Journal of Advanced Zoology
ISSN: 0253-7214
Volume 45 Issue S-3 Year 2024 Page 265-273

Trace Elements In Health & Disease- A Boon In Disguise

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ABSTRACT

Research on the existence of various elements in the universe has been extensive, but their role in the human body is not fully understood. About 98% of the human body mass consists of nine non-metallic elements, categorized into abundant and non-abundant/trace elements. Micronutrients, including trace elements, vitamins, and antioxidants, play a vital role in regenerative processes, coping with oxidative stress, and providing immunity against pathogens. Dental health is also dependent on these nutrients, which help in the production and development of oral mucosa, teeth, and surrounding tissues. The recommended intake of these nutrients remains variable due to factors such as geography, altitude, age, weight, physiological needs, pathological backlogs, and other recognizable/unrecognizable factors. Essential trace elements are broadly categorized into macro-elements, micro-elements or trace elements, probably essential elements, and potentially toxic elements. The current review focuses on the role of essential trace elements in maintaining oral health and their implications in various oral diseases and disorders.

KEYWORDS: Trace elements, Carbon, Micronutrients, Macronutrients, Applications

INTRODUCTION

Massive amount of research has been carried out to analyze the existence of various elements in the universe, yet the importance of role of such elements is limited in terms of their activity in the human body is not fully

understood yet. These elements are found to be a part of our daily food and their other constituents, yet their daily requirements still remains unfulfilled most of the times.[1,2]

Approx. 98% of human body mass is built from nine non-metallic elements, categorized as abundant and non- abundant elements.[3] Amongst the electrolytes, the four main electrolytes accounting for 1.89% of elements explicitly found are sodium, magnesium, potassium, and calcium, while remaining 0.02% constitutes the other 11 trace elements with their deficiency projecting as a plethora of conditions.[4,5]

Micronutrients are vitamins, non-abundant elements with antioxidants playing an indispensable part in regenerative processes with the capability to counteract oxidative stress as well as in providing ample immunity against pathogens.[6] Similarly, dental health is no exception and is also dependent on such nutrients/elements which help in production, development of oral mucosa, teeth as well as their surrounding tissues.[7,8]

The recommended intake of such nutrients/elements for maintaining complete human body (health) remains variable due to various factors such as the geography, altitude, age, weight, physiological needs, pathological backlogs as well as other recognizable/unrecognizable factors.[6,9]

Abundant elements are involved in the creation of covalent bonds; components of tissues as well as semi-major elements existing in ionic state, whilst performing normal functions of the living body by upkeeping osmotic pressure and membrane potentials at admissible levels. [3]

Non-abundant elements refer to "elements that occur in natural and perturbed environments in small amounts and that when present in sufficient bioavailable concentrations are toxic to living organisms."[3]

CLASSIFICATION OF ELEMENTS

Essential trace elements

- Macro-elements
- Micro-elements or Trace elements

WHO Classification (1973)[10]

Total of 19 trace elements into 3 groups:

- Essential elements: Zinc (Zn), copper (Cu), selenium (Se), chromium (Cr), cobalt (Co), iodine (I), manganese (Mn), and molybdenum (Mo)
- Probably essential elements
- Potentially toxic elements

Frieden's Classification of Elements (1981)[11]

Biological classification of trace elements created on their amount in tissues

- Essential trace elements - Boron, cobalt, copper, iodine, iron, manganese, molybdenum, and zinc.
- Probably essential trace elements - Chromium, fluorine, nickel, selenium, and vanadium.
- Physically promotive trace elements - Bromine, lithium, silicon, tin, and titanium.

MODIFIED FRIEDEN'S CATEGORICAL CLASSIFICATION OF ELEMENTS [12]	
Group I Basic elements	Basic components of macromolecules such as carbohydrates, proteins, and lipids Carbon, hydrogen, oxygen, and nitrogen
Group II Macro/Principal elements	Nutritionally important minerals also referred to as the principal or macro elements. The daily requirement for an adult person is above 100mg/day Sodium, potassium, chloride, calcium, phosphorous, magnesium, and sulfur
Group III Minor/Essential trace elements	An element requirement per day is below 100mg Deficiency of these elements is rare but may prove fatal Copper, iron, zinc, chromium, cobalt, iodine, molybdenum, and selenium
Group IV Additional trace elements	Role is yet unclear May be essential Cadmium, nickel, silica, tin, vanadium, and aluminum. Equivalent to probably essential trace elements in the WHO classification
Group V: Non-essential	Functions are not known May produce toxicity in excess amounts Gold, mercury, and lead Equivalent to potentially toxic elements defined in the WHO classification

MAJOR ELEMENTS [13,14]

Approx. 6.2% of the mass of the human body

- Oxygen (O)
- Carbon (C)
- Hydrogen (H)
- Nitrogen (N)

The interaction of 4 major elements produces molecules are absolutely necessary for the functioning of the human body.

