The mercury (or amalgam) controversy is a public discussion about the relative safety of dental amalgam restorations due to the inclusion of Hg in the metallurgical structure of the material. It has changed in quality and intensity over the years but continues even today. There are numerous websites devoted to coercing patients, dentists, or scientists toward one side or the other of the issue.

For the current presentation, the goal is to present the science available and the key information for potential discussions of the issues with patients.
Quickly, let's review the status of Hg. Just about everyone has had the experience of playing with small droplets of Hg from a broken thermometer or in a lab or whatever. One of the impressions that sticks with you is how the droplets tend to coalesce quickly when they touch each other. What you tend not to remember is the droplets are easily broken up into smaller and smaller ones as well. Also, there is a high vapor pressure of Hg which is invisible.

The picture to the left is of a Hg mine worker from South Africa. He is sitting on a vat of raw mercury. Because the density of Hg is so high, he actually floats. Once he gets down off of the vat, his pockets and cuffs are filled with small droplets of mercury that easily penetrate through the holes in his clothing.

[CLICK] In set dental amalgam, the Hg which was mixed with alloy resides only in the matrix phase (predominantly Ag-Hg). It is not in the particles of unreacted alloy. The matrix melts at 128°C and so just above the boiling point of water, you can melting dental amalgam and release Hg from the matrix phase. In most cases, when amalgam is being polished, small amounts of heat melt the surface, smear the Hg rich layer around, and give it a mirror-like appearance. Remember that old mirrors were actually a coating of Hg with silver on the back of a piece of glass.

Once Hg is released as vapor it can be breathed and absorbed into your system. [CLICK] Persons who are exposed to Hg vapor may display a toxicity or sensitivity reaction. [CLICK] Vapor limits (TLV) for toxicity are set by the Industrial Hygiene group and [CLICK] establish 0.05 mg/m³ as a safe upper limit. [CLICK] This is equal to 50 μg/m³ and these are the more common units used for reporting Hg in dentistry. The level is extremely small (5 ppb) but still it is relatively easy to stay below the level. [CLICK] Sensitivity is extremely rare and very low level. Allergic individuals do not go into anaphylactic shock. The ADA estimates that fewer than 1 person in 100,000,000 are involved. In the US, that translates into only 2-3 people. Therefore, there is no practical worry for anyone in dentistry in this regard.
Chemical Forms of Hg

- Elemental Hg (Mercury)
- Inorganic Hg-S (Cinnabar)
- Organic Hg-(CH₃)₂ (Dimethyl Mercury)

Absorption Routes for Hg

<table>
<thead>
<tr>
<th></th>
<th>Skin</th>
<th>Lungs</th>
<th>GI Tract</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elemental</td>
<td>-----</td>
<td>80 %</td>
<td>0.01 %</td>
</tr>
<tr>
<td>Inorganic</td>
<td>-----</td>
<td>80 %</td>
<td>7 %</td>
</tr>
<tr>
<td>Organic</td>
<td>-----</td>
<td>-----</td>
<td>95-98 %</td>
</tr>
</tbody>
</table>

Hg exists in three basic forms: (a) elemental (pure Hg), (b) inorganic (principally cinnabar – HgS – as it is found in nature), and (c) organic mercury (primarily as dimethyl mercury for its use in farming as a fungicide and herbicide). These forms are convertible but not necessarily in a practical way.

