Dental Fluorosis

3.1 Introduction

Many studies suggest that fluoride may be an essential element for both animals and humans. However, it is true that the essentiality of fluoride for humans has not been demonstrated indisputably. Further, data on the minimum nutritional requirement are also inadequate. Incidentally, many epidemiological studies have clearly demonstrated possible adverse effects and health issues that arise due to the continuous ingestion of fluoride that is derived mainly through drinking water. These studies clearly show that fluoride primarily produces effects on skeletal tissues, especially bones and teeth. However, low concentrations of fluoride provide protection against dental caries, especially in children. According to the World Oral Health Report 2003, for a considerable percentage of people, especially children, in most of the industrialized countries, dental decay (dental caries) still remains a major public health issue. The changing living conditions and dietary habits are expected to be reasons for increased incidences of dental decay. Although considerable advancements have been made in preserving and improving global oral health issues, many of such issues related to the poor, marginalized, and disadvantaged groups still persist. Scientific research on the oral health issues related to fluoride started more than a century ago and focused on establishing a link between fluoride, dental caries, and fluorosis. Studies suggest that fluoride toothpastes and mouth rinses can significantly reduce the occurrence and prevalence of dental decay.¹

3.2 Dental Effects of Fluoride

The presence of fluoride in water has dual significance on human health, that is, the concentration of fluoride in the drinking water defines both its beneficial and harmful effects. Although a minimum level of fluoride in drinking water may reduce dental caries, as stated earlier, higher concentrations
Fluoride in Drinking Water

may initiate dental fluorosis in various proportions. Though water fluoridation at minimal levels may be beneficial, minimizing the adverse fluorotic effects on teeth at higher concentrations should be cautioned. Accordingly, the optimum concentration of fluoride in drinking water is generally limited to 1 mg/L, as it may ensure maximum dental protection without initiating any adverse health problems.

Fluoride was considered to improve the crystal lattice stability of enamel and render it less soluble to acid demineralization. Since fluoride is incorporated into enamel as partially fluoridated hydroxyapatite, it is considered best when it is ingested. However, an increasing body of evidence suggests that a substantial part of the cariostatic activity of fluoride is due to its effects on erupted teeth. Further, the mechanism of action is mainly centered on the presence of fluoride in the fluid phase of dental plaque and saliva. The fluoride available in saliva and dental plaque reduces the demineralization of teeth and enhances the remineralization, mainly through an interaction with the surface of the enamel. Fluoridated toothpastes, mouth rinses, and topically applied dental treatments such as varnishes, gels, and solutions are also used in addition to water fluoridation. In addition, fluoridated milk, fluoridated salt, and other fluoride supplements are also used in many countries. Of late, considering the average annual maximum daily air temperature of the region, the optimum recommended range of fluoride in drinking water is from 0.5 to 1.2 mg/L. The population using fluoride toothpastes (containing 10 g of fluoride per kg) for preventing dental caries may be twice as those consuming groundwater with excess fluoride. It is suggested that in many developed countries, use of these products is considered helpful for the gradual decline in the prevalence of dental decay. However, many studies suggest that fluoride supplements have only a limited role in enhancing dental health. It is pointed out in some studies that applications of fluoridated mouth rinses have become popular among school children and kids. However, their efficacy in preventing dental decay is dependent on the frequency of usage, level of compliance, and exposure to other fluoride sources. Proper caution is to be maintained in recommending the usage of mouth rinses for children younger than 6 years, as they may swallow it during rinsing, thereby increasing the risk of dental fluorosis. Thus, it would be appropriate to recommend a mouth rinse only for the elderly people with elevated risks of dental decay.