These molecules can be categorized into 4 major types

- Carbohydrates (C,H,O): provides energy to cells, stores energy, forms body structures
- Lipids (C,H,O): stores energy, forms cell membranes, carries messages
- Proteins (C,H,N,O,S(sulfur)): aids the cells in maintaining their shape, makes up muscles, speeds up chemical reactions, transmits messages and materials
- Nucleic acid (C,H,O,N,P(phosphorus)): encloses instructions for proteins which pass instructions from parents to offspring, and aids in fabrication of proteins.

CARBON (C)

Carbon forms strong single bonds to itself that are stable enough to resist chemical attack under ambient conditions, forming structural basis for many compounds that comprise the living cell with DNA being the most important. Therefore, carbon is regarded as the basic structural component, or "backbone," of the macromolecules.[15,16]

All the food consumed comprises of carbon compounds with average 300 g/day carbon intake.[17]

Carbon dioxide lasers have been extensively in soft tissue surgery, endoscopic resection of malignant laryngeal tumors to the exactness of laser stapedotomy, cosmetic skin treatment, laryngology, bronchoesophagology and being explored in the field of biomedical applications.[18,19]

ORAL/DENTAL APPLICATIONS[20-22]

- Carbon monoxide (CO) - component of tobacco smoke, which has led to suspect their association amid exhaled CO level & oral health indicators.
- Carbon dots (CDs) have been used in oral cancer detection.
- Dyeing the oral tissue with CDs was found to be an effective means to stain oral tissue sections.
- Sulphur-doped carbon dots as a highly efficient nano-photodynamic agent towards OSCC used as a nano-photosensitizer for OSCC.

HYDROGEN (H)

Hydrogen is the common universal element wherein Dole and colleagues being the first ones to report the biological effects of hydrogen in science in 1975.[23,24]

A human body lacking hydrogen is not capable of assimilation of water, fatty nutrients & also lacks a vital material for joints, marrows, nerves, brains, auditory structures as well as other body parts in terms of its role as a lubricant for optimum movement.[25,26]

Hydrogen deficiency can be expressed in terms of signs such as irritability, dry/wrinkled skin with dehydration, excess body heat, emaciation, crampy tendons, appetite for salty food, lack of perspiration, gout with presentation of arthritis, & liver shrinkage.[25,26]

ORAL/DENTAL APPLICATIONS

In dentistry effects of hydrogen-rich water has been studied in wound healing and periodontal conditions.[27] In a rat model, the accelerated palatal than in the control group.[28] Furthermore, hydrogen-rich water intake reduced pro-inflammatory cytokine levels & endorsed manifestations of healing-associated factors of palatal tissue of rat. Hydrogen rich water may have anti-aging effects on periodontal oxidative damage.[28]

OXYGEN (O)

Oxygen (Z = 8), is a colorless, odorless essential gas with 50% body mass made of oxygen (49/80 kg).[13]

Cellular respiration requires oxygen for glucose metabolism with majority of O2 disbursed by mitochondria for ATP generation. Reactive O2 species mediate physiological & pathophysiological roles.[29,30]

Oral/dental applications of HBO[31-46]

- Treating periodontal conditions: HBO increases local oxygen distribution, probably at base of the periodontal pocket, when combined with scaling and root planning esp. AgP.
- Treating osteoradionecrosis – ozone therapy in dentistry.
- Treating oral pathogens - Elimination of microbial pathogens due to the antimicrobial activity of oxygen.
- Wound healing - Filippi.et al., accelerates healing of oral mucosa, esp. in the first two postoperative days with ozonized water.
- Treatment of dental caries - antimicrobial properties of ozone with oxidation of pyruvic acid to acetate & carbon dioxide produced by cariogenic bacteria.
- Endodontics - Intracanal gas circulation of ozone with flow rate of 0.5–1 l/min with a net volume of 5 gm/ml for 2–3 min showed encouraging results against pathogenic microbes in the root canal. Further, ozonated water can be used as an intracanal irrigant and in infected necrotic canals, helping in tissue regeneration and bone healing.
- Hypersensitive teeth - In attrition, abrasion, erosion, trauma from occlusion may cause wearing of enamel and dentin thereby causing hypersensitivity. Ozone application has been found to effectively reduce the sensitivity of not only exposed enamel and dentin but also in cases of root sensitivity.
- Prosthodontics - Dentures are commonly inhabited by several micro-organisms especially C. albicans. Ozone can be applied for cleaning the surface of removable partial denture alloys without compromising the physical properties of the alloy such as reflectance, surface roughness, and weight.
- Periimplantitis - Karapetian et al., reported decontamination of implant surface & surrounding tissue, which can be addressed by ozone-treatment.
- Oral surgery - Ozone augments wound healing, supports erythrocytes, & helps oxygen release in tissues.

