MEDICAL IMPLICATIONS OF DENTAL MERCURY: A REVIEW

Hal A. Huggins, DDS, MS[1#]

Silver-mercury fillings–also called dental or mercury amalgams–have been used in dentistry since 1832. In 1840, the dental association of the day argued over whether to use mercury as a filling material because it was cheap, or to withdraw it because it was toxic. The safety debate had already begun and could be called "Amalgam War I." In the late 1920s, Dr Alfred Stock, a biochemist and researcher, wrote close to 30 articles describing the toxicity of mercury and linking it to dental amalgam fillings–this then became "Amalgam War II." In 1973, some dentists and their patients began to question the safety of silver-mercury fillings when it became apparent that some patients were reporting health improvements after removal of their mercury amalgam fillings. The primary purpose of this review is to bring together much of the available research and literature that focuses on health issues associated with mercury in dental fillings, some of the basic science information that is known about how the body processes mercury, and to offer some observations from the practices of dentists removing dental mercury from their patients. We also hope this review will draw attention to the potential connections between mercury released from dental fillings and autoimmune diseases. Many autoimmune diseases are classified as diseases of unknown etiology; yet, the well-documented toxic effects of mercury may explain some of the symptoms observed in autoimmune diseases.

INTRODUCTION

Mercury is generally accepted to be one of the most toxic of all the metals in the periodic chart that are not radioactive. It comes in several forms–some are more destructive than others–and each has its own mechanism of toxicity. There are four possible forms of mercury (called oxidation states), yet only three are commonly encountered. One is the vapor form (Hg^0), another is the ionic form, (Hg^{++}), and the most toxic is the organic form (CH_3-Hg^+) or methyl mercury.

Mercury vapor damage (Hg^0) is almost entirely limited to the central nervous system.[1] This is the state in which mercury commonly escapes from silver-mercury fillings. Ionic mercury (Hg^{++}) toxicity is often acute and produces local damage to adjacent tissues–primarily directed toward organ systems. The kidney is often the primary target organ, although it can damage many other tissues.

Methyl mercury is by far the most toxic of the mercury compounds. This is due to its motility. It effortlessly travels to any tissue, recognizes no barriers, and can enter any cell without permission. Within a cell, it can destroy the various components selectively or in totality by unleashing lysosomes, damaging DNA, and by rupturing the cell membrane. Its effects upon the peripheral nervous system are demonstrated in diseases like seizures, tremors, multiple sclerosis (MS), and amyotrophic lateral sclerosis, to name but a few. Mental and emotional diseases may also result, as well as interferences in hormonal production and function.

Dental fillings containing mercury are often called silver fillings, primarily as a marketing tool that describes their color. Mercury is the primary component, making up close to 50% of the content; copper is next, comprising almost 30%. The remaining 20% is divided among tin, silver, and zinc. There are several other names associated with these fillings. Dentists frequently refer to the silver-colored filling as an *amalgam*, which means mixed with mercury. Mercury appears to dissolve many metals into a liquid phase that can be easily placed into multishaped containers, like the spaces dentists cut into teeth as they remove cavities. Other names are also seen, most of which seem to be an effort to avoid using the word *mercury*. Given the underlying toxicity of mercury, our first consideration should be how much mercury is being released from dental fillings containing mercury.

RELEASE OF MERCURY FROM AMALGAMS

Mercury is released from silver-mercury-amalgam-alloy fillings by four basic methods:

1. Mechanical Compression. Articles on the increased (up to 15,000%) release of mercury from chewing gum have been published.[2] Eating and trauma are also contributing factors to the release and subsequent storage of mercury in various parts of the body.
2. Chemical. When dissimilar metals are placed together in saliva (an electrolytelike solution), an electrochemical reaction can occur. With dental amalgams, the combination of the five different positively charged metals form at least 16 different corrosive products on the surface of the filling.[3] Other foods bring a variety of chemicals in contact with the electrically charged metallic fillings, with a resultant multitude of other potentially corrosive products created, many of which may be toxic. These products may be abraded off during chewing or washed off by acidic foods like vinegar and oil dressing, soft drinks, fruits, and juices, and released along with mercury vapor.
3. Electrical. Chemical reactions among the various combinations of metals on the surface of amalgam produce electrical current that can be measured. The negative pole of the electrical current produced by these metals can release mercury vapor. When measured, the amounts given off can exceed OSHA's limits for 40 hour per week

1 Huggins Applied Healing, Colorado Springs, CO

Corresponding Author. Address:
5082 List Drive, Colorado Springs CO 80919
email@drhuggins.com

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exposures. Further confusion is created by the fact that different federal agencies have different safe-level standards.[4] And exposures from fillings occur 24 hours per day, not 40 hours per week, and therefore could exceed the recommended safe limits.

