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Heavy metals in human teeth dentine: A bio-indicator of metals exposure and environmental pollution

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HIGHLIGHTS

- Human teeth dentine are analysed to obtain metal exposure due to environmental pollution.
- Concentration of heavy metal in tooth dentine was found in the following order: As < Mn < Ba < Cu < Cr < Pb < Zn < Hg < Sb < Al < Sr < Sn.
- Among the ethnic groups, Chinese teeth showed higher metal levels than the Indian and Malay teeth.
- Obtained correlations of Pb with As, Cr, Mn, Sr, Ba, Cu, Zn, Al suggests that they come from similar anthropogenic origins.

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ABSTRACT

With rapid urbanization and large-scale industrial activities, modern human populations are being increasingly subjected to chronic environmental heavy metal exposures. Elemental uptake in tooth dentine is a bioindicator, the uptake occurring during the formation and mineralization processes, stored to large extent over periods of many years. The uptake includes essential elements, most typically geogenic dietary sources, as well as non-essential elements arising through environmental insults. In this study, with the help of the Dental Faculty of the University of Malaya, a total of 50 separate human teeth were collected from dental patients of various ethnicity, age, gender, occupation, dietary habit, residency, etc. Analysis was conducted using inductively coupled plasma-mass spectrometry (ICP-MS), most samples indicating the presence of the following trace elements, placed in order of concentration, from least to greatest: As, Mn, Ba, Cu, Cr, Pb, Zn, Hg, Sb, Al, Sr, Sn. The concentrations have been observed to increase with age. Among the ethnic groups, the teeth of ethnic Chinese showed marginally greater metal concentrations than those of the Indians and Malays, the teeth dentine of females generally showing greater concentrations than that of males. Greater concentrations of Hg, Cu and Sn were found in molars while Pb, Sr, Sb and Zn were present in greater concentrations in incisors. With the elevated concentration levels of heavy metals in tooth dentine reflecting pollution from industrial emissions and urbanization, it is evident that human tooth dentine can provide chronological information on exposure, representing a reliable bio-indicator of environmental pollution.

1. Introduction

Human civilization and the environment (both terrestrial and aquatic) are currently being exposed to the greatest levels of heavy metals of any period within recorded history. Among the sources of exposure are that due to anthropomorphic activities such as the use of coal and oil, oil and gas-exploration and exploitation, disposal of industrial effluents, modern agricultural practices (e.g. use of fertilizers, fungicides, insecticides, herbicides and waste water from use in irrigation), rapid urbanization, atmospheric deposition of dust/aerosols, vehicular emissions, sewage sludge etc (Bhuiyan et

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al., 2015; Korkmaz Gorur et al., 2012: Barton, 2011).

The discharge of heavy metals into the natural environment, either from geogenic sources or as a result of anthropogenic activities, can be associated with numerous environmental consequences resulting from their non-biodegradability and persistence. Once heavy metals enter into the body, via ingestion, inhalation or dermal contact, they accumulate in various organs including the calcified tissues, bones and teeth (the latter being part of the exo-skeletal system), posing a risk to human health due to their toxicity and long-term persistence (Alina et al., 2012; Millour et al., 2012; Alomary et al., 2006; Amr, 2011; Keshavarzi et al., 2015). As such, it is considered imperative to assess heavy metals intake in human populations, evaluating the risk, informing the efficacy of systems of control or lack thereof.

Evaluation of environmental pollution can be performed using physical and chemical methods and through bio-indicators (Kamberi et al., 2012). Bio-monitoring of heavy metal exposure of human beings gives a sign of the current body burden of an individual, which is a function of recent and/or past environmental exposure (Kantamneni, 2010). Thus, the right choice of and development of suitable biomarkers to assess heavy metal exposure is of crucial importance, for primary prevention, health-care management and decision-making in public health. Recently, there has been growing interest among researchers in respect of the use of human body fluids and organs as bio-indicators, including blood, urine, bone, teeth, nails, hair and saliva, in order to investigate environmental pollution through detection of toxic heavy metals (Kamberi et al., 2012; Kantamneni, 2010; Abdullah et al., 2012; Arruda-Neto et al., 2010).