[CLICK] Absorption into the human body occurs via: (a) the skin, (b) lungs, and/or (c) gastrointestinal tract. These routes are very unequal in transport efficiency. For all practical purposes, Hg is not quickly absorbed through even clean skin in any form. Elemental and inorganic mercury are readily absorbed across alveoli in the lungs into the blood but only difficulty absorbed in the GI tract. Organic mercury is not practically absorbed in the lungs but is readily absorbed in the GI tract. In other words, Hg from amalgams that is released into air in the mouth can be breathed and directly absorbed but Hg mixed in saliva and swallowed is probably not absorbed at all. Organic mercury that is a contaminant in almost all food is readily absorbed. All people have some circulating Hg in their systems from the food they eat. This probably represents >99% of the body burden. Because the Hg is actively excreted, there are never any symptoms of Hg toxicity that develop.
The complex routes of absorption, migration, distribution, and excretion are summarized above. Assaying Hg in blood or urine or hair does not reveal the original source of the Hg or the time of absorption. On average, the half-life Hg circulating in the body is 55 days. Therefore, whatever Hg is measured should be related to exposures that would primarily have occurred over the last 2 months.
Hg is released from dental amalgams but in very small quantities. Remember that the recommendation for exposure is that one stay below an average of 50 μg/m³ for a 40-hour work week. Below that level there are no known health effects. Above that level, small changes can be detected. Yet, until the level is 5 to 2- times that limit, most symptoms are very mild, and reversible. In dentistry, it is very simple to stay well below the 50 μg/m³ level.

[CLICK] For a patient, chewing on amalgams puts in mechanical energy that is converted into sublimation energy. Hg along the amalgam surface is release in very tiny amounts. [CLICK] When you stop chewing the vapor pressure for the solid quickly drops almost to zero. [CLICK] One of the tricks for anti-amalgamists is to have a patient chew, keep their mouth closed to concentrate the sublimed Hg vapor, and then measure the concentration. [CLICK] Under these conditions, it is possible to accumulate enough Hg to actually produce measurable amounts. If you monitor the change over time in a patient’s closed mouth, it looks like the light blue curves. However, this information is of no real value. Patients only chew about 1% of the time. Any released Hg is mixed with saliva and swallowed, not inhaled. Therefore, the real exposure is miniscule.
To test the effects of eating amalgams, a recent clinical trial set out to monitor the appearance of Hg from amalgams that were ingested. [CLICK] With a bribe of a good grade in dental materials, the authors of the study shown above, had dental students swallow pulverized fresh dental amalgams that have been weighed into gelatin capsules. The students had blood samples drawn over the next 90 days to monitor the blood level of Hg. Note that the scale is in nano moles of Hg in plasma. [CLICK] While the first traces could be quickly detected, the amounts were incredibly small and continually dropped after the exposure as the body eliminated the last traces. [CLICK] Hg rapidly dropped back to background levels. Measured half-lives for Hg in this experiment were about 37 days.
There are both natural and pollution sources for Hg entry into the environment. Most of the Hg available on the surface of the planet was deposited from erupting volcanoes. The material then settled on land or into the oceans. This continues to happen, but [CLICK] most current sources in air, water, and food can be related to human pollution – primarily from the use of dimethyl mercury in agriculture or the burning of soft coal as a source of heat.

[CLICK] Air pollution is extremely important although the actual concentrations are relatively low. Coal burning power plants increase the local air pollution levels of Hg. Working in a HgS mine generates the highest exposure (>300 µg/m³).

Hg in the environment is concentrated by food that is grown and by fish or mammals in the food chain. Tunafish, swordfish, and a couple of other special fishes (1000 µg/kg) contain very high levels because they are effectively at the top of the food chain. Cattle can be considered to be at the top of the food chain as well and have high levels (160 µg/kg).
In Spain, there is a HgS mine that has been in continuous operation for more than 2400 years. HgS is mined like coal, shipped to the surface, heated to drive off the S, and collected as >99% liquid Hg before refinement. HgS is a reddish ore that is attractive and used in jewelry for that purpose as well.

Workers in the mine are obviously exposed to enormously high levels of HgS in the air. They are monitored monthly by having them trace over a gray sinusoidal line on a registration card with a red pen as an estimate of the exposure effects on their peripheral nervous system as they become toxified with Hg. If they can trace it fairly well, they are left in the mine. If they do not pass the test, they are removed from the mine duty for about 2-3 months, so that their systems can eliminate about half of the body burden and retested for continued service. This is one of the key points about Hg exposure. There is no permanent accumulation in the body. The material is actively excreted. Also, the low level effects are reversible. After a recovery time, they are re-introduced into the mine.
The most notorious Hg contamination event is the Minamata incident in 1953. The Chisso corporation built a factory that produced fertilizer, low grade chemicals, and plastics using Hg catalyst technology. They discarded their waste materials directly into Minamata Bay. The bay can barely be seen in the background of the picture. The local community obtained most of their food (which was fish) from the same bay and quickly started becoming sick. Without knowing the cause and effect, it took many months for the public health service to connect the two things, and by that time, 52 people had died and over 200 had become very sick. During the documentation of the Hg poisoning event, it was recorded that the typical symptoms were (a) ataxic gait, (b) convulsions, (c) numbness in the mouth and limbs, (d) constriction of the visual field, and (e) difficulty speaking. One of the things that anti-amalgamists argue is that this set of symptoms is very similar to certain diseases such as multiple sclerosis. However, these symptoms are relatively diffuse and common for many different afflictions. These are also the general symptoms of alcohol intoxication.
### Body-Burden Calculations