4. Temperature. Hot beverages, hot soups, and other hot foods increase the temperature of the surface of the fillings. Mercury follows the law of physics that states that chemical reactions double for every 10°C increase in temperature. Coffee and tea are at the top of the list for increasing mercury release due to temperature increases.

Where Does Mercury Go After Being Released From the Fillings?

Mercury mixed with foods goes into the stomach, and from there it can go into the intestinal tract and then on to the blood stream. The mercury released directly into the mouth is absorbed into the cheeks or sublingually–both routes of absorption end up in the blood stream. Most of the mercury that reaches the gastrointestinal tract is converted into methyl mercury by gastrointestinal tract bacteria[5] that can be absorbed through most cell membranes.

Inhalation of mercury vapor directly from the oral cavity may enter the lungs, where it may be absorbed directly into the blood stream. If mercury vapor remains in the blood stream for more than a few seconds, it may be methylated–as methyl mercury it could pass through the blood brain barrier (BBB), after which it can be oxidized into the ionic form that damages brain tissue. Glial cells in the brain have the highest affinity for absorption and storage of mercury of any cells in the body.

Another method by which mercury is released from a filling into the body is by going from the filling, through the dentin, into the pulp chamber of the tooth,[6,7] and into the blood stream, or by retrograde axonal transport, going directly into the brain.[8]

Different forms of mercury in the body and different potential modes of toxicity have been associated with the following:

- interaction with macromolecules[9]
- cross-linking of cell membranes[10,11]
- rupturing the cell membrane[9]
- lysing DNA[11]
- mitochondrial interference[12]
- interference with nerve impulse transmission[13]
- alteration of the three-dimensional structure of a molecule[14,15]
- interference with DNA replication[11]
- interference with DNA repair[15,16]
- alteration of cell membrane permeability[17]
- altering the methylation/demethylation balance in the gut[18]
- destruction of lysosomes within cells, releasing hydrolytic enzymes that destroy cell contents and surrounding structures[19]

From the practical standpoint, interference with these mechanisms may be responsible for potential functional aberrations, including:

- stimulation of the onset of autoimmune diseases[20]
- interference with endocrine function[21]
- alteration of enzyme function[22]
- displacement of other minerals, such as Ca, Mg, Zn, and Cr[11]
- alteration in digestion and absorption[23]
- formation of plasmids[24]
- creation of birth defects[23,25-29]

MERCURY VAPOR

Mercury vapor (Hg^0) released from fillings is the first form that attacks the body.[2,30-32] It can travel through the nervous system to the optic nerve and create optic neuritis,[33] or it can travel into the nasal sinus from which it has direct access into the temporal region of the brain.[34,35] In the brain, mercury vapor can produce high neurological damage, but low systemic damage.[36,37]

On the way to the lungs, mercury vapor can travel via the vagus nerve to the central nuclei in the brain stem,[38] directly to the lung,[39] or to the gastrointestinal tract.[38] From the lungs, mercury vapor can be transported into the blood stream, where it may react with cells in the blood. Mercury vapor has been documented to suppress the activity of polymorphonuclear leukocytes.[10] When mercury vapor enters erythrocytes, it may be oxidized to form ionic mercury, which can immediately kill red blood cells.[37] If the mercury vapor does not immediately kill the cell, it may displace oxygen on hemoglobin,[37] altering the three-dimensional structure of the molecule.[14] Mercury does not release from hemoglobin once it attaches, which means that a complete blood count may show a normal red cell count, hemoglobin, and hematocrit; however, the displacement of oxygen by mercury means the peripheral tissues may not be adequately oxygenated. The hematocrit can show as much as a 4% drop in less than a week by using procedures designed to rid the body of mercury-contaminated hemoglobin, whereas the urine mercury increases several hundred percent, suggesting increased mercury elimination from the contaminated red blood cells. There is also a simultaneous increase in oxyhemoglobin saturation of between 10% and 30%.

