A COMPREHENSIVE REVIEW OF THE TOXIC EFFECTS OF MERCURY IN DENTAL AMALGAM FILLINGS ON THE ENVIRONMENT AND HUMAN HEALTH

The International Academy of Oral Medicine and Toxicology

October 2020 Update

About the IAOMT:

Representing a network of over 1,000 dentists, physicians, and other health professionals in more than 30 countries, the International Academy of Oral Medicine and Toxicology (IAOMT) has been researching the risks of dental mercury since our non-profit organization was founded in 1984. Our members have been expert witnesses for government bodies and health agencies around the world. We are an accredited member of the United Nations Environment Programme (UNEP)'s Global Mercury Partnership and were involved in the negotiations leading to UNEP's Minamata Convention on Mercury.

Brief Overview of Mercury Used in Dentistry:

Millions of dentists around the world routinely use dental amalgam as a filling material in decayed teeth. Often referred to as "silver fillings," all dental amalgams actually consist of 45-55% metallic mercury.[1] Mercury is a neurotoxin that can cause harm to humans, especially children, pregnant women, and fetuses. Furthermore, the use of dental amalgam results in substantial quantities of toxic mercury released annually into the environment. Once in the environment, mercury pollution damages animals, plants, and the entire ecosystem, while creating "hotspots that last for centuries."[2]

Many people do not realize that all silver-colored dental fillings contain approximately 50% mercury.

According to the United States Environmental Protection Agency (EPA), there are currently over 1,000 tons of mercury in the mouths of Americans, which is more than half of all the mercury being used in the U.S. today.[3] While amalgams are currently used for 45% of all direct dental restorations worldwide,[4] articles published in the *Journal of the American Dental Association* have established that these mercury fillings are used on 51.0% of White/Caucasian Americans, on 53.4% of Black/African Americans, on 72.9% of American Indians/Alaska Natives/Asians/Pacific Islanders,[5] and on more than 75% of posterior restorations for new recruits to the U.S. Navy and Marines.[6]

Controversy has surrounded the use of mercury in dentistry since the 1800's, when the hazardous material was first widely introduced as a filling component. The American Society of Dental Surgeons, the predecessor to the American Dental Association (ADA), made its members pledge not to use mercury because of its known toxicity,[7] and in more recent years, government officials, scientists, dentists, consumers, and many others have raised serious concerns about the threats dental mercury poses to humans and to the environment at large.

In 2013, the United Nations Environment Programme (UNEP)'s Intercessional Negotiating Committee formalized a global, legally-binding mercury treaty, which has now been signed by over 100 countries, including the U.S. Part of UNEP's "Minamata Convention on Mercury" text includes initiatives with regards to dental mercury amalgam such as setting national objectives aimed at minimizing its use, promoting the use of cost-effective and clinically effective mercury-free alternatives for dental restoration, discouraging insurance policies that favor dental amalgam use over mercury-free dental restoration, and promoting the use of best environmental practices in dental facilities to reduce releases of mercury and its compounds to water and land.[8]

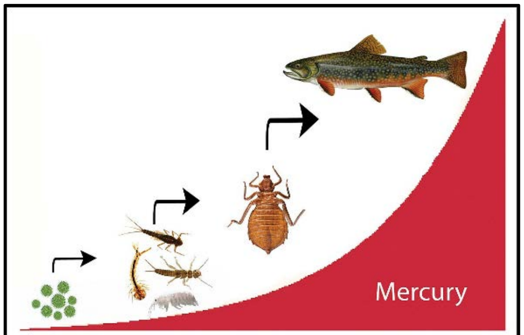
A number of countries have taken action against the use of dental mercury amalgam fillings. In Norway and Sweden, dental amalgam is no longer in use.[9] Bangladesh, the Czech Republic, Finland, Ireland, Nepal, and Slovakia are phasing it out.[10] [11] [12] Denmark uses dental amalgam for only 5% of restorations, and Germany for about 10%.[13] The government of Canada has recommended that dentists not use amalgam for children, pregnant women, and persons with kidney disorders.[14]

As part of the Minamata Convention on Mercury, the European Parliament voted in March 2017 to reduce dental mercury use. In addition to reporting "on the feasibility of a phase out of the use of dental amalgam in the long term, and preferably by 2030,"[15] the new European Union regulation qualifies that dental amalgam not be used for children under 15 years and pregnant or breastfeeding women.

Details in the U.S. Food and Drug Administration (FDA)'s public statements about dental amalgam on its website have changed over the years, including information about amalgam's potentially harmful impact on pregnant women, fetuses, and children under the age of six. However, finally, in September 2020, **the FDA advised that the following groups avoid getting dental amalgam whenever possible and appropriate: pregnant women and their developing fetuses; women who are planning to become pregnant; nursing women and their newborns and infants; children, especially those younger than six years of age; people with pre-existing neurological disease such as multiple sclerosis, Alzheimer's disease or Parkinson's disease; people with impaired kidney function; and people with known heightened sensitivity (allergy) to mercury or other components of dental amalgam.[16]**

Meanwhile, scientific studies continue to demonstrate that the mercury used in dentistry poses serious risks to all populations and to the environment.

