DENTAL FLUOROSIS: THE SOURCES OF FLUORIDE EXPOSURE AS A TOOL FOR CLINICAL DECISION-MAKING

Gowri Sivaramakrishnan[a], Maram Majed Altawash[a], Fatema AlSulaiti[a], Maryam Ahmed Ahmadi[a], Muneera Alsobaiei[a], Leena Alsalihi[a], Taghreed Omran Ajoor[a]

Bahrain

ABSTRACT: Dental fluorosis is characterized by the presence of irregularities on the surface of the teeth. It is caused by the excessive intake of fluoride during the first year of life. This can lead to a significant impact on the esthetics. The pooled estimate of worldwide date on dental fluorosis reported a prevalence rate of around 13%. The fluoride content in ground water and other fluoridated dental products are the two major sources of fluoride that can lead to dental fluorosis. Different treatment options are available that can be used alone or in combination, depending on the severity and the needs of the patient. Diagnosis of this condition is made by considering the factors that contributed to excessive fluoride exposure during early years of age. The aim of this paper is to provide a comprehensive literature review on the various factors that can influence the exposure of fluoride leading to dental fluorosis. The data from Bahrain is used as an example to arrive at the diagnosis. The paper also presents a decision tree for the dentist in order to diagnose and treat these conditions. The differential diagnoses of this condition are also presented. A case report that applies the discussed literature is also presented as an example. The key to prevent the development of dental fluorosis is to prevent the exposure as early in life as possible. Government entities should bring about strategies that can prevent early high concentration fluoride exposures to reduce the incidence of this disease.

Key words: Enamel mottling, Hypoplasia, Hypomineralisation, Subsurface porosity, Pitting, Primary Health Care Centers, Bahrain

INTRODUCTION

Dental fluorosis is primarily defined as the development of opacities in the enamel or enamel mottling, caused due to excessive fluoride exposure during teeth development. [1] Similar clinical presentation has also been reported to occur in fluoride deficient areas, and the differential diagnosis of these non-fluoride induced enamel mottling is critical. [2] The condition presents as enamel hypomineralisation with varying degrees of subsurface porosity. The clinical presentation in chronic low dose exposures may be different from acute fluoride exposures. Hence, the amount and time of exposure are critical, leading to increased plasma fluoride concentration. Other factors that influence the plasma levels include renal function, rate of bone metabolism, metabolic activity, genetic factors, etc. [1,2] In mild cases, white opaque areas are observed due to the subsurface porosity. In moderate to severe cases, deeper layers are affected with pitting and loss of tooth structure. The enamel is fragile which can lead to fracture. This leads to particular disruption in the normal tooth development and poor esthetic appearance. [1] The natural history of mild fluorosis is that it can diminish with age. It is reported that daily fluoride supplementation within optimum limits is an important factor for preventing dental caries and a mitogenic stimulus for osteoblasts, as fluoride increases mineral deposition in bone. However fluoride is not considered by the Scientific Committee on Health and Environmental Risks (SCHER), European Commission, to be an essential element for human

[a]Primary Health Care Centers, Bahrain.
For correspondence: Dr.Gowri Sivaramakrishnan, Specialist Prosthodontist, Primary Health Care Centers, Bahrain. Email- gowri.sivaramakrishnan@gmail.com

growth.[3] Excessive consumption of fluoride results in a serious public health problem, which is characterized by harmful effects on teeth (dental fluorosis—dental mottling), bone (skeletal fluorosis, crippling deformities, osteoporosis, and osteosclerosis), and soft tissues (nonskeletal fluorosis). [1,2] Although there are contradictory evidences on the concentration of fluoride in the enamel and development of dental fluorosis, the more recent studies point towards a positive linear relationship. [2,4,5] As the degree of exposure increases, the surface appears more hypomineralised and are more prone to decay.

Dean in 1942 coined the term “Dental Fluorosis” following his reports on the lower incidence of dental caries in children with dental fluorosis, caused due to increased fluoride content in drinking water in specific geographic locations. [6] Dean concluded that fluoride had significant inhibitory effects on dental caries, thus introducing the paradigm of introducing fluoride sources into the enamel during the early phases of tooth development. [7] However, fluoride should be considered a double-edged sword. The fluoride intake occurs from two major sources such as drinking water and fluoridated dental products, during and after tooth development. [5,6] Reports from past studies indicate that the probability of developing severe fluorosis is more with acute high concentration fluoride exposure during the first few years of life, essentially during the post secretory or early maturation period of enamel development. [3,4,5] Although increased concentration of fluoride in drinking water have been attributed to the development of severe fluorosis in specific regions, the use of fluoride agents by dental professionals for the prevention of dental decay, possible ingestion of fluoridated toothpaste and mouthwashes in young children, also contribute to the development of fluorosis. In areas with and without fluoridated drinking water, there has been evidence of a drop in dental caries and a rise in the prevalence of mild to moderate dental fluorosis because of the widespread use of alternate fluoride sources. [8] Another reported extrinsic source of high fluoride is tea. [9,10]