3.2.1 Dental Caries (Tooth Decay)

Dental caries (decay) is one of the most prevalent chronic childhood diseases worldwide. The disease develops in both the crowns and roots of teeth, and it grows into aggressive tooth decay. It is presumed that there exists a physiological stability between the oral microbial films and teeth minerals. The alterations in this stable equilibrium may contribute to the initiation of dental caries. It could be viewed as an “infectious and multifactorial disease” that is characterized by demineralization of inorganic components of teeth
Dental Fluorosis and dissolution of organic substances of microbial etiology. Unhygienic oral cavities invite bacterial growth, resulting in caries, which further leads to acid production by fermentation. This may etch away enamel, leaving black spots or cavities on teeth. These microorganisms can damage the soft pulp tissues by infiltrating through the dentin.\textsuperscript{3} Dental decay ultimately leads to a state of acute systemic infection through different phases such as devastating pain, bacterial contagion resulting in pulpal necrosis, reduced dental function, tooth extraction, and so on. \textit{Streptococcus mutans} and lactobacilli in dental plaque are mainly the two types of specific bacteria that are responsible for inducing caries.

### 3.2.2 Prevention of Dental Caries by Fluoride

The mineral crystals of calcium and phosphate form enamel and dentin, which are entrenched in an organic protein–lipid medium. Fluoride is utilized by cariogenic bacteria for fermentation, resulting in the production of acids. The absorbed/ingested fluoride inside the bacterial cell can interfere and alter the enzymic activities of the bacterial cell. Thus, bacterial activities and the resulting acid production get disturbed so that demineralization of dental mineral gets reduced. Incidentally, the adsorbed fluoride attracts calcium ions in saliva. Thus, fluoride aids the calcium and phosphate ions and chemically produces a crystal surface that is more resistant against acid solubility than the natural tooth mineral, thereby enhancing remineralization of the teeth.\textsuperscript{4–6}

### 3.2.3 Role of Fluoride in Dental Decay

The presence of fluoride in water has dual significance. Since fluoride has both positive and negative impacts on human health, the stressful effects of fluoride in drinking water constitute a subject of intense scientific deliberation. As a result, many research findings in this direction are either contradicting or inconclusive. The population consuming fluoridated drinking water increased from 210 million in 1994 to 355 million in 2005.\textsuperscript{2,7} In addition, it was estimated that more than 50 million people are consuming water with a naturally fluoridated concentration of 1 mg/L.\textsuperscript{7} A systematic review investigating the association between fluoride and dental caries suggested that fluoridation of drinking water supplies reduces the occurrence of dental decay. Furthermore, since fluoride was found to be highly valuable when continually present at lower concentrations in plaque fluid and saliva, the WHO recommended the use of fluoridated mouth rinses to reduce elevated risk of dental caries.\textsuperscript{2}

The effectiveness of fluoride in preventing tooth decay is a topic of intense scientific debate. Dental caries in children is said to be a bacterial disorder.\textsuperscript{3} Several factors, namely, nutrition, oral bacteria, oral hygiene, and educational
and economic statuses of parents, are cited as reasons for poor dental health. Large temporal reductions in tooth decay could be attributed to dietary patterns and immune status of populations. It is suggested that dietary control of caries without the use of fluoride is possible, as even chewing cheese reduces tooth decay. It is also recommended that fluoride need not be treated as an essential nutrient to humans, as its absence has not proved to result in any disease. Since the essentiality of fluoride in humans is not established unambiguously, data on the minimum nutritional requirement of fluoride are unavailable. It was also pointed out that majority of teeth decay issues develop on fissures and pits of the teeth, areas where fluoride is proved ineffective. This further demonstrates the topical action of fluoride on the teeth surface. Thus, many studies reserve apprehensions in actually consuming or ingesting fluoride.