Dental Amalgam Pollutes the Environment in a Variety of Ways:



This graphic from the National Park Service shows how mercury levels increase exponentially up the food web as larger species eat smaller ones and "bioaccumulate" the mercury. Most fish advisories, which warn people to limit or avoid eating certain types of fish, are due to dangerous mercury levels.

Some 340 tonnes of mercury is used per year in dentistry, of which about 70-100 tonnes (i.e. 20- 30%) likely enters the solid waste stream.[17]
--United Nations Environment Programme (UNEP), Global Mercury Assessment, 2013

1) Wastewater from Dental Offices

After mercury is released into the environment, it can contaminate the food web and harm wildlife in the area for multiple generations. According to the United States Geological Survey, in 2010, dental amalgam was the leading end-use sector of mercury in the U.S.[18] The use of mercury for dental amalgam in the U.S. has been estimated at 35.2 tons/year,[19] and the discharge per dentist is an average of 250 milligrams/day (for an equivalent of 12 tons collectively released to the environment each year).[20] For example, a 2002 New York Academy of Sciences report found over 40% of the mercury entering the New York/New Jersey harbor through wastewater was the result of discharges from dental offices.[21]

Additionally, in a 2014 document, the EPA recognized that "dental offices are the largest source of mercury discharges to POTWs [publicly-owned treatment works], contributing about half of the mercury received by POTWs."[22] This is dangerous because wastewater treatment facilities are designed to process human waste, not heavy metals. Thus, the mercury from dental discharges is separated out into sludge or biosolids.[23] The sludge is usually incinerated, which releases mercury pollution into the atmosphere,[24] and the biosolids are often used as fertilizer, which contaminates soil with mercury.[25]

"Human waste is second only to direct release from dental offices as a contributor of dental mercury to wastewater plants (AMSA 2001)."[26]
--Cited in Letter to the Editor by Larose & Basciano (IAOMT), Journal of Dental Research, 2008

2) Human Waste

Research has shown that amalgam fillings contribute to notable mercury levels in saliva, urine, and feces, and patients with dental amalgam excrete more than ten times more mercury in their feces than those without mercury fillings.[27] Based on figures provided in scientific studies, the IAOMT has estimated that in the U.S., this amounts to over eight tons of mercury being flushed out to sewers, streams, and lakes per year.[28] The same types of calculations were derived in Sweden in 1994, when researchers suggested that 100 kilograms (over 220 pounds) of mercury was being released to their country's environment annually as a result of dental mercury excretion in feces and urine.[29]

Human waste from people with dental amalgam mercury fillings is another route of mercury pollution, especially because treatment works cannot remove all of the mercury.

Considering that dental mercury is released in feces and urine,[30] and methylmercury (such as that taken in from fish consumption), is also released in feces and urine,[31] the impact of human waste containing various forms of mercury is a pertinent factor in water pollution.

"Amalgam fillings not replaced before death will cause emissions to air, soil, and water upon cremation or burial."[32]
--Hylander & Goodsite, Science of the Total Environment, 2006

3) Cremation and Burial

Rates of cremations are expected to rise over the next several decades, which means that the levels of mercury released into the atmosphere from corpses with dental amalgam fillings will also continue to increase.

A 2013 assessment on mercury from UNEP reported: "Global emissions from use of mercury in dental amalgam resulting from cremation of human remains are estimated at 3.6 (0.9 – 11.9) tonnes in 2010."[33] With this consequential amount of mercury being released, it is apparent that cremation of bodies with amalgam fillings adds to air emissions and deposition onto land and into waterways. To illustrate this point, in 1992, the IAOMT applied scientific data to calculate that the cremation of 320,372 bodies in the U.S. during the preceding year added an estimated 2,800 pounds of mercury emissions into the atmosphere.[34]

Austria, Belgium, Germany, the Netherlands, Norway, Sweden, and Switzerland have applied measures to reduce mercury pollution from cremations.[35] Although legislation has yet to be passed in the U.S.,[36] Colorado, Maine, Minnesota, and Vermont have attempted to achieve regulations that would make removing amalgam fillings before cremation mandatory.[37] Meanwhile, citizens in the U.S. have fought crematoriums in their neighborhoods by filing lawsuits[38] and initiating protests.[39]

A variety of trends suggest that mercury releases from amalgam fillings in crematoriums will continue to increase.[40][41] However, one alternative to cremation is a traditional burial, but burying an individual with amalgam fillings means that the mercury is deposited directly into the soil. This means that whether a person is cremated or buried, the mercury is released back to the environment.[42]

"Hg [mercury] vapor release to the atmosphere from dental vacuums can be substantial and can exceed human exposure limits."[43]
--Stone, Cohen, & Debban, Naval Institute for Dental and Biomedical Research, 2007

4) Mercury Vapor
In offices with air/water separator tanks as part of the central vacuum system, mercury vapor has been found in air vented to the *outside* of the dental office.[44, 45] Dr. Paul G. Rubin of IAOMT has explained: "This mercury-containing material is discharged into waste streams via the dental office vacuum-pump system. This system also discharges large quantities of air, either into the atmosphere exterior to the office building or into the sewer system, depending on the type of equipment used."[46]

Indoor air can also be dangerously polluted as a result of dental mercury. A study published in 2014 comparing air measurements at 42 dental sites in 17 countries found that mercury levels at most of the clinics were above safe limits. Their comparison included ten sites in the U.S., eight of which reportedly had levels higher than the EPA reference concentration in air. The authors noted that one of the two sites in the U.S. with mercury levels *below* the EPA reference level was from an office that had not placed mercury fillings in 20 years.

