Amalgam and Composite Resin Interface Investigation by Opical Coherence Tomography

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Abstract: - The aim of this study was to analyze the interface between the amalgam and composite resin restorations using a noninvasive method like the optical coherence tomography working in Time Domain. The conclusions point out the importance of investigation the integrity of every interface after every direct restoration into the oral cavity.

Key-Words: - Amalgam fillings, Composite resin fillings, Optical Coherence Tomography

1. Introduction

The interface between amalgam and composite resin fillings are a good subject of scientific evaluation.

Mercury is a highly toxic metal associated with damage to the kidneys and central nervous system [1]. Mercury vapors are emitted from volcanoes, coal-burning power stations, and municipal incinerators and returns to the earth through rain contaminated with metallic mercury. Metallic mercury is methylated to methyl mercury in oceans and lakes and enters the food chain via fish and other seafood. Long-lived predator fish such as shark, swordfish, tilefish, king mackerel, and pike and bass in fresh water are the main sources of methyl mercury. Dental amalgams are an important source of mercury vapors and the vaccine preservative thimerosal is a significant source of ethyl mercury.

Researchers at the University Of Rochester School Of Medicine recently published a review of what is currently known about mercury toxicity. Among the highlights:

- Mercury vapors, methyl mercury and ethyl mercury all target the central nervous system and mercury vapors and ethyl mercury also target the kidneys. Inorganic (metallic) mercury primarily targets the kidneys and stomach.
- Chelators such as DMSA are effective in removing all forms of mercury from the body, but cannot reverse central nervous system damage.
- The allowable or safe intake of mercury has recently been reduced to 0.1 microgram/day per kilogram of body weight.
- The concentration of mercury in the brain, blood and urine correlates with the number of amalgam fillings in one's mouth. The concentration increases markedly with increased chewing. Long-term use of nicotine gum by people with amalgam (silver) fillings may increase levels by a factor of 10, thus approaching occupational safety limits.
- There is concern, but no clear evidence, that mercury emitted from amalgam fillings may cause or worsen degenerative diseases such as ALS, Alzheimer's disease, multiple sclerosis, and Parkinson's disease.
- Ethyl mercury (thimerosal) is used as a preservative in vaccines. Recent concerns about its toxicity have caused US authorities to take steps to remove it by switching from multi-dose vials to single-dose vials that do not require a preservative.

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- A recent move by power companies to replace mercury containing pressure-control devices for domestic gas supplies has led to numerous spills of mercury in homes. Some 200,000 homes were affected in one recent incident. The liquid mercury is difficult to remove and gives off highly toxic vapours, which are particularly harmful to infants and children.

- Several studies have found an association between mercury exposure and cardiovascular disease, but other studies have failed to confirm the connection.

Extensive amalgam restorations involving portion of facial surfaces are judged to be distracting. Esthetic corrections can be made with posterior composite resins placed in cavities cut in existing set amalgam restorations to remove the offensive facial portions. Application of dental adhesives onto roughened amalgam surfaces was used to increase interfacial bond of composite resins to dental amalgam.

The American Dental Association (ADA) has launched an advertising campaign to discourage patients from having their amalgam (silver) fillings removed. Many patients and sometimes even their physicians believe that mercury, the main component of amalgams, plays a role in promoting such varied diseases as Alzheimer's, multiple sclerosis, and autism. The ADA says the evidence is not there and their Code of Ethics forbids dentists from advising their patients that there could be a link. Scientists at the University of Milan disagree with the ADA and point out that several studies have confirmed that mercury from amalgam dental fillings does enter tissues and that the mercury content of brain, thyroid, kidney, and pituitary gland tissue is proportional to the number of amalgam fillings. They conclude that the health effects of amalgam fillings are not at all clear and need further investigation. German researchers point out that some of the composite materials used in the replacement of amalgam fillings may in themselves be toxic. [2, 3]. Mercury and removed amalgam fillings are classified as hazardous materials and require extreme caution in disposal. Why they would be hazardous outside the mouth, but not inside defies comprehension. It is also a scientifically proven fact that the blood level of mercury is twice as high in dentists as in non-dentists. This fact and the fact that savvy patients don't want mercury in their mouths is no doubt what is leading many dentists to put a, albeit discrete, sign in their waiting rooms "Mercury-free practice".

