CONCENTRATIONS OF SOME HEAVY METALS (Se, Sn, Cd, Pb, Cu) IN THE TEETH OF MALES AND FEMALES OF DIFFERENT AGES AND THE CORRELATION TO CARIES

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II

COMMITTEE DECISION

This Thesis (Concentrations of Some Heavy Metals (Se, Sn, Cd, Pb, Cu) in the Teeth of Males and Females of Different Ages and the Correlation to Caries) was Successfully Defended and Approved on May 10, 2009.

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DEDICATION

DEDICATED TO MY FATHER, MY MOTHER, AND MY BROTHERS

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ABSTRACT

The present study aims to measure the concentrations of some heavy metals like cadmium (Cd), copper (Cu), lead (Pb), selenium (Se), and tin (Sn) in human teeth by using graphite furnace atomic absorption spectrometry (GFAAS). Fourty one Teeth samples were collected from people living in Amman city in Jordan. A questionnaire was used to collect information about each person like age, gender, caries degree, smoking, number of deliveries (for women), teeth brushing, and the visits to the dental clinic.

The results show that there are relations between the concentrations of Cd, Cu, Pb, Se, Sn and gender, age, smoking, and caries degree. The results indicate that Cd, Cu, Pb, Se, Sn concentrations in teeth of male smokers were higher than those from male nonsmokers but the concentrations of these heavy metals were approximately the same for female smokers and female nonsmokers. Also, the results indicate that caries doesn't significantly increase or decrease the concentrations of Cd, Cu, Pb, Se, Sn in human teeth.

Furthermore, the results show that nonbrushing the teeth daily but randomly through the week and rareness of the frequent visits to the dentist clinic are the main reasons to induce caries at people. The concentrations of Cd, Cu, Pb, Se, Sn are found to increase with age due to accumulation.

Chapter One: Introduction

1-1 Introduction:

The enamel of human teeth is the hardest mineralized tissue of the entire body, it neither contains cells nor it exhibits metabolic activity. Owing to the enamel's minor organic fraction, (about 4%) and strong hardness, it is considered the best indicator of the burden of heavy metals in human body (Oprea, et al., 2007).

Dental caries is a disease which damages the structure of teeth. Dental caries has a long history with evidence showing the disease was present in the Bronze, Iron, and Middle ages. The largest increases in the prevalence of caries have been associated with diet changes. In the United States, dental caries is the most common childhood disease, being at least five times more common than asthma .Among children in the United States and Europe, 60-80% of cases of dental caries occur in the population (Touger-Decker, et al., 2003).

The samples were analyzed in the Chemistry department at the University of Jordan by using the instrument of graphite furnace atomic absorption spectrometry (GFAAS) to determine the concentrations of heavy metals .

1-2 Literature survey:

There were many previous studies that have been tried to correlate between the distribution of heavy metals in human teeth and many important factors such as caries, gender, age, local environmental pollution, smoking, place of residence, amalgam fillings, and brushing the teeth.

Many researches were performed on human teeth by using FAAS. According to the review by Nadhum and Hassan (2002) from Iraq, a negative correlation was obtained between tin and caries. Also they found that the concentrations of tin in men were higher than those in women and a positive correlation between tin and age. Another research was done by Nadhum and Hassan (2004) from Iraq where their study indicated that a positive correlation between selenium and the incidence of caries. The other study was performed by Alomary, et al. (2006) in Jordan where they found that lead and cadmium concentrations in samples obtained from Al-Mafraq and Irbid were higher than those obtained from Amman and Zarqa. Lead was highest in Mafraq whereas cadmium was highest in Irbid. Lead and cadmium concentrations in teeth from smokers were higher than those from nonsmokers, and the concentrations for both elements in teeth of patients with amalgam fillings were significantly higher than those from patients without amalgam fillings. Their results also showed that brushing the teeth daily with toothpaste didn't greatly decrease the concentrations of both elements.

Other important studies were done by PIXE technique. Anttila (1986) collected 193 primary teeth with low and high caries from Finnish towns in Finland and analyzed their content of Zn, Sr, and Pb. There were no significant correlations between Zn and caries, or Pb and caries, but a weak positive correlation existed between Sr and caries. In other report

Baranowska, et al. (2004) collected 38 teeth samples from the inhabitants of Katowice, Gliwice, Pyskowise and Tychy cities in Poland . In these samples Ca, P, Na, Mg, Al, S, K, Fe, Ni, Cu, Zn, Sr, Pb content were determined. Several correlations between the concentration of some elements and personal features (age, smoking, environmental contamination) were indicated. There were positive correlations between age and Mg, Fe, Cu, Sr and Pb content in teeth samples. There were high levels of Zn and Pb concentrations in teeth samples from smokers. Zn, S and Pb content were higher in teeth samples collected from Katowice and Gliwice which are highly industrial and polluted cities compared with those from Tychy and Pyskowice which are known for their agricultural character.

Oprea et al. (2007) collected teeth from Oradea (Romania) inhabitants to measure their content of chemical elements from carbon to lead. They found that all trace heavy metals showed clear rise in concentrations of 1.5-3 times for the urban population, which was exposed to significant pollution levels released by local industry compared with concentrations similarly estimated in a rural population without such exposure.

Inductively coupled plasma- mass spectrometry (ICP-MS) has recently emerged as a method to solve questions that may be answered by examination of the spatial distribution of trace elements in hard tissues including human teeth. Reitznerova, et al. (2000) determined the concentrations of seven elements (Cu, Fe, Mg, Mn, Pb, Sr, and Zn) in whole enamel and surface layers of extracted non-carious human teeth. Enamel samples were analyzed for populations under and over 20 years of age. With exception of Sr and Mg, all elements showed significantly higher concentrations in the first layer than in whole enamel and higher concentration in teeth of individuals over 20 years, which demonstrated the cumulative effect of these elements.

Kang, et al. (2004) investigated the spatial distribution of trace metals Cu, Fe, Mg, Sr, Pb, and Zn in micro regions of a deciduous tooth encompassing enamel, dentine-enamel junction, dentine region, and the dentine-pulp junction. The order of magnitude of normalized elemental intensities in all tooth regions follows the general pattern Sr > Mg > Zn > Pb > Fe > Cu.

1-3 Human Tooth:

1-3-1 Anatomy:

Dental anatomy is a field of anatomy dedicated to the study of human tooth structures. The development, appearance, and classification of teeth fall within its field of study. It is also a taxonomical science as it is concerned with the naming of teeth and their structures. Figure 1 demonstrate the two anatomic landmarks which are crown and root.

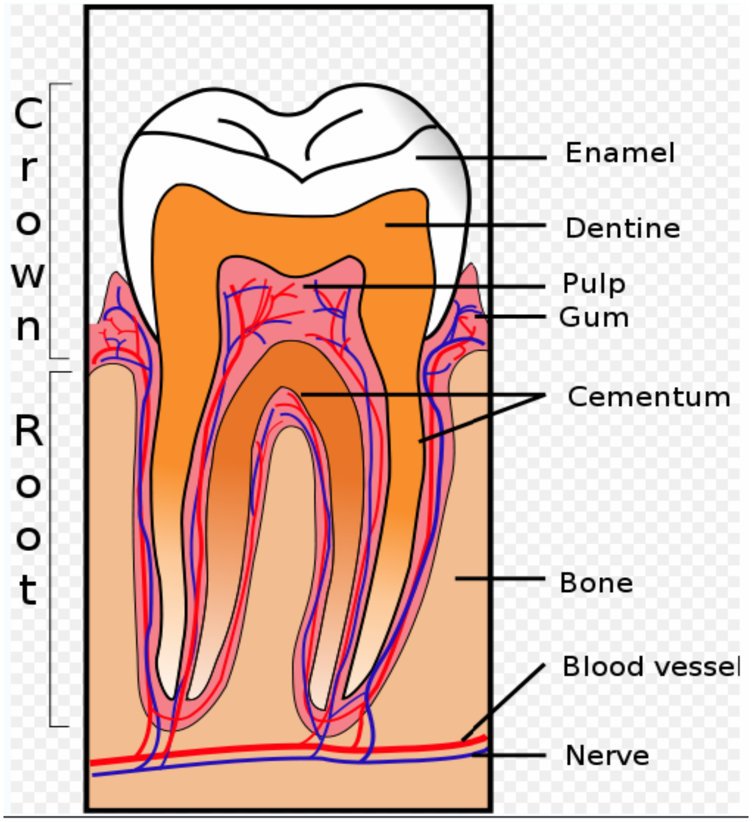

Figure 1 : The anatomic landmarks of a human molar

The anatomic crown of a tooth is the area covered in enamel above the cementoenamel junction (CEJ). The majority of the crown is composed of dentine with the pulp chamber in the center. After eruption, it is almost visible. The anatomic root is found below the cementoenamel junction and covered with cementum. Dentin composes most of the root, which normally has pulp canals. A tooth may have multiple roots or just one root. For example, canines and most premolars usually have one root. Maxillary first premolars and mandibular molars usually have two roots (Ash and Stanley, 2003) ; (Cate, 1998).

Teeth can belong to one of two sets: primary teeth or permanent teeth. Humans usually have 20 primary teeth (also called deciduous, baby, or milk teeth) and 32 permanent teeth (also called adult teeth). Figure 2 shows adult and baby teeth diagram. Among primary teeth, 10 are found in the maxilla and the other 10 in the mandible. Among permanent teeth, 16 are found in the maxilla and the other 16 in the mandible. There are four classes of teeth: incisors, canines, premolars, and molars. Premolars are found only in permanent teeth, there are no primary premolars. Incisors are divided into central and lateral incisors (Kokten, et al., 2007).

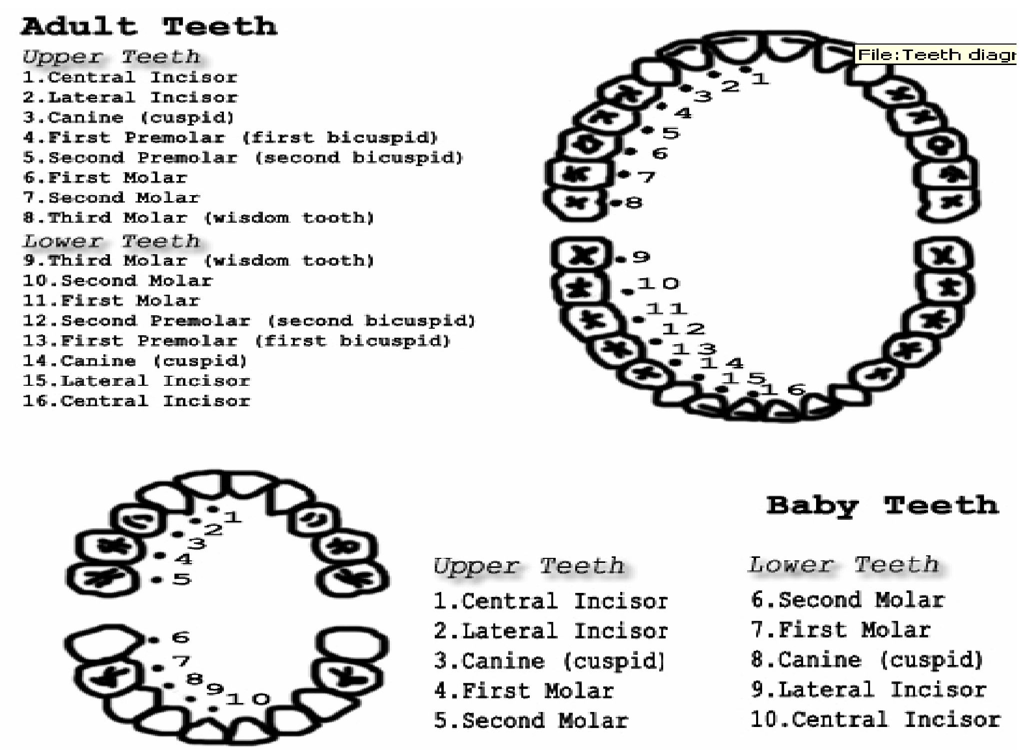

Figure 2 :Adult and baby teeth diagram.

1-3-2 Parts of tooth:

There are four major parts which make up the human teeth . Figure 1 and figure 3 represent these major parts(Kang, et al., 2004) .

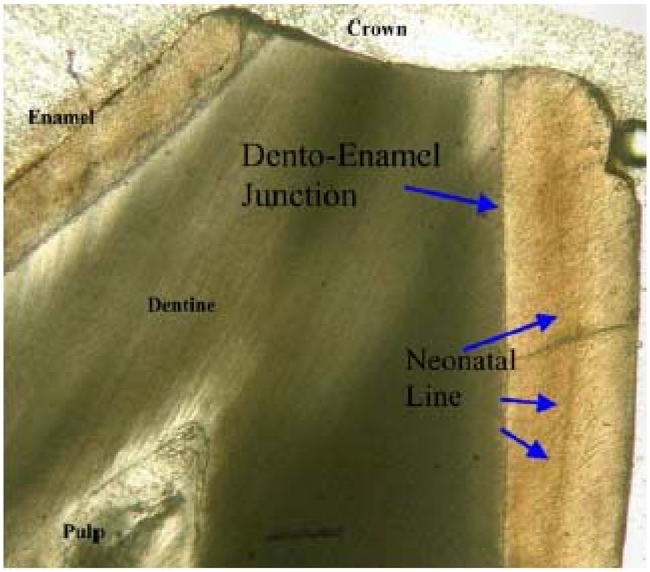

Figure 3: Enamel, dentin, and pulp tissue regions of a deciduous tooth.

1-3-2-1 Enamel:

Enamel is the hardest and most highly mineralized substance of the tooth. It is normally visible and must be supported by the underlying dentin. About 96% of the enamel consists of minerals, water and organic material composing the rest. The normal color of the enamel varies from light yellow to grayish white. The primary mineral of the enamel is hydroxyapatite ($Ca_5(PO_4)_3OH$), which is a crystalline calcium phosphate. The large amounts of minerals in enamel accounts for its strength. Enamel doesn't contain collagen, instead it has two unique classes of proteins called amelogenine and enamelins which aid in the development of enamel by serving as framework support (Tichenor, et al., 1983) (Fukumoto and Yamada, 2005) ; (Ross, et al., 2002) ; (Johnson, 1998) ; (Cate, 1998).

1-3-2-2 Dentin:

Dentin is the substance between enamel or cementum and the pulp chamber. It is secreted by the odontoblasts of the dental pulp. The formation of dentin is known as dentinogenesis. Dentin is made up of 70% inorganic materials, 20% organic materials, and 10% water by weight. It acts as a protection layer and supports the crown of the tooth. Dentin is a mineralized connective tissue with an organic matrix of collagenous proteins. Dentin has microscopic channels, called dentinal tubules, which radiate outward through the dentin from the pulp cavity to the exterior cementum or enamel border (Cate, 1998) (Ress, et al., 2003).

1-3-2-3 Cementum:

Cementum is a specialized bony substance covering the root of a tooth. It consists of 45% inorganic material (mainly hydroxyapatite), 33% organic material (mainly collagen) and 22% water. Cementum is excreted by cementoblasts within the root of the tooth. It serves as a medium by which the periodontal ligaments can attach to the tooth for stability (Ross, et al., 2003).

1-3-2-4 Pulp:

The pulp is commonly called the nerve of the tooth. The dental pulp is the central part of the tooth filled with soft connective tissue. This tissue contains blood vessels and nerves that enter the tooth from a hole at the apex of the root. Along the border between the dentin and the pulp are odontoblasts, which initiate the formation of dentin (Cate, 1998).

1-5 The poisoning effects of the heavy metals on the human beings:

1-5-1 Lead (Pb):

Lead is a solid metal with a bluish gray color, its atomic number is 82, its standard atomic weight is 207.2, its specific density is 11.34 g/cm^3, its melting point is 327.46 ̊C, and its boiling point is 1749 ̊C .

Lead is one of the pollutants which have cumulative fatal effect. The consequences of exposure at lower doses cause no symptoms particularly in children include behavioral disorders, learning difficulties, school failure, deficits in intelligence quotient (IQ) scores, reading disabilities, and disturbances in fine motor function.

Clinical symptoms in children at high doses are abdominal pain, clumsiness, followed by headache and behavioral changes, which are signs of early encephalopathy. This may progress to alternations of consciousness, stupor, and convulsions.

Children are more sensitive to lead than adults for several reasons: Their exposure is increased by their common hand-to-mouth activity, their gut absorbs lead more readily than adults and their developing central nervous system (CNS) is more vulnerable to toxicants than the mature CNS (Needleman, 2004).

Much of lead toxicity can be attributed to distortion of enzymes and structural proteins. Lead can cleave the ribophosphate backbone of tRNA catalyticallyat specific sites, with no evidence of a beginning (Shaik, et al., 2006).

Lead poisoning in adults can affect the peripheral and central nervous systems, the kidneys, and blood pressure. The symptoms of lead poisoning include painless wrist or foot drop (weakness of the extensor muscles of hand and foot), severe colic, motor clumsiness, clouded consciousness, weakness, nausea, insomnia, metal taste in oral cavity, excess hyperactivity, chest pain, anemia, hypertension (Needleman, 2004) .

There are also associated gastrointestinal problems like diarrhea, vomiting, poor appetite, weight loss. Other associated effects are reproductive problems like high incidence of stillbirths, neonatal deaths, and a decreased fertility rate in women employed in the ceramic industry. Males may manifest decreased sperm counts(Needleman, 2004).

Various sources of lead contribute to exposure in children and adults. The main sources of poisoning are from ingestion of lead contaminated soil and from ingestion of lead dusts or chips from deteriorating lead based paints. This is a particularly a problem in older houses where the sweet-tasting lead paint is likely to chip, but deteriorating lead-based paint can also powder and be inhaled as dust. Lead has also found in drinking water. Ground and surface water naturally contain very low levels of lead. Lead contamination in water commonly results from the leaching of lead from pipes, lead soldering, and lead-containing brass faucets. The most common sources of lead poisoning in adults are hazardous occupations like ship breaking (disassembly of spent ships), metal welding, and lead smelting. Lead can also be found in some imported cosmetics like Kohl from the Middle East, India, Pakistan, and some parts of Africa and from imported toys, such as many made in China (Gracia and Snodgrass, 2007).

1-5-2 Selenium (Se):

Selenium is a solid metal with a gray-black color and metallic luster, its atomic number is 34, its standard atomic weight is 78.96, its specific density is 4.81 g/cm^3, its melting point is 221 ̊C, and its boiling point is 685 ̊C.