Amalgam Separators Can Reduce Dental Mercury Releases to the Environment:

Amalgam separators can successfully reduce the amount of mercury discharge in wastewater from dental offices[47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59] with reported capture efficiency rates ranging between 95-99%.[60] Recently, the U.S. Environmental Protection Agency (EPA) utilized measures in the Clean Water Act to develop standards for dental offices/clinics to use amalgam separators so that dental mercury is not flushed down the drain and into the environment.[61] EPA estimates about 103,000 dental offices use or remove amalgam in the U.S. and that almost all of these send their wastewater to POTWs [publicly owned treatment works].[62] The new guidelines went into effect in July 2017, and the EPA has estimated that these new measures could reduce dental discharges of mercury by 5.1 tons annually.[63]

However, even with required standards, there should be enforced maintenance requirements for amalgam separators, as the Royal College of Dental Surgeons has done in Ontario, Canada.[64] It must also be remembered that amalgam separators only contribute to solving the problem of dental mercury in wastewater and not the additional burdens placed by amalgam fillings on the environment and human health.

Human Health Risks of Dental Amalgam Mercury:

NOTICE TO PATIENTS

PROPOSITION 65 WARNING: Dental Amalgam, used in many dental fillings, causes exposure to mercury, a chemical known to the state of California to cause birth defects or other reproductive harm.

Root canal treatments and restorations, including fillings, crowns and bridges, use chemicals known to the State of California to cause cancer.

The U.S. Food and Drug Administration has studied the situation and approved for use all dental restorative materials. Consult your dentist to determine which materials are appropriate for your treatment.

Warning proposed by settlement in *As You Sow v. Roger Feldman, DDS and California Dental Association* (CGC-01-402974). **Sign designed by OEHHA.**

Mercury particulate can be discharged from dental amalgam fillings, and mercury vapor is continuously emitted from dental mercury amalgam fillings,[65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90] which means that people are directly exposed to mercury as a result of their dental mercury amalgam fillings. The output of mercury is intensified by the number of amalgam fillings in the mouth[91, 92, 93, 94, 95, 96, 97, 98, 99] and/or the number of amalgam surfaces in the mouth,[100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111] the type of the amalgam filling (i.e. specific content of metals),[112, 113] and other factors such as chewing, teeth-grinding, brushing, dental treatments and procedures, and the consumption of hot liquids.[114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133] Mercury is also known to be released during the placement, replacement, and removal of dental mercury amalgam fillings.[134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148]

"And I think that there really is perhaps no place for mercury in children."[149]
--Dr. Suresh Kotagal, pediatric neurologist at the Mayo Clinic; FDA Dental Products Panel, 2010

A number of countries have banned dental amalgam fillings for children and pregnant women, although this use of dental mercury is still allowed in the U.S.

1) Pregnant Women and Children

Authorities have issued distinct warnings about mercury's use in children and pregnant women. For example, a 2005 World Health Organization (WHO) report identified harmful effects of mercury exposure, including areas of risk specifically linked to mercury in fetuses and children: "Adverse health effects from mercury exposure can be: tremors, impaired vision and hearing, paralysis, insomnia, emotional instability, developmental deficits during fetal development, and attention deficit and developmental delays during childhood."[150]

Moreover, as stated at the top of page 2 in this document, international legislation has warned of the clear and present danger that the mercury in dental amalgam fillings poses to pregnant women and children. Also, 19 members of the U.S. Congress wrote a letter to the FDA in 2009 to express their concern about mercury used in amalgam fillings, with a focus on potential dangers to pregnant women and children,[151] and when Representative Diane Watson of California proposed a *Mercury Filling Disclosure and Prohibition Act* (H.R. 2101{not enacted}), she explained: "It is, in fact, children who are at greatest risk from these fillings."[152]

Pregnant women, lactating women, and women of childbearing age should be aware that mercury from their dental amalgam fillings can pose a risk to fetuses and children.

Fetal and infant exposure to mercury is known to have potentially serious health consequences, and the number of maternal amalgam fillings has been associated with mercury levels in cord blood;[153 154 155] in the placenta;[156] in the kidneys[157 158] and liver[159] of fetuses; in fetal hair;[160 161] and in the brain[162] and kidneys[163] of infants. Additionally, mercury is excreted in breast milk of mothers with dental mercury amalgam fillings, and the mercury concentration in breast milk increases as the number of amalgam fillings in the mother increases.[164 165 166 167] Significantly, a study published in 2018 by researchers in Norway involved over 72,000 pregnant women with data on the number of teeth containing dental amalgam fillings. The researchers discovered a "statistically significant association between the number of teeth filled with dental amalgam and the risk of perinatal death."[168]

Although two studies[169 170] (commonly referred to as the "New England Children's Amalgam Trial" and the "Casa Pia Children's Amalgam Trial") have repeatedly been used to defend the use of amalgam in children, other researchers have since demonstrated that factors such as long term effects, genetic predisposition, and measurement errors must be taken into account.[171 172 173 174 175 176] Furthermore, researchers studying the same cohort (of the Children's Amalgam Trials) have provided data that has identified potential risks to these subjects from mercury exposure based on gender,[177 178 179] genetic predisposition,[180 181 182] and even gum-chewing.[183] Risk assessments have also explored designating safe levels for children, who are smaller and still developing,[184] especially since many dose levels are based on a one-size-fits-all scale for children and adults.