Several studies have shown that regular fish consumption protects against cardiovascular disease. Other studies have shown that consuming mercury-contaminated fish increases the risk of coronary heart disease. The beneficial effect of fish consumption is believed to be due to the presence of the omega-3 fatty acids, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) in the tissue of fish and shellfish. Two recent studies have attempted to answer the question "Are the beneficial effects of fish oils (EPA and DHA) outweighed by the negative effects of mercury"?

The first study, carried out by a team of researchers from eight European countries, Israel and the United States, involved 684 men who had suffered a first non-fatal heart attack and 724 matched controls. All participants had their mercury level measured in toenail clippings and their level of DHA measured in a fat tissue sample taken from the buttock. Participants with a mercury level of 0.66 mcg/gram were found to have twice (odds ratio of 2.16) the risk of having a first heart attack when compared with participants having a mercury level of 0.11 mcg/gram. This risk assessment was arrived at after adjusting for age, DHA level in adipose tissue, body-mass index, waist:hip ratio, smoking status, alcohol intake, HDL cholesterol level, diabetes, history of hypertension, family history of heart attack, blood levels of vitamin E and beta-carotene, and toenail level of selenium. The research team also found that participants with a high (0.44% of total fatty acids) fat tissue content of DHA had a 41% lower risk of having a first heart attack than did those with a low (0.10% of total fatty acids) fat tissue level of DHA. This risk assessment was arrived after adjusting for all other known risk factors including toenail mercury level. The researchers point out that the main sources of mercury are occupational exposure (dentists), exposure to silver-mercury amalgam in dental fillings, and fish consumption. They conclude that the health benefit of fish consumption is significantly diminished if the fish is high in mercury. They also confirm the cardio protective effect of fish oils (DHA) [4,5].

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The second study was part of the Health Professionals Follow-Up Study begun in 1986 as a cooperative venture between the Harvard School of Public Health, the Brigham and Women's Hospital, and Harvard Medical School. The study involved 33,737 male health professionals who had toenail clippings analyzed for mercury in 1987. After 5 years of follow-up 470 participants had been diagnosed with coronary heart disease. The researchers observed that dentists, who are habitually exposed to mercury, had toenail mercury levels (0.91 mcg/gram) that were twice as high as the levels found in non-dentists (0.45 mcg/gram). They also found a direct relationship between fish consumption and mercury level with participants consuming an average of 357 grams (3/4 lb) of fish per week having a level of 0.75 mcg/gram while those who consuming 145 grams (1/3 lb) per week had a level of 0.29 mcg/gram. After adjusting for age, smoking and other risk factors for heart disease the researchers conclude that there is no clear association between total mercury exposure and the risk of coronary heart disease, but that a weak relation cannot be ruled out [6].

Dr. Gary Null, PhD and Dr. Martin Feldman, MD have released a major report concerning the health hazards of dental amalgam (silver) fillings [7]. They point to incontrovertible evidence that mercury continually leaches from amalgam fillings at a rate of about 10-50 times the safe limit (0.28 microgram/day) set by the US Public Health Service. Mercury has been linked to birth defects, multiple sclerosis, fatigue, Alzheimer's disease, depression, anxiety, reduced immune function, antibiotic resistance, and impaired kidney function. Researchers have found that mercury is a potent killer of white blood cells and that proper removal of amalgam fillings will restore white blood cell counts to healthy levels. There is also evidence that the number of T-cells (an important part of immune defenses) decreases substantially when amalgam fillings are placed in the mouth, but increases again once the fillings are removed.

The American Dental Association (ADA) maintains that amalgam fillings are safe – a position made completely untenable by the fact that the Environmental Protection Agency (EPA) has declared amalgam to be a hazardous material. It is interesting that the ADA, when confronted by a lawsuit regarding the use of amalgam fillings, made the following statement in its defense, "The ADA owes no legal duty of care to protect the public from allegedly dangerous products used by dentists."

Several studies have found that chewing markedly increases the amount of mercury released from amalgam fillings into the mouth and that these mercury vapours easily find their way into the pituitary gland and the brain. Autopsies performed at the Karolinska Institute in Sweden revealed that people with amalgam fillings had three times more mercury in the brain and nine times more in the kidneys than did people with no amalgam fillings.