Methylation of mercury vapor in the blood[40] can also easily enter the placenta. Developmental effects may include:

- exposure at weeks 0 to 2 may result in a lack of implantation[40]
- exposure at weeks three to four may result in adverse effects involving the brain, heart, eyes, limbs, and ears[40]
- exposure at weeks six to seven may result in adverse effects involving the brain, heart, eyes, limbs, and ears, and contribute to the formation of cleft palate[40]
- exposure at weeks 9 to 12 may result in adverse effects involving the eyes[40]

Not only can the placental barrier be penetrated by the methylation of mercury vapor, but the BBB and the central nervous system can also be breached.[41,42] Mercury vapor interacts with amino acid carriers in the BBB as well as with sulfhydryl groups in the barrier itself.[42]

IONIC MERCURY

Ionic mercury (Hg^{++}) species can be formed on the surface of amalgam[3,43] and be swallowed with or without food, ending up

in the stomach. In the intestinal tract, there is absorption through the adjacent linings[36] that may leave a leaky membrane in its wake.[9] Ionic mercury enters cells by access through the calcium channels[9] and interferes with cell membrane function, including both the entrance of raw materials and the exit of waste products. In the stomach, ionic mercury forms mercuric chloride that may kill friendly bacteria, leading to indigestion and malabsorption,[44-46] or it may cause ulcers.[9]

Cells destroyed by ionic mercury spread their contents throughout the surrounding tissues[9] and are ultimately absorbed into the lymphatic drainage system; this may stress the liver or kidney. When ionic mercury enters tissue cells, it can alter its DNA[10] as well as destroy mitochondria.[12] There is also a reduction in cellular energy if the mercury interferes with the sodium-potassium pump mechanism.[42]

In the nervous system, ionic mercury is again toxic.[42] Even though it (unlike methyl mercury) cannot pass through the BBB,[47] methyl mercury can be converted into ionic mercury once it has passed the BBB. It can then enter the cells via the sodium and calcium channels[48] and disrupt nerve impulse transmission by displacing ionic calcium from the cell membrane.[9] Excretion of ionic mercury from the brain is especially slow and is measured in years.[42]

In the immune system, ionic mercury exposure lowers the viability of lymphocytes.[20] Consequently, the differential count from a complete blood count may give a false impression of the body's defense ability. These compromised lymphocytes may still appear in the cell counters or on histopathologic slides. It is ironic that in scientific laboratories, injection of ionic mercury is used to increase the percentage of experimental animals with autoimmune disease.[20] Could this effect be at work in humans as well?

METHYL MERCURY

Mercury vapor can be converted to methyl mercury (MeHg) by the action of bacteria.[5,49] Plasmids, a defense mechanism for bacteria to survive mercury toxicity, have the ability to convert ionic mercury to methyl mercury.[24] This is a life-saving procedure for the bacteria because methyl mercury can be eliminated by the bacterium through its cell wall before the ionic species can destroy the contents of the bacterium. To make matters worse, when bacteria form plasmids to deal with mercury toxicity, they may simultaneously become resistant to many antibiotics. Methylation of mercury is encouraged by antibiotics, while at the same time demethylation is slowed.[9]

Methyl mercury can also be formed by the action of negative electrical charge on the surface of saliva-coated amalgam fillings as mercury vapor escapes from the fillings.[5,50,51] A little recognized method of methylation may be the action of vitamin B_{12}.[52] Cysteine, a dietary supplement, also methylates mercury.[53] As methyl mercury cysteine, it is resorbed in the large bowel and transported via the hepatic portal system to the duodenum.