In the meantime, scientific research continues to show that children are, in fact, at-risk for health impairments potentially caused by dental amalgam mercury fillings.[185 186 187 188 189 190 191 192 193 194] In summary, authors of a study from 2011 cautioned: "Changes in dental practices involving amalgam, especially for children, are highly recommended in order to avoid unnecessary exposure to Hg [mercury]."[195]

2) Dentists and Dental Personnel

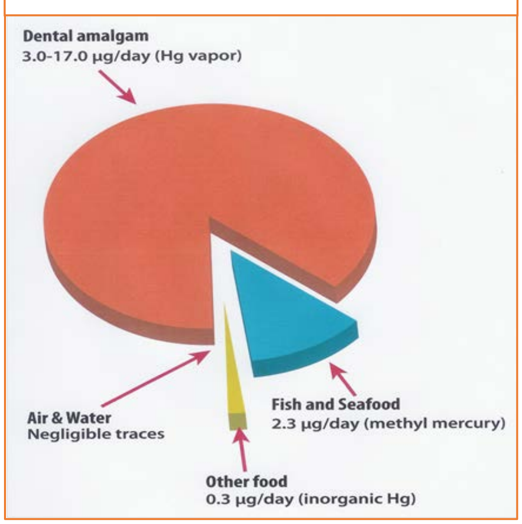
Dentists, dental staff, and dental students are exposed to mercury at a greater rate than their patients. Severe exposures from past practices include hand-squeezing of fresh amalgam, where drops of liquid mercury could run over the dentist's hands and contaminate the entire office.[196] Dangerous levels of mercury are still generated in the dental workplace, and research has clearly identified that exposure to these mercury levels can cause ill-health to dental workers,[197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232] and dental students.[233 234 235] Another area that has received attention is the possibility of reproductive hazards to female dental personnel, including menstrual cycle disorders, fertility issues, and pregnancy risks.[236 237 238 239 240 241 242 243]

Dental workers require protection from mercury exposures when working with mercury amalgam, and a variety of studies have specifically called for protective measures to be taken in the dental office as a means of limiting mercury releases.[244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264] Significantly, research published in 2019 in the peer-reviewed *Journal of Occupational Medicine and Toxicology (JOMT)* showed that the safety thresholds for mercury exposure can be exceeded during dental procedures involving drilling on amalgam fillings if special precautions are not in place.[265] The researchers emphasized that specific safety measures can mitigate these mercury levels and provide more rigorous protection for patients and dental workers. More on the importance of safety measures is provided in the "Safe Removal of Existing Amalgam Fillings" section on page 10 of this document, which outlines the [IAOMT's Safe Mercury Amalgam Removal Technique (SMART)].

A growing body of scientific research has recognized risks of mercury exposure for dentists, dental professionals, and dental students who routinely clean, polish, place, remove, and replace amalgam fillings. Also, based on efforts by dental nurses who had been harmed by mercury, the Norwegian Labour and Welfare Service officially recognized mercury injury as an occupational disease in 2012.

3) The General Population

Sources of Human Mercury Exposure; World Health Organization [WHO], 1991



Dental amalgam constitutes a main source of mercury exposure to people with these fillings in their mouths, as the chart to the left shows. 80% of the mercury vapor emitted from dental amalgam is absorbed by the lungs and passed to the rest of the body.[266] In research published in 2011, Dr. G. Mark Richardson reported that more than 67 million Americans aged two years and older exceed the intake of mercury vapor considered "safe" by the U.S. EPA due to the presence of dental mercury amalgam fillings, whereas over 122 million Americans exceed the intake of mercury vapor considered "safe" by the California EPA.[267]

Properly diagnosing "adverse health effects" related to dental mercury amalgam fillings is impeded by the intricate list of potential responses to the elemental form of the substance, which include over 250 specific symptoms.[268] One reason for the wide-range of symptoms is that mercury taken into the body can accumulate in virtually any organ.

Another reason for the wide-range of symptoms is that an array of co-existing factors influence each person's reaction to dental mercury, including the presence of other health conditions, the number of amalgam fillings in the mouth, gender, genetic predisposition, dental plaque, selenium levels, exposure to lead, consumption of milk or alcohol, methylmercury levels from fish consumption, and the potential for mercury from dental amalgam fillings to be transformed into methylmercury within the human body.[269]

This is an abbreviated table of common symptoms of elemental mercury vapor inhalation[270] [271] [272] [273] [274] [275] [276] [277] [278] [279] to be considered by practitioners when evaluating the possible side effects of dental mercury amalgam:

