Fluoride in Dentistry

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From toothpaste to mouthwashes, dental varnishes and fluoridated water, fluoride plays a vital role in the integrity of our teeth. It's importance throughout life, starting from the development of our teeth – namely, during amelogenesis when enamel is formed.

Amelogenesis consists of five stages where multiple events unfold, including the crystallisation of hydroxyapatite, which makes up ~96% of our enamel. The abundance of this inorganic mineral renders our enamel as the hardest biological tissue, but despite this, our teeth are still susceptible to hostile bacterial decay [1]. Thus, one amazing property of fluoride is that it can increase the resistance of enamel to bacterial-derived acids that so frequently attack it. To understand why this is, we should first discuss the structure of hydroxyapatite.

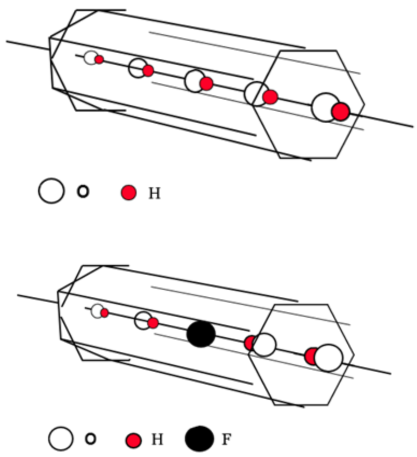

Figure 1: The hexagonal apatite structure with hydroxyl ions and fluoride ions [2].

Hydroxyapatite crystals form hexagonal structures where the hydroxyl ions sit in the centre. However, this is not the ultimate arrangement – in fact, the hydroxyl group is too large and doesn't fit perfectly into the hexagon, which results in a monoclinic structure. A better arrangement is the substitution of hydroxyl ions with fluoride to form fluorapatite whereby the fluoride ions sit more comfortably within the hexagon. As a result, any fluoride ingested during development produces fluorapatite, which is more chemically stable and has a smaller surface area to volume ratio resulting in an increased resistance to acid, thereby making enamel stronger [2]. Figure 1 shows this substitution diagrammatically.

Our teeth also benefit from fluoride's anti-cariogenic effects:

Fluoride halts bacterial metabolism by preventing the function of the enzymes enolase and ATPase.

It stops bacteria from adhering to the enamel by reducing the rate of their extracellular polysaccharide formation.

Figure 2: cases of dental fluorosis [5]

These properties mean that enamel has a reduced exposure and is more resistant to bacterial acid, so there is a reduced rate of dental decay. As such, fluoride can be added to toothpaste as calcium fluoride and can also appear in mouthwashes and water supplies [3] [4].

Nevertheless, excess fluoride can have negative effects on our teeth, one example being dental fluorosis. This condition is the hypomineralisation of enamel and is characterised by chalky white or brown markings with shallow or deep pits depending on severity. Dental fluorosis arises from an excessive amount of fluoride ingestion during tooth development: here, fluoride inhibits the proteolytic enzymes that are needed to degrade the matrix proteins that precede the hydroxyapatite crystals during amelogenesis. If these enzymes don't perform their function, the matrix proteins are not removed, which hinders the growth of the inorganic crystals and leads to smaller crystals and greater enamel porosity [3][4][6]. Figure 2 shows examples of fluorosis.

Given the both harmful and beneficial actions of fluoride, it is imperative that we consume fluoride in moderation to exploit its therapeutic effects whilst simultaneously avoiding the consequences from excessive intake.

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