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Trace Elements in Dentistry: A Review

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ABSTRACT

As human body needs in and around two thirds of all the elements so as to maintain the health and our human body contains elements which are well known as abundant elements as well as trace elements. Due to biological and chemical reactions, trace elements, being part of a few enzymesare very important. They work not in collaboration with proteins but definitely with other co-enzymes. At earlier stage dental profession was involved with the field of trace elements and their association with dental disease. So, understanding of these trace elements is essential and significant for disease control as well as for optimal health.

KEYWORDS: Health, Trace elements, Dental caries, Periodontal diseases

INTRODUCTION

Many of the mineral elements are present in such minute amounts in plant and animal tissues that even the workers were unable to measure their precise concentrations during the earlier time with the analytical methods.[1,2] They were therefore narrated as occurring in traces, hence the term 'Trace element' was coined for them. Despite the evolution of recent analytical laboratory methods such as Atomic Absorption Spectrometry and Neutron Activation Analysis which have the capability to measure all trace elements in the slight form of biological samples with exact clarity but still this term is in use.[1,3] In fact, it could be argued that since the occurrence of these highly enlightened techniques, the term 'trace' has become scientifically outmoded. It has generally been accepted that the term trace refers to a relative content of a constituent of not more than 100 ppm (100 parts/ 10^6 or 100 mg/l).[1,3,4]

The dental profession was actively involved with the field of trace elements and dental disease at an early stage. In 1908, a mine chemist, F.S. McKay, suggested at a meeting of the El Paso (Texas) Dental Society that mottled teeth and a concomitant resistance to caries were related to a factor in drinking water. This factor was subsequently identified as fluoride, a trace element now known to be essential for calcification, growth, and fertility.[1,4,5,6.]

Although there was an early start with fluoride, dental research has not seriously considered other trace elements until relatively recently. Indeed, dental research has been almost mesmerized by the element fluorine, to practical exclusion of consideration of other trace elements. It is unfortunate if fluoride alone of all the elements should be assumed to have the unique property of influencing susceptibility to caries. Such uniqueness has not yet been explained. Fluoride is known to become consolidated into the enamel apatite, influencing its chemical, crystallographic, and biologic characteristics. This is also known to be true of several other elements such as strontium, magnesium, and carbon. Therefore, it is understandable that in recent years, particularly as techniques suitable for analyzing a broader range of elements have been developed, interest in elements other than fluoride has also increased.[3,6,7,8]

Of all the dental tissues, more analytical work has been carried out on enamel than on any other because its chemical composition may materially affect the occurrence of the major dental disease, “Caries”. Research has sought to define those elements found in enamel, and which elements affect the caries process.[8,9]

WHAT ARE TRACE ELEMENTS?

Trace elements, as the name implies, are those that we need to consume only in minute form-typically in the range of micrograms to milligrams per day - in order to maintain good level of health. It is generally accepted that the nine vital trace elements - the ones without which good health (or even life itself) would not be possible - are chromium, cobalt, copper, iodine, iron, manganese, molybdenum, selenium, and zinc. These are the ones that play absolutely essential (and, for the most part, fairly well-understood) roles in myriad aspects of human physiology.[1,2,10] The other trace elements - those that are not much essential in the Big Nine sense but considered to be important for our health are aluminum, arsenic, boron, bromine, cadmium, fluorine, germanium, lead, lithium, nickel, rubidium, silicon, tin, vanadium, and perhaps others.[11,12]

All categories of foods - fruits, vegetables, legumes, nuts, grains, meats, seafood, etc. are likely to be capable sources of trace elements, most of which are present there in the form of inorganic salts. When we consume them, they are assimilated by the stomach or intestines and are then brought by the blood to receipt places throughout the body, either as free ions or bound to protein carriers. Their distribution may be very uneven throughout the body, depending on where they are most needed. Most of the iodine we ingest, e.g., goes to the thyroid gland, with a small amount going to the ovaries and a few other places. Ultimately, the trace elements are excreted in the bile, urine, stool, and sweat, that is why we must continue to consume them.[3,4,10,11]

USES OF TRACE ELEMENTS[11,12,13]

It has been reported that the essentiality of many of the trace elements is conjectural, i.e., it is based on distinguishable symptoms which occur may be due to accidental or induced deficiencies and the response of those symptoms to dietary supplementation with the elements in question, rather than on direct evidence of the biochemical roles played by the elements. Basically their uses fall into three major categories:

1. **Catalytic**, in which the element is a part of an enzyme cofactor, which is also known as coenzyme, without which the enzyme could not perform its function. For example the role of a catalyst for any specific chemical reaction, such as one involved in cellular metabolism or cellular reproduction;
2. **Structural,** in which the element is an ingredient of a physiologically vital molecule, such as hemoglobin (trace element: iron), thyroxine (iodine), or cyanocobalamin (cobalt) and,
3. **Regulatory,** in which the element interacts chemically with macromolecules in order to strengthen or prevent their function. Overall, the trace minerals are involved in all of the major metabolic pathways. Hence they are having major role in human physiology.