3.3 Dental Fluorosis: History and Occurrence

Dental fluorosis may appear as a cosmetic effect that ranges in appearance from scarcely discernible to a marked staining or pitting of the teeth in severe forms. However, it could be treated as an early sign of fluoride attack that is visible to the naked eye; it also induces an irreversible toxic effect on tooth-forming cells. Although it histologically represents a hypocalcification, clinically it ranges from barely visible white striations on the teeth to gross defects and staining of teeth enamel. The first report on dental fluorosis was from Mexico in 1888, where a family from Durango was identified with “black teeth.” In 1891, cases of dental fluorosis were reported among Italian migrants from Naples to the United States. From 1900 onward, there was a pouring in of the prevalence and issues of dental fluorosis from different parts of the world, including the United States. Dental fluorosis was first related to drinking water in 1925, though it was shown to be “specifically caused by fluoride in drinking water much before.” It was Dr. Frederick S. McKay who first reported the development of an unusual permanent stain or “mottled enamel” on the teeth surface. This initiated and channelized a lot of scientific research on the relationship between fluoride in drinking water and fluorosis. In 1930, fluorosis was rated and identified as an “occupational disease in human.” Subsequently, in 1932, in Denmark, the prevalence of skeletal fluorosis in cryolite miners was reported. In the 1930s, in India, fluorosis was first detected among cattle by the farmers of Nellore district of Andhra Pradesh. In 1937, the first medical report to this effect was published in the Indian Medical Gazette. In 1978, it was suggested that “fluorosis might be one of the most widespread endemic health problems” associated with natural geochemistry.
3.4 Development of Dental Fluorosis

The progression of dental fluorosis is believed to take place through multiple stages. Initially, teeth become opaque and chalky due to "subsurface hypomineralization." Subsequently, the teeth lose enamel, which initiates the development of grooves and pits. Enamel and dentin, the calcium-rich constituents of teeth, have much affinity for fluoride in the formation and development of teeth. During mineralization of teeth, fluoride essentially combines with calcium to form calcium fluorapatite crystals. Due to such fluoride accumulation, calcium gets lost from teeth. As a result of this loss of calcium, fluorosed teeth move from a "mild to severe" state. Since calcium ions are lost to fluoride, teeth become weaker. Further, the severely fluorosed enamel becomes more discolored, pitted, porous, and prone to wear and fracture, as the "well mineralized zone is very fragile to mechanical stress." Due to the reduction in mineral content, mutilation of enamel mineralization, and associated structural alterations coupled with the morphological abnormalities on the teeth surface, the fluorosed teeth readily and easily get fractured.\(^{3,16}\)

Most of the recent research suggests that "dental fluorosis results from a fluoride-induced delay in the hydrolysis and removal of amelogenin matrix proteins during enamel maturation and subsequent effects on crystal growth."\(^{6}\) The proteins secreted by ameloblasts are known as amelogenins. These amelogenins slow down the growth of enamel crystallites. Once amelogeninases remove the amelogenins from the enamel matrix, the crystallite growth is increased in the initial maturation phase of tooth development. This most crucial enamel maturation phase turns out to be the most sensitive time for a higher level of fluoride exposure.\(^{6,17,18}\) Depending on the level of exposure and nutritional status of the child, Dean (1934) classified the fluorosis on a scale from 0 to 4 as follows:\(^{19}\) “class 0, no fluorosis; class 1, very mild fluorosis (opaque white areas irregularly covering about 25% of the tooth surface); class 2, mild fluorosis (white areas covering about 50% of the tooth surface); class 3, moderate fluorosis (all surfaces affected, with some brown spots and marked wear on surfaces subject to attrition); and class 4, severe fluorosis (widespread brown stains and pitting).”\(^{6}\) Figure 3.1 shows the classification of dental fluorosis symptoms into seven categories according to Dean’s classification (normal, questionable, very mild, mild, moderately severe, and severe), and each of these seven categories was given a numerical weight between 0 and 4.\(^{20}\) Mild dental fluorosis is making its presence felt through the manifestation of small white areas in the enamel. Teeth that are stained and pitted or mottled in appearance denote the severe form of dental fluorosis. The hypomineralization of the enamel is the most prominent feature in human fluorotic teeth. The excessive fluoride assimilation into the enamel may interfere with its maturation process, resulting in alterations in the rheologic structure of the enamel matrix.
and/or effects on cellular metabolic processes that are associated with normal enamel development.\textsuperscript{21,22}