Selenium is considered an essential element for humans required in very small amounts for the basic functions of life. Selenium form the active center of some enzymes like glutathione peroxidase, which is responsible for the removal of hydrogen peroxide from cells, and thioredoxin reductase, which indirectly reduce certain oxidized molecules in animals and some plants, and three known deiodinase enzymes which convert one thyroid hormone to another (Grinberg, et al., 2005). Selenium possesses antineoplasmatic properties since studies have demonstrated that dietary selenium supplementation can inhibit chemically induced tumors (Bohrer, et al., 2007). Selenium has been proven to help chemotherapy treatment by enhancing the efficiency of the treatment, reducing the toxicity of chemotherapeutic drugs, and preventing the body resistance to the drugs (Grinberg, et al., 2005). Selenium is a component of proteins and enzymes required for various biological functions such as antioxidant defense, reduction of inflammation, thyroid hormone production, fertility, and DNA synthesis. Selenium has been shown to inhibit genotoxicity (Griffiths and Matulka, 2006).The adequate daily dietary selenium intake ranges from 50 to 200 µg, with an average value of 55 µg for adult humans (Bohrer, et al., 2007).

Selenium deficiency can occur in patients with gastrointestinal disorders and people dependent on food grown from selenium deficient soil. The clinical symptoms of selenium deficiency are muscular weakness and myalgia, fatigue, loss of appetite, cardiac arrhythmia, and palpitations. Selenium deficiency can lead to Keshan disease, its primary symptom is mycocardial necrosis which cause weakening of the heart. It also makes the body more susceptible to illness caused by other diseases. Selenium deficiency also contribute to Kashin-Beck disease which results in atrophy, degeneration and necrosis of cartilage tissue. Also it can cause symptoms of hypothyroidism like severe fatigue, mental slowing, goiter, cretinism and recurrent miscarriage.

On the other hand, selenium toxicity, called selenosis, has many clinical symptoms like hair and nail loss, skin lesions, diarrhea, and garlic-like odor of the breath and in body secretions, liver cirrhosis, splenomegaly, pancreatic enlargement, anemia, fatigue, irritability, neurological damage, pulmonary edema, and death (Griffiths and Matulka, 2006).

Food is the main source of selenium for human. Dietary selenium comes from nuts, Brazil nuts are the richest ordinary dietary source, wheat, soybeans and selenium-enriched yeast, cereals, meats like kidney and liver meats, eggs, sea food and fish like tuna, crab, and lobster (Grinberg, et al., 2005) ; (Bohrer, et al., 2007).

1-5-3 Copper (Cu):

Copper is a solid with a metallic bronze color, its atomic number is 29, its standard atomic weight is 63.546, its specific density is 8.96 g/cm^3, its melting point is 1084.62 ℃, and its boiling point is 2562 ℃ .

Copper is an essential trace nutrient. In excess amounts, copper can be poisonous and even fatal to humans. Copper is carried mostly in the bloodstream on a plasma protein called ceruloplasmin. When copper is first absorbed in the gut it is transported to the liver bound to albumin. Copper is found in a variety of enzymes like cytochrome c oxidase, superoxide dismutase, dopamine-β-hydroxylase, tyrosinase and lysyl oxidase. In addition to its enzymatic roles, copper is used for biological electron transport. The blue copper proteins that participate in electron transport include azurin and plastocyanin (Singh, et al., 2006). The DRI Tolerable Upper Intake level for adults of dietary copper is 10 mg/day.

Chronic copper deficiency leads to anemia-like symptoms, abnormalities in metabolism of fats, high triglycerides, non-alcoholic steatohepatitis, fatty liver disease and poor melanin and dopamine synthesis causing depression .

However, copper is required in trace amounts for many metabolic pathways but is toxic in excess amounts due to free radical generating ability through Fenton type reaction which damage DNA and other macromolecules (Held, et al., 1996). The symptoms of copper toxicity include convulsions, palsy, insensibility, hepatitis, liver cirrhosis, jaundice, hemolytic crisis, and leukocytosis. Copper can also inhibit the enzyme dihydrophil hydratase, an enzyme involved in haemopoiesis (Singh, et al., 2006).

There are four major genetic disorders of copper metabolism that are Wilson disease (WND), Indian childhood cirrohosis (ICC), Menkes disease (MNK), and aceruloplasmenia (Singh, et al., 2006). The symptoms of Wilson disease are caused by an accumulation of copper in body tissues, since copper is not excreted by the liver into the bile (Prasad, et al., 1998).

Rich sources of copper include oysters, beef or lamb liver, lobster, Brazil nuts, black strap molasses, cocoa, black pepper, nuts, sunflower seeds, green olives, avocados, and wheat bran.

1-5-4 Cadmium (Cd):

Cadmium is a solid metal with a silvery gray metallic appearance, its atomic number is 48, its standard atomic weight is 112.411, its specific density is 8.65 g/cm^3, its melting point is 321.07 ̊C, and its boiling point is 767 ̊C.

Clinical symptoms for acute cadmium exposure include flue like symptoms involving chills, fever, and muscle ache. More severe exposure can cause pneumonia and pulmonary edema. Symptoms of inflammation may start hours after the exposure and include cough, dryness and irritation of the nose and throat, headache, dizziness, weakness, fever, chills, and chest pain. In addition, the bones become soft (osteomalacia), lose bone mineral density (osteoporosis) and become weaker. This cause the pain in the joints and the back and also increases the risk of fractures. Inhalation of Cd-laden dust quickly leads to respiratory tract, liver, and kidney problems. The dysfunction of kidney causes gout, a form of arthritis due to the accumulation of uric acid crystals in the joints because of high acidity of the blood (hyperuricemia). Another side effect is increased levels of chloride in the blood (hyperchloremia). The kidneys can also shrink up to 30% (Shannon, 1998).

Cadmium has many toxic effects on the reproductive system. Cadmium can cause many dangerous changes in testis like defective sperm formation, decreased sperm counts, male infertility, changes in testicular morphology which leads to reduced testicular size, decrease in the motility and the viability of sperms. Furthermore, cadmium toxicity reduce the total number of oocytes and ovarian necrosis, cause reduction in ovarian weight and fertilization rate, inhibit the ovulation process, induce toxicity in the ovaries, uterus, and cervix, decrease progesterone production . Cadmium may also reduce the possibility of a successful pregnancy by interfering with the development of the gamete. Also, there is a strong association between maternal cadmium exposure and early delivery. It was proven that cadmium exposure during pregnancy increased the incidence of skeletal retardations, urogenital abnormalities, diaphragmatic hernia, and cardiovascular anomalies (Thompson and Bannigan, 2008) ; (Acharya, et al., 2008).

Cadmium is an omnipresent environmental pollutant. Buildup of Cd levels in the water, air, and soil has been occurring particularly in industrial areas. Food is another source of cadmium. Plants may only contain small or moderate amounts in urban areas, but high levels maybe found in the liver and kidneys of adult animals. Cigarette smoking is also a significant source of cadmium exposure. Workers can be exposed to cadmium in air from the smelting and refining of metals, or from air in plants that make cadmium products like batteries, coatings, or plastics. Workers can also be exposed when soldering or welding metal that contains cadmium. Other human activities increase cadmium in environment like the usage of some fertilizers increase cadmium in soil and combustion of fossil fuels increase cadmium in air (Thompson and Bannigan, 2008) ; (Taylor, 1997).

1-5-5 Tin (Sn):

Tin is a solid metal with a silvery lustrous gray color, its atomic number is 50, its standard atomic weight is 118.710, its specific density is 5.769 g/cm^3, its melting point is 231.93 ̊C, and its boiling point is 2602 ̊C.

Tin has been established to be an essential trace element. The daily intake of tin from food and water (excluding canned food) is 1 mg-3 mg per day.

Deficiency symptoms of tin include fatigue, depression, low cardiac output, low adrenals, shortness of breath, asthma, headaches, and insomnia. On the other hand, symptoms of tin poisoning include vomiting, skin rash, stomach complaints, nausea, diarrhea, abdominal pain, headache, palpitations, vertigo, photophobia, rapid loss of weight, retention of urine and even paralysis in some cases.

There are many sources of tin like canned foods, cereal grains, dairy, meat, vegetables, and some toothpastes (Nadhum and Hassan, 2002).

1-6 The aims of the study:

● To determine the mean concentrations of Cd, Cu, Pb, Se, and Sn in human teeth from Jordan.

● To investigate the factors affecting the levels of these elements in the human teeth. These factors include: status of dental caries, smoking, # of deliveries for women, brushing the teeth with toothpaste, and frequent visits to the dental clinic.

Chapter Two: Experimental

2-1 Apparatus: Graphite furnace atomic absorption spectrometer (GFAAS):

Graphite furnace atomic absorption spectrometer (GFAAS) used was the AI 1200 model from Aurora company (Canada). This model is directly controlled by a personal computer and equipped with a laser printer. The GF instrument need argon (99.999% purity) as a purge gas. The AI instrument is equipped with a hollow cathode lamp (HCL) turret which can hold five lamps & each HCL is held in the turret by an individual housing. By using the AI instrument one can measure the atomic absorption or the atomic emission via a single beam mode or a double beam mode. The GFAAS needs also hollow cathode lamps (HCLs), fume hood, compressed gas cylinder, and a cooling bath.

2-2 Other used equipment:

Oven, balance, magnetic stirrer, and aquasonic.

2-3 Solvents and reagents:

- **Pure hydrochloric acid (HCL):**

Purchased from Tedia company (U.S.A).

- **Pure nitric acid (HNO_3):**

Purchased from Tedia company (U.S.A).

- **Pure perchloric acid ($HCLO_4$):**

Purchased from Tedia company (U.S.A).

- **Nitric acid (HNO_3):**

It was used to wash the glasswares & cups. Purchased from Panreac company (E.U)

- **Phosphoric acid (H_3PO_4):**

Purchased from Sigma-Aldrich company (Switzerland).

- **Nickel (II) nitrate hexahydrate ($N_2NiO_6.6\ H_2O$):**

Purchased from Sigma-Aldrich company (Germany).

- **Ascorbic acid ($C_6H_8O_6$):**

Purchased from Sigma-Aldrich company (Japan).

- **Ammonium citrate dibasic ($C_6H_{14}N_2O_7$):**

Purchased from Sigma-Aldrich company (Germany).

- **Ammonium phosphate monobasic (NH_6PO_4):**

Purchased from Sigma-Aldrich company (Germany).

- **Cd, Cu, Pb, Se, Sn, Pd standard solutions:**

Cd, Cu, Pb, Se, Sn, Pd standard solutions were commercially prepared by Fluka company (Switzerland) with 1000 ppm concentration.

- **Deionized water.**

2-4 Collection of samples:

Teeth samples were collected from people living in Amman city in Jordan. The number of samples was 41. A questionnaire was used to gather information on each person such as height, weight, gender, caries, number of deliveries (for women), smoking, teeth brushing, and the frequency of the visits to the dental clinic. The teeth were taken from both genders (male and female) and classified to four different categories according to age.

2-5 Sample preparation procedure:

The aim of the digestion process of the samples was to transfer the samples to liquid solutions in order to measure their content of heavy metal ions by means of the graphite furnace atomic absorption spectrometer (GFAAS).

The following steps were performed:

1- Cleaning tooth sample with diluted nitric acid (5% HNO_3).

2- Washing tooth sample with deionized water.

3- Drying tooth sample overnight at 120 ̊C in drying oven.

4- Digesting for two hours at 160 ̊C ± 10 ̊C in 8 mL concentrated perchloric acid and 2 mL concentrated nitric acid with continuous stirring using mechanical stirrer.

5- Transferring the solution to a 50 mL volumetric flask and diluting it to the mark with deionized water.

6- Transferring 1 mL of the final solution to 10 mL volumetric flask and diluting it to the mark by using the appropriate modifiers for each element (Nadhum & Hassan,2002) ; (Nadhum & Hassan,2004). Table (1) shows the chemical modifiers used and their effects on analyzed elements.

7- All the glasswares and sample cups were cleaned with detergent and tap water and were immersed in a 10% HNO_3 overnight. Prior to their use, they were washed several times with tap water and finally rinsed with deionized water (Alomary, et al., 2006).

Table(1): Chemical modifiers used in GFAAS analysis.

Element	Modifier	Effect of modifier
Cd	● 1000 ppm H_3PO_4, 5000 ppm $NH_4H_2PO_4$	Increases sensitivity, allows higher ashing temperature, raises atomization temperature, low background absorption (Shoji, et al., 2004) ; (Ajtony, et al., 2007) ; (Sun, et al., 2008).
	●200 ppm Pd and 1% w/v ascorbic acid	Prevent the vaporization of analyte element during drying and ashing processes, increases signal (Terui, et al., 1991). Increases sensitivity, decreases background signals (Bruhn, et al., 1999) ; (Xiao-Quan and Bei, 1995).
Pb	● 1000 ppm H_3PO_4, 5000 ppm $NH_4H_2PO_4$	Increases sensitivity, allows higher ashing temperature, raises atomization temperature, low background absorption (Shoji, et al., 2004) ; (Ajtony, et al., 2007) (Sun, et al., 2008).
	●200 ppm Pd and 1% w/v ascorbic acid	Prevent the vaporization of analyte element during drying and ashing processes, increases signal (Terui, et al., 1991). Increases sensitivity, decreases background signals (Bruhn, et al., 1999) (Xiao-Quan and Bei, 1995) (Voth-Beach and Shrader, 1987).
Se	●200 ppm Pd and 1% w/v ascorbic acid.	Higher ashing temperature, atomization signals become more symmetrical and are shifted to higher atomization temperature (Xiao-Quan and Bei, 1995) (Terui, et al., 1991).
	●La 1% w/v	Increases sensitivity, increases signal (Nadhum and Hassan, 2004).
	●1000 ppm $Ni(NO_3)_2$	Increases sensitivity, increases signal, stabilizes Se at higher temperature and minimize matrix effects during the atomization step, allows higher ashing and atomization temperatures (Rosa, et al., 2002) (Niedzielski, et al., 2002) ; (Alexiu and Vladescu, 2005).
Sn	●100 ppm Pd	Enhances sensitivity, allows higher ashing and atomization temperatures (Xiao-Quan and Bei, 1995) (Gong, ewt al., 1993).
	●La 1% w/v	Increases sensitivity, increases signal (Nadhum and Hassan, 2002).
	●0.1% $C_6H_{14}N_2O_7$	Stabilizes Sn

Cu	●200 ppm Pd and 1% w/v ascorbic acid	Increases signal, allows higher ashing temperature(Lin and Huang, 2001).

2-6 GFAAS operating conditions:

The measurement of the concentrations of various heavy metals in the standard solutions and the samples was done by GFAAS which uses argon as a purge gas.

Table (2) shows the optimized instrumental conditions for each element.

Table (2): Optimized instrumental conditions for GFAAS.

Item/metal	Cd	Cu	Pb	Se	Sn
Lamp	HCL	HCL	HCL	HCL	HCL
Lamp current (mA)	6.2	8.5	10.5	17.7	10.0
Slit width (nm)	0.6GF*	0.6GF	0.6	1.2	1.2
Wavelength, λ (nm)	228.8	324.7	217.0	196.0	224.6
Purge gas	Ar	Ar	Ar	Ar	Ar
Background correction	none	none	none	none	none
Injection volume (μL)	10	10	10	15	10
PMT Voltage** (V)	573	325	500	605	525

0.6GF* : 0.6 nm with reduced slit height.

PMT Voltage** : Photomultiplier tube voltage.

The samples were analyzed for their content of Cd, Cu, Pb, Se, and Sn elements according to the heating programs recommended by the manufacturing company. Tables (3-7) described the proposed heating programs for determining Cd, Cu, Pb, Se, and Sn elements.

Table (3): Graphite furnace heating program for determining Cd concentration in teeth samples.

Step	Temp (̊C)	Ramp time (s)	Hold time (s)	Gas flow rate (L/min)
1	75	0	2	2
2	80	2	2	4
3	95	15	5	4
4	120	15	5	4
5	250	5	5	4
6	1200	0	2	0
7	75	0	5	4

Table (4): Graphite furnace heating program for determining Cu concentration in teeth samples

Step	Temp (̊C)	Ramp time (s)	Hold time (s)	Gas flow rate (L/min)
1	75	0	2	2
2	80	2	2	2
3	95	15	5	2
4	120	15	5	2
5	800	5	3	2
6	2300	0	2	0
7	75	0	5	2

Table (5): Graphite furnace heating program for determining Pb concentration in teeth samples

Step	Temp (̊C)	Ramp time (s)	Hold time (s)	Gas flow rate (L/min)
1	75	0	2	2
2	80	2	2	2
3	95	15	5	2
4	120	15	5	2
5	400	5	3	2
6	2100	0	2	0
7	75	0	5	2

Table (6): Graphite furnace heating program for determining Se concentration in teeth samples

Step	Temp (̊C)	Ramp time (s)	Hold time (s)	Gas flow rate (L/min)
1	75	0	2	2
2	80	2	2	2
3	95	15	5	2
4	120	15	5	2
5	1000	5	3	2
6	2600	0	2	0
7	75	0	5	2

Table (7): Graphite furnace heating program for determining Sn concentration in teeth samples

Step	Temp (Ċ)	Ramp time (s)	Hold time (s)	Gas flow rate (L/min)
1	75	0	2	2
2	80	2	2	2
3	95	15	5	2
4	120	15	5	2
5	700	5	3	2
6	2600	0	2	0
7	75	0	5	2

2-7 Measurement of heavy metals concentrations in real samples:

Graphite furnace atomic absorption spectrophotometer (GFAAS) is used frequently in analytical chemistry for the determination of very low levels of trace metals in a variety of sample matrices. The samples were injected into a pyrolytically coated graphite tube of 5.7 mm internal diameter and 19 mm length by means of XYZ autosampler with a small liquid volume (10 to 15 µL). The graphite tube was heated in programmed steps to achieve three principle stages. First, the drying step which aimed to remove all the solvent from the sample by slow boiling the solvent away. Second, the ashing (or charring or pyrolysis) step which removed any dry or semidry matrix from the sample that was left over from the drying step. Third, the atomization step which converted all sample compounds into the ground state analyte atoms that absorbed part of the light which is generated by the HCL. The sample vapor was purged from the graphite furnace by argon gas to prepare the tube for the following injection. The amount of light energy absorbed by the atomized atoms depended on the concentration of the atoms in the sample. The magnitude of the sample absorbance was recorded as a function of concentration by the readout system, then the concentration of the unknown sample was calculated from the linear equation between absorbance and concentration (Skoog, et al., 1997).

2-8 Calibration method:

The stock standard solutions of the heavy metals, that were used, were available commercially in 1000 ppm concentrations. Series of standards were prepared from the 1000 ppm stock standards by serial dilutions in order to minimize errors. The series of standards would bracket the concentration range where the teeth samples concentrations were expected to fall. All working standard solutions that were used in the analysis were daily prepared from the stock standards. Table (8) shows the various standard solutions that were used for each heavy metal. A plot of absorbance versus concentration was constructed for the several standards and the curve that gave the best linear equation was drawn. Then, the concentrations of tooth samples were determined from substituting the signal response of the unknown sample into the linear calibration curve then calculated the concentration of the unknown sample.