Acrodynia or similar symptoms such as emotional instability, loss of appetite, general weakness, and skin changes *(Magos and Clarkson, 2006)*	**Anorexia** *(Bernhoft, 2011)*	**Cardiovascular problems**/ labile pulse [frequent changes in heart rate]/tachycardia [abnormally rapid heartbeat] *(Klassen, 2008)*
Cognitive/neurological impairments/memory loss/decrease in mental function/difficulties with verbal and visual processing *(Echeverria et al., 1998; Clarkson and Magos, 2006; Magos and Clarkson, 2006; Syversen and Kaur, 2012; USEPA, 2016)*	**Delusions/delirium/hallucination** *(Bernhoft, 2011; Syversen and Kaur, 2012)*	**Dermatological conditions**/ dermographism [skin condition characterized by raised red marks]/dermatitis *(Bernhoft, 2011; Klassen, 2008)*
Endocrine disruption/enlargement of thyroid *(Bernhoft, 2011; Klassen, 2008)*	**Erethism** [symptoms such as irritability, abnormal responses to stimulation, and emotional instability] *(Bernhoft, 2011; Clarkson et al., 2003; Clarkson and Magos, 2006; Magos and Clarkson, 2006)*	**Fatigue** *(Bernhoft, 2011; Echeverria et al., 1998)*
Headaches *(USEPA, 2016)*	**Hearing loss** *(Rothwell and Boyd, 2008)*	**Immune system impairments** *(Bernhoft, 2011; Clarkson and Magos, 2006)*
Insomnia *(USEPA, 2016)*	**Nerve response changes**/peripheral neuropathy/decreased coordination/ decreased motor function/ polyneuropathy/ neuromuscular changes such as weakness, muscle atrophy, and twitching *(Bernhoft, 2012; Clarkson et al., 2003; Clarkson and Magos, 2006; Echeverria et al., 1998; USEPA, 2016)*	**Oral manifestations**/ gingivitis/metallic taste/oral lichenoid lesions/stomatitis/salivation *(Bernhoft, 2011; Camisa et al., 1999; Clarkson et al., 2003; Clarkson and Magos, 2006; Klassen, 2008; Magos and Clarkson, 2006)*
Psychological issues/mood changes related to anger, depression, excitability, irritability, mood swings, and nervousness *(Echeverria et al., 1998; Klassen, 2008; Magos and Clarkson, 2006; USEPA, 2016)*	**Renal [kidney] problems**/ proteinuria/nephrotic syndrome *(Bernhoft, 2011; Clarkson et al., 2003; Clarkson and Magos, 2006; Klassen, 2008; USEPA, 2016; Syversen and Kaur, 2012)*	**Respiratory problems**/ bronchial irritation/bronchitis/cough/ dyspnea [breathing difficulties]/ pneumonitis/respiratory failure *(Bernhoft, 2011; Clarkson et al., 2003; Echeverria et al., 1998; Klassen, 2008; Magos and Clarkson, 2006; Syversen and Kaur, 2012; USEPA, 2016)*
Shyness [excessive shyness]/social withdrawal *(Magos and Clarkson, 2006; USEPA, 2016)*	**Tremors**/mercurial tremors/ intention tremors *(Bernhoft, 2011; Clarkson and Magos, 2006; Klassen, 2008; USEPA, 2016; Syversen and Kaur, 2012)*	**Weight loss** *(Bernhoft, 2011)*

While the symptoms of mercury exposure are individualized and have the potential to change over time, specific health conditions related to dental mercury exposure are also aptly documented in scientific literature, as the table below demonstrates.

Dental mercury amalgam fillings can potentially exacerbate and/or contribute to the conditions included below, as well as a myriad of other health outcomes:

Allergies[280 281 282]	Alzheimer's disease[283 284 285 286 287]	Amyotrophic lateral sclerosis (Lou Gehrig's disease)[288]	Antibiotic resistance[289 290 291 292]	Autism spectrum disorders[293 294 295 296]	Autoimmune disorders/ immunodeficiency[297 298 299 300 301 302 303 304 305]
Cardiovascular problems[306 307 308]	Chronic fatigue, fatigue, and/or myalgic encephalomyelitis /chronic fatigue syndrome[309 310 311 312 313 314 315 316]	Dermatitis[317 318]	Fibromyalgia[319 320 321 322]	Gastrointestinal issues and/or irritable bowel syndrome[323 324 325]	Hearing loss[326]
Kidney disease[327 328 329 330 331 332 333 334]	Multiple sclerosis[335 336 337 338]	Oral lichenoid reaction[339 340 341 342 343 344 345 346 347 348 349 350 351 352 353 354 355] and oral lichen planus[356 357 358 359 360]	Orofacial granulomatosis[361 362]	Parkinson's disease[363 364 365 366 367 368 369]	Periodontal disease[370 371]
Psychological issues such as depression and anxiety[372 373 374 375 376 377 378]	Reproductive dysfunction[379 380]	Suicidal ideations[381 382]	Symptoms of chronic mercury poisoning[383]	Systemic lupus erythematosus[384]	Thyroiditis[385 386 387 388 389]

4) Genetic Predisposition

The association of genetic predisposition with specific, adverse effects from mercury exposure has been examined in several studies. It has been found that mercury exposure from dental mercury amalgam particularly threatens individuals with genetic variants that can impact their response to mercury exposures such as those with CPOX4,[390 391 392] APOE(3,4),[393 394 395 396] and BDNF (brain-derived neurotropic factor) polymorphisms.[397 398 399] For example, the researchers of a study published in 2006 linked the polymorphism CPOX4 (coproporphyrinogen oxidase, exon 4) to decreased visuomotor speed and indicators of depression in dental professionals. [400] Furthermore, the CPOX4 genetic variation was identified as a factor for neurobehavioral issues in a study of children with dental amalgams. The researchers noted, "…among boys, numerous significant interaction effects between CPOX4 and Hg [mercury] were observed spanning all 5 domains of neurobehavioral performance…These findings are the first to demonstrate genetic susceptibility to the adverse neurobehavioral effects of Hg [mercury] exposure in children."[401]

The ability of specific genetic variants to negatively impact the body's reaction to dental mercury exposure has even achieved attention in the mainstream media. A January 2016 article by Greg Gordon of McClatchy News included interviews with some of the researchers of the studies mentioned in this document.