Each of the detected elements can be associated with particular advantages in respect of physiological function or of risks and limits to normal bodily function. Blood and urine data reflect information on recent exposures, with blood-lead levels being widely used as a marker of lead exposure (Roels et al., 1994, 1995). Given that the half-life of lead in blood is relatively short (approximately 28–30 days), it does not constitute a reliable indicator of chronic exposure. Conversely, hair and finger-nails are regarded as medium-range bio-monitoring agents, associated with exposure times from a few months to years (Amr, 2011; Kern and Mathiason, 2012). Thus said, they are constantly contaminated by external agents, including from exposure to airborne dust, hair-dyes, shampoo, and nail polish, etc., consequently these samples are often impure and are not ideal as bio-indicators. Calcified tissues such as bone and teeth have a high affinity towards accumulation of metals, heavy and otherwise, particularly when individuals are exposed during early development (Green et al., 1993a,b; Gdula-Argasinska et al., 2004; Zhang et al., 2011). In contrast to other tissues, bone is typically considered to be suitable as a bio-indicator of long-term exposure, but clearly human bone is usually not readily available for sampling and measurement (Mountford et al., 1994; Kumagai et al., 2012). On the other hand, dental tissues are also very hard, additionally being similar to the materials making up bone (Arruda-Neto et al., 2010; Webb et al., 2005) and as previously mentioned they are generally regarded as part of the exo-skeleton. Unlike bone, in which the mineral phase is subject to turnover, the dental hard tissues (e.g., dentine and enamel) are not subject to significant turnover and therefore provide a permanent, cumulative and sound record of past and/or recent environmental exposure to heavy metals (Alomary et al., 2006; Appleton et al., 2000; Kolak et al., 2011). These biopsy tissues have recently received considerable attention in support of research into biological modeling, not least because of their easy extraction as a result of medically-indicated needs, and very low rate of pollutant clearance relative to other organs (Kumagai et al., 2012). Consequently, a precise chronological record of exposure to a number of elements is retained in the hard calcified tissues of the teeth (Gdula-Argasinska et al., 2004). Furthermore, teeth of different ages of people can be easily accessed to compare the metal concentrations of multiple generations at one time. Teeth (dentine, enamel or whole-teeth) thus offer particular advantages as suitable bio-indicators of environmental heavy metal exposures (Barton, 2011; Alomary et al., 2006; Kamberi et al., 2012; Kantamneni, 2010; Abdullah et al., 2012; Arruda-Neto et al., 2010; Gdula-Argasinska et al., 2004; Kumagai et al., 2012; Appleton et al., 2000; Kolak et al., 2011).

Many studies have been devoted to analyzing metal concentrations in whole-teeth, in order to make correlations between samples and environmental pollution by heavy metals (Barton, 2011; Alomary et al., 2006; Amr, 2011; Arruda-Neto et al., 2010; Zhang et al., 2011; Chew et al., 2000; Kern and Mathiason, 2012). Conversely, data on the heavy metal concentration of tooth dentine is scarce. To increase knowledge of the spatial distribution of elements in each tissue of human teeth, (such as dentine, enamel, pulp and cementum) and their affinity for environmental pollution, it is important to study the elemental concentrations in the dentine and enamel separately.

During the sixth week *in utero*, dental hard tissues, specifically the dentine and enamel compartments, begin to grow and then teeth in each mandible become the deciduous teeth that are later replaced by the permanent teeth (Kohn et al., 2013; Webb et al., 2005). Dentine, which is richer in organic content and biologically more active than enamel, is a typical composite material containing inorganic hydroxyapatite crystals and organic collagen matrix proteins (Arnold and Gaengler, 2007; Webb et al., 2005). Odontoblasts, situated in the pulp adjacent to dentine, continuously produce dentine throughout the whole lifespan of a tooth until shed (Arnold and Gaengler, 2007). Dentine is not affected by the oral environment since it is surrounded by enamel and cementum. (Kumagai et al., 2012). Additionally, heavy metals are easily deposited in tooth dentine during formation and mineralization processes by replacing the mineral tooth compounds throughout the entire human life. There is no active metabolism of elements that occurs after the completion of dental dentine formation (Kumagai et al., 2012). Consequently, the tooth dentine would appear to be an appropriate long-term bio-indicator of exposure to environmental pollution, representing an excellent vehicle for pollution studies (Webb et al., 2005; Zhang et al., 2011).

The aim of present study is to investigate heavy metal levels in human tooth dentine, further seeking to evaluate and understand correlation with a number of parameters, including the ethnicity of the tooth donor, age, sex, tooth condition and tooth type.

2. Materials and methods

2.1. Sample collection and preparation

Upon approval by the Ethics Committee of the Dental Faculty, University of Malaya, a total of 50 filling-free permanent teeth (18 molars, 12 premolars, 9 canines and 11 incisors) from subjects of various ages and sex were collected from populations heavily polluted areas in the Klang valley of Malaysia. The same areas are representative of a multi-ethnic demography. Of the three predominant ethnic groups represented within the Klang valley, 19 of the teeth used in this study were from Malays, 16 were from Chinese donors and 15 teeth were from the Indian community.

The Klang valley, including Kuala Lumpur the capital of Malaysia, is the main economic hub of Malaysia. This valley is highly polluted due to large-scale industrialization and urban activities, including steel, copper, iron and aluminium smelting, palm oil production and refining, rubber production and processing, together with their various linkage enterprises, other agro-based