Table (8): The concentrations of the prepared standard solutions (ppb)

Symbol	Concentrations (ppb)				
	Solution 1	Solution 2	Solution 3	Solution 4	Solution 5
Cd	50	100	150	200	250
Cu	100	200	300	400	500
Pb	200	400	600	800	1000
Se	200	400	600	800	1000
Sn	100	200	300	400	500

2-9 Standard addition method:

In this method, a series of spikes, with different increased concentrations, were prepared for each unknown sample. Table (9) explains the concentrations of the several spikes that were prepared for each heavy element. A plot of sample spike concentrations versus absorbances was constructed, the unspiked sample being at zero concentration, then the concentration of the sample was determined by extrapolating the calibration curve to the left until it intercepted the x-axis. The concentration of the unknown sample was equal to the absolute value of the concentration at this intersection.

Table (9): The concentrations of the prepared spikes (ppb).

Symbol	Concentrations (ppb)				
	Spike 1	Spike 2	Spike 3	Spike 4	Spike 5
Cd	25	50	75	100	125
Cu	50	100	150	200	250
Pb	100	200	300	400	500
Se	100	200	300	400	500
Sn	50	100	150	200	250

2-10 Recovery experiment:

The recovery experiment was carried out by adding a spike containing a known amount of analyte standard solution to a known volume of known sample, the recovered amount of the added standard solution was calculated by substracting the calculated amount of the added standard solution from the total amount of analyte found.

Chapter Three : Results and Discussion

3-1 Method validation:

3-1-1 Cadmium:

● **Calibration Curve:** The linearity of the method was evaluated by analyzing five standard solutions (Wang, et al., 1997). Table 10 represents the results of analysis for five cadmium standard solutions by using GFAAS. Figure 4 shows a linear calibration curve for cadmium using the results mentioned in table 10.

Table (10): Calibration curve for cadmium.

	Absorbance	Concentration(ppb)
blank	0.08	0
standard-1	0.26	50
standard-2	0.48	100
standard-3	0.72	150
standard-4	0.96	200
standard-5	1.20	250

R^2* : Product moment correlation coefficient.

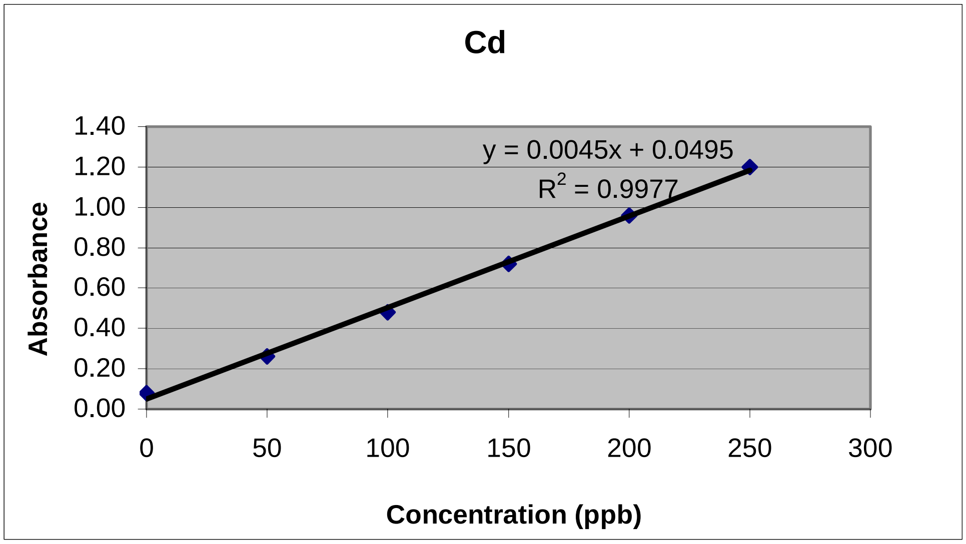

Figure 4 : Calibration curve for cadmium.

● **Limit of detection (LOD):** The LOD obtained using GFAAS was evaluated as the concentration corresponding to three times the standard deviation for 10 reagent blank determinations (Melaku, et al., 2005). LOD for cadmium was 5.89 ppb.

● **Limit of quantitation (LOQ):** The LOQ obtained using GFAAS was evaluated as the concentration corresponding to ten times the standard deviation for 10 reagent blank determinations (Wang, et al., 1997). LOQ for cadmium was 20.11 ppb.

● **Precision:** The precision of the method was determined from results of six replicates of five teeth samples (Wang, et al., 1997). RSD was found to be 4.44-5.94%.

● **Recovery:** Table (11) shows the results of recovery experiments for cadmium. The recoveries were between 94.81 – 102.22% .

Table (11): Recovery results for cadmium.

Sample#	Tooth weight (g)	Cd content (ppb)	Cd added (ppb)	Absorbance	Total Cd found (ppb)	Recovered Cd added (ppb)	Recovery%
1	0.3166	20.11	50	0.37	71.22	51.11	102.22
2	0.3945	20.11	50	0.35	70.11	50	100
3	0.3670	29.00	75	0.50	100.11	71.11	94.81
4	0.5340	24.56	75	0.49	97.89	73.33	97.77
5	0.5609	33.44	100	0.65	133.44	100	100
6	0.5510	20.11	100	0.60	122.33	102.22	102.22

3-1-2 Copper:

● **Calibration curve:** Table (12) represents the results of analysis for five copper standard solutions by using GFAAS. Figure 5 represents a linear calibration curve for copper using the results listed in table (12).

Table (12): Calibration curve for copper.

	Absorbance	Concentration(ppb)
blank	0.12	0
standard-1	0.26	100
standard-2	0.48	200
standard-3	0.65	300
standard-4	0.82	400
standard-5	1.02	500

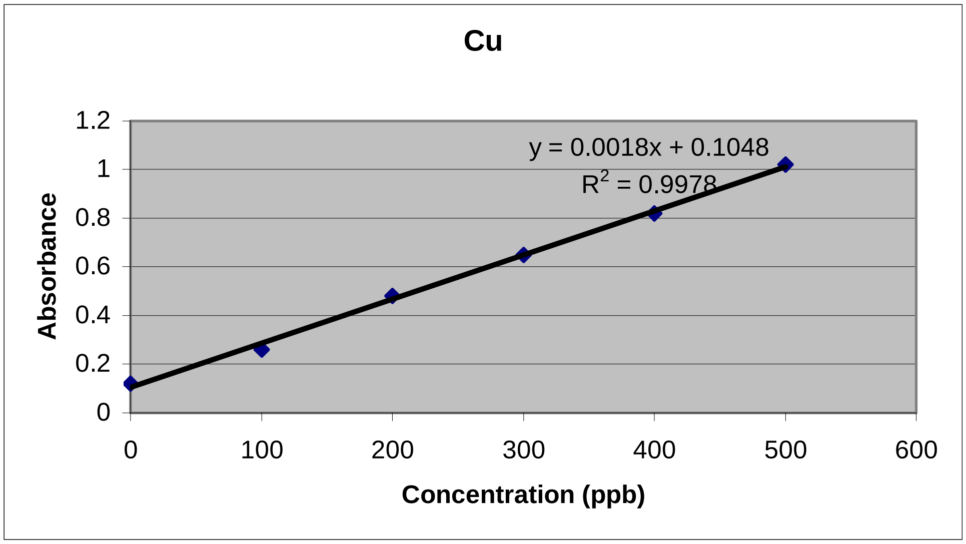

Figure 5 : Calibration curve for copper.

● **LOD:** LOD for copper was found to be 19.56 ppb.

● **LOQ:** LOQ for copper was 64.00 ppb.

● **Precision:** RSD was found to be 2.69 – 5.11%.

● **Recovery:** Table (13) shows that the recoveries of Cu are between 88.90 and 103.70%

Table (13): Recovery results for copper.

Sample#	Tooth weight (g)	Cu content (ppb)	Cu added (ppb)	Absorbance	Total Cu found (ppb)	Recovered Cu added (ppb)	Recovery%
1	0.3166	97.33	50	0.37	147.88	50	100
2	0.3945	97.33	50	0.36	141.78	44.45	88.90
3	0.3670	114.00	100	0.48	208.44	94.44	94.44
4	0.5340	108.44	100	0.47	202.89	94.45	94.45
5	0.5609	119.56	150	0.60	275.11	155.55	103.70
6	0.5510	108.44	150	0.56	252.89	144.45	96.30

3-1-3 Lead:

● **Calibration curve:** Table (14) represents the results of analysis for five lead standard solutions by using GFAAS. Figure 6 represents a linear calibration curve for lead using the results mentioned in table (14).

Table (14): Calibration curve for lead.

	Absorbance	Concentration(ppb)
blank	0.09	0
standard-1	0.26	200
standard-2	0.48	400
standard-3	0.72	600
standard-4	0.96	800
standard-5	1.20	1000

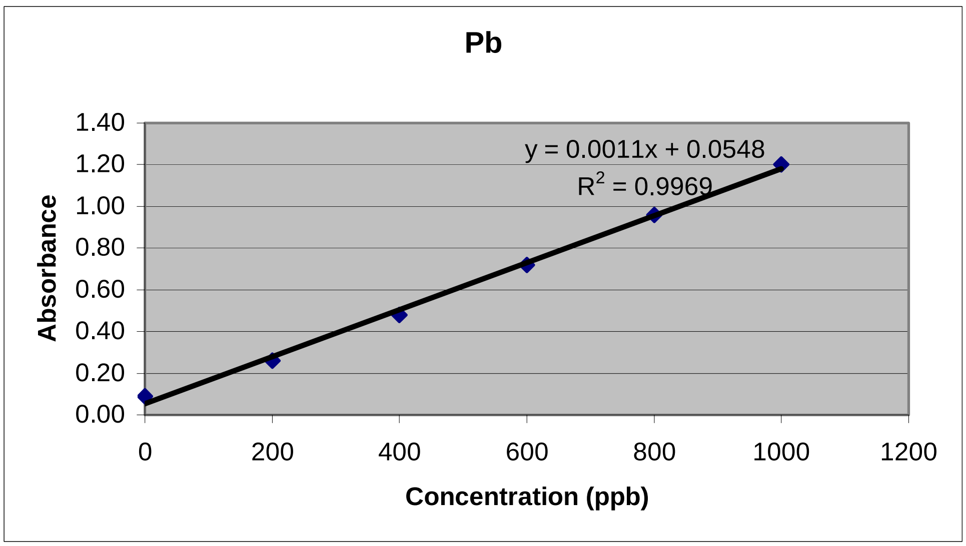

Figure 6 : Calibration curve for lead.

● **LOD:** LOD for lead was 22.91 ppb.

● **LOQ:** LOQ for lead was 77.45 ppb.

● **Precision:** RSD was found to be 2.89–5.04 %.

● **Recovery:** Table (15) shows that the recoveries for Pb are between 90.91 and 103.03%.

Table (15): Recovery results for lead.

Sample#	Tooth weight (g)	Pb content (ppb)	Pb added (ppb)	Absorbance	Total Pb found (ppb)	Recovered Pb added (ppb)	Recovery%
1	0.3166	177.45	100	0.36	277.45	100	100
2	0.3945	168.36	100	0.34	259.27	90.91	90.91
3	0.3670	150.18	150	0.37	286.55	136.37	90.91
4	0.5340	150.18	150	0.39	304.73	154.55	103.03
5	0.5609	122.91	200	0.41	322.91	200	100
6	0.5510	177.45	200	0.46	368.36	190.91	95.46

3-1-4 Selenium:

● **Calibration curve :** Table (16) represents the results of analysis for five selenium standard solutions by using GFAAS. Figure 7 represents a linear calibration curve for selenium using the results mentioned in table (16).

Table (16): Calibration curve for selenium.

	Absorbance	Concentration(ppb)
blank	0.16	0
standard-1	0.58	200
standard-2	0.93	400
standard-3	1.28	600
standard-4	1.61	800
standard-5	1.89	1000

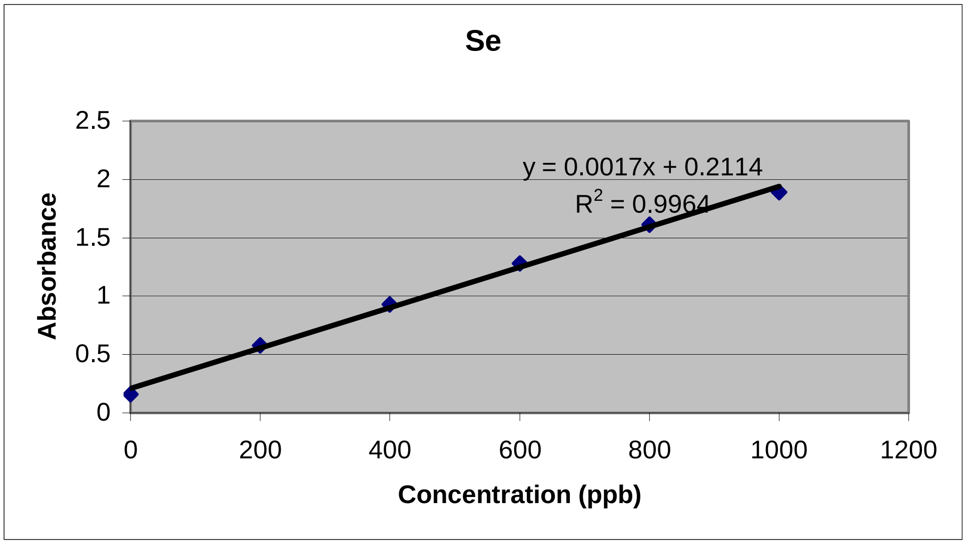

Figure 7 : Calibration curve for selenium.

● **LOD:** LOD for selenium was 22.71 ppb.

● **LOQ:** LOQ for selenium was 75.65 ppb.

● **Precision:** RSD was found to be 1.92 – 5.61 %.

● **Recovery:** Table (17) shows that the recoveries for Se are between 94.11 and 101.96% .

Table (17): Recovery results for selenium.

Sample#	Tooth weight (g)	Se content (ppb)	Se added (ppb)	Absorbance	Total Se found (ppb)	Recovered Se added (ppb)	Recovery%
1	0.3166	258.00	100	0.81	352.11	94.11	94.11
2	0.3945	228.59	100	0.77	328.59	100	100
3	0.3670	181.53	150	0.77	328.59	147.06	98.04
4	0.5340	175.65	150	0.77	328.59	152.94	101.96
5	0.5609	140.35	200	0.78	331.53	191.18	95.59
6	0.5510	234.47	200	0.94	428.59	194.12	97.06

3-1-5 Tin:

● **Calibration curve:** Table (18) represents the results of analysis for five tin standard solutions by using GFAAS. Figure 8 represents a linear calibration curve for tin using the results mentioned in table (18).

Table (18): Calibration curve for tin.

	Absorbance	Concentration(ppb)
blank	0.11	0
standard 1	0.38	100
standard 2	0.56	200
standard 3	0.76	300
standard 4	1.02	400
standard 5	1.20	500

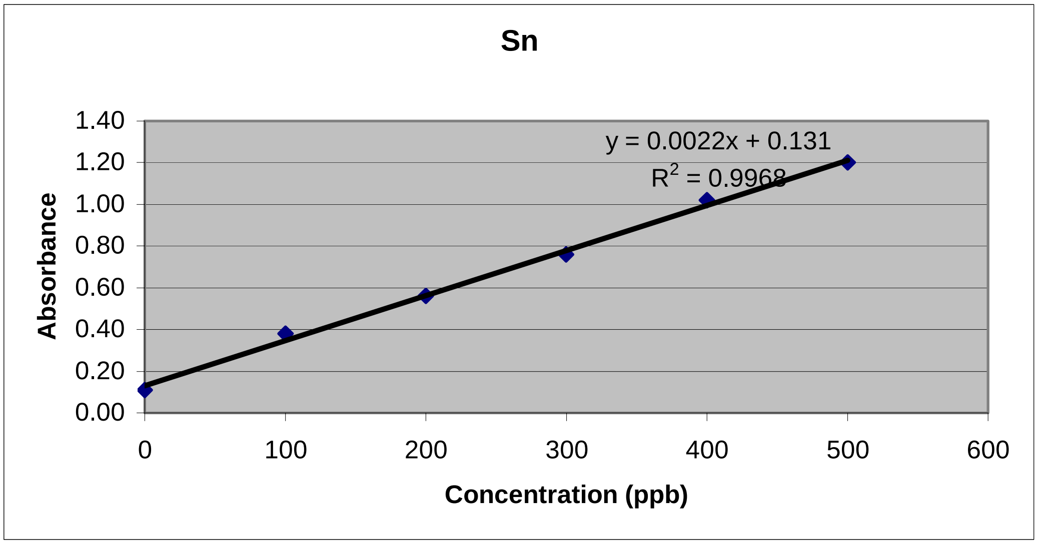

Figure 8 : Calibration curve for tin.

● **LOD:** LOD for tin was 13.18 ppb.

● **LOQ:** LOQ for tin was 49.55 ppb.

● **Precision:** RSD was found to be 3.84 – 5.74%.

● **Recovery:** Table (19) shows that the recoveries for Sn are between 90.90 and 103.03% .

Table (19): Recovery results for tin.

Sample#	Tooth weight (g)	Sn content (ppb)	Sn added (ppb)	Absorbance	Total Sn found (ppb)	Recovered Sn added (ppb)	Recovery%
1	0.3166	72.27	50	0.39	117.72	45.46	90.91
2	0.3945	76.82	50	0.41	126.82	50	100
3	0.3670	95.00	100	0.55	190.45	95.45	95.45
4	0.5340	99.55	100	0.55	190.45	90.90	90.90
5	0.5609	117.73	150	0.73	272.27	154.54	103.03
6	0.5510	72.27	150	0.62	222.27	150	100

3-2 Data of samples:

Samples data are mentioned in tables (20) and table (21). Table (20) includes age, gender, tooth weight, caries degree, smoking, and number of deliveries (for women), but table (21) explains caries degree, tooth brushing, and the frequency of the visits to the dental clinic.

Table (20): Samples information about gender, age, tooth weight, caries degree, smoking, and # of deliveries for samples.

Sample #	Age	Gender	Tooth weight (g)	Caries degree	Smoking	Deliveries #
1	11	M	0.3766	carious	NS	
2	12	M	0.3945	carious	NS	
3	9	M	0.3670	mottle	NS	
4	5	M	0.5340	mottle	NS	
5	10	M	0.5609	intact	NS	
6	13	F	0.3510	carious	NS	
7	7	F	0.3399	carious	NS	
8	10	F	0.3791	mottle	NS	
9	12	F	0.3851	mottle	NS	
10	11	F	0.5427	intact	NS	
11	10	F	0.5531	mottle	NS	
12	37	M	0.5392	carious	S	
13	37	M	0.5415	mottle	S	
14	32	M	0.4993	mottle	NS	
15	37	M	0.5023	mottle	NS	
16	39	M	0.4889	intact	NS	
17	34	F	0.5732	carious	S	0
18	28	F	0.5510	carious	S	7
19	21	F	0.4950	carious	NS	2
20	27	F	0.5062	carious	NS	3
21	38	F	0.5041	mottle	NS	6
22	47	M	0.5789	carious	S	
23	54	M	0.5471	mottle	S	
24	51	M	0.5892	intact	S	
25	58	M	0.5724	carious	NS	
26	58	M	0.4957	mottle	NS	
27	48	F	0.6090	mottle	S	8

Table (20 – continue).