Markedly, **Dr. James Woods stated:**

"'Twenty-five percent to 50 percent of people have these (genetic variants).'"

In the same article, **Dr. Diana Echeverria discussed**

"'a lifetime risk'" of neurological damage

related to this population, and she elaborated:

"'We're not talking about a small risk.'"

Another area of genetic susceptibility in relation to dental mercury risk that has merited attention is the APOE4 (apo-lipoprotein E4) genetic variation. A 2006 study found a correlation between individuals with APOE4 and chronic mercury toxicity.[402] The same study found that removal of dental amalgam fillings resulted in "significant symptom reduction," and one of the symptoms listed was memory loss. The symptom of memory loss is quite interesting, as APOE4 has also been associated with a higher risk for Alzheimer's disease.[403 404 405] Importantly, the authors of a study which found a connection between number of mercury fillings and neurotoxic effects for those with APOE genotype explained: "APO-E genotyping warrants investigation as a clinically useful biomarker for those at increased risk of neuropathology, including AD [Alzheimer's disease], when subjected to long-term mercury exposures…An opportunity could now exist for primary health practitioners to help identify those at greater risk and possibly forestall subsequent neurological deterioration."[406]

Research has also shown that dental mercury fillings can play a role in immune system problems for genetically predisposed patients. Whereas research on animals has established a connection between dental mercury and autoimmunity,[407 408] research involving human subjects has confirmed that genetic susceptibility to reactions from dental mercury is potentially related to chronic fatigue syndrome,[409] as well as amyotrophic lateral sclerosis, multiple sclerosis, and rheumatoid arthritis.[410] In addition, scientific data has linked mercury and genetic traits to autism,[411 412] chemical sensitivities,[413] and Kawasaki's disease,[414] and research has also suggested that genetic transporters could be involved in the toxicokinetics of mercury.[415]

Other than CPOX4, APOE, and BDNF polymorphisms, genetic traits that have been examined for association with health impairments caused by mercury exposure include metallothionein (MT) polymorphisms,[416 417] catechol-O-methyltransferase (COMT) variants,[418] PON1 variants,[419 420] MTHFR mutations and other genetic aspects.[421 422 423] The authors of one of these studies concluded: "It is possible that elemental mercury may follow the history of lead, eventually being considered a neurotoxin at extremely low levels."[424]

5) Mercury and Metal Allergies

In some genetically susceptible individuals, metals can also induce allergies.[425] A study published in 2018 in the journal *Dermatitis* was conducted on 686 adults who were patch tested for allergies. The results demonstrated that "38.9% of patients had 1 or more positive patch-test reactions to a metal allergen, most commonly nickel (17.4%), mercury (12.3%), and palladium (9.2%)…Among patients with positive reactions to nickel, 34.5%, 15.1%, and 5.0% had positive reactions to 1, 2, or 3 additional metals, respectively."[426] That study involved individuals with suspected allergies; however, the statistics are relevant, as studies involving the general population and the prevalence of metal allergies are rare.[427] However, a 1993 study reported that 3.9% of healthy subjects tested positive for metal reactions in general.[428] If this figure is applied to the current U.S. population, this would mean that dental metal allergies potentially impact as many as 12.5 million Americans.

The number of affected individuals is likely much higher, though, because recent studies and reports tend to agree that metal allergies are on the rise.[429 430] Part of this could be caused by increased exposure to metals, including ear/body piercings, because exposure to metals has been cited as a potential trigger for the development of allergies to them.[431] Additionally, it has been hypothesized that contact with metals during an infection could increase chances of developing a metal allergy later in life.[432]

An issue is the wide-range of symptoms patients allergic to dental metals can exhibit. In a 2014 publication, Dr. Vera Stejskal wrote: "Metal-induced inflammation may be involved in the pathology of various autoimmune and allergic diseases, where abnormal fatigue, joint and muscle pain, cognitive impairment and other non-specific symptoms are often present."[433] Additionally, a gamut of health conditions has been linked to dental metal allergies, including autoimmunity,[434 435] chronic fatigue syndrome,[436 437 438] fibromyalgia,[439 440] metallic pigmentation,[441] multiple chemical sensitivities,[442 443] multiple sclerosis,[444] myalgic encephalitis,[445] oral lichenoid lesions,[446 447 448 449 450] orofacial granulomatosis,[451] and even infertility in both women and men.[452]

Another issue with calculating the number of patients with adverse reactions to a metallic material is that the onset of symptoms can be delayed and therefore might not be associated with the implant or device. For example, researchers writing about dental amalgam fillings warned: "Sensitization appears most frequently after the amalgam has been present in the mouth for more than 5 years."[453] Furthermore, there may not be any local reaction to help the patient and doctor identify the metal as the culprit in ill health,[454] and even if hypersensitivity reactions are noticed, they can be misdiagnosed as infection.[455]

