In general, practitioners with high levels tended to "show practice characteristics that were conducive to these higher levels. They concluded that dentists in the United States, as a group, "practice good mercury hygiene."[102] Hefferren, in 1976, recommended hair analyses as a means to measure mercury exposure by the dentist and his staff.[103]

In 1977, the Commission on Dental Materials, Instruments, Equipment and Therapeutics chaired by Dr. J.W. Sanford published its recommendations for handling mercury products. Ten percent of all dental offices in the United States, Canada, and England had air levels of mercury vapor in excess of 0.05 mg/m. Although neither a dentist nor an assistant had suffered from "chronic mercurialism," there was cause for concern.[104] In 1978, the ADA Council on Dental Materials and Devices issued new guidelines for mercury hygiene.

Basically they were the same as the 1974 rules, with the addition of the avoidance of ultrasonic amalgam condensers, use of "water spray and high volume evacuation," and use of a face

mask.[105] However, Roydhouse, professor of restorative dentistry at the University of British Colombia, still felt that "most mercury contamination is needless and a sign of poor occupational hygiene."[106]

Carpeting also came under criticism again in 1981; however, Kantor and Woodcock's survey of 1,064 rooms in 528 North Carolina dental offices showed "no difference in ambient breathing zone concentrations of mercury vapor between offices with hard floors and offices with carpets." They recommended that the exposure limit for mercury vapor for dental personnel be reduced from 0.05 mg/cu m to 0.02 mg/cu m.[107] Yamanaka and his associates at the Tokyo Dental College in their 1981 survey of Japanese dental workers showed that dentists had "statistically higher mercury levels in hair and urine" than the control group. Occupational handling of mercury and eating fish was thought to be the causal factor. The dental assistant's hair mercury was not elevated, but their urinary mercury was higher than the control group. They recommended regular monitoring of hair and urine mercury.[108]

Another method recommended was the use of commercial monitors. Basically, there were two types: the palladium chloride film detector and the gold film detector.[109]

Despite the popularity of composites, it was estimated that 85 percent of posterior restorations inserted in the United States in 1984 were amalgams. Langan et al. found "no evidence in the scientific literature that the minute amounts of mercury vapor that may be released from amalgam restoration can cause mercury poisoning." However, they admitted the association between amalgam restorations and oral lichen planus "requires further investigation."[110] In 1984, the ADA Council on Dental Materials, Instruments, and Equipment issued new guidelines for mercury hygiene, which were much more detailed than the earlier recommendations. They recommended a well-ventilated operating room; monitoring for mercury vapor once a year or after a mercury spill; following the National Institute for Occupational Safety and Health's threshold limit for mercury of 50 µg/m, based on a eight-hour workday; periodic urinalyses for all dental staff; using single-use, precapsulated alloy; using water spray and high-volume evacuation when removing old amalgam; wearing a face mask to avoid breathing amalgam dust; storing amalgam scrap covered by a sulfide solution in tightly closed containers; avoiding direct handling of mercury or amalgam; and checking clothing for mercury before leaving the office.[111] In 1985, the ADA reported that the urinary mercury levels for 4,272 dentists who participated in their health assessment program (1975-1983) had a mean level of 14.2 µgm/l.[112]

The ADA estimated that each year, more than 100 million amalgam fillings were inserted in the United States, and that fewer than 50 cases of allergic reactions to mercury had been reported since 1905.

U.S. Air Force investigators even found that amalgam-contaminated instruments placed in a chemical vapor sterilizer contaminated the sterilizer. Paper sterilization bags were effective in containing mercury vapor and reduced it to zero, but once a sterilizer became contaminated; it could not be effectively decontaminated. Still, from 1989 to November 1990, eight episodes of mercury exposure in private homes or schools were reported to the Agency for Toxic Substances and Disease Registry. In one case, an individual was smelting dental amalgam in a casting furnace in his basement to recover the silver from the amalgam. Apparently, mercury fumes had entered the air ducts and circulated throughout the house.[113] Agocs studied the effects of paint companies using phenylmercuric acetate as a preservative to prolong the shelf life of interior latex paint. She tested 74 exposed people in recently painted homes and 28 control people in homes not painted, and found that "potentially hazardous exposure to mercury" had occurred among those in the painted homes at approximately 2½ times the Environmental Protection Agency's recommended limits.[114]