Methyl mercury is 45 times more lipid soluble than ionic mercury (Hg^{++}).[49] This makes it particularly dangerous to nerve cells, where the cell membranes have a higher lipid content (75% vs 40%) compared with cells from other tissue. Upon arrival in the cell, methyl mercury is oxidized into ionic mercury and begins its destruction as outlined in the previous section. Plasma membranes are the primary organ target for methyl mercury (MeHg).[54] It attacks myelin protein,[9] creates degeneration of nerve cones,[55] and causes the development of sensory neuropathy.[56] Methyl mercury may prevent synaptic transactions[13,57] that may lead to numbness and tingling of the hands and feet,[58] some of the first signs associated with MS. Motor nuclei accumulation of methyl mercury may also cause constriction of visual fields, another sign of MS.[59,60] Demethylation may decrease, but does not eliminate, the toxicity of MeHg.[56,61]

Methyl mercury is not only dangerous because of its ability to enter cell membranes–another aspect of its toxicity is related to its interactions with enzyme bonds. This bonding induces a change in conformation of the tertiary structure of proteins that may result in a loss on enzymatic activity.[18]

Methyl mercury may also cause birth defects, as noted above, for mercury vapor. These may include alterations in the brain, heart, eyes, limbs, ears, cleft palate, cleft lip, and sex organs, as well as chromosomal damage, single strand breaks, and DNA–DNA cross-links.[10,62] There may be enough mercury in sperm at the time of conception to create birth defects.

DENTAL RELEASE OF MERCURY

Direct exposure of mercury in the oral cavity is not the only method of introduction of mercury into the brain and nervous system through retrograde axonal transport backwards along the trigeminal nerve to the brain. This fifth cranial nerve enervates all of the teeth and has direct communication with the brain. Mercury can be transported from fillings into the pulp chamber.[6,7,48] From the pulp chamber, it may be transported into the main branch of the nervous system via the trigeminal nerve. As mercury travels along the trigeminal nerve, it creates inflammation, resulting in adhesions on the ganglion that may contribute to trigeminal neuralgia and migraine headaches.[48]

In the maxillary branch of the trigeminal nerve, mercury that has traveled from the filling through the dentinal tubules into the pulp chamber can move backward up the trigeminal nerve. The speed of retrograde axonal transport of mercury along the mandibular branch of the trigeminal nerve has been measured at 70 mm per 24 hours into the trigeminal ganglion at the base inside the skull.[63] This provides a pathway for microbial toxins as well as mercury into the cranial cavity.[63] Retrograde axonal transport is not limited to mercury.[7,35,63-69] This retrograde axonal transport system may move copper, antiseptics, bleach, decay products, root canal toxins, and antibiotics.[6,70]

The hypoglossal nerve (XII) may also transport ionic and methyl mercury sublingually into the brain from the motor nerve terminals via sodium and calcium channels.[48] This mercury may be picked up sublingually because this is a primary absorption area close to the fillings.

Mercury can also travel along the parallel valveless cranial venous system as well and might contribute to neurological diseases such as MS.[21] Mercury in the central nervous system concentrates in the glial cells, which act as scavengers for the nervous system.

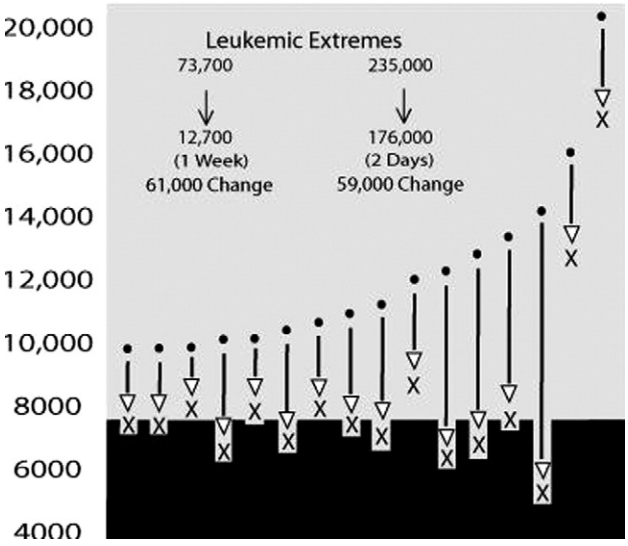

Figure 1. White blood cell reponse to sequential removal of silver-mercury fillings.

Bacterial infection and inflammation at the apex of teeth may occur around root canals or dead teeth. Specifically, *Actinomyces* bacteria may move by retrograde axonal transport from dead teeth directly into the brain.[70]

CLINICAL IMPLICATIONS

Does Mercury Play a Role in Autoimmune Disease?