Clinical screening for metal allergy has been recommended,[456] and the importance of patients reporting reactions to metals to their doctors has also been emphasized in the scientific literature.[457 458 459 460 461 462] In addition to reporting any rashes from jewelry, watches, or other metal exposures, it is essential for each patient to recognize the gamut of symptoms that can be related to the presence of a metal implant or device in their body. **It is also vital for patients to remember that sensitization to metal can develop years after an implant or device has been placed and that adverse effects can occur *with or without* the sign of a rash or eruption on the skin or in the mouth.**

Many patients are not aware that reactions they have to jewelry and other metal accessories are a warning sign that they could have allergic reactions to dental amalgam fillings and/or metal implants in their bodies.

Unfortunately, in some reported cases, the only way to fully establish that a metal implant or device was causing health problems was to have it removed and then document the results. Researchers from Harvard School of Medicine wrote in 2016: "Paradoxically, a patient can sometimes only be diagnosed with metal allergy when the symptoms resolve upon replacement with an immunologically inert implant."[463]

A few examples of conditions reportedly improved and/or cured as a result of removing dental metal allergens include amyotrophic lateral sclerosis,[464] chronic fatigue syndrome, [465] dermatitis,[466] fibromyalgia,[467] multiple sclerosis,[468] oral lichen planus, [469 470 471] oral lichenoid lesion, [472 473 474] orofacial granulomatosis,[475] and other symptoms.[476] In a 2011 report, Hosoki and Nishigawa suggested: "In principle, all restorations with allergy-positive metal elements need to be removed."[477]

Safety Measures for Removal of Dental Amalgam Mercury Fillings:

Although individual response varies, in addition to the recovery situations listed above, research has documented the reduction of other health issues after the removal of amalgam fillings.[478] [479] [480] [481] [482] [483] [484] [485] [486] [487] [488] However, it is important to note that removal of any dental material requires a number of precautions. This is because an unsafe removal process can cause serious injury to the patient, including the possibility of increased metal exposure. For example, if dental amalgam fillings are removed unsafely, patients can be exposed to increased levels of mercury.

To assist in mitigating the potential negative outcomes of mercury exposure to dental professionals, students, staff members, patients, and others, the IAOMT has developed safety recommendations for removal of existing dental mercury amalgam fillings.[489] IAOMT's Safe Mercury Amalgam Removal Technique (SMART) is located online at https://iaomt.org/safe-removal-amalgam-fillings/.[490] The innovative recommendations build upon traditional safe amalgam removal techniques such as the use of masks, water irrigation, and high volume suction by supplementing these conventional strategies with a number of additional protective measures, the need for which have only recently been identified in scientific research. In addition to the dozens of studies that support each separate step of the recommendations, the overall technique has been supported by two studies published in peer-reviewed journals in 2019.[491] [492] IAOMT recommends that patients familiarize themselves with the recommendations to ensure protective strategies will be applied during amalgam removal.

Alternatives to Amalgams as a Filling Material:

Obviously, once amalgams have been removed, they must be replaced with a different dental filling material. Alternatives to amalgam include composite resin, glass ionomer, porcelain, and gold, among other options. When given the choice, most consumers opt for direct composite fillings because the white coloring matches the tooth better and the cost is considered moderate.

In the past, a common argument against composite fillings was that they were not as durable as amalgam. However, recent studies have debunked this claim. Researchers of a study which was published in 2016 and conducted on over 76,000 patients for over ten years found that posterior amalgam fillings had a *higher* annual failure rate than composites.[493] Two separate studies published in 2013 found that composite fillings performed as well as amalgam when comparing failure rates[494] and replacement filling rates.[495] Other research offers similar findings in support of composite filling durability.[496] [497] [498] [499]

Many patients choose dental filling materials that match the natural coloring of teeth after they have their mercury amalgam fillings removed.

Research has further confirmed that composite resins present a lower risk for chemical exposures. In a 2016 publication co-authored by risk assessment specialist Dr. G. Mark Richardson, it was reported: "Relative risks of chemical exposures from dental materials decrease in the following order: Amalgam>Au (Gold) alloys>ceramics>composite resins."[500]

Yet, composite fillings have been criticized because some of them contain fluoride and/or bisphenol-A (BPA). Dentists have a variety of opinions about the safety of fluoride, BPA, and other types of bisphenol, such as Bis-GMA and Bis-DMA. Patients who are concerned about the specific components of their fillings often choose to speak with their dentists about using a material that does not contain certain ingredients. For example, a product named Admira Fusion[501]/Admira Fusion X-tra[502] released in January 2016 by the dental company VOCO is being touted as "the first purely ceramic-based restorative material"[503] and does not contain Bis-GMA or BPA before or after it has been cured. No matter which replacement material is selected, whether it be ceramics, composites, gold, or other materials, it should be assessed for safety and biocompatibility with special consideration for all populations and all known risk factors. [504]