<table>
<thead>
<tr>
<th></th>
<th>Elemental</th>
<th>Inorganic</th>
<th>Organic</th>
<th>= TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIR</td>
<td>0.5 μg/day</td>
<td>.....</td>
<td>.....</td>
<td>= 0.5 μg/day</td>
</tr>
<tr>
<td>WATER</td>
<td>.....</td>
<td>10 μg/day</td>
<td>.....</td>
<td>= 10 μg/day</td>
</tr>
<tr>
<td>FOOD</td>
<td>.....</td>
<td>100 μg/day</td>
<td>.....</td>
<td>= 100 μg/day</td>
</tr>
<tr>
<td>Amalgams</td>
<td>20 μg/day</td>
<td>.....</td>
<td>.....</td>
<td>= 20 μg/day</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td>= 130.5 μg/day</td>
</tr>
</tbody>
</table>

18 occlusal amalgams = all Hg release absorbed

Actual body burden due to amalgam estimated as <0.5% of total

Presumably the effects of Hg toxicity are due to the actual concentrations developed within the body (or body burden) and not the rate of absorption or levels of exposure. To assess this, many individuals have tried to construct a “balance sheet for the Hg body burden.” One of the assumptions of any exercise must assume a certain number of amalgams present in the patient. [CLICK] A primitive version of this is shown above based on estimates for an individual with 18 amalgam restorations and a normal diet in a typical city environment. The air, water, food, and amalgam contributions are shown in the columns representing the elemental, inorganic, or organic form. The conclusion for this extreme example for the current balance sheet assuming that any released Hg were totally absorbed would be that the contributions from the amalgams could about 15% of the body burden. Most mercury is mixed with saliva, swallowed, and never absorbed. [CLICK] In addition, since most patients have very few amalgam restorations, the real level is most likely much less than 1%.
Historically, the greatest exposures contributing to mercury toxicity have been HgS mine workers, thermometer technicians, and tanners of animal hides. We just discussed the most famous incident -- at Minamata Bay in Kyushu, Japan in the 1950s.

Within the last 15 years, there was quite a stir in Sweden as the government developed provisions for banning Hg use in dentistry and other industries. Other European countries were going through similar inspections and considerations of limiting Hg use. Quickly, let’s review what happened there.
In the early 1990s, the Swedish National Board of Health was examining potential connection between Hg levels and health problems in the population. The Swedish government had been tracking Hg levels in human brains measured during autopsies (which are mandatory in Sweden) since the 1950s and noticed relatively high levels being reported. Scientists argued that this rise in the Hg levels corresponded exactly to the use of dimethyl mercury as a seed-coat treatment for grain as a means of protecting the stored seed against consumption by vermin. However, the organic mercury then released during germination into the soil and re-absorbed by the roots of the growing crop, becoming a part of the harvested new grain. When consumed it became part of the human body-burden.

At the same time that the Swedish National Board of Health and Welfare was considering this issue, the mercury controversy was raging in public. [CLICK] The Board of Health adopted the position that all sources of Hg pollution entering the environment should be minimized and they adopted a phase out of the use of dental amalgam. [CLICK] The German government for reasons of widespread industrial pollution adopted a similar limit on the use of Hg-containing materials.