Common bacteria found in the mouth and intestines can convert mercury to methylmercury, a compound that is 100 times more toxic than is elemental mercury. Methylmercury passes both the blood-brain and placental barriers and following a large exposure can remain in the brain for 10 years or more. Considering that dentists still place about one million amalgam fillings in the mouths of American citizens every day it is clear that disorders caused by amalgam toxicity is a horrendous problem. Not everyone is sensitive to mercury, but various studies estimate the percentage that are to be somewhere between 10 and 44 per cent. Fortunately, a few governments are beginning to wake up to the dangers and are passing laws restricting or outright banning the use of amalgam fillings. The German, Norwegian, Swedish, Canadian and British governments have advised dentists not to install or remove amalgam fillings in pregnant women. Since November 2000 the following sign has been posted in all dental offices in California, "WARNING – Amalgam fillings contain a chemical element known to the State of California to cause birth defects or other reproductive harm". The California Dental Association apparently lobbied successfully to ensure that the word mercury did not appear in the warning.

The Australian Society of Oral Medicine and Toxicology has concluded that mercury in amalgam fillings is continuously released from the fillings and accumulates in tissues throughout the body where it interferes with many physiological functions.

Medical researchers at the Catholic University in Rome report that patients with congestive heart failure (idiopathic dilated cardiomyopathy or IDCM) have vastly elevated concentrations of mercury and antimony in their heart tissue. They compared trace element

concentrations in biopsy samples from the left ventricle among patients with IDCM and patients with valvular disorders or no heart disease at all. The IDCM patients had mercury concentrations 22,000 times higher than in the controls. Antimony concentrations were 12,000 times higher and silver, gold, chromium and arsenic levels were also highly elevated. Holter monitoring revealed frequent ectopic (premature) beats in all the IDCM patients and ventricular tachycardias in six of the 13 patients. None of the patients had had occupational exposure to the trace elements. Researchers at the University of Calgary point out that dental amalgams would be the most likely source of the mercury [8, 9].

Dr. William Cheshire, a physician at the Mayo Clinic, reports on a case where a woman's trigeminal neuralgia (tic douloureux) was traced to a galvanic reaction between an amalgam filling and an adjacent gold-alloy crown. Consumption of tomatoes and other acidic foods produced intense jolts described as being like those of an "electrical battery". The jolts in turn resulted in excruciating pain in the trigeminal nerve. Replacing the amalgam filling with a composite resolved the problem. Dr. Cheshire points out that dissimilar metal in contact with saliva can form a galvanic cell which can generate electrical currents with several hundred millivolts of potential. He points out that many patients with trigeminal neuralgia describe their pain in terms of "electrical" jolts and concludes that his patient's neuralgia may well have been triggered by the galvanic reaction between the amalgam filling and the gold crown [10].

Another concern in dentistry has been how to best repair amalgam restorations.[11 - 15] Fruits and others studied the interfacial bond strengths between fresh amalgam and old and fresh amalgam with abraded and unabraded surfaces, showing that there were no significant differences in bond strength between abraded and unabraded surfaces, and the mean bond strength was greater in groups of specimens that did not use a bonding agent. Other studies have suggested that adhesive systems could improve bonding between old and new amalgam through mechanical interlocking between the adhesive system and freshly condensed amalgam [12, 13]. Also, resin composites have been used to repair amalgam restorations; Özcan and others13 evaluated the effect of different surface conditioning methods on the shear bond strength of resin composite to fresh amalgam, concluding that bond strengths of resin to amalgam substrates varied according to surface conditioning techniques. Abu-Hanna and Mjör reported an alternative technique using resin composite and amalgam to restore teeth that normally would require indirect restorations as a low-cost alternative, with successful clinical results over a short-term [16].

Composite resins bonded to dental amalgam, as all other restorative materials, function in a complex environment. The clinical performance of these restorative materials is dependent on externally imposed variables, such as temperature, oral medium and applied loads. The interactive effect of these variables, often unpredictable and transient in nature, affects the short- and long-term stability of such restorations.

A durable resin bond to dental amalgam is required for the clinical success of composite resin-veneered amalgam restorations. The reported bond strengthens of such restorations differ for various adhesive resins. Laboratory procedures utilized to simulate aging of these restorations in the oral cavity vary widely.4'8" In addition, water storage at a constant temperature (37 °C) or thermo cycling are the most often used conditions.I0,12'n The effect of thermo mechanical variables on the strength of bonding composite resins to amalgam has not yet been investigated.

2. Problem Formulation

The aim of this study is to investigate the amalgam-composite resin interface resulting after optimization of pre-existing amalgam fillings by means of optical coherence tomography (OCT).