The Anti-Amalgamists: 1980-90s

The anti-amalgamists became active again in the 1980s, despite the lack of evidence. The National Institute of Dental Research issued a statement in 1984 that "health hazards of blood mercury levels associated with dental amalgams have not been documented … and there appears to be little correlation between (mercury) levels in urine, blood or hair, and toxic effects." The same year, the U.S. Public Health service stated that patients "should not seek replacement of amalgam fillings … based on a fear of harm." The ADA estimated that each year, more than 100 million amalgam fillings were inserted in the United States, and that fewer than 50 cases of allergic reactions to mercury had been reported since 1905. The National Multiple Sclerosis Society issued a strongly worded statement that amalgam had no cause or effect on the disease. Groups carrying the torch against amalgam were identified as Dental Amalgam Mercury Syndrome, and the Foundation for Toxic Free Dentistry.[115]

However, the main protagonist against amalgam seems to have been Dr. Hal A. Huggins, a Colorado dentist. In 1982, he published a paper, "Mercury: A Factor in Mental Disease." He blamed the "mercury leaching out" of dental amalgam fillings for affecting the "peripheral nervous system, immune system, and cardiovascular system."[116] All these charges were made

without scientific proof. Alexander A. Fisher, MD, in response to these charges, reiterated that dental amalgam presented "no known general health threats" to patients.[117]

In 1984, Miller and his associates at Baylor College of Dentistry conducted patch tests on 171 dental students for mercury sensitivity as they passed through the dental curriculum. They found "no significant increase in development of allergic reactions" although there apparently was a correlation between the number of alloy restorations and the incidence of positive reactions. Their conclusion was that mercury was not a "significant allergen for practicing dentists and their assistants."[118] Their results differed from the earlier (1976) study of White and Brandt, who concluded there was an increase in student hypersensitivity.[119] A 1985 survey of dentists and dental assistants (21,634 dentists and 21,202 assistants) for birth defects, conducted at Stanford University School of Medicine, found that the levels of mercury exposure commonly present in the dental environment apparently "do not influence the rate of spontaneous abortions or the number of children born with congenital abnormalities."

General dental practitioners as a group do have "blood mercury levels higher than those of the general population."[120] However, a Swedish 1986 necropsy study found large amounts of mercury in the pituitary glands of dentists. They concluded that patients with amalgam fillings may have increased levels of mercury in their pituitary glands and that "dentists should handle amalgam carefully."[121] However, in 1986, the ADA reaffirmed its position that amalgam did not "pose a health hazard to the nonallergic patient," and said that its removal from nonallergic patients for the "alleged purpose of removing toxic substances from the body, when such treatment is performed solely at the recommendation or suggestion of the dentist, is improper and unethical."[122]

The Debate Continues: 1990-2002

Haikel and his group at the Pasteur University in their study of the patient's exposure to mercury vapors in 1990 found that mercury vapor was released "during insertion, condensation, carving, and removal of amalgam." The mercury was measured in the intraoral air using atomic absorption spectrometry.[123] The same year, Clarkson reported

that acrodynia or mercury poisoning in young children was not caused by chewing on amalgam fillings.[124] One British wit even brought up the subject of the effect which "cremation of deceased people with amalgam restorations has on the ambient atmosphere near a crematorium."[125]

The "mercury scare" was highlighted by television network CBS in their 1990 *60 Minutes* show, which presented a "gaggle of less-than-credible patients … to testify to their miraculous recovery from a variety of specific or amorphous maladies." By contrast, the message *Consumer Reports* had conveyed to its readers back in 1986 was that "if a dentist wants to remove your fillings because they contain mercury, watch your wallet."[126] In 1991, the FDA dental devices panel concluded that "none of the data presented show a direct hazard to humans from dental amalgams."[127] The same year, Dr. L. Jackson Brown, acting director of Epidemiology and Disease Prevention Program, National Institute of Dental Research, National Institute of Health, Bethesda, Md., called the amalgam question "an issue serious enough to merit additional research."[128] Moreover, in 1991, Mortensen brought up the question of the safety of the composite restorations that are replacing amalgam. Do composite materials remain "unchanged in the hostile oral environment of physical and chemical attacks"; and are the dental professionals who inhale the "solvent-laden vapors" on a daily basis safe? Has our experience with composites been long enough to "presume safety?"[129] Eley and Cox also brought up the "long-term biocompatibility" of composites and their shorter clinical life, adding to both the cost and "progressive tooth destruction."[130]

In 1996, at a symposium held by the International Association for Dental Research (Continental European and Scandinavian Divisions) in Berlin, Germany, Ekstrand et al. concluded that "exposure to amalgam fillings does not cause serious health risks to large numbers of individuals in the general population and, consequently, removal of intact amalgam fillings is not indicated." Despite this statement, the Swedish government in 1995 banned the use of amalgam in all public health clinics for children, and recommended that it not be used in adults after 1997.[131] The same year, Sandborgh-Englund et al. in Sweden investigated kidney function in 10 subjects after exposure to mercury during dental treatment and found "no signs of renal toxicity in conjunction to and after mercury exposure from the removal of amalgam fillings."[132]

As a sign of the times, in 1999, some 86 million composite restorations were placed in the United States as contrasted to 71 million amalgam restorations.