TRACE ELEMENTS IN TEETH (ENAMEL AND DENTIN)

The mineralized dental tissues are enamel, dentin, cementum, and alveolar bone. Most of the studies carried out on the content of trace element of tissues which are related with dental enamel and lesser extent to a dentin. As such there is a little information on the content of trace element in bone and virtually none on cementum.[1,3]

The content of trace elements in the mineralized tissues is closely related to those elements which are assimilated into the apatite crystal lattice during the mineralizing period and to those which diffuse into the tissue after the completion of mineralization. It follows that the amount of trace element in teeth reflects both the trace element from biological environment during the time of tooth development and the oral environment (for enamel) or the vascular environment (for dentin) associated with erupted tooth. For example, Pb and Sr concentrations in surface enamel are age dependent, the levels being associated with the availability of trace elements in the environment. Absorption occurs from dietary food and water or adverse oral habits such as smoking or chewing. On the other side, Mg is preferentially lost with age apparently because of the selective reactivity of the apatite with the oral fluids. The pulpal layer of dentin has been noted to reflect the uptake of trace elements into the vascular system.[4,7]

Many studies have described the influence of age and environmental factors on the trace element content of tooth tissue. Although some studies have been concerned with identifying the range and types of trace elements in dental tissues, the majority had an ultimate objective of, directly or indirectly, determining the influence, if any of one or more trace elements on the susceptibility of the teeth to dental caries. Some trace elements influence the chemical properties of mineralized tissues; others are important cofactors in enzymatic transformations and play a role in the nucleation of mineralized tissues.[3,5,7]

Hydroxyapatite is not a single entity but rather a continual series or pattern of apatites each differing by atomic substitutions for some of the basic stoichiometric elements. For instance, Sr, Sn, Mo, Cd, Pb, rare earths, Na, and Mg may substitute for Ca, and V, As, and S for phosphorus. Evidence gradually accumulated to confirm the variable nature of biologic apattite which may result from environmental factors present at the time of apatite formation.[5,7]

X-ray diffraction evaluation of the apatites showed variation in the quality of crystal structure associated with the element content of the water phase. It has also been proposed that poor crystal structure associated with Ca-deficient enamel may be improved with mineralizing solutions containing Zn and Sr.[5,6]

The greater number of naturally occurring trace elements along with variety of analytical techniques; and the uneven distribution of elements between people and teeth, depth of tissue, and other variables have, together, resulted in considerable accumulation of data. A few elements such as Sr and Pb have been extensively studied from many aspects whereas most others have unfortunately attracted little interest. Even where epidemiologic evidence has implicated several elements (Mo, Se, V, and Li) with susceptibility to caries, the occurrence of these elements in dental tissues has received only cursory study.[5,6,7,9]

TRACE ELEMENTS IN BONE

Interest in the trace element content of bone has increased for two reasons. Incorporation of trace elements into bone with their effects on the electrical as well as the physicochemical properties can apparently affect both matrix and apatite phases.[5,7] Both effects may be in relation with the equilibrium of the periodontium. This similarity of cementum to bone implies that the potential role of trace nutrients is equally true for cementum as for bone. Attempts have been made to separate trace elements consistently incorporated into bone from those present as contaminants resulting from dietary and environmental factors; much more research is required to gain a proper perspective of the role of trace elements in bone.[4,9,12]

TRACE ELEMENTS IN CALCULUS

Calculus is a biologic apatite which like enamel and dentin is liable to incorporate foreign elements into the crystal lattice during crystallization and, by diffusion, to exchange with elements in the oral environment after mineralization.[14]

The factors affecting the deposition of calculus can at best be only speculative. It is a common observation that the rate, distribution, and volume of calculus formation vary widely from person to person, and although it seems unlikely that trace elements play a role in calculus formation, it should be retained in mind that X-ray diffraction patterns of synthesized hydroxyapatite differ with the concentration of elements available during precipitation and theoretically many substitutions are possible for Ca or P. Also the presence or absence of some elements, such as alkaline earths, may affect the crystallization nuclei of apatite or the role of bacteria proliferation and activity on the surface of calculus.[14,15]

The gross distribution varies as to whether it is subgingival or supragingival and also by tooth-to-tooth location. These variations may influence the element incorporation into calculus because of the varying oral biochemical environment. For example, gingival exudate will influence subgingival more than supragingival calculus; proximity to salivary gland ducts will produce differing biochemical environments.[15]

TRACE ELEMENTS IN SALIVA

No broad screening of saliva for total trace elements content has been attempted although the techniques to do so are available. Saliva presents major problems in evaluation because of its heterogeneous and variable nature which includes physiologic as well as biochemical factors. The composition and secretion of saliva and their influence on oral health has been the subject of numerous reviews and symposia that adequately emphasize the complexity of the subject.[16]