NITROGEN (N)

A colorless, odorless, tasteless element occurring in all living organisms; which forms a constituent element of amino acids. Nitrogen present in many biomolecules including amino acids, proteins, nucleobases, RNA, and DNA, making it an essential element.[47]

Protein-containing foods such as meat, fish, legumes, nuts, eggs & milk A healthy adult male needs about 105 milligrams of nitrogen per kilogram, or 2.2 pounds per day. Nitric oxide (NO) is an important signaling molecule in the body, responsible for the regulation of numerous biological processes including neurotransmission, smooth muscle contraction, and immune reactions.

Nitrogen is often used in the packaging of medical supplies as it maintains sterility and cleanliness of the product such as test kits for doctors' offices, blood supplies, specimen containers, and other medical devices are some examples of items frequently packaged with N2 gas.[47]

ORAL/DENTAL APPLICATIONS [48-50]

- Management of pain and anxiety - combination of inhaled nitrous oxide and oxygen is done.
- Fabrication of materials used in dentistry - Titanium nitride and/or nitrogen ion implanted coated dental materials, implants, abutments, orthodontic wires, endodontic files, periodontal/oral hygiene instruments, and casting alloys for fixed restorations.
- Liquid nitrogen cylinders - assess tooth vitality via thermal testing.

SODIUM (Na)

Sodium is an essential element occurring at high concentrations in the body, wherein majority of sodium that people consume comes from processed foods/that prepared in restaurants.[51]

Sodium chloride is the principal source of sodium in the diet, and also used as seasoning and preservative in commodities such as pickled preserves and jerky.[51]

ORAL/DENTAL APPLICATIONS[52-64]

- Bleaching - Aqueous sodium hypochlorite solution is widely used in dental practice during root canal treatment.
- Irrigant - Sodium hypochlorite is an effective antimicrobial endodontic irrigant with tissue-dissolving capabilities.
- Oral care - Sodium bicarbonate as a regular product,.
- Prevention of dental caries: acid-neutralizing property, bactericidal effect against cariogenic bacteria of sodium bicarbonate. Bicarbonates are available the form of chewing gums to increase salivary flow to wash away the food debris.

- ❖ Periodontal disease: Sodium bicarbonate neutralizes butyric acid and hinders inflammation, aiding in the healing of periodontal tissues besides mechanical debridement.
- ❖ Dentifrice: alkalinity (pH of 8.3) as well as bactericidal property cleanses around teeth, implant surfaces & soft tissues.
- ❖ Denture cleansers: in form of powder, tablet, and soaking solutions
- ❖ Mucositis patients: Sodium bicarbonate protects inflamed and sensitive mucosa, buffers the intraoral pH, and lubricate whilst clearing viscous salivary secretions.
- ❖ Oral examination and impression making: thick and ropy saliva makes diagnosis of mucosal lesions difficult as well as distort impressions, which can be overcome by use of 1%–1.5% of sodium bicarbonate oral rinses.
- ❖ Halitosis: Sodium bicarbonate transforms volatile sulfur compounds to a nonvolatile state. Has a deodorizing effect lasting up to 3 h when dentifrices containing >20% sodium bicarbonate are used.
- ❖ Role in implant osseointegration: enhances hydrophilicity and protein adsorption of titanium surfaces.
- ❖ Teeth-whitening systems: sodium fluoride, hydrated silica, sodium mono fluorophosphate, sodium pyrophosphate, sodium tripolyphosphate, and sodium bicarbonate for whitening of teeth, which can also be used to remove intrinsic stains.
- ❖ Air polishing: stains are removed when warm water mixed with prophylactic paste is sprayed under pressure using a specific handpiece.

POTASSIUM (K)

Potassium is the third essential element that occurs at high concentrations in the body, after calcium and phosphorous.