On May 13, 1997, the NBC network aired a segment on *Dateline*, which provided a "very accurate and well-balanced review of the dental amalgam issue."[133] The same year, Eley reviewed the dental literature and noted that a pacifying layer of corrosive products is formed on amalgam fillings, which is disturbed by tooth brushing and chewing. The mercury released is in the form of vapor, which passes into the intraoral air or as mercury ions, which passes into the saliva and gastrointestinal tract (between 1 to 2 µg per day).[134] The ADA Council on Scientific Affairs adopted new recommendations for mercury hygiene in October 1998 to update the 1991 guidelines published by the former ADA Council on Dental Materials, Instruments and Equipment. Basically they were the same as the previous ones, but recommended recycling scrap amalgam according to state and federal laws, disposing of mercury-contaminated items in sealed bags, and removing professional clothing before leaving the workplace.[135] As far as scrap amalgam as a source of pollution in the United States, in 1992, batteries "accounted for 86 percent of discarded mercury and dental amalgam a mere 0.56 percent."[136]

As a sign of the times, in 1999, some 86 million composite restorations were placed in the United States as contrasted to 71 million amalgam restorations. The reasons were the improvements in composite materials and techniques, and the public demand for more esthetic, tooth-colored restorations.[137] In 2002, the Food and Drug Administration proposed to upgrade dental mercury from a Class I (low risk to patients) to a Class II medical device, which would require amalgam manufactures to list the special controls and regulations of manufacture of the product ingredients on their labels.[138]

Gottwald and associates, in their 2002 publication *Psychotherapy and Psychosomatics* found "no significant correlation between psychic distress and mercury burden." They concluded that "the theory that amalgam-related complaints are often an expression of underlying psychic problems seems to be more reasonable than the theory of mercury intoxication or the theory of an amalgam allergy."[139]

In December 2003, Dr. Frederick Eichmiller, director of the ADA Foundation's Paffenbarger Research Center, testified, "The overriding body of scientifically valid and peer-reviewed research supports only one conclusion: that amalgam is a safe, affordable, and durable material." He added that the major U.S. and international scientific and health organizations, including the national Institutes of Health, U.S. Public Health Service, Food and Drug Administration, Centers for Disease Control and Prevention and World Health Organization have all stated that "dental amalgam is a safe restorative material."[140]

Anti-Amalgam Bills: 2003

As a sign of the times by 2003, anti-amalgam groups had persuaded lawmakers in nine states (Arizona, Arkansas, California, Georgia, Illinois, Maine, Massachusetts, Oregon, and Washington) to introduce legislation to "restrict or eliminate the use of amalgam in dental restorations." Cathy Mudge of the California Dental Association stated, "Opponents of dental amalgam have not been successful in raising concerns about the safety of amalgam as a restorative material, so they appear to have changed their strategy and are attempting legislation that will make it more difficult for dentists to continue using amalgam. ... All this at the expense of so many patients who benefit from the durability, longevity and safety of dental amalgam."[141]

Rick Murray of the Arizona Dental Association emphasized the fact that the anti-amalgamists were "very clever in their tactic to blur the line between amalgam and mercury," using "amalgam as a synonym for mercury." As a consequence the lawmakers believe that "amalgam and mercury are one and the same."[142]

On Feb. 18, 2003, the New York Supreme Court dismissed two amalgam-related lawsuits against organized dentistry, stating the plaintiffs had "failed to show a 'cognizable cause of action." Originally, the suit had been filed in Syracuse, N.Y., by Shawn Khorrami, a Los Angeles attorney. The plaintiffs blamed the ADA, the New York Dental Association, and the Fifth District Dental Society for deceiving the "public about health risks allegedly associated with dental amalgam." Khorrami also filed similar suits in California and Maryland.[143]

Conclusion

Amalgam has served the dental profession for more than 150 years. Incidents of true allergy to mercury have been rare (only 41 cases have been reported since 1905), and attempts to link its usage with such diseases as multiple sclerosis and Alzheimer's have not been scientifically proven, although there may be some association between amalgam restorations and oral lichenoid lesions.[144,117] As recently as May 2005, the ADA endorsed amalgam as being safe for pregnant women.[145] Still, the anti-amalgamists persist in their efforts to discredit the dental profession and the ADA for supporting amalgam as an economical, long-lasting, tooth-saving, and effective restorative material. On the positive side, perhaps because of their efforts, more emphasis has been placed on mercury hygiene in the dental office. Where the story of amalgam will end remains for the future. CDA

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