Saliva is secreted from four glandular sources – parotid, submandibular, sublingual, and mucosal. With few exceptions interest in salivary composition has been restricted to the major elements and a few trace elements which contribute to the electrolyte balance. Different glands not only secrete saliva differing composition, but also their contribution to the overall salivary flow rate. Submandibular, parotid, sublingual glands contribute less than 60% of total saliva production; the remainder is derived from the small mucosal glands. Saliva, together with the oral flora, diet, and dental enamel, must be considered as a potentially important factor in the cause of caries, because the oral environment is pervaded at all times by a salivary phase which influences both dental plaque and the enamel surface. It is well known that reduction in salivary flow due to damage to these glands results in higher incidence of caries.[16,17]

Whole (mixed) saliva overcome the problems of variations in saliva composition from different glands and have advantages because they deal with a more representative salivary environment contributing to oral biology. However, mixed saliva is nevertheless subject to changed composition with varying flow from various participating sources, particularly as the contribution of each gland varies flow rate, time of day, and type of stimuli.[17,18,19]

The constituents of saliva rather than major components were predominantly concerned with Na, K, Cl, and Mg with Fe, Cu, Co, S, Br, Mo, and Ni receiving brief mention:[16,17,18]

1. The % concentrations of Na in unstimulated saliva varied from 1 to 65 mg %, but the concentration is increased on stimulation. It was also suggested that Na is the main cation in the buffer system for stimulated saliva but that no relationship between oral health and Na concentration in saliva has been demonstrated. Salivary levels of Na are not influenced by serum Na levels.
2. The concentration of K in unstimulated saliva varied between 30 to 95 mg %, it varied greatly between individuals and was not much influenced by stimulation. Salivary levels of K are not affected by serum K levels. Thus, K is the major cation of the buffer system of unstimulted saliva.
3. The concentration of Cl in unstimulated saliva varied between 30 and 145 mg %. Levels increased in stimulation but were not influenced by blood circulation of Cl.
4. The concentration of Mg was possibly 0.1 to 07 mg %, but techniques available for analysis gave rise to doubt on the range of concentration.
5. The concentration of Fe varied from 0 to 0.6 mg; Cu from 10 to 48 μg%; Br from 0.2 to 7.1p mg/l.
6. The concentration of S varied from 3 to 20 mg and was probably associated with salivary thiocyanates.

Trace element concentrations in saliva account for a substantial numbers of elements. Fe was the only element consistently identified while Mo and Cd were present least often. The salivary glands produce secretions which differ in trace element composition according to the type and intensity of the stimulus applied.[17]

TRACE ELEMENTS AND DENTAL CARIES

Evidence of a relationship of trace elements to caries prevalence has accumulated to a degree that indicates that further research be undertaken on this subject. Although the inverse relationship between fluoride availability and dental caries is beyond dispute, several trace elements in the water supplies have been claimed to be either cariostatic or cariogenic. High levels of Ba, Li, Mo, Sr, and V was significantly correlated with lower caries prevalence and a positive correlation exists between Copper and Lead levels and high caries.[17, 10, 21]

Biologic apatite like in enamel and dentin differs from a pure hydroxyapatite by its inclusion of very small amounts of proteinaceous material and trace elements.[21,22] While the organic fraction reflects the residue of odontogenesis, even the period of tooth formation is also influenced by the composition of trace elements which further reflect the oral environment after tooth eruption.[23, 24] These environments differ in many ways, including the trace element composition of ingested water and foodstuffs which in turn are dependent on geographic, dietary, and cultural factors. These same factors are often observed to be closely associated with the prevalence of caries.[21,22,25]

TRACE ELEMENTS AND PERIODONTAL DISEASE

Even the result of paltry attention said that excesses of trace elements may affect periodontal health also.[15] It could be postulated that an element such as Zn, which influences inflammation and collagen production, could affect periodontal tissues and disease susceptibility. Likewise, if Sr affects calcification and bone metabolism, then it may be possible that this element could modify the effects of bone resorption.[15,24]

The electrical properties of alveolar bone have been considered as possibly contributing to periodontal health. Although trace elements have not been marked as altering electrical properties of bone or tooth tissues, it is well established that the same elements become incorporated into apatite and thereby alter the properties of the crystal lattice. These questions remain unanswered.[23,24,25,26]

CONCLUSION

Existence of trace minerals are in relationship to one another rather than by themselves. Too much of one trace element can lead to imbalances among others resulting in disease, rather than the absence of disease. Persistent contact of saliva and dental plaque with the dental hard tissues are well known established reservoirs of the trace elements. Hence professionals involved in treating dental disease and, in the perpetual quest for delivery of optimal dental care, should possess a profound understanding as well as knowledge of the role of trace elements in oral health and disease.

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