28	45	F	0.5808	carious	NS	3
29	46	F	0.6173	carious	NS	5
30	43	F	0.5800	mottle	NS	9
31	56	F	0.5948	intact	NS	7
32	62	M	0.5027	carious	S	
33	62	M	0.5408	mottle	S	
34	73	M	0.5512	intact	S	
35	85	M	0.4766	mottle	NS	
36	75	M	0.5223	intact	NS	
37	65	F	0.5182	carious	NS	1
38	78	F	0.5268	mottle	NS	9
39	63	F	0.5219	mottle	NS	8
40	69	F	0.5157	mottle	NS	0
41	62	F	0.5212	intact	NS	6

The information of table (20) will be used to discuss the results of each element.

Table (21): Samples information about caries degree, tooth brushing, and the frequency of the visits to the dental clinic for samples .

Sample #	Caries degree	Tooth brushing	Dentist visits
1	carious	twice/week	at sick cases
2	carious	twice/week	at sick cases
3	mottle	twice/week	at sick cases
4	mottle	not at all	at sick cases
5	intact	twice/week	at sick cases
6	carious	twice/week	at sick cases
7	carious	twice/week	at sick cases
8	mottle	twice/week	at sick cases
9	mottle	once/day	at sick cases
10	intact	twice/day	at sick cases
11	mottle	once/week	at sick cases
12	carious	once/week	at sick cases
13	mottle	once/week	at sick cases
14	mottle	twice/week	at sick cases

Table (21 – continue).

Sample #	Caries degree	Tooth brushing	Dentist visits
15	mottle	twice/week	once/year
16	intact	once/week	at sick cases
17	carious	twice/week	once/year
18	carious	not at all	at sick cases
19	carious	twice/day	at sick cases
20	carious	twice/week	at sick cases
21	mottle	3 times/day	at sick cases
22	carious	once/week	at sick cases
23	mottle	once/week	at sick cases
24	intact	not at all	at sick cases
25	carious	twice/week	at sick cases
26	mottle	twice/week	at sick cases
27	mottle	twice/week	at sick cases
28	carious	twice/week	once/year
29	carious	once/week	at sick cases
30	mottle	twice/week	at sick cases
31	intact	not at all	at sick cases
32	carious	not at all	at sick cases
33	mottle	twice/week	at sick cases
34	intact	not at all	at sick cases
35	mottle	once/week	at sick cases
36	intact	not at all	at sick cases
37	carious	once/week	at sick cases
38	mottle	not at all	at sick cases
39	mottle	not at all	at sick cases
40	mottle	twice/week	once/year
41	intact	not at all	at sick cases

From table (21) we note that the majority of patients don't visit dental clinic until they feel pain due to dental caries or other reasons. Also, they don't brush their teeth daily after meals. So, teeth carelessness represented by nonbrushing the teeth daily but randomly through the week and rareness of the frequent visits to the dental clinic was the main reason for caries.

3-3 Calibration method results:

3-3-1 Cadmium:

Table (22) shows the results of cadmium analysis in solutions of tooth samples (ppb) by using GFAAS.

Table (22): Concentration of cadmium in the final solutions (ppb) of the tooth samples.

Sample #	Absorbance			Concentration (ppb)			Recovery corrected conc(ppb)		
	1	2	3	1	2	3	1	2	3
1	0.14	0.14	0.13	20.11	20.11	17.89	19.67	19.67	17.50
2	0.14	0.16	0.14	20.11	24.56	20.11	19.67	25.12	19.67
3	0.19	0.18	0.18	31.22	29.00	29.00	31.22	30.59	30.59
4	0.14	0.15	0.17	20.11	22.33	26.78	19.67	21.85	27.39
5	0.20	0.20	0.21	33.44	33.44	35.67	33.44	33.44	35.67
6	0.14	0.16	0.12	20.11	24.56	15.67	19.67	25.12	19.67
7	0.13	0.13	0.15	17.89	17.89	22.33	17.50	17.50	21.85
8	0.17	0.18	0.18	26.78	29.00	29.00	27.39	30.59	30.59
9	0.17	0.19	0.19	26.78	31.22	31.22	27.39	31.22	31.22
10	0.22	0.21	0.21	37.89	35.67	35.67	37.89	35.67	35.67
11	0.18	0.19	0.18	29.00	31.22	29.00	30.59	31.22	30.59
12	0.43	0.42	0.42	84.56	82.33	82.33	84.56	82.33	82.33
13	0.44	0.44	0.45	86.78	86.78	89.00	86.78	86.78	89.00
14	0.39	0.37	0.35	75.67	71.22	71.22	75.67	71.22	71.22
15	0.37	0.36	0.37	71.22	69.00	71.22	71.22	69.00	71.22
16	0.41	0.39	0.39	80.11	75.67	75.67	80.11	75.67	75.67
17	0.40	0.41	0.41	77.89	80.11	80.11	77.89	80.11	80.11
18	0.41	0.40	0.39	80.11	77.89	75.67	80.11	77.89	75.67
19	0.35	0.33	0.33	66.78	62.33	62.33	66.78	62.33	62.33
20	0.32	0.32	0.30	60.11	60.11	55.67	60.11	60.11	55.67
21	0.36	0.36	0.35	69.00	69.00	66.78	69.00	69.00	66.78
22	0.65	0.65	0.64	133.44	133.44	131.22	133.44	133.44	131.22
23	0.65	0.66	0.66	133.44	135.67	135.66	133.44	135.67	135.66
24	0.66	0.68	0.67	135.66	140.11	137.89	135.66	140.11	137.89
25	0.59	0.60	0.60	120.11	122.33	122.33	120.11	122.33	122.33

Table (22-continue).

Sample #	Absorbance			Concentration (ppb)			Recovery corrected conc(ppb)		
	1	2	3	1	2	3	1	2	3
26	0.61	0.61	0.60	124.56	124.56	122.33	124.56	124.56	122.33
27	0.58	0.60	0.60	117.89	122.33	122.33	117.89	122.33	122.33
28	0.55	0.53	0.53	111.22	106.78	106.78	111.22	106.78	106.78
29	0.53	0.52	0.52	106.78	104.56	104.56	106.78	104.56	104.56
30	0.54	0.55	0.56	109.00	111.22	113.44	109.00	111.22	113.44
31	0.56	0.56	0.55	113.44	113.44	111.22	113.44	113.44	111.22
32	0.94	0.96	0.98	197.89	202.33	202.33	197.89	202.33	202.33
33	0.98	0.97	0.97	206.78	204.56	204.56	206.78	204.56	204.56
34	0.99	0.99	0.98	209.00	209.00	206.78	209.00	209.00	206.78
35	0.87	0.86	0.86	182.33	180.11	180.11	182.33	180.11	180.11
36	0.87	0.89	0.89	182.33	186.78	186.78	182.33	186.78	186.78
37	0.79	0.79	0.78	164.56	164.56	162.33	164.56	164.56	162.33
38	0.81	0.82	0.82	169.00	171.22	171.22	169.00	171.22	171.22
39	0.83	0.81	0.81	173.44	169.00	169.00	173.44	169.00	169.00
40	0.89	0.87	0.87	186.78	182.33	182.33	186.78	182.33	182.33
41	0.84	0.83	0.85	175.67	173.44	177.89	175.67	173.44	177.89

Table (23) demonstrates the cadmium concentration in the dry teeth samples as average value (X), standard deviation(S), and coefficient of variation (CV).

Table (23): Concentration of cadmium in the dry tooth samples (ppm).

Sample #	Concentration (ppm)			X ± S	CV
	1	2	3		
1	0.52	0.52	0.46	0.50 ± 0.03	6.00
2	0.50	0.64	0.50	0.55 ± 0.08	14.55
3	0.85	0.83	0.83	0.84 ± 0.01	1.19
4	0.37	0.41	0.51	0.43 ± 0.07	16.28
5	0.60	0.60	0.64	0.61 ± 0.02	3.28
6	0.56	0.72	0.56	0.61 ± 0.09	14.75
7	0.51	0.51	0.64	0.56 ± 0.08	14.29
8	0.72	0.81	0.81	0.78 ± 0.05	6.41
9	0.71	0.81	0.81	0.78 ± 0.06	7.69
10	0.70	0.66	0.66	0.67 ± 0.02	2.99
11	0.55	0.56	0.55	0.56 ± 0.01	1.79
12	1.57	1.53	1.53	1.54 ± 0.02	1.30

Table (23-continue).

Sample #	Concentration (ppm)			X ± S	CV
	1	2	3		
13	1.60	1.60	1.64	1.62 ± 0.02	1.23
14	1.52	1.43	1.43	1.46 ± 0.05	3.42
15	1.42	1.37	1.42	1.40 ± 0.03	2.14
16	1.64	1.55	1.55	1.58 ± 0.05	3.16
17	1.36	1.40	1.40	1.39 ± 0.02	1.44
18	1.45	1.41	1.37	1.41 ± 0.04	2.84
19	1.35	1.26	1.26	1.29 ± 0.05	3.88
20	1.19	1.19	1.10	1.16 ± 0.05	4.31
21	1.37	1.37	1.32	1.35 ± 0.03	2.22
22	2.31	2.31	2.27	2.29 ± 0.02	0.87
23	2.44	2.48	2.48	2.47 ± 0.02	0.81
24	2.30	2.38	2.34	2.34 ± 0.04	1.71
25	2.10	2.14	2.14	2.13 ± 0.02	0.94
26	2.51	2.51	2.47	2.50 ± 0.03	1.20
27	1.94	2.01	2.01	1.98 ± 0.04	2.02
28	1.91	1.84	1.84	1.86 ± 0.04	2.15
29	1.73	1.69	1.69	1.70 ± 0.02	1.18
30	1.88	1.92	1.96	1.92 ± 0.04	2.08
31	1.91	1.91	1.87	1.90 ± 0.02	1.05
32	3.94	4.02	4.02	3.99 ± 0.05	1.25
33	3.82	3.78	3.78	3.80 ± 0.02	0.53
34	3.79	3.79	3.75	3.78 ± 0.02	0.53
35	3.83	3.78	3.78	3.79 ± 0.03	0.79
36	3.49	3.58	3.58	3.55 ± 0.05	1.41
37	3.18	3.18	3.13	3.16 ± 0.03	0.95
38	3.21	3.25	3.25	3.24 ± 0.02	0.62
39	3.32	3.24	3.24	3.27 ± 0.05	1.53
40	3.62	3.54	3.54	3.57 ± 0.05	1.40
41	3.37	3.33	3.41	3.37 ± 0.04	1.19

From table (23) we note variations in the cadmium concentration in all samples. The lowest cadmium concentration is 0.43 ppm and the highest cadmium concentration is 3.99 ppm. From table (47), the average cadmium concentration for all samples is 1.90 ppm dry weight.

● Discussion:

The influence of gender, age, caries degree, and smoking on tooth cadmium concentration are shown in table (24).

Table (24): Tooth cadmium concentrations (ppm) according to gender, age, caries degree, and smoking.

	Cd (ppm) (X ± S)	
Gender		
Male	2.06 ± 1.21	
Female	1.74 ± 1.02	
Age group	Male	Female
5 - 20	0.59 ± 0.16	0.66 ± 0.10
21 - 40	1.52 ± 0.09	1.32 ± 0.10
41 - 60	2.35 ± 0.15	1.87 ± 0.11
61 - 80	3.78 ± 0.16	3.32 ± 0.16
Smoking		
Smoker	2.73 ± 0.99	1.59 ± 0.34
Nonsmoker	1.61 ± 1.17	1.55 ± 0.96
Caries degree		
Carious	1.83 ± 1.30	1.46 ± 0.77
Mottle	2.03 ± 1.07	1.76 ± 1.07
Intact	2.37 ± 1.33	1.98 ± 1.35

This table and figure 9 show that the concentration of cadmium in human teeth according to gender. For males, the average is 2.06 ppm but in females the average is only 1.74 ppm. By applying t-test, there was no significant difference between them.

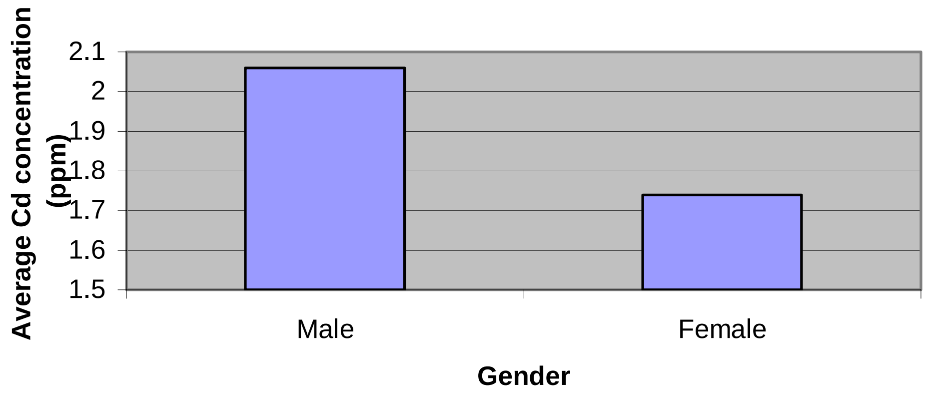

Figure 9 : Cd concentration of human teeth as a function of gender.

Table (24) and figure 10 also show that cadmium concentration in human teeth for male smokers , which is 2.73 ppm , was higher than its concentration in male nonsmokers, which was 1.61ppm ($P<0.05$), but cadmium concentration was nearly the same for female smokers and female nonsmokers (1.59 ppm and 1.55 ppm respectively) ($P>0.05$), because female smokers don't smoke frequently like male smokers as a result of social rejection for smoker women. With respect to age, table (24) and figure 11 showed that the concentration of cadmium increased significantly with age. Noting that for the first age group the cadmium concentration for female was higher than that for male because in this age group both male and female are nonsmokers. Figure 12 and table (24) demonstrate the relationship between cadmium concentration and caries degree. The highest values were observed in the intact teeth but the lowest values were observed in the carious teeth. However, statistically no significant difference among them. These results indicate that dental caries doesn't affect Cd concentration in human teeth. These results were comparable to those obtained in the literature (Alomary, et al., 2006).

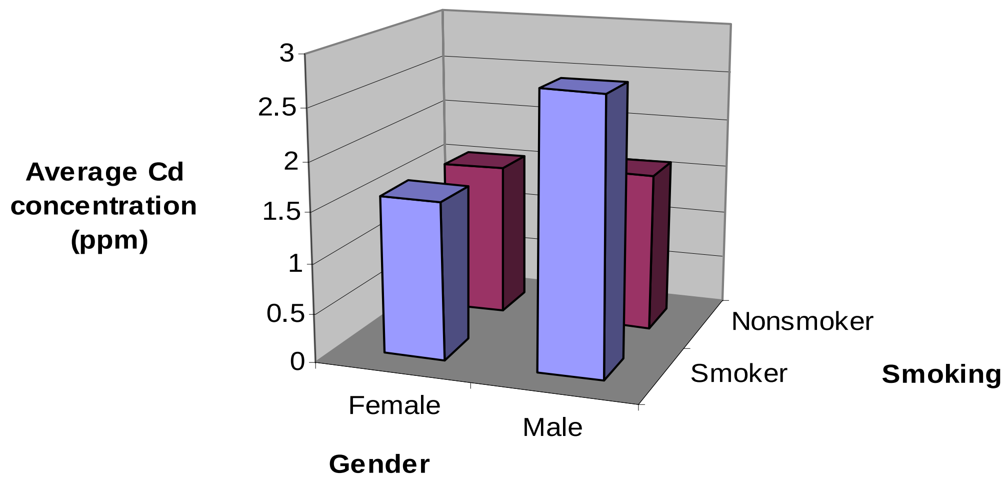

Figure 10: Cd concentration of human teeth as a function of smoking.

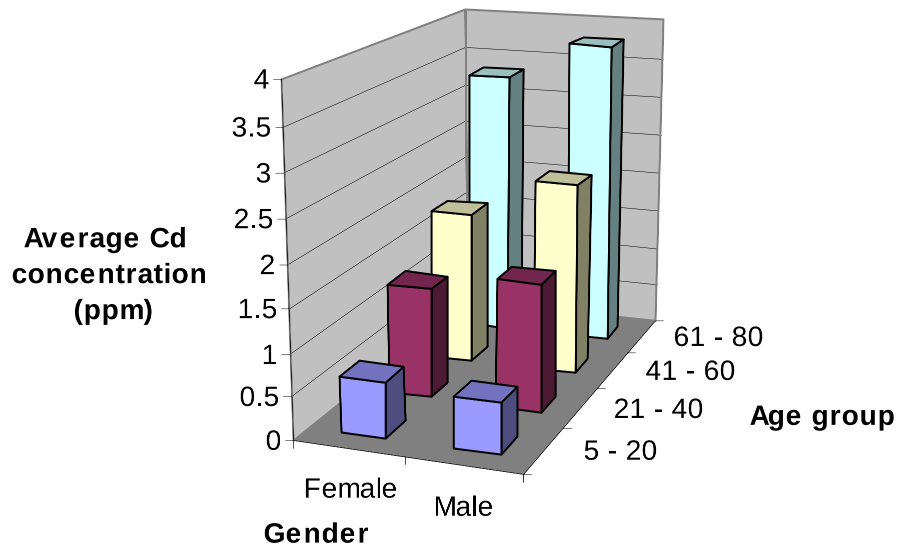

Figure 11: Cd concentration of human teeth as a function of age group.

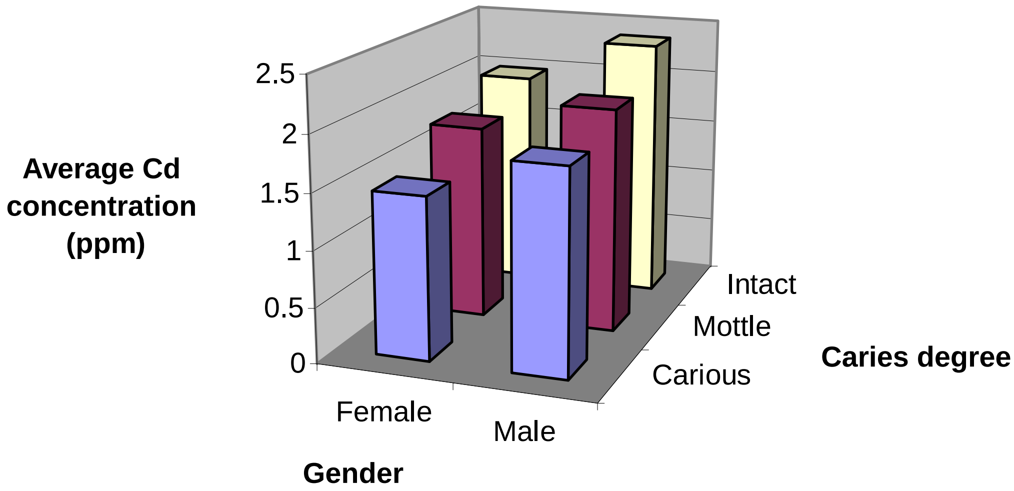

Figure 12 : Cd concentration of human teeth as a function of caries degree.

