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Aluminium and oral health

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Abstract

Aluminium (Al) is the most common metal and the third most abundant chemical element in the Earth's crust. Its widespread application in household, manufacturing and, industry makes the metal-related toxicity important for to human health. In enamel and dentin, the concentration of aluminium is significantly higher in the group of healthy teeth than in that of carious and obturated teeth. Aluminium levels in carious enamel and dentin do not decrease as the carious process progresses. Studies have shown that deciduous teeth containing higher concentrations of Al had fewer cavities than teeth with lower concentrations of Al. Results suggest that aluminium acts as a possible cariostatic agent.

Deciduous teeth without caries are most useful for biological monitoring of aluminium. Salivary Al levels are significantly higher in children with treated caries than in children without caries. Topical application of aluminum reduced the incidence of fissure caries in rats. Higher levels of Al reduced the extent of lesion penetration into dentin.

Aluminium is a major constituent of glass ionomer cements. It has an inhibitory effect on bone mineralization. The significant release of aluminium from glass ionomer cements during early exposure to water may explain the lack of mineralisation of the predentin. The release of aluminium from glass ionomer cements into the mouth represents a negligible health hazard.

Aluminium oxide and aluminium ions included in the composition of MTA are dominant suppressors of the osteoclastogenesis process. They significantly suppress it by inhibiting osteoclast activity and appear to be capable of suppressing bone resorption in periapical lesions.

Alumina is the most commonly used abrasive in air abrasion to degrade dental tissues.

Orthodontic agents release negligible amounts of aluminum and do not significantly increase its amount in the mouth.

The incorporation of alumina nanoparticles adversely affects the flexural strength of polymethylmethacrylate but increases its thermal conductivity.

Keywords: aluminium, oral health, toxicity, glass ionomer cements, MTA

Introduction

Aluminium (Al) is the most abundant metal and the third most abundant chemical element in the Earth's crust. Its widespread application in domestic, manufacturing and industrial applications makes metal-related toxicity important to human health. Aluminium is ingested regularly with food and water. It is used in antiperspirants and as an ingredient in vaccines. Small amounts are found in the air, medicines and cosmetics. It is widely used in vehicles, construction, packaging, appliances and apparatus (1-2).

Absorption of aluminum in the body after chronic exposures can cause adverse health effects. Exposure to high levels of aluminium interrupts or disrupts enzymatic activities, alters protein synthesis, cell membrane permeability, induces oxidative stress, disrupts DNA stability, and alters cellular iron homeostasis (2). Excessive intake can cause anemias, musculoskeletal disorders, Alzheimer's disease, intestinal disorders (3), affects the kidneys, liver, respiratory system, nervous system, and carcinogenicity has been discussed (4). Higher levels of the metal are found in aluminum welders and workers in the aluminum industry. Deterioration in neuropsychological test scores (attention, memory, learning) has been found at aluminium concentrations exceeding 100 µg/g in urine (1). Humans are relatively protected from metal toxicity because of its low absorption and effective renal excretion (4).

The extent of poisoning can be diagnosed by testing for aluminium compounds in blood, urine, hair, nails and sweat (2). Reference values for aluminium load are above 5 µg/L in serum and above 15 µg/L in urine (1). Keeping these concentrations below the permissible levels is important to prevent the development of manifest and subclinical signs of aluminium toxicity (1).

Aim

The aim of our literature review is to identify and describe information from the available literature on aluminium and its relation to oral health.

Results

Aluminium and teeth

Aluminium content is detected in the enamel and dentin of human teeth most commonly by atomic absorption spectrometry. No differences are found according to sex, but its amounts depend on the type of tooth. In the enamel, the concentration of Al is significantly higher in the group of healthy teeth (42.8 micrograms/g) than in the groups of teeth with caries (20.7 - 24.9 micrograms/g) and in the group of obturated teeth (27.3 micrograms/g). In dentin, the concentration of Al is also significantly higher in the group of healthy teeth (36.2 micrograms/g) than in that of carious teeth (15.1 -24.5 micrograms/g) and in the group of obturated teeth (17.2 micrograms/g) (5).

Al levels in carious enamel and dentin do not decrease as the carious process progresses. Studies have shown that deciduous teeth containing higher concentrations of Al had fewer cavities than teeth with lower concentrations of Al. The results suggest that Al acts as a possible cariostatic agent (5).

The Al content of three hundred twenty-three deciduous teeth of children born in Sweden was determined by atomic absorption spectrophotometry in a graphite furnace. The arithmetic mean concentration of Al in the teeth was 0.58 ppm, being about twice as high in incisors (1.05 ppm) compared with canines (0.48 ppm) and molars (0.53 ppm). A significant difference was found between teeth with and without caries. Al concentration correlated significantly with the weight of incisors and canines, but not of molars. No significant change in Al concentration was found with time. It has been suggested that deciduous teeth without caries are most useful for biological monitoring of aluminum (6).

A 2011 study by Watanabe K et al. of 562 mixed saliva samples determined Al and Fe concentrations using atomic absorption spectrometry. Al concentrations in children without caries was 0.093 ppm. Al and Fe levels were significantly higher in children with treated caries than in children without caries. In children without a history of caries, Al levels were inversely proportional to the number of deciduous teeth and increased with the number of permanent teeth. The authors suggest that more Al is extracted from healthy permanent teeth than from healthy deciduous teeth (7).

Topical application of aluminium reduced the incidence of pit and fissure caries in rats. In a study by Putt MS et al., the effect of solutions containing different concentrations of aluminium on caries formation on the smooth surfaces and the cervical region in carious factor-exposed rats infected with Streptococcus sobrinus was investigated. Aluminum applied topically reduced caries formation and progression on both the smooth surface (by 49-71%) and the cervical region (by 27-53%). Al also significantly reduced the extent of lesion penetration into dentin (8).