The immune system has a surveillance team of white blood cells that constantly monitor the cells of the body for their permission to be there. This monitoring is done through the major histocompatibility complex (MHC), which identifies the cells of the body as "self." All the body's cells are coded with the same MHC, except red blood cells and sperm. If the MHC is altered–as with organ transplants–the surveillance team flags the cell and another cell of the immune system will come along and destroy it. When normal cells (such as nerve cells) have as little as a single atom of mercury attached to a free sulfhydryl bond, the MHC is distorted by one digit, and the immune system may identify this cell as "nonself." This type of cell with a hitchhiker is called a hapten, a normal cell with an MHC distortion.

White blood cells are particularly sensitive to the presence of mercury and other toxic materials, many of which are used in modern dentistry. In human studies, it is sometimes difficult to differentiate which material might have caused damage in a living organism; however, we can isolate the biochemical reactions in the laboratory.

Figure 1 demonstrates the trend for white blood cells to drop toward the stability point when the total protocol is followed. Even in extreme cases like leukemia, a positive responsive can be determined within a few days.

Even more difficult than reducing high white blood cells is raising low white blood cell counts (Figure 2). The trend seems to be that upon initial exposure to mercury, white cells elevate in an effort to eliminate the cause of hapten formation. Since mercury

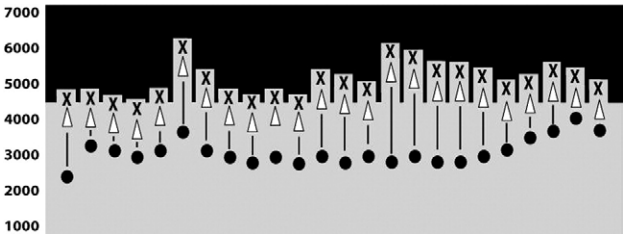

Figure 2. White blood cell response to sequential removal of silver-mercury fillings.

cannot be "killed" and is difficult to eliminate, it in turn may kill white blood cells, and after a period of time the white blood cell count may drop below the stability point. Figure 2 demonstrates that there can still be a quick response toward the stability point when the primary irritant is removed sequentially.

Viability tests can be run on separated lymphocytes in a laboratory by using a standardized test focusing on lymphocyte degradation to separate living from dead cells. It is frequently assumed in a conventional complete blood count differential count that all the white cells were alive at the time the slide was exposed to air, dipped in alcohol, and stained. This may not be true, and if so, could give a false estimate of actual immune capacity.

Figure 3 demonstrates what happens when isolated live lymphocytes are viewed under a fluorescent microscopy by using special dyes, such as propidium iodide, to allow visual separation of live from dead cells in live cultures. On the initial day of the test, 100% of the lymphocytes are alive–or viable–in this patient. Viability counts use state-of-the-art method for separating live from dead lymphocytes. A small amount of mercury (approximating the amount that could theoretically be in the blood of someone with four amalgams) was added. By day two, the control segment has dropped to 97% and the mercury test group has dropped to 92%. By day four, the control group of cells still maintains a viability of 97%, but the viability of the mercury-exposed lymphocytes has dropped to 21%. This difference will not be shown on the conventional differential count, which does not look at viability.

In the case of autoimmune diseases, the nervous system–part of your "self"–is being destroyed by your own immune system,

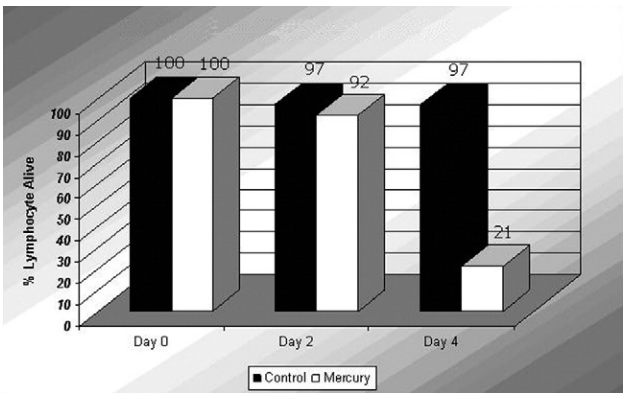

Figure 3. Lymphocyte viability when exposed to mercury.