The influence of the number of deliveries (for women) and the age group for each woman on tooth cadmium concentrations are shown in table (25).

Table (25): Tooth cadmium concentrations (ppm) of women according to the number of deliveries and age group.

Age group	Deliveries #	X ± S
21 - 40	0	1.39 ± 0.02
	2	1.29 ± 0.05
	3	1.16 ± 0.05
	6	1.35 ± 0.03
	7	1.41 ± 0.04
41 - 60	3	1.86 ± 0.04
	5	1.70 ± 0.02
	7	1.90 ± 0.02
	8	1.98 ± 0.04
	9	1.92 ± 0.04
61 - 80	0	3.57 ± 0.05
	1	3.16 ± 0.03
	6	3.37 ± 0.04
	8	3.27 ± 0.05
	9	3.24 ± 0.02

Noting that cadmium concentration for the third age group was higher than that of the second age group which, in turn, was higher than that of the first age group. This indicated that heavy metal accumulate in human body with age. In the first age group, the first sample, which had no deliveries, was the highest in cadmium (1.39 ppm) compared with the second and third samples, which had two and three deliveries respectively. The fifth sample, which had seven deliveries, showed higher cadmium concentration (1.41 ppm) than the first sample which had no deliveries. It may be concluded, therefore, that there is no clear relationship between cadmium concentration in women's teeth and their number of deliveries.

3-3-2 Copper:

Table (26) explains the results of copper analysis in solutions of tooth samples (ppb) by using GFAAS.

Table (26): Concentration of copper in final solutions (ppb) of the tooth samples .

Sample #	Absorbance			Concentration (ppb)			Recovery corrected conc (ppb)		
	1	2	3	1	2	3	1	2	3
1	0.28	0.28	0.27	97.33	97.33	91.78	97.33	97.33	91.78
2	0.29	0.28	0.27	102.89	97.33	91.78	106.84	97.33	91.78
3	0.29	0.31	0.33	102.89	114.00	108.44	106.84	120.71	112.60
4	0.30	0.30	0.29	108.44	108.44	102.89	112.61	112.61	106.80
5	0.31	0.32	0.32	114.00	119.56	119.56	120.71	115.29	115.30
6	0.30	0.30	0.29	108.44	108.44	102.89	112.61	112.61	106.80
7	0.31	0.29	0.30	114.00	102.89	108.44	120.71	106.84	112.60
8	0.30	0.31	0.32	108.44	114.00	119.56	112.61	120.71	115.30
9	0.31	0.31	0.30	114.00	114.00	108.44	120.71	120.71	112.60
10	0.33	0.34	0.33	125.11	130.67	125.11	120.65	126.01	120.70
11	0.32	0.32	0.31	119.56	119.56	114.00	115.29	115.29	120.70
12	0.48	0.48	0.49	208.44	208.44	214.00	201.00	201.00	206.40
13	0.52	0.50	0.50	230.67	219.56	219.56	222.44	211.73	211.70
14	0.41	0.41	0.40	169.56	169.56	164.00	163.51	163.51	158.20
15	0.40	0.41	0.40	164.00	169.56	164.00	158.15	163.51	158.20
16	0.43	0.45	0.44	180.67	191.78	186.22	174.22	184.94	179.60
17	0.48	0.46	0.47	208.44	197.33	202.89	201.00	190.29	195.70
18	0.45	0.44	0.43	191.78	186.22	180.67	184.94	179.58	174.20
19	0.37	0.38	0.40	147.33	152.89	164.00	142.07	147.43	158.20
20	0.37	0.37	0.36	147.33	147.33	141.78	142.07	142.07	136.70
21	0.40	0.40	0.41	164.00	164.00	169.56	158.15	158.15	163.50
22	0.69	0.70	0.69	325.11	330.67	325.11	313.51	318.87	313.50
23	0.70	0.70	0.71	330.67	330.67	336.22	318.87	318.87	324.20
24	0.70	0.72	0.74	330.67	341.78	352.89	318.87	329.59	340.30
25	0.62	0.63	0.61	286.22	291.78	280.67	276.01	281.37	270.70
26	0.65	0.65	0.64	302.89	302.89	297.33	292.08	292.08	286.70
27	0.69	0.69	0.68	325.11	325.11	319.56	313.51	313.51	308.20
28	0.60	0.59	0.59	275.11	269.56	269.56	265.29	259.94	259.90
29	0.58	0.58	0.57	264.00	264.00	258.44	254.58	254.58	249.20
30	0.61	0.63	0.59	280.67	291.78	269.56	270.66	281.37	259.90
31	0.63	0.62	0.62	291.78	286.22	286.22	281.37	276.01	276.00

Table (26-continue).

Sample #	Absorbance (AU)			Concentration (ppb)			Recovery corrected conc (ppb)		
	1	2	3	1	2	3	1	2	3
32	0.86	0.86	0.85	419.56	419.56	414.00	404.59	404.59	399.20
33	0.88	0.89	0.87	430.67	436.22	425.11	415.30	420.66	409.90
34	0.90	0.90	0.91	441.78	441.78	447.33	426.02	426.02	431.40
35	0.80	0.80	0.79	386.22	386.22	380.67	372.44	375.44	367.10
36	0.82	0.81	0.83	397.33	391.78	402.89	383.15	377.80	388.51
37	0.77	0.77	0.78	369.56	369.56	375.11	356.37	356.37	361.70
38	0.77	0.77	0.78	369.56	369.56	375.11	356.37	356.37	361.70
39	0.74	0.76	0.78	352.89	364.00	375.11	340.30	351.01	361.70
40	0.81	0.80	0.81	391.78	386.22	391.78	377.80	375.44	377.80
41	0.79	0.80	0.79	380.67	386.22	380.67	367.09	372.44	367.10

Table (27) demonstrates the copper concentrations in dry tooth samples as the average value (X), standard deviation(S), and coefficient of variation (CV).

Table (27): Concentration of copper in the dry tooth samples (ppm).

Sample #	Concentration (ppm)			X ± S	CV
	1	2	3		
1	2.58	2.58	2.44	2.53 ± 0.08	3.16
2	2.71	2.47	2.33	2.50 ± 0.19	7.60
3	2.91	3.29	3.07	3.09 ± 0.19	6.15
4	2.11	2.11	2.00	2.07 ± 0.06	2.90
5	2.15	2.06	2.06	2.09 ± 0.05	2.39
6	3.21	3.21	3.04	3.15 ± 0.10	3.17
7	3.55	3.14	3.31	3.34 ± 0.20	5.99
8	2.97	3.18	3.04	3.07 ± 0.11	3.58
9	3.13	3.13	2.92	3.06 ± 0.12	3.92
10	2.22	2.32	2.22	2.26 ± 0.06	2.65
11	2.08	2.08	2.18	2.12 ± 0.06	2.83
12	3.73	3.73	3.83	3.76 ± 0.06	1.60
13	4.11	3.91	3.91	3.98 ± 0.11	2.76
14	3.27	3.27	3.17	3.24 ± 0.06	1.85
15	3.15	3.26	3.15	3.18 ± 0.06	1.89
16	3.56	3.78	3.67	3.67 ± 0.11	3.00
17	3.51	3.32	3.41	3.41 ± 0.09	2.64
18	3.36	3.26	3.16	3.26 ± 0.10	3.07

Table (27-continue).

19	2.87	2.98	3.19	3.01 ± 0.17	5.65
20	2.81	2.81	2.70	2.77 ± 0.06	2.17
21	3.14	3.14	3.24	3.17 ± 0.06	1.89
22	5.42	5.51	5.42	5.45 ± 0.05	0.92
23	5.83	5.83	5.93	5.86 ± 0.06	1.02
24	5.41	5.59	5.78	5.59 ± 0.18	3.22
25	4.82	4.92	4.73	4.82 ± 0.09	1.87
26	5.89	5.89	5.78	5.86 ± 0.06	1.02
27	5.15	5.15	5.06	5.12 ± 0.05	0.98
28	4.57	4.48	4.48	4.51 ± 0.05	1.11
29	4.12	4.12	4.04	4.09 ± 0.05	1.22
30	4.67	4.85	4.48	4.67 ± 0.18	3.85
31	4.73	4.64	4.64	4.67 ± 0.05	1.07
32	8.05	8.05	7.94	8.01 ± 0.06	0.75
33	7.68	7.78	7.58	7.68 ± 0.10	1.30
34	7.73	7.73	7.83	7.76 ± 0.06	0.77
35	7.81	7.88	7.70	7.80 ± 0.09	1.15
36	7.34	7.23	7.44	7.34 ± 0.10	1.36
37	6.88	6.88	6.98	6.91 ± 0.06	0.87
38	6.76	6.76	6.87	6.80 ± 0.06	0.88
39	6.52	6.73	6.93	6.73 ± 0.21	3.12
40	7.33	7.28	7.33	7.31 ± 0.03	0.41
41	7.04	7.15	7.04	7.08 ± 0.06	0.85

From table (27) we note variations in the copper concentration in all samples. The lowest copper concentration is 2.07 ppm and the highest copper concentration is 8.01 ppm. From table (47), the average copper concentration for all samples is 4.49 ppm dry weight.

● Discussion:

The influence of gender, age, caries degree, and smoking on tooth copper concentrations are shown in table (28).

Table (28): Tooth copper concentrations (ppm) according to gender, age, caries degree, and smoking.

	Cu (ppm)(X ± S)	
Gender		
Male	4.81 ± 2.08	
Female	4.31 ± 1.71	
Age group	Male	Female
5 - 20	2.46 ± 0.42	2.83 ± 0.51
21 - 40	3.57 ± 0.34	3.12 ± 0.25
41 - 60	5.52 ± 0.43	4.61 ± 0.37
61 - 80	7.72 ± 0.24	6.97 ± 0.23
Smoking		
Smoker	6.01 ± 1.67	3.93 ± 1.03
Nonsmoker	4.02 ± 1.99	3.97 ± 1.77
Caries degree		
Carious	4.51 ± 2.09	3.83 ± 1.28
Mottle	4.75 ± 2.11	4.42 ± 1.73
Intact	5.29 ± 2.41	4.67 ± 2.41

This table and figure 13 show that the concentration of copper in human teeth according to gender. For males, the average was 4.81 ppm but in females the average was only 4.31 ppm. By applying t-test, there was no significant difference between them

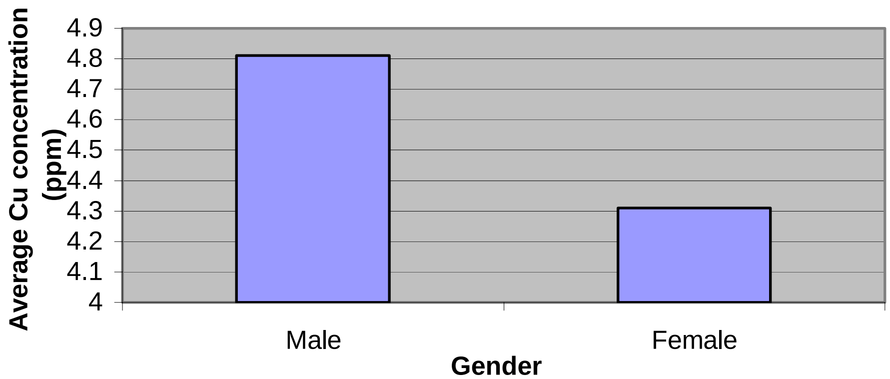

Figure 13 :Cu concentration of human teeth as a function of gender.

Table (28) and figure 14 also show that copper concentration in human teeth for male smokers , which is 6.01 ppm , is higher than its concentration in male nonsmokers , which is 4.02 ppm ($P<0.05$), but copper concentration is nearly the same for female smokers and female nonsmokers (3.93 ppm and 3.97 ppm respectively) ($P>0.05$), because female smokers don't smoke frequently like male smokers as a result of social rejection for smoker women. With respect to age, table (28) and figure 15 show that the concentration of copper increased significantly with age. Noting that for the first age group the copper concentration for female was higher than that for male because in this age group both male and female are nonsmokers. Figure 16 and table (28) demonstrate the relationship between copper concentration and caries degree. The highest values were observed in the intact teeth but the lowest values were observed in the carious teeth. However, statistically no significant difference among them. These results indicate that dental caries doesn't affect Cu concentration in human teeth.

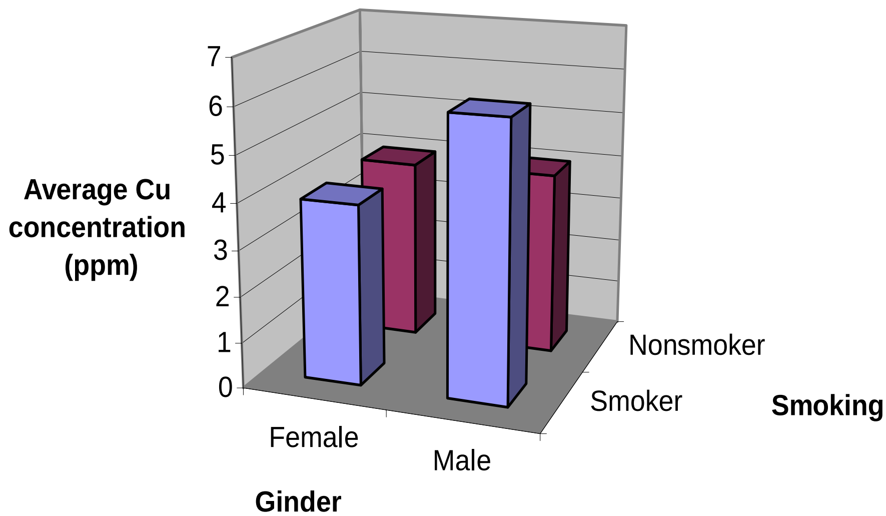

Figure 14 : Cu concentration of human teeth as a function of smoking.

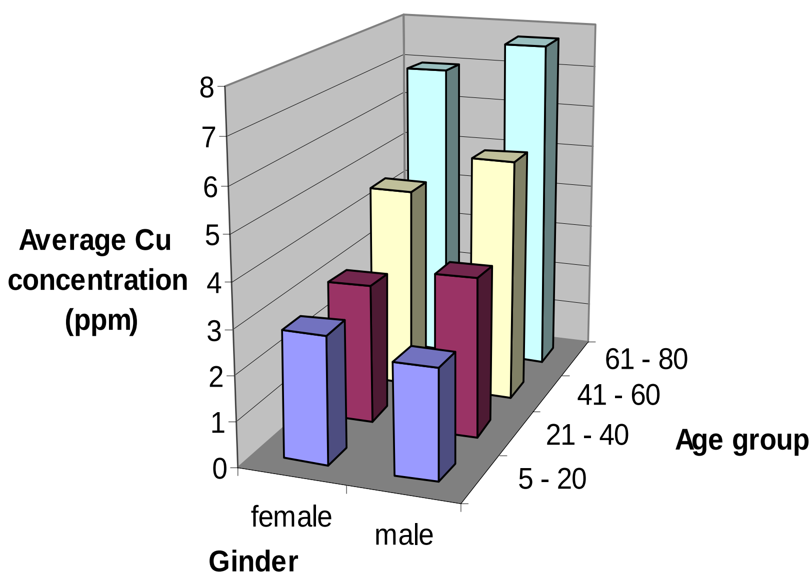

Figure 15: Cu concentration of human teeth as a function of age groups.

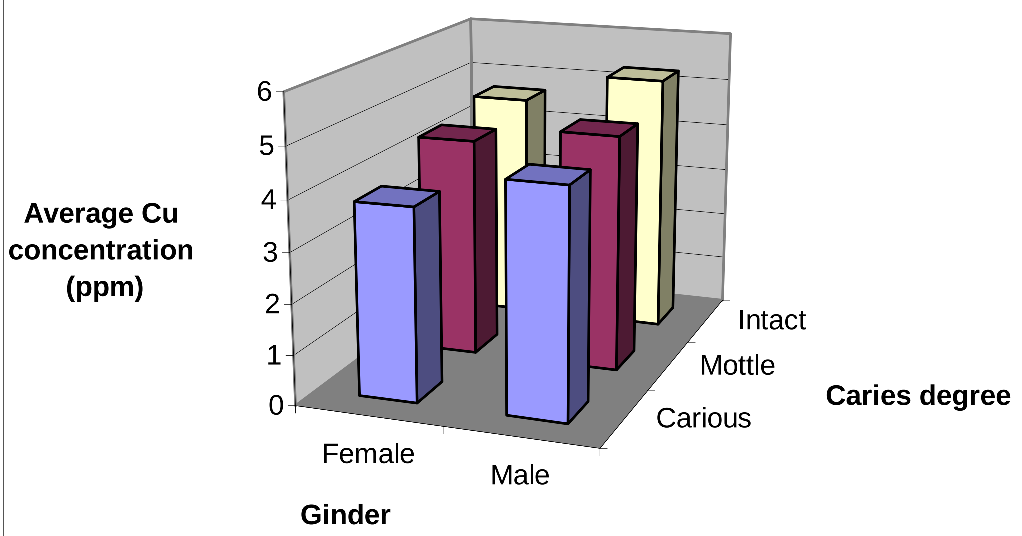

Figure 16: Cu concentration of human teeth as a function of caries degree.

The influence of the number of deliveries (for women) and the age group for each woman on tooth copper concentrations are shown in table (29).

Table (29): Tooth copper concentrations (ppm) of women according to the number of deliveries and age group.

Age group	Deliveries #	X ± S
21 - 40	0	3.41 ± 0.09
	2	3.01 ± 0.17
	3	2.77 ± 0.06
	6	3.17 ± 0.06
	7	3.26 ± 0.10
41 - 60	3	4.51 ± 0.05
	5	4.09 ± 0.05
	7	4.67 ± 0.05
	8	5.12 ± 0.05
	9	4.67 ± 0.18
61 - 80	0	7.31 ± 0.03
	1	6.91 ± 0.06
	6	7.08 ± 0.06
	8	6.73 ± 0.21
	9	6.80 ± 0.06

It is noteworthy, that copper concentration for the third age group was higher than that of the second age group which, in turn, was higher in copper concentration than that of the first age group. This finding pointed to the cumulative nature of copper in the body. In the first age group, the first sample, which had no deliveries, showed the highest copper concentration (3.41 ppm) compared to the second & third samples for women who had two and three deliveries, respectively. However, the fifth sample which belonged to women who had a history of seven deliveries scored higher concentration of copper (3.26 ppm) than those of the second and third samples for women who had two and three deliveries, respectively. It could be concluded, therefore, that there is no clear relationship between copper concentrations in women teeth and their number of deliveries.

3-3-3 Lead:

Table (30) explains the results of lead analysis in solutions of tooth samples (ppb) by using GFAAS.

Table (30): Concentration of lead in final solutions (ppb) of the tooth samples.