3. Problem Solution

Class I cavities were prepared on 10 upper molars and subsequently filled with non gamma 2 amalgam (Megalloy EZ, Dentply DeTrey) following the manufacturer’s instructions. After storing the samples for 30 days in distilled water at 30ºC, the palatal half of each filling was removed with a medium grit diamond bur. The resulting cavities were conditioned with 15% phosphoric acid for 15” and then filled with composite resin (SureFil. Dentsply

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DeTrey) using Xeno III (Dentsply DeTrey) as an adhesive.
The amalgam – hard dental tissue and the amalgam – composite resin interfaces were investigated by means of OCT in C scan and B-scan mode working at a 1300 nm wave-length (Fig. 1).

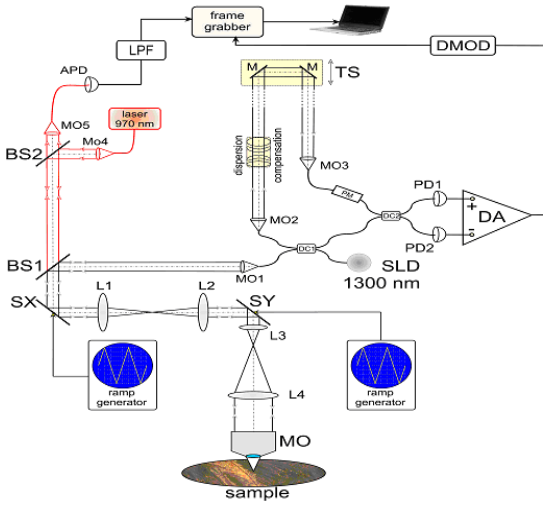


Fig.1. *En-face* OCT at 1300 nm/confocal at 970 nm system. SLD = superluminescent diode, SX, SY: X and Y scanners; IMG = index matching gel; APD: avalanche photodiode; L1, L2, L3, L4: lenses: MO1-5: microscope objectives; PD1, 2: pin photo detectors; BS1,2: beam splitters; LPF: low pass filter; PM: polarization.

4. Results

The results obtained after the OCT investigation in Time Domain pointed out some defects at the amalgam and composite resin interface (Fig. 2 to 9). In order to observe better the defects a 3D reconstruction was performed (Fig. 10, 11).

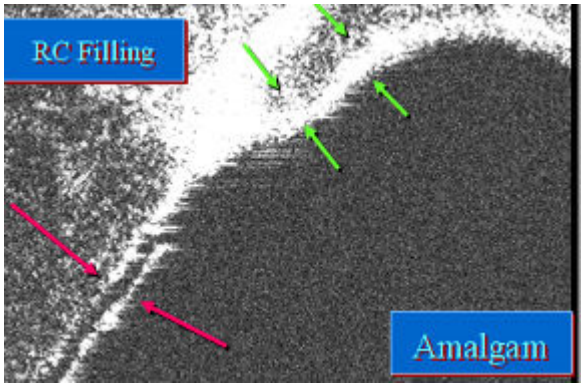
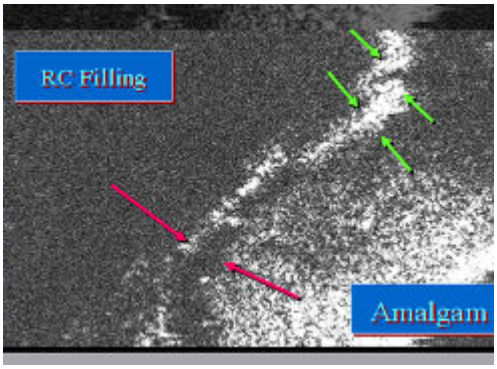


Fig. 2. C scan on OCT investigation reveling material defects inside the amalgam and composite resin interface.



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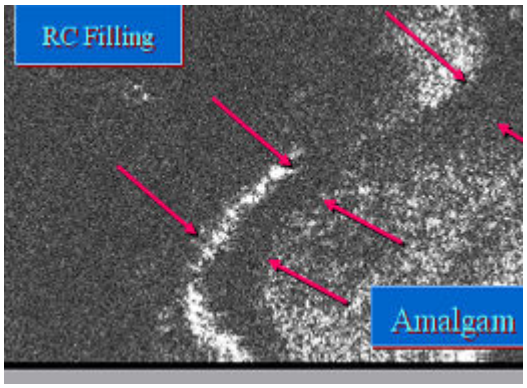

Fig. 3. C scan on OCT investigation reveling material defects inside the amalgam and composite resin interface.