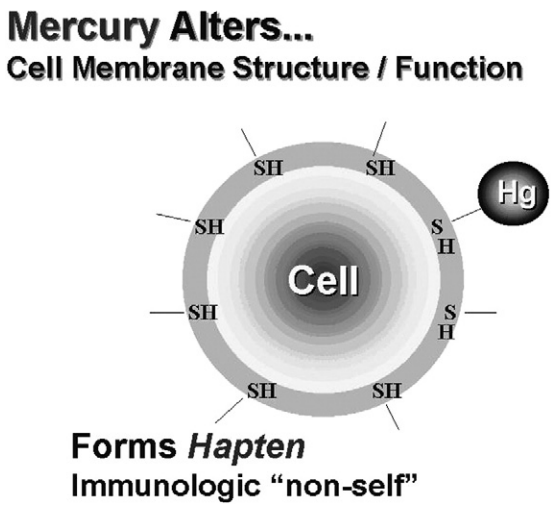

Figure 4. Effects of mercury on cell membrane structure and function.

see Figure 4. This onset may be associated with, but not limited to, mercury toxicity. Toxins from anaerobes associated with root canals may also be in part responsible for some of the same type of autoimmune reactions.

Figure 5 shows the results of [^{32}P]8N3ATP photo labeling of eight cerebrospinal fluid samples taken pre– and 48-hour post–dental revision procedures. These four patients were diagnosed with MS by magnetic resonance imaging prior to treatment. Cerebrospinal fluid solubilized proteins were then subjected to SDS-polyacrylamide gel electrophoresis. The only proteins that are expected to be seen in healthy persons are albumins, and they were present pretreatment and post-treatment. There were multiple abnormal proteins present in the pretreatment samples, but none in the posttreatment samples. All four patients improved symptomatically as the spinal fluid cleared.[71]

Evaluation by two-dimensional gel did not identify the abnormal proteins, and later it was postulated that they were fragments of brain tissue found floating down from the brain into the cerebrospinal fluid, and its source was eliminated by the removal of dental toxins.

Figure 6 demonstrates the very low (12 mcg per 24-hour urine collection) amount of urinary porphyrin in an adult who never had dental materials in his mouth. In other MS patients, the reduction of urinary porphyrins was related to clinical improvements.

As a comparison in Figure 7, another MS patient shows 2,100 μg of urinary porphyrin predental revision. These were divided between the 4, 5, 6, 7, and 8 carboxy porphyrins. This reduction