Sample #	Absorbance			Concentration (ppb)			Recovery corrected conc (ppb)		
	1	2	3	1	2	3	1	2	3
1	0.24	0.25	0.26	168.36	177.45	186.55	185.19	177.45	186.55
2	0.24	0.24	0.23	168.36	168.36	159.27	185.19	185.19	154.59
3	0.23	0.22	0.22	159.27	150.18	150.18	154.59	145.76	145.76
4	0.23	0.21	0.22	159.27	141.09	150.18	154.59	136.94	145.76
5	0.19	0.18	0.19	122.91	113.82	122.91	122.91	113.82	122.91
6	0.25	0.26	0.25	177.45	186.55	177.45	177.45	186.55	177.45
7	0.22	0.23	0.23	150.18	159.27	159.27	145.76	154.59	154.59
8	0.20	0.22	0.22	132.00	150.18	150.18	132.00	145.76	145.76
9	0.23	0.22	0.22	159.27	150.18	150.18	154.59	145.76	145.76
10	0.18	0.18	0.19	113.82	113.82	122.91	113.82	113.82	122.91
11	0.22	0.21	0.21	150.18	141.09	141.09	145.76	136.94	136.94
12	0.46	0.45	0.45	368.36	359.27	359.27	368.36	359.27	359.27
13	0.44	0.44	0.43	350.18	350.18	341.09	350.18	350.18	341.09
14	0.39	0.40	0.41	304.73	313.82	322.91	304.73	313.82	322.91
15	0.40	0.39	0.39	313.82	304.73	304.73	313.82	304.73	304.73
16	0.37	0.36	0.37	286.55	277.45	286.55	286.55	277.45	286.55
17	0.44	0.45	0.43	350.18	359.27	341.09	350.18	359.27	341.09
18	0.41	0.39	0.40	322.91	304.73	313.82	322.91	304.73	313.82
19	0.33	0.34	0.34	250.18	259.27	259.27	250.18	259.27	259.27
20	0.32	0.33	0.33	241.09	250.18	250.18	241.09	250.18	250.18
21	0.31	0.32	0.31	232.00	241.09	232.00	232.00	241.09	232.00
22	0.70	0.71	0.70	10.13	10.29	10.13	586.55	595.64	586.55
23	0.68	0.69	0.69	10.39	10.55	10.55	568.36	577.45	577.45
24	0.66	0.67	0.68	9.34	9.49	9.65	550.18	559.27	568.36
25	0.63	0.63	0.65	9.14	9.14	9.45	522.91	522.91	541.09
26	0.60	0.61	0.61	10.00	10.18	10.18	495.64	504.73	504.73
27	0.64	0.64	0.65	8.74	8.74	8.88	532.00	532.00	541.09
28	0.60	0.59	0.60	8.53	8.38	8.53	495.64	486.55	495.64
29	0.58	0.59	0.60	7.73	7.88	8.03	477.45	486.55	495.64
30	0.54	0.55	0.55	7.61	7.76	7.76	441.09	450.18	450.18
31	0.53	0.54	0.54	7.26	7.42	7.42	432.00	441.09	441.09

Table (30-continue).

Sample #	Absorbance (AU)			Concentration (ppb)			Recovery corrected conc (ppb)		
	1	2	3	1	2	3	1	2	3
32	0.99	1.00	0.99	16.91	17.09	16.91	850.18	859.27	850.18
33	0.96	0.97	0.97	15.22	15.38	15.38	822.91	832.00	832.00
34	0.94	0.96	0.94	14.60	14.93	14.60	804.73	822.91	804.73
35	0.88	0.89	0.89	15.74	15.93	15.93	750.18	759.27	759.27
36	0.85	0.86	0.87	13.84	14.01	14.19	722.91	732.00	741.09
37	0.89	0.88	0.88	14.65	14.48	14.48	759.27	750.18	750.18
38	0.84	0.84	0.86	13.55	13.55	13.90	713.82	713.82	732.00
39	0.82	0.83	0.84	13.33	13.50	13.68	695.64	704.73	713.82
40	0.87	0.88	0.88	14.37	14.55	14.55	741.09	750.18	750.18
41	0.81	0.80	0.81	13.17	13.00	13.17	686.55	677.45	686.55

Table (31) demonstrates the lead concentration in dry tooth samples as the average value (X), standard deviation(S), and coefficient of variation (CV).

Table (31): Concentration of lead in the dry tooth samples (ppm).

Sample #	Concentration (ppm)			X ± S	CV
	1	2	3		
1	4.92	4.71	4.95	4.86 ± 0.13	2.67
2	4.69	4.69	3.92	4.43 ± 0.45	10.16
3	4.21	3.97	3.97	4.05 ± 0.14	3.46
4	2.89	2.56	2.73	2.73 ± 0.17	6.23
5	2.19	2.03	2.19	2.14 ± 0.09	4.21
6	5.06	5.31	5.06	5.14 ± 0.15	2.92
7	4.29	4.55	4.55	4.46 ± 0.15	3.36
8	3.48	3.84	3.84	3.72 ± 0.21	5.65
9	4.01	3.78	3.78	3.86 ± 0.13	3.37
10	2.10	2.10	2.26	2.15 ± 0.10	4.65
11	2.64	2.48	2.48	2.53 ± 0.09	3.56
12	6.83	6.66	6.66	6.72 ± 0.10	1.49
13	6.47	6.47	6.30	6.41 ± 0.10	1.56
14	6.10	6.29	6.47	6.29 ± 0.18	2.86
15	6.25	6.07	6.07	6.13 ± 0.10	1.63
16	5.86	5.67	5.86	5.80 ± 0.11	1.90
17	6.11	6.27	5.95	6.11 ± 0.16	2.62
18	5.86	5.53	5.70	5.70 ± 0.16	2.81

Table (31-continue).

19	5.05	5.24	5.24	5.18 ± 0.11	2.12
20	4.76	4.94	4.94	4.88 ± 0.10	2.05
21	4.60	4.78	4.60	4.66 ± 0.10	2.15
22	10.13	10.29	10.13	10.18 ± 0.09	0.88
23	10.39	10.55	10.55	10.50 ± 0.09	0.86
24	9.34	9.49	9.65	9.49 ± 0.15	1.58
25	9.14	9.14	9.45	9.24 ± 0.18	1.95
26	10.00	10.18	10.18	10.12 ± 0.11	1.09
27	8.74	8.74	8.88	8.79 ± 0.08	0.91
28	8.53	8.38	8.53	8.48 ± 0.09	1.06
29	7.73	7.88	8.03	7.88 ± 0.15	1.90
30	7.61	7.76	7.76	7.71 ± 0.09	1.17
31	7.26	7.42	7.42	7.37 ± 0.09	1.22
32	16.91	17.09	16.91	16.97 ± 0.11	0.65
33	15.22	15.38	15.38	15.33 ± 0.10	0.65
34	14.60	14.93	14.60	14.71 ± 0.19	1.29
35	15.74	15.93	15.93	15.87 ± 0.11	0.69
36	13.84	14.01	14.19	14.01 ± 0.17	1.21
37	14.65	14.48	14.48	14.54 ± 0.10	0.69
38	13.55	13.55	13.90	13.67 ± 0.20	1.46
39	13.33	13.50	13.68	13.50 ± 0.17	1.26
40	14.37	14.55	14.55	14.49 ± 0.10	0.69
41	13.17	13.00	13.17	13.11 ± 0.10	0.76

From table (31) we note variations in the lead concentration in all samples. The lowest lead concentration is 2.14 ppm and the highest lead concentration is 16.97 ppm. From table (47), the average lead concentration for all samples is 8.14 ppm dry weight.

● Discussion:

The influence of gender, age, caries degree, and smoking on tooth lead concentrations are shown in table (32).

Table (32): Tooth lead concentrations (ppm) according to gender, age, caries degree, and smoking.

	Pb (ppm) (X ± S)	
Ginder		
Male	8.80 ± 4.59	
Female	7.52 ± 4.05	
Age group	Male	Female
5 - 20	3.64 ± 1.16	3.64 ± 1.13
21 - 40	6.27 ± 0.34	5.31 ± 0.60
41 - 60	9.91 ± 0.52	8.05 ± 0.58
61 - 80	15.38 ± 1.13	13.86 ± 0.63
Smoking		
Smoker	11.29 ± 3.97	6.87 ± 1.68
Nonsmoker	7.14 ± 4.34	6.86 ± 4.34
Caries degree		
Carious	8.73 ± 4.64	6.93 ± 3.16
Mottle	8.60 ± 4.07	6.71 ± 4.29
Intact	8.04 ± 5.37	4.76 ± 3.69

This table and figure 17 show that the concentration of lead in human teeth according to gender. For males, the average is 8.80 ppm but in females the average is only 7.52 ppm . By applying t-test, there was no significant difference between them. This result was incomparable to that obtained in the literature (Alomary, et al., 2006).

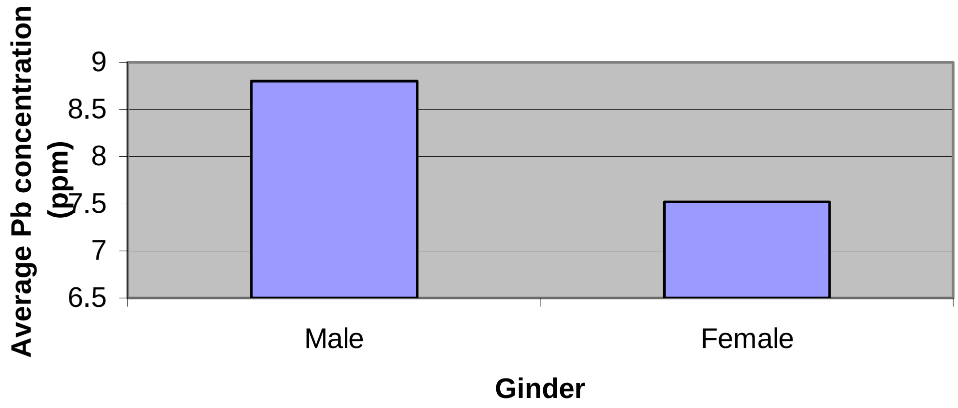

Figure 17: Pb concentration of human teeth as a function of ginder.

Table (32) and figure 18 also show that lead concentration in human teeth for male smokers , which is 11.29 ppm , is higher than its concentration in male nonsmokers , which is 7.14 ppm ($P<0.05$), but lead concentration is nearly the same for female smokers and female nonsmokers (6.87 ppm and 6.86 ppm respectively) ($P>0.05$), because female smokers don't smoke frequently like male smokers as a result of social rejection for smoker women. With respect to age, table (32) and figure 19 show that the concentration of lead increased significantly with age. Noting that for the first age group the lead concentration for female was equal to that for male because in this age group both male and female are nonsmokers. These results were comparable to those obtained in the literature (Alomary, et al., 2006).Figure 20 and table (32) demonstrate the relationship between lead concentration and caries degree. The highest values were observed in the carious teeth but the lowest values were observed in the intact teeth. However, statistically no significant difference among them. These results indicate that dental caries doesn't affect lead concentration in human teeth.

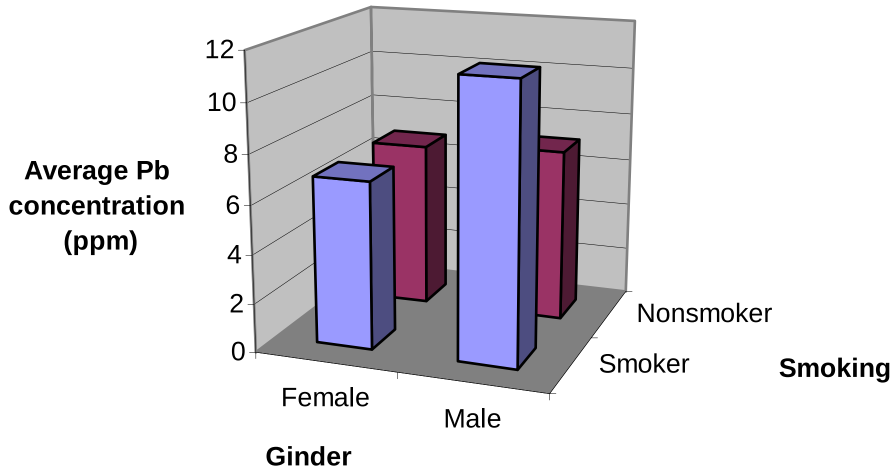

Figure 18 : Pb concentration of human teeth as a function of smoking.

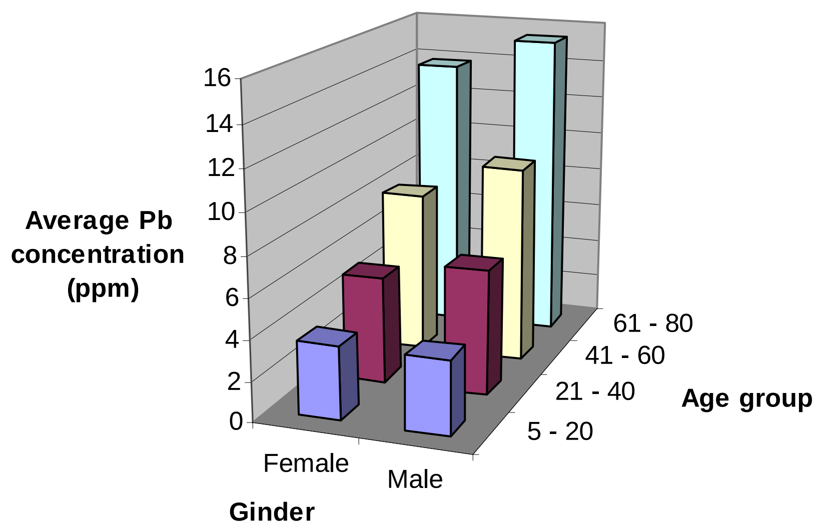

Figure 19: Pb concentration of human teeth as a function of age group.

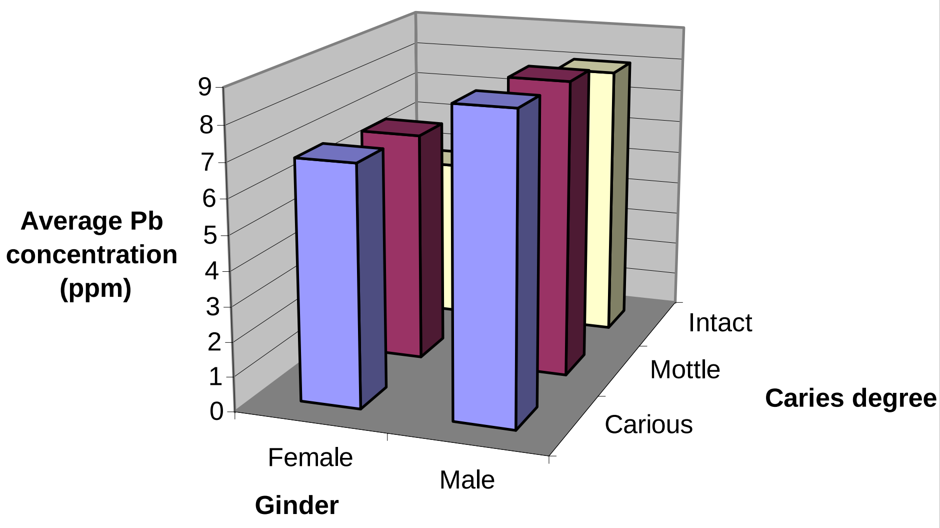

Figure 20: Pb concentration of human teeth as a function of caries degree.

The influence of the number of deliveries (for women) and the age group for each woman on tooth lead concentrations are shown in table (33).

Table (33): Tooth lead concentrations (ppm) of women according to the number of deliveries and age group.

Age group	Deliveries #	X ± S
21 - 40	0	6.11 ± 0.16
	2	5.18 ± 0.11
	3	4.88 ± 0.10
	6	4.66 ± 0.10
	7	5.70 ± 0.16
41 - 60	3	8.48 ± 0.09
	5	7.88 ± 0.15
	7	7.37 ± 0.09
	8	8.79 ± 0.08
	9	7.71 ± 0.09
61 - 80	0	14.49 ± 0.10
	1	14.54 ± 0.10
	6	13.11 ± 0.10
	8	13.50 ± 0.17
	9	13.67 ± 0.20

Noting that lead concentration for the third age group was higher than that of the second age group which, in turn, was higher than that of the first age group. This indicated that lead had accumulated in human body with age. Regarding the relationship of lead concentration in women teeth and the number of deliveries they had; the results showed (table 33) that in the first age group (21-40 years), women who had no babies had the highest tooth-lead concentration score (6.11 ppm) compared to that for women who had two or three deliveries. It was shown, however, that women with history of seven deliveries scored a higher level of lead concentration in their teeth than that scored by women who had two and three deliveries. It may be possible to conclude, therefore, that there is no clear relationship between lead concentrations in women teeth and the number of deliveries they had.

3-3-4 Selenium:

Table (34) explains the results of selenium analysis in solutions of tooth samples (ppb) by using GFAAS.

Table (34): Concentration of selenium in final solutions (ppb) of the tooth samples.

Sample #	Absorbance			Concentration (ppb)			Recovery corrected conc (ppb)		
	1	2	3	1	2	3	1	2	3
1	0.64	0.64	0.65	252.12	252.12	258.00	267.90	267.90	274.15
2	0.59	0.60	0.61	222.71	228.59	234.47	222.71	228.59	241.57
3	0.51	0.50	0.51	175.65	169.76	175.65	172.27	166.50	172.27
4	0.51	0.50	0.51	175.65	169.76	175.65	172.27	166.50	172.27
5	0.45	0.45	0.47	140.35	140.35	152.12	146.82	146.82	159.14
6	0.61	0.62	0.60	234.47	240.35	228.59	241.57	247.63	228.59
7	0.57	0.56	0.58	210.94	205.06	216.82	210.94	205.06	216.82
8	0.49	0.52	0.50	163.88	181.53	169.76	160.73	185.16	166.50
9	0.53	0.54	0.55	187.41	193.29	199.18	191.16	197.15	203.16
10	0.45	0.46	0.47	140.35	146.24	152.12	146.82	152.99	159.14
11	1.37	1.34	1.36	681.53	663.88	675.65	724.18	705.43	717.94
12	1.24	1.24	1.23	605.06	605.06	599.18	642.93	642.93	636.68
13	1.17	1.18	1.19	563.88	569.76	575.65	599.17	605.42	611.68
14	1.20	1.20	1.16	581.53	581.53	558.00	617.93	617.93	592.92
15	1.08	1.10	1.10	510.94	522.71	522.71	542.92	555.42	555.42
16	1.18	1.20	1.17	569.76	581.53	563.88	605.42	617.93	599.17
17	0.88	0.88	0.90	393.29	393.29	405.06	417.90	417.90	430.41
18	1.06	1.08	1.08	499.18	510.94	510.94	530.42	542.92	542.92
19	1.06	1.06	1.05	499.18	499.18	493.29	530.42	530.42	524.16
20	1.00	0.96	1.00	463.88	440.35	463.88	492.91	467.91	492.91
21	1.52	1.52	1.51	769.76	769.76	763.88	817.94	817.94	811.69
22	1.42	1.40	1.40	710.94	699.18	699.18	755.44	742.94	742.94
23	1.28	1.26	1.26	628.59	616.82	616.82	667.93	655.42	655.42
24	1.39	1.40	1.40	693.29	699.18	699.18	736.68	742.94	742.94
25	1.32	1.32	1.31	652.12	652.12	646.24	692.93	692.93	686.69
26	1.32	1.33	1.30	652.12	658.00	640.35	692.93	699.18	680.43
27	1.40	1.42	1.42	699.18	710.94	710.94	742.94	755.44	755.44
28	1.20	1.20	1.24	581.53	581.53	605.06	617.93	617.93	642.93
29	1.13	1.12	1.12	540.35	534.47	534.47	574.17	567.92	567.92
30	1.04	1.04	1.06	487.41	487.41	499.18	517.92	517.92	530.42

Table (34-continue).