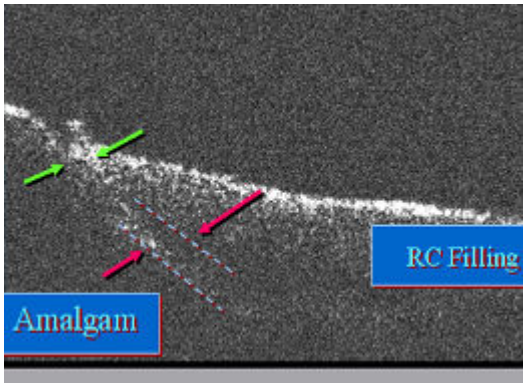

Fig. 4. B scan on OCT investigation reveling material defects inside the amalgam and composite resin interface.

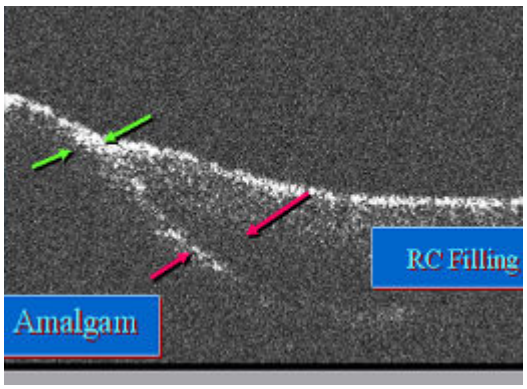

Fig. 5. B scan on OCT investigation reveling material defects inside the amalgam and composite resin interface.

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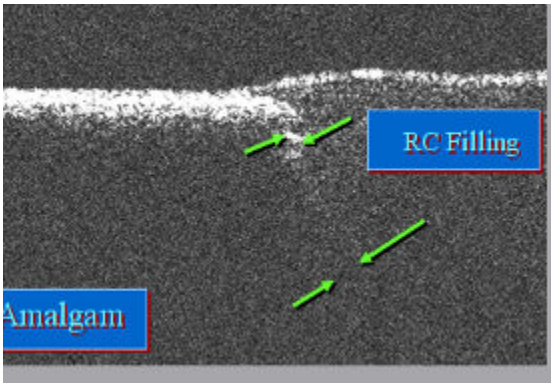

Fig.6. B scan on OCT investigation reveling material defects inside the amalgam and composite resin interface.

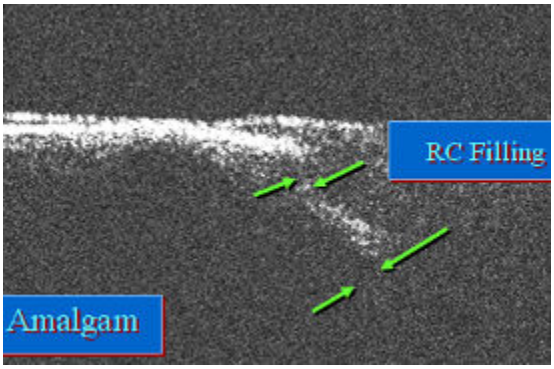

Fig. 7. B scan on OCT investigation reveling material defects inside the amalgam and composite resin interface.

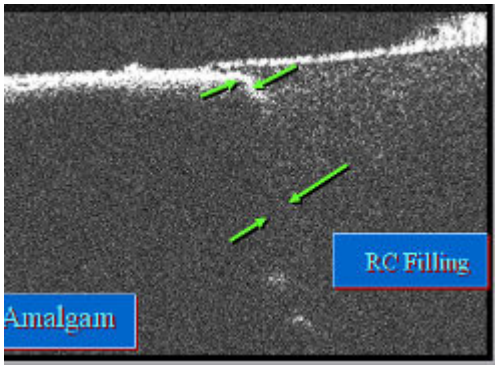

Fig. 8. B scan on OCT investigation reveling material defects inside the amalgam and composite resin interface.