Allergy testing can be used to assist in identifying some of the individuals susceptible to adverse reactions to metals. Patch testing is generally regarded as the "gold standard" in allergy testing; however, patch testing has also been criticized because it involves directly applying the allergen to the skin, it can exacerbate symptoms in patients, it can result in sensitization, and the results can be affected by other conditions.[505] Two relatively new alternatives to skin patch testing are a modified version of the Lymphocyte Transformation Test (LTT) known as MELISA[506] and the Lymphocyte Response Assay (LRA) by ELISA/ACT.[507]

Another option for testing has been created specifically for dental materials. If this biological testing is used, a patient's blood sample is sent to a laboratory where the serum is evaluated for the presence of IgG and IgM antibodies to the chemical ingredients used in dental products.[508] The patient is then provided with a detailed list of which name-brand dental materials are safe for their use and which ones could result in a reaction. Two labs that currently offer this service are Biocomp Laboratories[509] and Clifford Consulting and Research.[510]

It is important to note that many factors can influence whether or not a patient improves after the removal of dental amalgam fillings. While many patients improve or even recover, there are some who do not. One obvious reason for this is if the patient is still being exposed to the metal or a different sensitizer through another implant, device, or other source. Dr. Vera Stejskal has also noted that in order to get well, some patients further require the eradication of *Heliobacter pylori*,[511] the cessation of smoking,[512 513] and/or the adoption of a low nickel diet.[514 515] Some medical professionals and researchers have also suggested the need for detoxification and supplements to assist the body in recovering from metal exposure. Additional impediments in achieving improved health can include the presence of another illness and/or allergy, exposure to certain pesticides, solvents, molds, and foods, hormonal imbalances, stress, a sedentary lifestyle, and countless other factors.

For all these reasons and more, it is imperative for patients to work with their doctors and other healthcare professionals so that toxins and allergens are kept out of their bodies and healthier, safer options are put in to replace them.

Additional Resources:

The IAOMT has also developed free, online dental education resources detailing implementation strategies for mercury-free and mercury-safe practices, including information for dentists, physicians, health care professionals, patients, and the general public. These resources include the following:

- Dental Mercury Facts: https://iaomt.org/resources/dental-mercury-facts/
- Dental Mercury Education Videos: https://iaomt.org/free-online-learning/
- Position Statement against Dental Mercury Amalgam Fillings: https://iaomt.org/iaomt-position-paper-dental-mercury-amalgam/
- Safe Mercury Amalgam Removal Technique (SMART): https://iaomt.org/resources/safe-removal-amalgam-fillings/
- More resources available at www.iaomt.org

PHOTO CREDITS:

Middle of page 1: Mercury Amalgam Fillings; IAOMT File Photo

Bottom of page 2: Mercury (Hg) Biomagnification Graphic; National Park Service; https://npgallery.nps.gov/AssetDetail/ba40f463-9f49-4a28-bcd9-a1e65a0d1dee; Accessed October 2019

Top of page 3: Picture of a Honolulu city sign warning of sewage contamination, with Waikiki hotels and Diamond Head in background; Released under CC-BY-SA 2.5; Keith H.; https://commons.wikimedia.org/wiki/File:20060402_waikiki_sewage.jpg; Accessed October 2019 and cropped to fit page. (*For more about mercury contamination in sewage, see https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4764622/.*)

Bottom of page 3: Chimney Crematorium Peak Smoke Top, Stock Photo purchased by IAOMT from 123rf; https://www.123rf.com/photo_9682193_chimney-crematorium-peak-smoke-top.html?term=crematorium%2Bblack%2Bsmoke&vti=lsapn7cqoj9yci0ytl-1-11; Purchased March 2018

Bottom of page 4: Dental Office Warnings, Office of Environmental Health Hazard Assessment (OEHHA) of the California Environmental Protection Agency; https://oehha.ca.gov/media/downloads/proposition-65/presentation/dentalofficewarnings041514.pdf; Accessed October 2019

Top of page 5: Sri Lankan Woman and Child; Steve Evans; https://commons.wikimedia.org/wiki/File:Sri_Lankan_woman_and_child.jpg; Accessed October 2019 and slightly cropped to fit page; Originally posted at https://www.flickr.com/photos/64749744@N00/549738320; Shared in compliance with https://creativecommons.org/licenses/by-nc/2.0/.

Bottom of page 5: Patient with Dentist in Alaska; Official Website of the United States Navy; 090309-F-3646G-199; https://www.navy.mil/view_image.asp?id=69543; Accessed October 2019

Top of page 6: Protective Equipment during Amalgam Removal; Courtesy of Dr. Jack Kall

Bottom of page 6: Sources of Human Mercury Exposure based on 1991 World Health Organization [WHO] Report; Chart Made by the IAOMT from Statistics in http://www.inchem.org/documents/ehc/ehc/ehc118.htm

Top of page 8: Quotes on Genetic Variants from: Gordon G. Dental group defends mercury fillings amid mounting evidence of risks. McClatchy News Service. January 5, 2016. Available from: http://www.mcclatchydc.com/news/nation-world/national/article53118775.html. Accessed October 2019.

Middle of page 9: Pile of Old Jewelry; Retrieved from Pixabay; https://pixabay.com/photos/jewelry-junk-fake-gem-jewel-314473/; Accessed October 2019

Top of page 10: Before and After Photos of Teeth from Amalgam Removal; Courtesy of Dr. Michael Rehme from https://toothbody.com/the-inevitable-replacement-of-mercury-amalgam-fillings/

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