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Technical Bulletin: How Fluoride Works

Fluoride and Teeth

Dental caries, or cavities, are caused by dissolution of tooth enamel. Primarily, this occurs when oral bacteria and enzymes underneath plaque metabolize sugars and carbohydrates into acids that slowly decay the tooth.[1]

Specifically, when enough organic acid has been produced to decrease the pH below 5.5, the acid dissolves hydroxyapatite ($Ca_{10}(PO_4)_6OH_2$), the fundamental component of tooth enamel. This process of demineralization can be reversed by mineral recovery from ions in saliva during the absence of sugars – a process called remineralization. Tooth decay happens when the rate of demineralization is greater than that of mineralization.[2]

Fluoride ions (F^-) introduced to the mouth at low-levels, whether through fluoridated drinking water or other fluoride products, mix with the dissolved hydroxyapatite in the plaque fluid. The resultant minerals are hydroxyfluorapatite or fluorapatite, depending on substitution of one or two hydroxyl groups with fluoride, respectively. Both of these are less soluble in acid than hydroxyapatite and, consequently, provide greater resistance to tooth decay as they become incorporated into the enamel.[2]

Furthermore, fluoride is known to increase the rate of mineralization from higher concentrations of calcium phosphate salts. Also, fluoride inhibits the substrates of oral bacteria, reducing the amount of acid produced and slowing the rate of demineralization.[2]

Water fluoridation is accordingly used in the majority of U.S. cities to prevent this chronic disease.

Fluorosilicic Acid Mechanism

Hydrofluorosilicic acid (H_2SiF_6) is a product of the phosphate industry. Fluorosilicic acid does not exist as a discrete species, but rather refers to an equilibrium mixture with hexafluorosilicate anion (SiF_6^{2-}) in aqueous, protic solutions. Consequently, fluorosilicic acid completely dissociates in solution into hydrofluoric acid and silicon tetrafluoride. Hydrofluoric acid then quickly dissociates to a proton and fluoride ion.

$$H_2SiF_6 \leftrightarrow 2HF + SiF_4$$

$$HF \leftrightarrow H^+ + F^-$$

The silicon tetrafluoride reacts with water to form silicic acid and silicon diocide.

$$SiF_4 + 3H_2O \leftrightarrow 4HF + H_2SiO_3$$

$$SiF_4 + 2H_2O \leftrightarrow 4HF + SiO_2$$

These four moles of hydrofluoric acid will then dissociate as before, yielding complete ionization of fluorine. Accordingly, fluorosilicic acid is very effective in fluoridating water.[1]

References

[1]American Water Works Association. AWWA Manual M4, *Water Fluoridation Principles and Practices*. (5th ed.). 2004. Denver, CO. American Water Works Association.

[2]Featherstone, JD. Dental caries: a dynamic disease process. 2008. Aust Dent J. Sep;53(3):286-91.