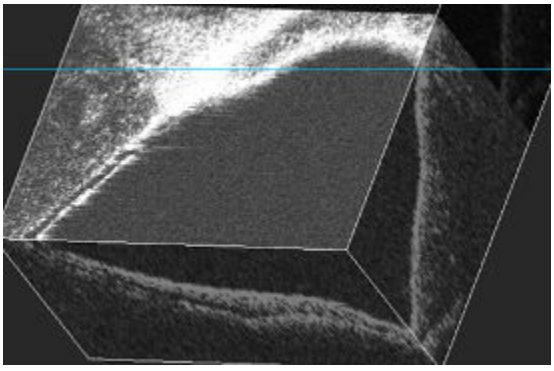

Fig. 9. 3D reconstruction of amalgam and composite resin interface.

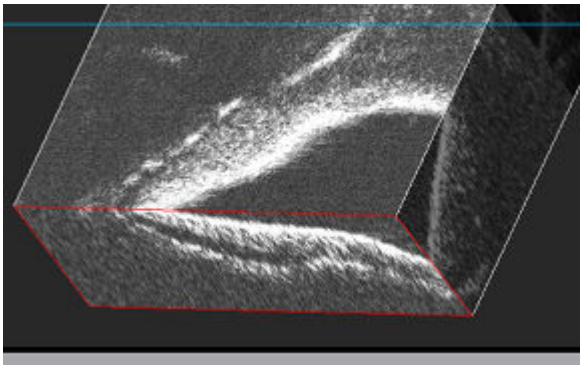

Fig. 10. 3D reconstruction of amalgam and composite resin interface.

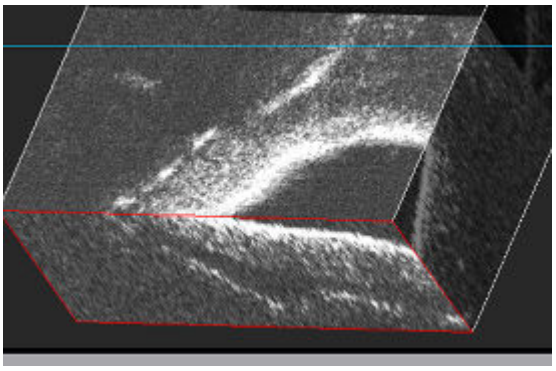

Fig. 11. 3D reconstruction of amalgam and composite resin interface.

4. Conclusion

OCT could act as a valuable noninvasive method in analyzing the amalgam and composite resin interfaces. Within the limitations of this study, optimizations of pre-existing amalgam fillings of class I cavities can be performed using composite resin materials.

Acknowledgments

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References:

[1] Clarkson, Thomas W., et al. The toxicology of mercury – current exposures and clinical manifestations. *New England Journal of Medicine*, Vol. 349, October 30, 2003, pp. 1731-37.

[2] Larkin, M. Don't remove amalgam fillings, urges *American Dental Association. The Lancet*, Vol. 360, August 3, 2002, p. 393.

[3] Guzzi, G, et al. Should amalgam fillings be removed? *The Lancet,* Vol. 360, December 21/28, 2002, p. 2081.

[4] Guallar, E, et al. Mercury, fish oils, and the risk

of myocardial infarction. *New England Journal of Medicine*, Vol. 347, November 28, 2002, pp. 1747-54

[5] Yoshizawa, K, et al. Mercury and the risk of coronary heart disease in men. *New England Journal of Medicine*, Vol. 347, November 28, 2002, pp. 1755-60

[6] Bolger, PM and Schwetz, BA. Mercury and health. *New England Journal of Medicine*, Vol. 347, November 28, 2002, pp. 1735-36.

[7] Null, Gary and Feldman, Martin. Mercury dental amalgams: the controversy continues. *Journal of Orthomolecular Medicine*, Vol. 17, No. 2, 2nd Quarter 2002, pp. 85-110.

[8] Frustaci, Andrea, et al. Marked elevation of myocardial trace elements in idiopathic dilated cardiomyopathy compared with secondary cardiac dysfunction. *Journal of the American College of Cardiology*, Vol. 33, May 1999, pp. 1578-83.

[9] Lorscheider, Fritz and Vimy, Murray. Mercury and idiopathic dilated cardiomyopathy. *Journal of the American College of Cardiology*, Vol. 35, March 1, 2000, p. 819.

[10] Cheshire, William P., Jr. The shocking tooth about trigeminal neuralgia. *New England Journal of Medicine*, Vol. 342, June 29, 2000, p. 2003.