After that planned phase out from the mid-1990s, the European Union in 2000 (of which Sweden and Germany are members) developed a uniform policy for the EU that did not prohibit amalgam use but which required sufficient recycling and other regulations to minimize environmental impacts.
It is crucial that everyone understand that the body burden of Hg comes from more than just the dental environment. Even greater risks may be encountered at home.

In order to know the level of risk, one must first monitor to detect sources of exposure. [CLICK]

Within the workplace, either lapel badges (like radiation badges) can be used and/or the air can be sampled periodically. [CLICK] In addition, it is important for dental personnel to participate in the voluntary ADA Annual Session screening tests for blood Hg. [CLICK] for patients, there are procedures that can determine their relative body burden but which would not normally indicate the source of exposure. While the anti-amalgamists would have one believe that the major source was from dental amalgam, that is probably not the case.
Patients are more likely to encounter anti-amalgamist literature than pro-amalgam information. This is unfortunate but true. Therefore, it is important for dental personnel to be familiar with anti-amalgamist arguments and be able to quickly and effectively counter these in patient discussions.

[CLICK] Hal Huggins was the original proponent of amalgam removal. [CLICK] In 1995, he was prosecuted by the State of Colorado for false advertisement and reckless endangerment of patients he was treating who had life-threatening diseases from which they did not recover. He continues to sell things from that location on the web. [CLICK] The details of the adjudication can be reviewed by clicking on the information in the panel above. [CLICK] He has since moved his office to Mexico City, Mexico and continues to practice and promote amalgam replacement.

Many others are aligned with the anti-amalgamist movement but a couple are notable. [CLICK] Michael Ziff is a dentist in Florida that is convinced that amalgams are bad. To increase his scientific credibility, he purchased a MS degree through the mail for $3000. [CLICK] His father who is also involved, purchased a PhD for $10,000.

Some of the positions of anti-amalgamists are published in "scientific-looking" journals or books. [CLICK] Roy Kupsinel, an MD, has become a printer and distributor of many of these materials. [CLICK] These often end up intentionally integrated into the magazine stacks in patient waiting rooms as a method of increasing patient questions and anxieties.
Early on [CLICK] there was an organization promoting amalgam replacement called the Academy of Oral Toxicology (Colorado Springs, Colorado). However, it was shut down by the IRS for lack of payment of taxes. [CLICK] It reorganized itself as the International Academy of Oral Medicine and Toxicology and has continued to exist ever since in Alberta, Canada.

[CLICK] One of the items that the organization touts as scientific evidence of amalgam problems is a sheep study [CLICK] performed by Lorscheider (MD) and Vimy (DMD). The study was rejected by 11 dental journals as fatally flawed and unscientific, but was finally published by the FASEB journal. [CLICK] Since that time, the article has been assailed by every major dental and medical association involved as flawed and useless. There was an important convening of the NIH-NIDCR to consider these issues at about the same time.
The sheep study involved placing 16 dental amalgams in a sheep using radioactive Hg. Sheep are ruminants with 4 molars per quadrant that continually erupt and are ground down during normal chewing.

After 30 days of feeding a sheep hay, [CLICK] it was placed on a radioactive exposure film to track the relative distribution of radioactivity in its body. [CLICK] As can be seen in the photograph above, most of the amalgam was consumed by the sheep grinding its teeth and it ended up in its 2 stomachs. [CLICK]

Radioactive material that had been absorbed and circulated throughout the body into various organ systems. Despite arguments by the authors, others have confirmed that measured levels in those organs were within acceptable limits in most cases. One of the major flaws in this scientific design was that humans do not consume their amalgams like sheep do when they wear down their teeth.
The anti-amalgamist dentists have a relatively straight-forward scam for patients. They suggest that “human disease is related to negative currents or electricity in the body.” [CLICK] Typically a patient fills out a health history questionnaire that infers that all complaints will probably disappear after treatment.

[CLICK] To develop the scam, negative electricity purportedly is measured with a voltmeter by placing one lead on the amalgam and the other on the tongue. The reading is recorded tooth-by-tooth for each quadrant. All the values in the quadrant are summed. The most negative quadrant is tackled first. After waiting for the patient to recover from the electrical shock of the first quadrant (about 4-7 days) then the other amalgams are replaced as well.