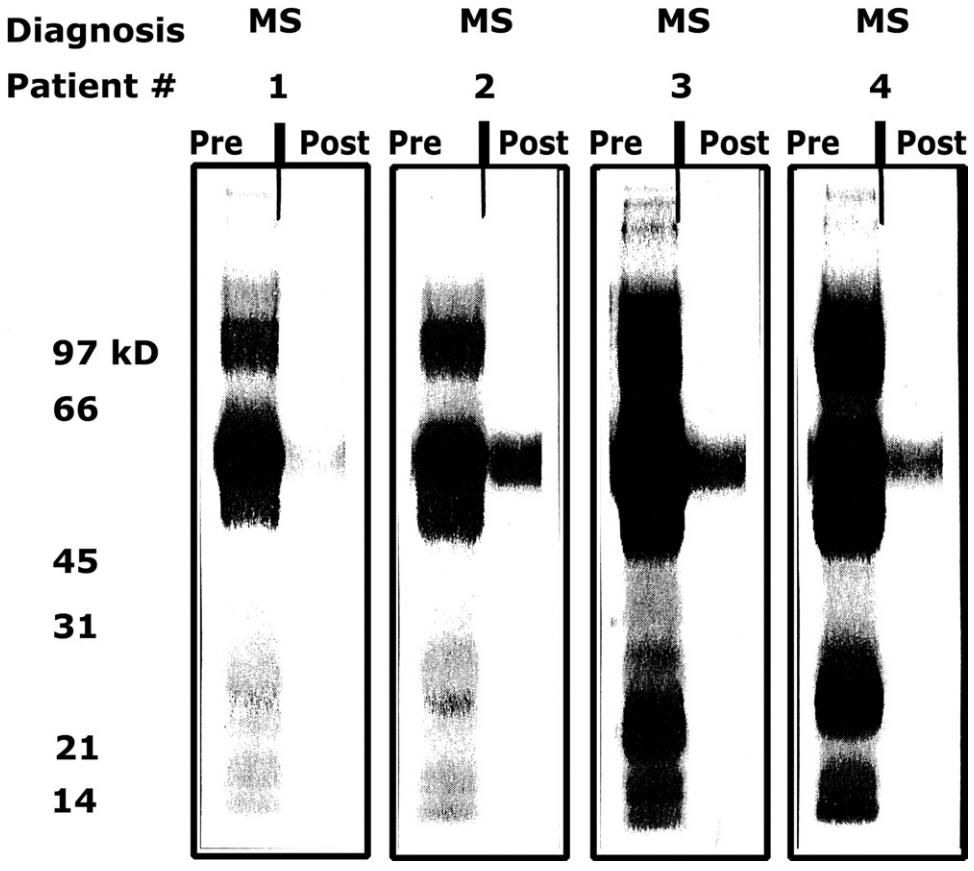

Figure 5. Cerebro spinal proteins before and after dental revision.

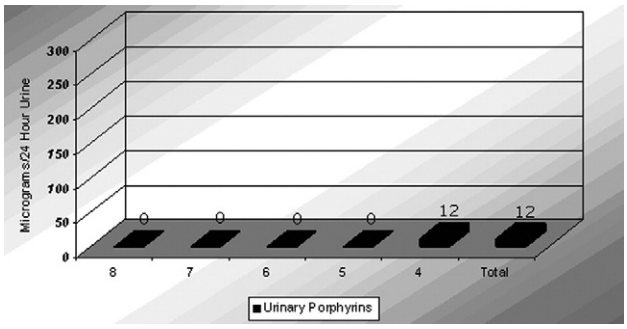

Figure 6. Urinary porphyrin profile on a patient with no previous dental treatment.

from 2,100 to 200 μg in 12 days gave the patient much more oxygen (from the formation of hemoglobin from porphyrin) as well as more adenosine triphosphate (derived from heme; also derived from porphyrin breakdown) traveling through the cytochrome oxidase system. Even though root canals and amalgam fillings are very different, they may result in the same type of autoimmune destruction.

DENTAL IMPLICATIONS

If having a root canal or putting in a mercury amalgam filling may produce an autoimmune process in a person at risk, why does the process of reversal or taking out mercury amalgams appear to be more complex? Factors to be considered include: (1) Is a protective rubber dam used? (2) Are negative ion generators used to remove mercury vapor from the dental atmosphere? (3) Is dental replacement material serum tested for compatibility and immune reactivity? (4) Is careful attention paid to balancing the blood chemistry as mercury amalgams are removed? (5) Are amalgams sequentially removed, first removing negatively charged fillings, followed by positively charged fillings?

It has been suggested that the removal of positively charged fillings may overstimulate the sympathetic division of the autonomic nervous system, whereas removal of the negatively charged fillings first stimulates the parasympathetic nervous system.

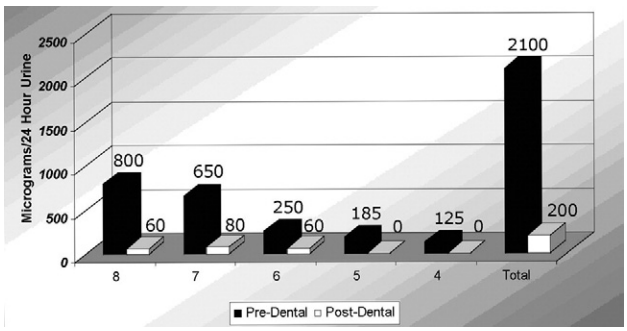

Figure 7. Urinary porphyrin profile on a patient with MS pre vs post dental treatment.

CONCLUSION

The toxicity of mercury has been known for centuries and has often been underestimated. We have yet to fully appreciate the potential relationship between illness and the body's exposure to mercury from a variety of sources, including dental amalgams. It behooves us to be aware of these relationships when assessing the health of patients today, and further research, although complex and fraught with many confounding variables, is urgently needed.

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