[11] Fruits TJ, Duncanson MG Jr & Coury TL (1998) Interfacial bond strengths of amalgam bonded to amalgam and resin composite bonded to amalgam *Quintessence International* 29(5) 327-334.

[12] Zardiackas LD & Stoner GE (1983) Tensile and shear adhesion of amalgam to tooth structure using selective interfacial amalgamation *Biomaterials* 4(1) 9-13.

[13]. Roeder LB, DeSchepper EJ & Powers JM (1991) *In vitro* bond strength of repaired amalgam with adhesive bonding systems *Journal of Esthetic Dentistry* 3(4) 126-132.

[14] Diefenderfer KE, Reinhardt JW & Brown SB (1997) Surface treatment effects on amalgam repair strength *American Journal of Dentistry* 10(1) 9-14.

[15] Hasegawa T & Retief DH (1996) Shear bond strengths of two commercially available dentine-amalgam bonding systems *Journal of Dentistry* 24(6) 449-452.

[16] Abu-Hanna AA & Mjör IA (2004) Combined amalgam and composite restorations *Operative Dentistry* 29(3) 342-344.

[17] Sinescu C., Meda Lavinia Negrutiu, Carmen Todea, Balabuc C., Laura Filip, and Roxana Rominu, Bradu A, Hughes M, and Adrian Gh. Podoleanu, Quality assessment of dental treatments using en-face optical coherence tomography, *J. Biomed. Opt*., Vol. 13, 054065
2008.

[18] Sinescu, C., Negruțiu, M., Petrescu, E., Rominu, M., Marcauteanu, C., Rominu, R., Hughes, M., Bradu, A., Dobre, G., Podoleanu, A. G., "Marginal adaptation of ceramic veneers investigated with en face optical coherence tomography" in *Optical Coherence Tomography and Coherence Techniques IV*, edited by Peter E. Andersen, Brett E. Bouma, Proceedings of SPIE Vol. 7372 (SPIE, Bellingham, WA 2009) 73722C.

[19] A. Gh. Podoleanu, M. Seeger, G. M. Dobre, D. J. Webb, D. A. Jackson and F. Fitzke, Transversal and longitudinal images from the retina of the living eye using low coherence reflectometry, *Journal of Biomedical Optics*, 3, 12, 1998

[20] Cosmin Sinescu, Adrian Podoleanu, Meda Negruțiu, Mihai Romînu – Optical coherent tomography investigation on apical region of dental roots*, European Cells & Materials Journal*, Vol. 13, Suppl. 3, 2007, p.14, ISSN 1473-2262.

[21] C Sinescu, A Podoleanu, M Negrutiu, C Todea, D Dodenciu, M Rominu, Material defects investigation in fixed partial dentures using optical coherence tomography method, *European Cells and Materials* Vol. 14. Suppl. 3, ISSN 1473-2262, 2007.

[22] Roxana Romînu, C Sinescu, A Podoleanu, M Negrutiu, M Rominu, A Soicu, C Sinescu, The quality of bracket bonding studied by means of oct investigation. A preliminary study, *European Cells and Materials* Vol. 14. Suppl. 3, ISSN 1473-2262, 2007.

[23] Cosmin Sinescu, Meda Negruțiu, Carmen Todea, Adrian Gh. Podoleanu, Mike Huighes, Philippe Laissue, Cezar Clonda - *Tomografia Optic Coerentă Optical Coherente Tomography as a non invasive method used in ceramic material defects identification in fixed partial dentures*, Dental Target, nr. 5, year II, 2007.

[24] A. Gh. Podoleanu, J. A. Rogers, D. A. Jackson, S. Dunne, *Three dimensional OCT images from retina and skin* Opt. Express, Vol. 7, No. 9, p. 292-298, (2000), http://www.opticsexpress.org/framestocv7n9.htm.

[25] B. R. Masters, *Three-dimensional confocal microscopy of the human optic nerve in vivo*, Opt. Express, 3, 356-359 (1998), http://epubs.osa.org/oearchive/source/6295.htm.

[26] J. A. Izatt, M. R. Hee, G. M. Owen, E. A. Swanson, and J. G. Fujimoto, *Optical coherence microscopy in scattering media*, Opt. Lett. 19, 590-593 (1994).

[27] C. C. Rosa, J. Rogers, and A. G. Podoleanu, *Fast scanning transmissive delay line for optical coherence tomography*, Opt. Lett. 30, 3263-3265 (2005).