Sample #	Absorbance			Concentration (ppb)			Recovery corrected conc (ppb)		
	1	2	3	1	2	3	1	2	3
32	1.70	1.70	1.68	875.65	875.65	863.88	930.45	930.45	917.95
33	1.60	1.62	1.62	816.82	828.59	828.59	867.94	880.45	880.45
34	1.58	1.58	1.60	805.06	805.06	816.82	855.45	855.45	867.94
35	1.54	1.52	1.52	781.53	769.76	769.76	830.44	817.94	817.94
36	1.48	1.48	1.49	746.24	746.24	752.12	792.94	792.94	799.19
37	1.54	1.52	1.52	781.53	769.76	769.76	830.44	817.94	817.94
38	1.44	1.44	1.43	722.71	722.71	716.82	767.94	767.94	761.68
39	1.40	1.40	1.36	699.18	699.18	675.65	742.94	742.94	717.94
40	1.54	1.50	1.50	781.53	758.00	758.00	830.44	805.44	805.44
41	1.27	1.27	1.26	622.71	622.71	616.82	661.68	661.68	655.42

Table (35) demonstrates the selenium concentration in dry tooth samples as the average value (X), standard deviation(S), and coefficient of variation (CV).

Table (35): Concentration of selenium in the dry tooth samples (ppm).

Sample #	Concentration (ppm)			X ± S	CV
	1	2	3		
1	7.11	7.11	7.28	7.17 ± 0.10	1.39
2	5.65	5.79	6.12	5.85 ± 0.24	4.10
3	4.69	4.54	4.69	4.64 ± 0.09	1.94
4	3.23	3.12	3.23	3.19 ± 0.06	1.88
5	2.62	2.62	2.84	2.69 ± 0.13	4.83
6	6.88	7.05	6.51	6.82 ± 0.28	4.11
7	6.21	6.03	6.38	6.21 ± 0.17	2.74
8	4.24	4.88	4.39	4.51 ± 0.34	7.54
9	4.96	5.12	5.28	5.12 ± 0.16	3.13
10	2.71	2.82	2.93	2.82 ± 0.11	3.90
11	13.43	13.08	13.31	13.28 ± 0.18	1.36
12	11.87	11.87	11.76	11.83 ± 0.07	0.59
13	12.00	12.13	12.25	12.13 ± 0.13	1.07
14	12.30	12.30	11.80	12.14 ± 0.29	2.39
15	11.10	11.36	11.36	11.28 ± 0.15	1.33
16	10.56	10.78	10.45	10.60 ± 0.17	1.60
17	7.58	7.58	7.81	7.66 ± 0.13	1.70

Table (35-continue).

19	10.72	10.97	10.97	10.88 ± 0.15	1.38
20	10.48	10.48	10.35	10.44 ± 0.07	0.67
21	9.78	9.28	9.78	9.61 ± 0.29	3.02
22	14.13	14.13	14.02	14.09 ± 0.06	0.43
23	13.81	13.58	13.58	13.66 ± 0.13	0.95
24	11.34	11.12	11.12	11.19 ± 0.12	1.07
25	12.87	12.98	12.98	12.94 ± 0.06	0.46
26	13.98	13.98	13.85	13.94 ± 0.07	0.50
27	11.38	11.48	11.17	11.34 ± 0.16	1.41
28	12.79	13.01	13.01	12.94 ± 0.13	1.00
29	10.01	10.01	10.42	10.15 ± 0.23	2.27
30	9.90	9.79	9.79	9.83 ± 0.06	0.61
31	8.71	8.71	8.92	8.78 ± 0.12	1.37
32	18.51	18.51	18.26	18.43 ± 0.14	0.76
33	16.05	16.28	16.28	16.20 ± 0.13	0.80
34	15.52	15.52	15.75	15.60 ± 0.13	0.83
35	17.42	17.16	17.16	17.25 ± 0.15	0.87
36	15.18	15.18	15.30	15.22 ± 0.07	0.46
37	16.03	15.78	15.78	15.86 ± 0.14	0.88
38	14.58	14.58	14.46	14.54 ± 0.07	0.48
39	14.24	14.24	13.76	14.08 ± 0.28	1.99
40	16.10	15.62	15.62	15.78 ± 0.28	1.77
41	12.70	12.70	12.58	12.66 ± 0.07	0.55

From table (35) we note variations in the selenium concentration in all samples. The lowest selenium concentration wais 2.82 ppm and the highest selenium concentration was 18.43 ppm. From table (47), the average selenium concentration for all samples is 10.83 ppm dry weight.

● Discussion:

The influence of gender, age, caries degree, and smoking on tooth selenium concentrations are shown in table (36).

Table (36): Tooth selenium concentrations (ppm) according to gender, age, caries degree, and smoking.

	Se (ppm) (X ± S)	
Gender		
Male	11.64 ± 4.59	
Female	10.03 ± 3.71	
Age group	Male	Female
5 - 20	4.71 ± 1.85	5.10 ± 1.56
21 - 40	12.13 ± 0.73	9.84 ± 1.31
41 - 60	13.16 ± 1.19	10.61 ± 1.59
61 - 80	16.54 ± 1.31	14.58 ± 1.32
Smoking		
Smoker	14.29 ± 2.38	9.87 ± 1.95
Nonsmoker	9.87 ± 4.94	9.70 ± 3.97
Caries degree		
Carious	11.96 ± 4.68	10.17 ± 3.04
Mottle	11.66 ± 4.77	9.77 ± 4.17
Intact	11.20 ± 5.19	8.09 ± 4.96

This table and figure 21 show that the concentration of selenium in human teeth according to gender. For males, the average was 11.64 ppm but in females the average was only 10.03 ppm . By applying t-test, there was no significant difference between them.

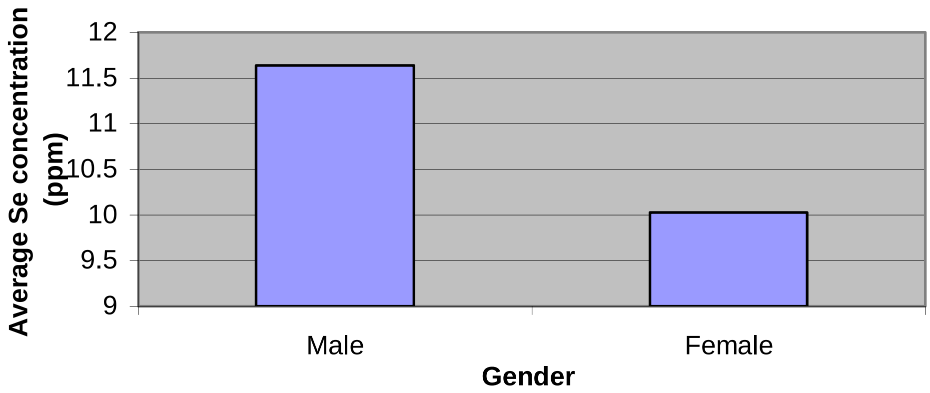

Figure 21: Se concentration of human teeth as a function of gender.

Table (36) and figure 22 also show that selenium concentration in human teeth for male smokers , which was 14.29 ppm , was higher than in male nonsmokers , which was 9.87 ppm ($P<0.05$), but selenium concentration was nearly the same for female smokers and female nonsmokers (9.87 ppm and 9.70 ppm respectively) ($P>0.05$), because female smokers don't smoke frequently like male smokers as a result of social rejection for smoker women. With respect to age, table (36) and figure 23 explain that the concentration of selenium increased significantly with age. Noting that for the first age group the selenium concentration for female was higher than that for male because in this age group both male and female are nonsmokers. This result was comparable to that obtained in the literature (Nadhum and Hassan, 2004). Figure 24 and table (36) demonstrate the variation in the selenium concentration with caries degree. The highest values were observed in the carious teeth but the lowest values were observed in the intact teeth. . However, statistically no significant difference among them. These results indicate that dental caries doesn't affect selenium concentration in human teeth.

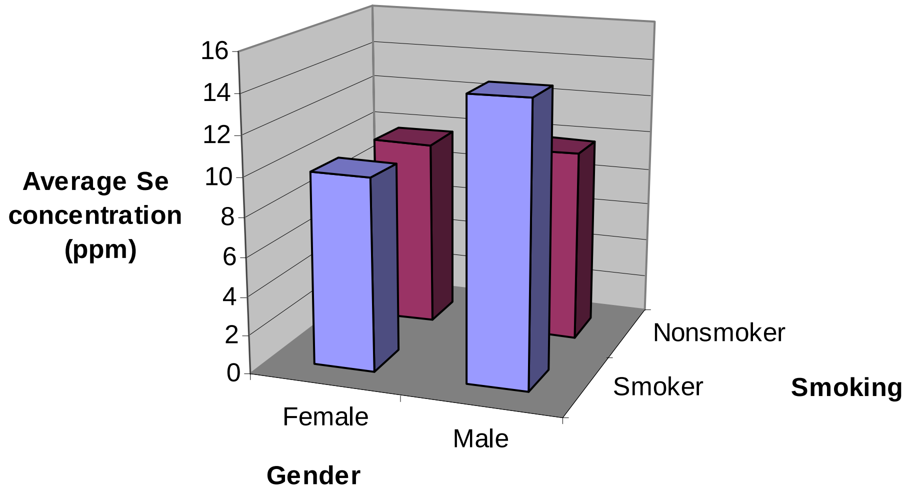

Figure 22: Se concentration of human teeth as a function of smoking

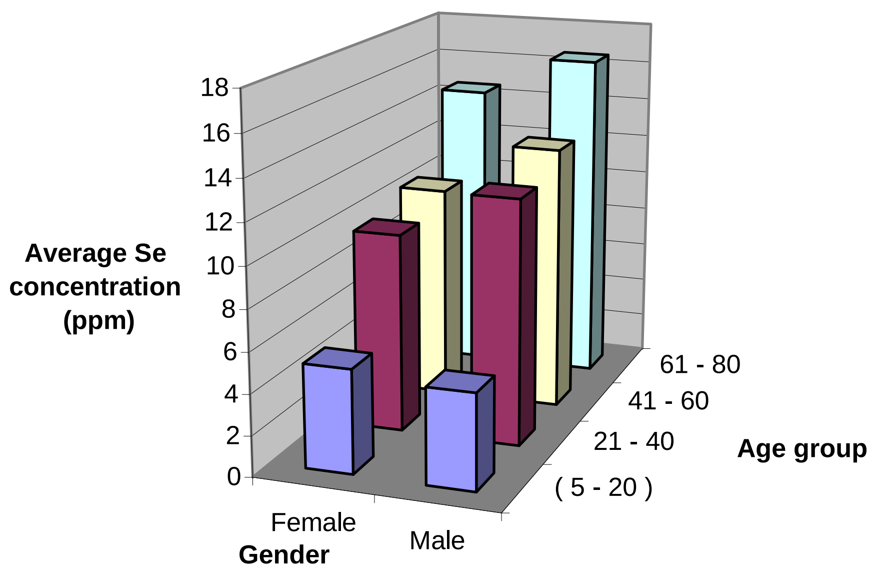

Figure 23: Se concentration of human teeth as a function of age group.

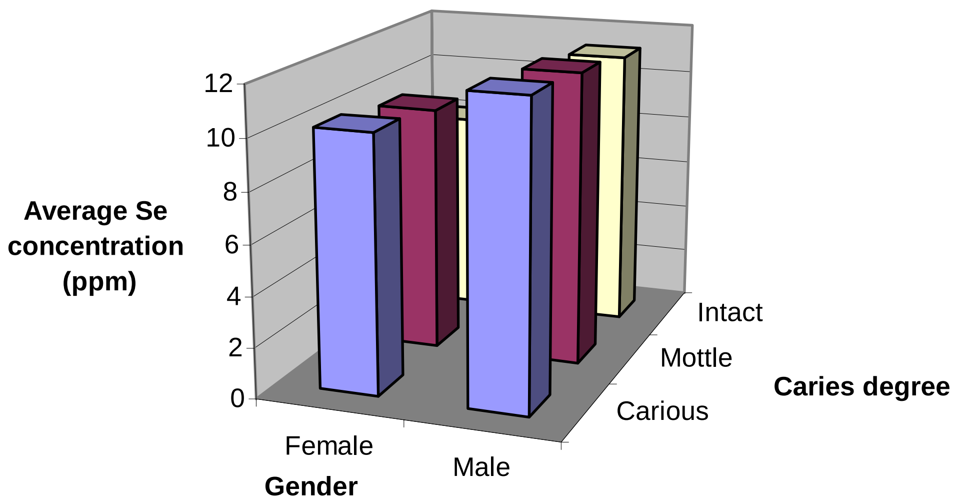

Figure 24: Se concentration of human teeth as a function of caries degree.

The influence of the number of deliveries (for women) and the age group for each woman on tooth selenium concentrations are shown in table (37).

Table (37): Tooth selenium concentrations (ppm) of women according to the number of deliveries and age group.

Age group	Deliveries #	X ± S
21 - 40	0	10.60 ± 0.17
	2	10.88 ± 0.15
	3	10.44 ± 0.07
	6	9.61 ± 0.29
	7	7.66 ± 0.13
41 - 60	3	12.94 ± 0.13
	5	10.15 ± 0.23
	7	8.78 ± 0.12
	8	11.34 ± 0.16
	9	9.83 ± 0.06
61 - 80	0	15.78 ± 0.28
	1	15.86 ± 0.14
	6	12.66 ± 0.07
	8	14.08 ± 0.28
	9	14.54 ± 0.07

Noting that selenium concentration for the third age group was higher than that of the second age group which, in turn, was higher than that of the first age group. This indicated that selenium accumulated in or on teeth with age. As for the relationship between selenium concentration in women's teeth and the number of deliveries they had, the results showed that women of the first age group, 21-40 years (table 37), who had no deliveries had selenium concentration score of 10.60 ppm. Whereas, women of the same age group who had two deliveries showed a tooth-selenium concentration of 10.88 ppm. On the other hand, women of the same age group and had more deliveries demonstrated tooth-selenium concentrations in a reducing order of magnitude (table 37). This finding indicated that there is no clear relationship between selenium concentrations in women teeth and their number of deliveries.

3-3-5 Tin:

Table (38) explains the results of tin analysis in solutions of tooth samples (ppb) by using GFAAS.

Table (38): Concentration of tin in final solutions (ppb) of the tooth samples.

Sample #	Absorbance			Concentration (ppb)			Recovery corrected conc (ppb)		
	1	2	3	1	2	3	1	2	3
1	0.28	0.29	0.30	67.73	72.27	76.82	67.73	72.27	76.82
2	0.29	0.30	0.30	72.27	76.82	76.82	72.27	76.82	76.82
3	0.33	0.34	0.35	90.45	95.00	99.55	94.76	99.55	109.52
4	0.35	0.36	0.34	99.55	104.09	95.00	109.52	114.50	99.53
5	0.39	0.37	0.39	117.73	108.64	117.73	114.27	105.50	114.27
6	0.28	0.29	0.29	67.73	72.27	72.27	67.73	72.27	72.27
7	0.29	0.31	0.29	72.27	81.36	72.27	72.27	81.36	72.27
8	0.31	0.32	0.33	81.36	85.91	90.45	81.36	85.91	94.76
9	0.32	0.33	0.32	85.91	90.45	85.91	85.91	94.76	85.91
10	0.38	0.37	0.36	114.44	108.64	104.09	108.6	105.50	114.51
11	0.30	0.31	0.31	76.82	81.36	81.36	76.82	81.36	81.36
12	0.58	0.57	0.57	204.09	199.55	199.55	198.09	193.70	193.68
13	0.60	0.59	0.58	213.18	208.64	204.09	206.91	202.50	198.09
14	0.55	0.54	0.53	190.45	185.91	181.36	184.85	180.40	176.03
15	0.56	0.55	0.54	195.00	190.45	185.91	189.27	184.90	180.44
16	0.58	0.56	0.56	204.09	195.00	195.00	198.09	189.30	189.27
17	0.55	0.58	0.56	190.45	204.09	195.00	184.85	198.10	189.27
18	0.55	0.54	0.54	190.45	185.91	185.91	184.85	180.40	180.44
19	0.54	0.52	0.52	185.91	176.82	176.82	180.44	171.60	171.62
20	0.50	0.51	0.51	167.73	172.27	172.27	162.80	167.20	167.20
21	0.53	0.53	0.52	181.36	181.36	176.82	176.03	176.00	171.62
22	0.75	0.75	0.77	281.36	281.36	290.45	273.09	273.10	281.91
23	0.76	0.76	0.77	285.91	285.91	290.45	277.50	277.50	281.91
24	0.77	0.79	0.78	290.45	299.55	295.00	281.91	290.70	286.32
25	0.72	0.71	0.71	267.73	263.18	263.18	259.86	255.40	255.44
26	0.74	0.72	0.72	276.82	267.73	267.73	268.68	259.90	259.86
27	0.70	0.69	0.70	258.64	254.09	258.64	251.03	246.60	251.03
28	0.66	0.64	0.67	240.45	231.36	245.00	233.38	224.60	237.79
29	0.66	0.68	0.67	240.45	249.55	245.00	233.38	242.20	237.79
30	0.69	0.68	0.68	254.09	249.55	249.55	246.62	242.20	242.21
31	0.67	0.68	0.69	245.00	249.55	254.09	237.79	242.20	246.62

Table (38-continue).

Sample #	Absorbance			Concentration (ppb)			Recovery corrected conc (ppb)		
	1	2	3	1	2	3	1	2	3
32	1.00	0.99	1.02	395.00	390.45	404.09	383.38	379.00	392.21
33	1.04	1.03	1.03	413.18	408.64	408.64	401.03	396.60	396.62
34	1.07	1.06	1.08	426.82	422.27	431.36	414.27	409.90	418.67
35	0.94	0.96	0.98	367.73	376.82	385.91	356.92	365.70	374.56
36	0.98	0.98	0.97	385.91	385.91	381.36	374.56	374.60	370.14
37	0.95	0.94	0.94	372.27	367.73	367.73	361.32	356.90	356.92
38	0.92	0.94	0.90	358.64	367.73	349.55	348.09	356.90	339.27
39	0.90	0.91	0.91	349.55	354.09	354.09	339.27	343.70	343.68
40	0.95	0.96	0.94	372.27	376.82	367.73	361.32	365.70	356.92
41	0.96	0.96	0.94	376.82	376.82	367.73	365.74	365.70	356.92

Table (39) demonstrates the tin concentration in dry tooth samples as the average value (X), standard deviation(S), and coefficient of variation (CV).