### 3.4.1 Physical Symptoms of Dental Fluorosis

As shown in Figure 3.1, the color of teeth may progress from white, yellow, and brown to black due to dental fluorosis. This “discoloration may be in spots, or appear as streaks invariably horizontal in orientation, as new layers of the matrix are added on horizontally” during the tooth development process.\textsuperscript{3,6} Thus, the discoloration will usually appear in pairs based on developmental patterns and will not appear as a single isolated tooth. As against normal belief, the discoloration appears away from the gums, that is, on the enamel. As it may progress, in due course, the enamel will lose its brightness, luster, and shine. However, the discoloration due to other factors (e.g., dirty teeth, smoking, tobacco chewing, coffee or tea stains) may appear along the gums and only on the periphery of the teeth. Because “enamel lines are laid down in incremental lines during prenatal and post-natal periods,” dental fluorosis may appear invariably as horizontal lines or bands (but never as vertical bands) on the teeth surface.\textsuperscript{3,6}

**FIGURE 3.1**
3.4.2 Issues of Dental Fluorosis

Teeth are important components of our facial skeleton, as they are vital in aesthetics, phonation, and speech. An attractive smile is the biggest human asset; however, a person with dental fluorosis gets deprived of this privilege. Dental fluorosis may impart psycho-sociological problems that arise due to distress, self-insolence, and loneliness. Children with dental fluorosis may be afraid to laugh, fearing embarrassment, and isolation, which may ruin their one and only childhood and their self-esteem. Such frustrations may eventually lead to deep psychological depressions. The fluoride endemic areas of the developing world agonizingly accommodate many human beings in this direction.\textsuperscript{3,23,24} Figure 3.2 shows a girl from a rural Indian village who is suffering from dental fluorosis.

3.4.3 Prevalence of Dental Fluorosis

The correlation between the concentration of fluoride in water and the prevalence of dental fluorosis is well documented. As a consequence of

\textbf{FIGURE 3.2}
A girl from Garhtipli village in Dhar district in Madhya Pradesh suffering from dental fluorosis. (From UNICEF, Photo essay, UNICEF/India/2006/Ruhani kaur, fluorosis-mitigating the scourge, \url{http://www.unicef.org/india/1425.html}).
the increased fluoride intake through multiple sources, the severity of dental fluorosis is increasing the world over. Only 50% of absorbed fluoride is retained in adults, whereas 80% is retained in children. Thus, children and adolescents become more susceptible to dental caries. Indian literature showed 100% prevalence of dental fluorosis at a fluoride level of 3.4–3.8 mg/L.\(^5,26\) The "prevalence of dental fluorosis at a water fluoride level of 1 mg/L was estimated to be 48% in fluoridated areas and 15% in nonfluoridated areas. Limiting consideration to aesthetically important levels of severity, the prevalence of fluorosis is 12.5% in fluoridated areas and 6.3% in nonfluoridated areas. Increasing the water fluoride level from 0.4 to 1 mg/L, would mean that one additional person for every 22 people would have fluorosis of aesthetic concern, but with no risk."\(^6,27\) Thus, it could be undoubtedly inferred that the benefit of reduction in dental decay due to fluoride is at the expense of the increased prevalence of dental fluorosis. A 100% prevalence of dental fluorosis was reported at a daily total fluoride intake of 2.78 mg/child/day. Further, at higher levels of daily total intake of fluoride, the prevalence of dental caries increased. It is important to monitor total fluoride exposure of children and excessive fluoride intake, especially during the years of tooth development.\(^28\) The elevated fluoride content of the surrounding geological environment also imparts rich prevalence to dental fluorosis. Children in the age group of 3–14 years are more likely at the risk of fluorosis from consumption of vegetables and cereals grown in fluoridated areas.\(^29\) This suggests the need for revising the maximum permissible limits of fluoride in drinking water prescribed by different regulatory bodies where sizable fluoride intake takes place through the food chain.