Most common sources of potassium are vegetables such as green leafy cruciferous plants (spinach, kale broccoli, as well as carrots, potatoes, cucumbers, sweet potatoes, and beetroots) & fruits (bananas, apricots, oranges, and grapefruit), whole grains (brown rice, wheat bread, and oat bran seeds and nuts including hazelnuts, pistachios, sunflower seeds, flax seeds , and almonds.[65]

ORAL/DENTAL APPLICATIONS[66-68]

- ❖ Improves bone mineral density.
- ❖ Prevent blood from becoming too acidic, can leach calcium from your bones and teeth).
- ❖ Mouth rinse used as an adjunct to tooth-brushing reduces dentinal hypersensitivity.
- ❖ Combination of desensitizing toothpaste containing potassium citrate with oral hygiene education can effectually reduce dentin hypersensitivity.

FLUORINE (F)

Fluoride helps prevent decay in patients.[69] In late 19th and beginning of the 20th century, Black and McKay were the pioneers who observed & labelled the effects of fluoride as brown stains on enamel, termed mottled enamel. However, later it was Churchill in the year 1931; that made the chemical analysis exposing the cause for the changes in the teeth due to fluoride.[70]

Fluoride toothpaste, gel & mouthwashes are used to prevent cavities & treat tooth plaque. Volume of fluoride is influenced by the quantity consumed, swallowing control, and the frequency of use of toothpaste. [71,72]

ORAL/DENTAL APPLICATIONS[71,72]

- ❖ Beneficial in caries prevention
- ❖ Used/available as mouth rinses, topical fluoride preparations
- ❖ Used as dental devices - dental sealants, glass-ionomer, orthodontic bracket adhesives).
- ❖ Gels - applied 1-4 times a year
- ❖ Varnishes - less used

CALCIUM (Ca)

Constitutes 1.9% of the body by weight with 90% of the body's calcium is located in the skeleton with remaining 1% is equally distributed between the teeth and soft tissues, whereas only 0.1 % in the extracellular fluid (ECF).[73]

Milk, yogurt, and cheese are rich natural sources of calcium whereas non-dairy source includes vegetables (chinese cabbage, kale, and broccoli).

Most grains do not have high amounts of calcium & require fortification (in form of fruit juices and drinks, tofu, and cereals).[74,75]

ORAL/DENTAL APPLICATIONS [8,76-79]

- Protection of mineralized tooth structure - By maintaining the mineral composition of teeth whilst maintaining the tooth in a mineralized state between the process of demineralization and remineralization.
- Decay - The more the concentration of calcium, the more is the rate of demineralization as well as the jeopardy of dental decay.
- Pre-eruptive Effects of Calcium Mineralization of primary teeth - It starts from about 4 month's in-utero with the same in case of permanent teeth around birth and continues till 6 to 13 years of age.
- Amongst Geriatric Patient – Calcium has an explicit role in geriatric patients, with its deficiency projecting on the distinctive physiological, psychological and environmental aspects of their life.
- Periodontal health - Likewise, the more the concentration of calcium in plaque, the more is the drop in pH that can be tolerated before demineralization occurs. Reduced calcium level has an impact on bone mineralization which further instigates pathological periodontal changes with the end result being less support for the teeth.
- Osteoporosis/alveolar ridge resorption - It is found that patients receiving 1gm calcium supplement daily for 12 months showed an increase in bone density in the mandible of approximately 12.5%.

IRON (Fe)

Iron may show indirect effect on the soft tissues as well as hard tissue structures of the oral cavity. A classic example of that is the use of iron supplements in the treatment of glossitis due to iron deficiency anemia. Further, mucosal injuries of GI tract because of therapeutic oral iron supplementation is reported.[80]
Ferrous sulfate is known to reduce the progression of dental caries in the cariogenic dietary regimen.[81]

SELENIUM (Se)

Selenium is suspected to render the teeth more susceptible to caries attack however the mechanism is not very clear. It is observed that organo-selenium compounds covalently attach to dissimilar biomaterials hindering bacterial biofilms which helps in caries prevention and is therefore being incorporated into dental sealers.[82,83]

CONCLUSION

We conclude that that in-depth evaluation levels of elements in health and disease as well their interactions with other elements inside the human body and their impact on bodily function is the need of the hour. This will not only help in the prevention of toxicities but could also the answer to the pathogenesis behind several diseases that are not understood to date or diseases with known pathogens not having definitive treatments.

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