Glass ionomer cements

Aluminium is a major constituent of glass ionomer cements. During mixing and curing, some of this aluminium may not bind to the polyalceonic acid and be released.
Andersson OH et al. investigated the release of aluminum from fully cured and slightly cured glass ionomer cements during early exposure to water. The significant release of aluminum from glass ionomer cements during early water exposure may explain the lack of predentin mineralization in the pulp beneath glass ionomer cements. Aluminum has an inhibitory effect on bone mineralization (9).
Resin-modified glass ionomer cement releases a small amount of aluminum for a limited time. This biomaterial may be useful in regenerating the pulp-dentin complex (10).

Al is released under neutral acidity but to a greater extent under acidic conditions. Al release occurs in two steps, an initial rapid (half-life: 12-18 hours) and a longer and slower second phase (11).

The largest amounts of aluminium are separated from the resin-modified Vitremer glass ionomer cement in double distilled water (12). In artificial saliva, no aluminum release was observed from glass ionomer cement. The storage medium and method of analysis should be taken into account when assessing the release of aluminium from dental materials (12).

Glass ionomer cement with added TiO_2 significantly reduces the rate of Al release compared with similar cements without TiO_2 (13).

Al_2O_3 is incorporated into the composition of glass ionomer cements to impart basic activity and allow it to participate in acid-base coupling reactions.
Larger amounts of Al are released under acidic conditions, and it can bind to fluoride (14).

If the glass ionomer obturation were to dissolve completely over 5 years, it would add an additional 0.5% of the recommended maximum aluminum intake for an adult patient. The release of aluminium from glass ionomer cements into the mouth poses a negligible health hazard (14).

MTA

MTA is an important biomaterial with diverse dental applications. MTA Angelus contains more aluminium than Micro Mega MTA. The bioaggregate contains traces of aluminium (15).
Aluminum oxide and Al^{3+} included in the composition of MTA are dominant suppressors of the osteoclastogenesis process. MTA significantly inhibits osteoclastogenesis and osteoclast activity and appears capable of suppressing bone resorption events in periapical lesions (16).
Demirkaya K et al. in 2016 looked at oxidative damage to neurons to investigate the possible toxic effects of calcium silicate cements on the brain associated with the release of aluminum from MTA (17).

Air abrasion

Intraoral air abrasion is a technique in which abrasive particles are used to remove or alter tooth structure. Aluminum oxide is the most commonly used abrasive for abrading dental tissues.
Air abrasion of dentin and enamel with aluminum oxide at a pressure of 60 psi results in a visibly rougher surface, and does not adversely affect bond strength. Applications of intraoral air abrasion in dentistry include preparation of cavities, cleaning of prosthetic structures, braces, removal of plaque and stains prior to restoration of teeth (18).
Air abrasion treatment of enamel results in a significant increase in roughness (Ra=5.131 μm), which is higher than using a low-speed burr but lower than high-speed turbine or laser surface treatment (19).

Orthodontics

Orthodontic screws and mini-implants release metals into the oral mucosa, with the amount of isolated metals increasing in the following order: Cr-Ni-Ti-Cu-Al (20).
Elastic ligatures released the highest levels of Al (mean 28.2 μg), followed by stainless steel ligatures (3.6 μg). Longer storage time in artificial saliva resulted in higher levels of Al released (21).
Because of the low quantification, the authors considered that orthodontic agents did not significantly increase the release of metals into the mouth (17). The additional release of aluminium from orthodontic appliances is 0.04 to 0.09% and they can be considered safe (21).

Other

The incorporation of aluminium oxide nanoparticles adversely affects the flexural strength of polymethylmethacrylate, a material used in the manufacture of dentures. However, a positive effect is the increase in their thermal conductivity (22).
Antimicrobial photodynamic therapy with aluminum phthalocyanine, performed simultaneously with root surface cleaning and smoothing, provided no additional benefit in reducing probing depth and clinical clinical insertion gain (23).

Conclusion

In enamel and dentin, the concentration of Al is higher in the group of healthy teeth than in that of carious and obturated teeth. Al levels in carious enamel and dentin did not decrease as the carious process progressed. Studies have shown that deciduous teeth containing higher concentrations of Al had fewer cavities than teeth with lower concentrations. The results suggest that Al acts as a possible cariostatic agent.

It is suggested that deciduous teeth without caries are most useful for biological monitoring of aluminium. Salivary Al levels were significantly higher in children with treated caries than in children without caries. Topical application of aluminum reduced the incidence of fissure caries in rats. Aluminum also significantly reduced the rate of penetration of lesions into dentin.

Aluminium is a major component of glass ionomer cements. It has an inhibitory effect on bone mineralization. The significant release of aluminium from glass ionomer cements during early exposure to water may explain the lack of mineralization of predentin in the pulp beneath glass ionomer cements. The release of aluminium from glass ionomer cements into the mouth represents a negligible health hazard.
Aluminum oxide and aluminum ions included in the composition of MTA are dominant suppressors of the osteoclastogenesis process. They significantly inhibit osteoclastogenesis and osteoclast activity and appear capable of suppressing bone resorption events in periapical lesions.
Aluminum oxide is the most commonly used abrasive in air abrasion to degrade dental tissues.
Orthodontic agents release negligible amounts of aluminum and do not significantly increase its amount in the mouth.
The incorporation of alumina nanoparticles adversely affects the flexural strength of polymethylmethacrylates but increases their thermal conductivity.

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