On examining more than 480,000 students covering 18 districts of Gujarat\(^6\) (one of the three worst affected states in India), the percentage prevalence of dental fluorosis was found to vary from 2.6% to 33%. In Rajasthan (India), "maximum prevalence of dental fluorosis (77.1%) was observed among 17–22 year age group with severe dental fluorosis with black staining at 2.6 mg/L” fluoride.\(^5\) The highest overall prevalence of dental fluorosis (77.2%) was observed at 3.2 mg/L. The study in Haryana (India) also demonstrates the correlation between dental fluorosis and dental caries in certain fluoride endemic locations. The “prevalence rate of dental fluorosis increases from 13% to 77% with increase in fluoride level from 0.64 mg/L to a range of 1.89–3.83 mg/L.”\(^6\) Incidentally, there is a steady increase in dental caries from 65% to 98%. This experimental evidence substantiates the poor correlation of dental caries with groundwater fluoride concentration levels. However, in Kolar district of Karnataka, India, genu valgum was prevalent among children with and without dental fluorosis.\(^30\) These observations reveal that the prevalence and occurrences of fluorosis widely vary in populations at different regions, though they consume waters with almost the same fluoride concentrations. Other
factors such as climate, individual biological responses, nutritional status, individual vulnerability, extent of fluoride exposure, and presence of other dissolved salts in the groundwater also have significant roles.\textsuperscript{3,27,31}

### 3.5 Summary

- Literature suggests that fluoride may be an essential element for both animals and humans. However, for humans, the essentiality of fluoride has not yet been demonstrated indisputably. Thus, data indicating the minimum nutritional requirement of fluoride are unavailable.

- Many epidemiological studies have demonstrated possible adverse effects and health issues arising due to long-term ingestion of fluoride through drinking water. These studies clearly show that fluoride primarily produces effects on skeletal tissues, especially on bones and teeth.

- Considerable literature suggests that the usage of different water fluoridation techniques, applications of mouth rinses, and fluoride toothpastes significantly reduce the prevalence of dental caries.

- The acceptable and recommended permissible level of fluoride in drinking water for preventing dental caries ranges from 0.5 to 1.2 mg/L. This range of limit is fixed based on the annual average maximum daily air temperature of a region. In general, regulatory agencies suggest a general acceptable maximum fluoride concentration of 1 mg/L in drinking water. This is to ensure the maximum level of protection of dental caries and to avoid the prevalence of dental fluorosis.

- The ecological imbalance between physiological equilibrium of tooth minerals and oral microbial biofilms is a causative factor for dental caries.

- The effectiveness of fluoride in preventing tooth decay is a topic of intense scientific debate, as many studies reserve apprehensions in actually consuming or ingesting fluoride.

- Dental fluorosis could be treated as an early sign of fluoride attack that is visible to the naked eye. It induces an irreversible toxic effect on tooth-forming cells.

- It could be inferred that fluorosis may be regarded as one of the most pervasive endemic health problems generated and coupled with natural geochemistry.

- Most of the recent research suggests that “dental fluorosis results from a fluoride-induced delay in the hydrolysis and removal of
amelogenin matrix proteins during enamel maturation and subsequent effects on crystal growth.”

- Dental fluorosis may impart psycho-sociological problems arising due to distress, self-insolence, and loneliness. Children with dental fluorosis may be afraid to laugh, fearing embarrassment, and isolation, which may ruin their one and only childhood and their self-esteem.
- Indian literature demonstrates a 100% prevalence of dental fluorosis at a fluoride level of 3.4–3.8 mg/L.
- Considerable literature suggests the need for revising the maximum permissible limits of fluoride in drinking water prescribed by different regulatory bodies where sizable fluoride intake takes place through the food chain.

References