Table (39): Concentration of tin in the dry tooth samples (ppm) .

Sample #	Concentration (ppm)			X ± S	CV
	1	2	3		
1	1.80	1.92	2.04	1.92 ± 0.12	6.25
2	1.83	1.95	1.95	1.91 ± 0.07	3.66
3	2.58	2.71	2.98	2.76 ± 0.21	7.61
4	2.05	2.14	1.86	2.02 ± 0.14	6.93
5	2.04	1.88	2.04	1.98 ± 0.09	4.55
6	1.93	2.06	2.06	2.02 ± 0.07	3.47
7	2.13	2.39	2.13	2.22 ± 0.15	6.76
8	2.15	2.27	2.50	2.30 ± 0.18	7.83
9	2.23	2.46	2.23	2.31 ± 0.13	5.63
10	2.00	1.94	2.11	2.02 ± 0.08	3.96
11	1.39	1.47	1.47	1.44 ± 0.05	3.47
12	3.67	3.59	3.59	3.62 ± 0.05	1.38
13	3.82	3.74	3.66	3.74 ± 0.08	2.14
14	3.70	3.61	3.53	3.61 ± 0.09	2.49
15	3.77	3.68	3.59	3.68 ± 0.09	2.45
16	4.05	3.87	3.87	3.93 ± 0.10	2.54
17	3.22	3.46	3.30	3.33 ± 0.12	3.60
18	3.35	3.27	3.27	3.30 ± 0.05	1.52

Table (39-continue).

19	3.65	3.47	3.47	3.53 ± 0.10	2.83
20	3.22	3.30	3.30	3.27 ± 0.05	1.53
21	3.49	3.49	3.40	3.46 ± 0.05	1.45
22	4.72	4.72	4.87	4.77 ± 0.09	1.89
23	5.07	5.07	5.15	5.10 ± 0.05	0.98
24	4.78	4.93	4.86	4.86 ± 0.07	1.44
25	4.54	4.46	4.46	4.49 ± 0.05	1.11
26	5.42	5.24	5.24	5.30 ± 0.10	1.89
27	4.12	4.05	4.12	4.10 ± 0.04	0.98
28	4.02	3.87	4.09	3.99 ± 0.12	3.01
29	3.78	3.92	3.85	3.85 ± 0.07	1.82
30	4.25	4.18	4.18	4.20 ± 0.04	0.95
31	4.00	4.07	4.15	4.07 ± 0.07	1.72
32	7.63	7.54	7.80	7.66 ± 0.13	1.70
33	7.42	7.33	7.33	7.36 ± 0.05	0.68
34	7.52	7.44	7.60	7.52 ± 0.08	1.06
35	7.49	7.67	7.86	7.67 ± 0.19	2.48
36	7.17	7.17	7.09	7.14 ± 0.05	0.70
37	6.97	6.89	6.89	6.92 ± 0.05	0.72
38	6.61	6.78	6.44	6.61 ± 0.17	2.57
39	6.50	6.59	6.59	6.56 ± 0.05	0.76
40	7.01	7.09	6.92	7.01 ± 0.09	1.28
41	7.02	7.02	6.85	6.96 ± 0.10	1.44

From table (39) it was clear that variation existed in all samples. The lowest tin concentration was 1.44 ppm and the highest was 7.67 ppm. From table (47), the average tin concentration for all samples is 4.26 ppm .

● Discussion:

The influence of gender, age, caries degree, and smoking on tooth tin concentrations are shown in table (40).

Table (40): Tooth tin concentrations (ppm) according to gender, age, caries degree, and smoking.

	Sn (ppm) (X ± S)	
Gender		
Male	4.55 ± 2.02	
Female	3.97 ± 1.80	
Age group	Male	Female
5 - 20	2.12 ± 0.36	2.05 ± 0.33
21 - 40	3.72 ± 0.13	3.38 ± 0.11
41 - 60	4.90 ± 0.31	4.04 ± 0.13
61 - 80	7.47 ± 0.22	6.81 ± 0.21
Smoking		
Smoker	5.58 ± 1.69	3.58 ± 0.45
Nonsmoker	4.60 ± 2.32	3.67 ± 1.72
Caries degree		
Carious	4.06 ± 2.15	3.60 ± 1.41
Mottle	4.58 ± 1.95	3.89 ± 1.92
Intact	5.09 ± 2.30	4.35 ± 2.48

This table and figure 25 show that the concentration of tin in human teeth according to gender. For males, the average was 4.55 ppm but in females the average is only 3.97 ppm. By applying t-test, there was no significant difference between them.

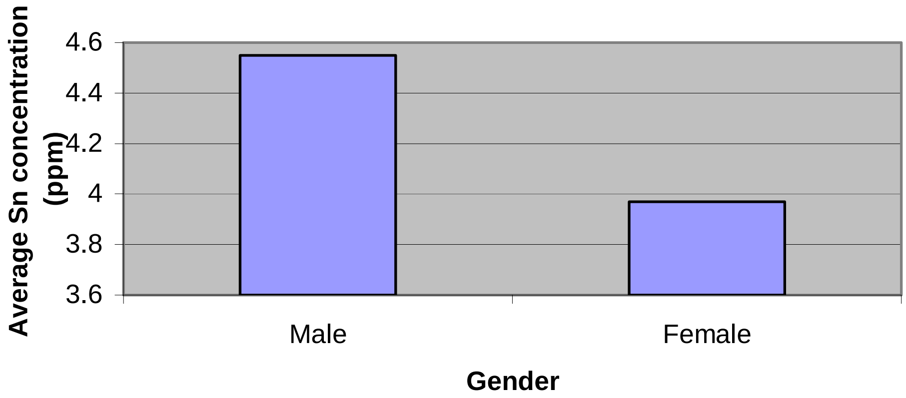

Figure 25: Sn concentration of human teeth as a function of gender.

Table (40) and figure 26 also show that tin concentration in human teeth for male smokers , 5.58 ppm , was higher than that for male nonsmokers , 4.60 ppm ($P<0.05$). Tin concentration was nearly the same for female smokers and nonsmokers (3.58 ppm and 3.67 ppm respectively) ($P>0.05$).This may be due to the fact that female smokers don't smoke frequently like male smokers as a result of social rejection for smoker women. These results were comparable to those obtained in the literature (Nadhum and Hassan, 2002). With respect to age, table (40) and figure 27 show that the concentration of tin increased significantly with age. Noting that for the first age group there is no significant difference among the tin concentration for female and that for male because in this age group both male and female are nonsmokers. Figure 28 and table (40) demonstrate the variations in the tin concentration with caries degree. Highest values were observed in the intact teeth but the lowest values were observed in the carious teeth. However, statistically no significant difference among them. These results indicate that dental caries doesn't affect tin concentration in human teeth.

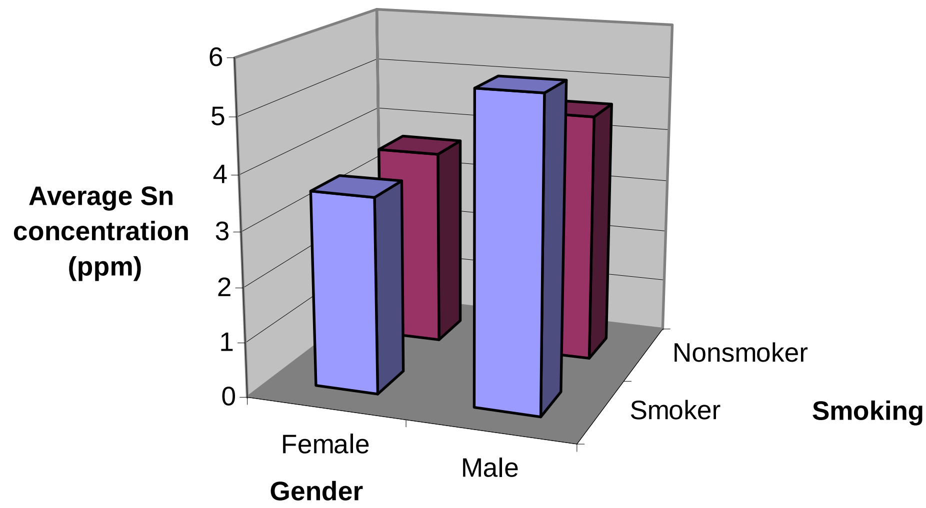

Figure (26): Sn concentration of human teeth as a function of smoking.

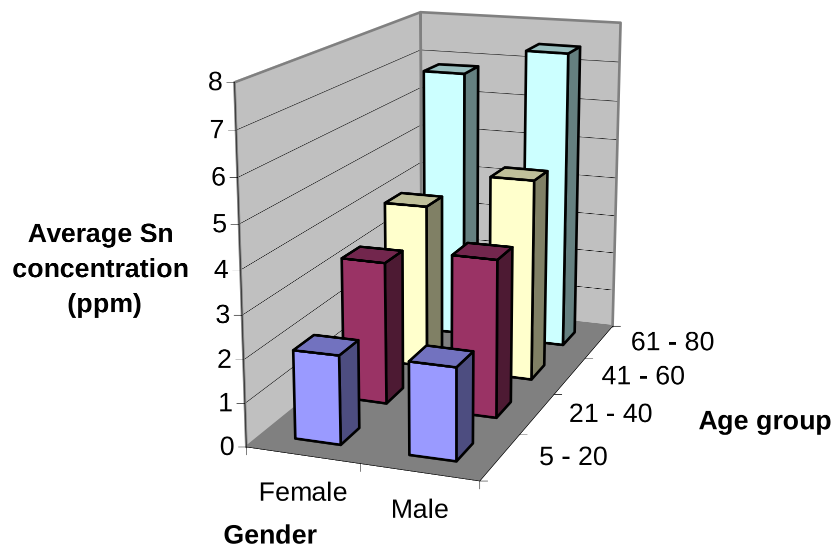

Figure 27: Sn concentration of human teeth as a function of age group.

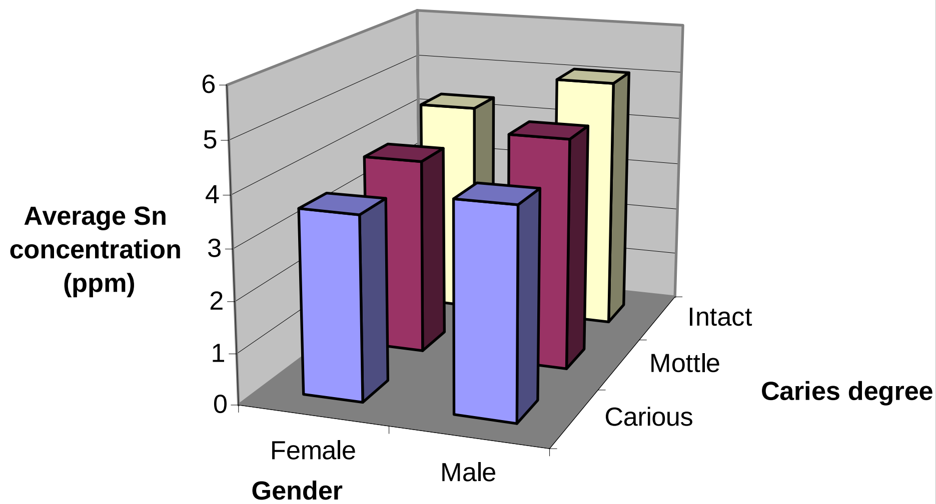

Figure 28: Sn concentration of human teeth as a function of caries degree.

The influence of the number of deliveries (for women) and the age group for each woman on tooth tin concentrations are shown in table (41).

Table (41): Tooth tin concentrations (ppm) of women according to the number of deliveries and age group.

Age group	Deliveries #	X ± S
21 - 40	0	3.33 ± 0.12
	2	3.53 ± 0.10
	3	3.27 ± 0.05
	6	3.46 ± 0.05
	7	3.30 ± 0.05
41 - 60	3	3.99 ± 0.12
	5	3.85 ± 0.07
	7	4.07 ± 0.07
	8	4.10 ± 0.04
	9	4.20 ± 0.04
61 - 80	0	7.01 ± 0.09
	1	6.92 ± 0.05
	6	6.96 ± 0.10
	8	6.56 ± 0.05
	9	6.61 ± 0.17

It was evident from the results expressed in table 41, that in the three age groups, the magnitude of tin concentration in women's teeth was not co-occurring with the number of deliveries given by the corresponding women. It could, therefore, be concluded that no clear relationship was found between tin concentration in women's teeth and the number of deliveries they had.

3-4 Standard addition method results:

Comparison between the calibration method in water and standard addition method in sample solution was done in order to check the influence of the real matrix of tooth samples on the results. The comparison for the five elements showed approximately the same results in the same tooth samples for both methods.

3-4-1 Cadmium:

Table (42) demonstrates the calculated concentrations of cadmium by the calibration method and by the standard addition method, with good agreement between both results: 20.11 – 33.44 ppb and 19.29 – 33.08 ppb, respectively.

Table (42): Cadmium concentrations in human teeth.

Sample	Weight of teeth (g)	Calibration method Cd content (ppb)	Std. addition method Cd content (ppb)
A	0.3766	20.11	19.29
B	0.3945	20.11	20.48
C	0.3670	29.00	30.55
D	0.5340	24.56	25.60
E	0.5609	33.44	33.08

3-4-2 Copper:

Table (43) demonstrates the calculated concentrations of copper by the calibration method and by the standard addition method, with good agreement between both results: 97.33 – 119.56 ppb and 97.62 – 119.81 ppb, respectively.

Table (43): Copper concentrations in human teeth.

Sample	Weight of teeth (g)	Calibration method Cu content (ppb)	Std. addition method Cu content (ppb)
A	0.3766	97.33	97.62
B	0.3945	97.33	97.50
C	0.3670	114.00	115.22
D	0.5340	108.44	109.13
E	0.5609	119.56	119.81

3-4-3 Lead:

Table (44) demonstrates the calculated concentrations of lead by the calibration method and by the standard addition method, with good agreement between both results: 122.91 – 177.45 ppb and 123.05 – 177.12 ppb, respectively.

Table (44): Lead concentrations in human teeth.

Sample	Weight of teeth (g)	Calibration method Pb content (ppb)	Std. addition method Pb content (ppb)
A	0.3766	177.45	177.12
B	0.3945	168.36	168.79
C	0.3670	150.18	149.98
D	0.5340	150.18	150.60
E	0.5609	122.91	123.05

3-4-4 Selenium:

Table (45) demonstrates the calculated concentrations of selenium by the calibration method and by the standard addition method, with good agreement between both results: 140.35 – 258.00 ppb and 140.10 – 257.82 ppb, respectively.

Table (45): Selenium concentrations in human teeth.

Sample	Weight of teeth (g)	Calibration method Se content (ppb)	Std. addition method Se content (ppb)
A	0.3766	258.00	257.82
B	0.3945	228.59	228.90
C	0.3670	181.53	182.00
D	0.5340	175.65	175.80
E	0.5609	140.35	140.10

3-4-5 Tin:

Table (46) demonstrates the calculated concentrations of tin by the calibration method and by the standard addition method, with good agreement between both results: 72.27 – 117.73 ppb and 73.00 – 118.15 ppb, respectively.

Table (46): Tin concentrations in human teeth.

Sample	Weight of teeth (g)	Calibration method Sn content (ppb)	Std. addition method Sn content (ppb)
A	0.3766	72.27	73.00
B	0.3945	76.82	77.50
C	0.3670	95.00	95.72
D	0.5340	99.55	98.96
E	0.5609	117.73	118.15

Table (47): The levels of Cd, Cu, Pb, Se, and Sn in (ppm) in human tooth samples.

Element	X	S	Range
Cd	1.90	1.11	0.43-3.99
Cu	4.49	1.89	2.07-8.01
Pb	8.14	4.31	2.14-16.97
Se	10.83	4.20	2.82-18.43
Sn	4.26	1.91	1.44-7.67

The main conclusions of this study were that the concentrations of the heavy metals (Cd, Cu, Pb, Se, Sn) were not gender dependent. Also, the concentrations of these heavy metals were higher in human teeth for male smokers than their concentrations in male nonsmokers but their concentrations were approximately the same for female smokers and female nonsmokers. The results showed that dental caries didn't significantly increase or decrease the concentrations of Cd, Cu, Pb, Se, Sn in human teeth and the concentrations of these heavy metals increased significantly with age due to their accumulation. Finally, it could be recommended that trying to explain the concentrations of the heavy metals (Cd, Cu, Pb, Se, Sn) in human teeth according to genetic point of view.

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دراسة تراكيز بعض العناصر الثقيلة (Cu, Pb, Cd, Sn, Se) في أسنان الذكور و الإناث من فئات عمرية مختلفة وارتباطها مع التسوس

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ملخص

تهدف هذه الدراسة إلى قياس تراكيز بعض العناصر الثقيلة (نحاس و رصاص و كادميوم و قصدير و سيلينيوم) في الأسنان البشرية باستخدام تقنية الامتصاص الذري-فرن الغرافيت. جمعت 41 عينة أسنان من أشخاص يعيشون في مدينة عمان في الأردن و قد استخدمت استبانة لجمع المعلومات عن كل شخص مثل العمر و الجنس و درجة التسوس و التدخين و عدد الولادات (للسيدات) و تنظيف الأسنان و الزيارات لعيادة طبيب الأسنان.

بينت النتائج وجود علاقات بين تراكيز هذه العناصر(نحاس و رصاص و كادميوم و قصدير و سيلينيوم) و الجنس و العمر و التدخين و درجة التسوس لدى المرضى. أشارت النتائج أيضا إلى أن تراكيز هذه العناصر في أسنان الذكور المدخنين أعلى مما هي في أسنان الذكور غير المدخنين لكن لا يوجد فرق يذكربين تراكيز هذه العناصر في أسنان الإناث المدخنات و غير المدخنات.

بالإضافة لذلك بينت النتائج أن التسوس لا يزيد أو يقلل من تراكيز هذه العناصر (نحاس و رصاص و كادميوم و قصدير و سيلينيوم) في الأسنان البشرية.

إهمال الأسنان المتمثل بعدم تنظيفها يوميا و عدم زيارة عيادة طبيب الأسنان إلا عند الحاجة يعتبر السبب الرئيسي لحدوث التسوس لدى المرضى. أوضحت النتائج أيضا إلى أن تراكيزجميع هذه العناصر الثقيلة تزداد مع العمر لدى الناس مما يدل على تراكمها في أجسامهم مع العمر.