For this treatment, an anti-amalgamist might charge 7-40 times the normal-and-customary fee for a restorative procedure. [CLICK] It is rumored that one famous anti-amalgamist charged a patient $18,000 [CLICK] to replace 6 posterior amalgam restorations.
To have some fun with this "scam" I personally tried out some similar equipment that had been sold many years ago. The device was called the ELECTREAT. In 1982 when my grandmother had passed away, I found this device in her attic as we inventoried her house. [CLICK] It had a set of instructions that explained how to place two electrodes on various parts of the body [CLICK] to drive out the negative electrical current that was causing ailments or disease. [CLICK] I shined up the equipment, powered it up with two new Eveready batteries, and [CLICK] personally tried it out. This is a picture of me at a much earlier time.

In my excitement to test it, I did not read the directions. The set up should have been using the components shown above. [CLICK] Only later did I discover, that [CLICK] the metal post electrode was actually a rectal electrode. No matter how we fiddled and played, we could not get much interesting action out of the device. It was trademarked in 1928. This same type of scam has been going on for more than 100 years in the US. It was once stated that almost 60% of the devices in the US Museum for such things are related to negative current theories.
Hg Release from Amalgam

Chemical and Electrochemical Corrosion → NO Hg RELEASED

a. Low-copper dental amalgam:

\[
\begin{align*}
[Sn-Hg] & \rightarrow [Sn] + saliva \rightarrow [Sn-O-Cl] \quad \text{(soluble)} \\
& \rightarrow [Sn] + saliva \rightarrow [Sn-O] \quad \text{(insoluble)} \\
& \rightarrow [Hg] + [Sn+Hg] \rightarrow [Sn-Hg] + [Sn+Hg] \quad \text{(more rx)}
\end{align*}
\]

---

b. High-copper dental amalgam:

\[
\begin{align*}
[Cu-Sn] & \rightarrow [Sn] + saliva \rightarrow [Sn-O-Cl] \quad \text{(soluble)} \\
& \rightarrow [Sn] + saliva \rightarrow [Sn-O] \quad \text{(insoluble)} \\
& \rightarrow [Cu] + saliva \rightarrow [Cu-Cl] \quad \text{(soluble)}
\end{align*}
\]

Another point of confusion perpetuated by anti-amalgamists is that corrosion releases Hg from dental amalgams. That just does not happen. [CLICK] Corrosion reactions for low-copper and high-copper dental amalgam are essentially the same and are summarized above. With low-copper amalgam, the corroding phase is Sn-Hg. Sn is transformed to SnO (insoluble) or Sn-O-Cl (soluble) and accumulates within the amalgam and at the margins. The Hg from the original phase is quickly reacted with residual Ag-Sn alloy within the amalgam. The Hg does not leave. In high-copper dental amalgams, the corroding phase is Cu-Sn. Sn again forms SnO or SnOCl. The copper forms Cu-Cl. No Hg is involved at all.
It is very complicated to deal with the wide range of questions that arise when patients are first confronted by the mercury controversy. [CLICK] Fortunately, Consumer Reports has visited this issue and published two separate and extremely valuable reports that are ideal to allow patients to see the issues from a neutral point of view. [CLICK] Consumer Reports has a very good professional reputation in the public’s eyes. [CLICK] In both articles they clearly condemn the anti-amalgamist view. Therefore, one should consider distributing copies of these to patients to deal with this issue.
At this particular point in time, the profession is in an age of decreasing amalgam use throughout first world regions of the world. The graph above tracks amalgam use by US dentists based on ADA survey data.

The reasons for the decrease include a number of forces: (a) impact of preventive measures (F and sealant use), (2) different decisions for amalgam replacement (longer-lived high-copper amalgam alloys; more hesitancy to replace amalgams based on marginal degradation criteria that are no longer considered appropriate; patient concerns for amalgam use), (3) composite use routinely for anterior and posterior composites, and (4) other approaches to restorations (such as CAD/CAM). The number of amalgam restorations placed are as replacements of existing ones. The general trend is toward amalgam disuse by the end of this decade.