Hence, the aim of this literature review is to help the dentist arrive at the diagnosis considering all the factors that are mentioned in this paper. This is the first of its kind of literature review that gives the detailed data regarding fluoride exposure sources in Bahrain. It is important that the diagnosis of dental fluorosis be made considering a wide variety of factors that are discussed in this paper. This paper also produces a decision tree for dental practitioners that helps to device an appropriate least invasive treatment option for these patients. Considering the relatively higher incidence of misdiagnosis as regards to dental fluorosis, and similar clinical presentation in other dental diseases, this paper has attempted to analyse the previous literature on the incidence of dental fluorosis, the factors influencing fluoride exposures, the clinical presentation and diagnosis of dental fluorosis, and the recommendations on management options. The data from Bahrain is presented as an example. This may particularly be more applicable to the Mediterranean population, however readers are required to apply the local data on the factors mentioned in this paper to arrive at a conclusion. A case report is also presented along with the description to show the steps to follow during clinical decision making.

THE FLUORIDE CONTENT OF GROUNDWATER IN BAHRAIN

Water with high concentrations of fluoride is found in extensive geographical belts extending from Iraq and Iran through Syria and Turkey, along the Mediterranean region. [11] Individual studies in Iranian region showed significantly higher concentrations of fluoride (0.68–10.03mg/l) in drinking water that had greater influence in the overall general health of the population.[12] A study by Yousefi et al. showed increased odds of hypertension in people that consumed increased concentration of fluoride in drinking water.[13] Another similar study also reported problems related to infertility and abortion in females that were exposed to increased concentration of fluoride in their drinking water.[14] Thus excessive amounts of fluoride causes significant medical and dental health related problems. [15] According to CDC (Centers for Disease Control and Prevention), [12] the concentration of fluoride in drinking water is considered high when the level exceeds 1 mg/L. If the concentration is 1.5-4 mg/L, dental fluorosis occurs. Concentrations above 4 mg/L can lead to severe dental and skeletal fluorosis and above 10 mg/L leads to degenerative bone changes. [16]

A study by Akhtar et al. [17] on the amount of fluoride in underground water in Bahrain showed that the fluoride concentration varied from 0.50 to 1.46 mg/L with a mean value of 0.94 mg/L. The water for the study was collected from 21 different locations across the country. Another study by Musaiger et al. [18] measured the fluoride content of various water sources used for drinking and cooking in Bahrain. The average level of fluoride ranged from 0.28mg/L in bottled mineral water, 0.6 mg/L in treated water, 0.5 mg/L in mineral water and 0.85 mg/L in tap water. A more recent study by Abouleish et al. [19] on the fluoride content of bottled water available in the Gulf region showed that most bottled water brands had fluoride content of less than 1mg/L. From the data above, the fluoride content of bottled water seems to be within the normal limits. Majority of the population in Bahrain use bottled water for drinking purposes. A clear history from the patient on the use of tap or well water for drinking in the Mediterranean region, during the first two years of age should indicate towards the diagnosis of dental fluorosis. In patients that purely use bottled water for drinking, the source of fluoride for development of fluorosis is mainly derived from other fluoride sources and supplements.

TEA CONSUMPTION IN BAHRAIN AND DENTAL FLUOROSIS

Tea is widely consumed source of caffeine in Bahrain. [20] A recent study by Waugh et al. showed that the fluoride content of all major tea brands infused with tap water was 1.6 to 6.1 mg/L with a mean of 3.3 mg/L. When prepared with deionized or bottled water, 96% of the tea products had fluoride concentrations that exceeded 1.5 mg/L. [21] This can be one of the major sources of fluoride. The tea brands included in the study are currently available in the region. In addition to water fluoridation, a through history regarding tea preparation and frequency of consumption is important in order to diagnose dental fluorosis.

FLUORIDATED DENTAL PRODUCTS AVAILABLE IN BAHRAIN

There is a strong association between the use of external fluoride sources and development of mild to moderate fluorosis. [23] Fluoride supplements can be provided to patients in the form of increased fluoride concentration toothpaste, fluoride

varnishes and gels, mouthrinse, fluoride tablets, etc.[23] Fluoridated toothpastes that are available in the market contain 1000–1500ppm of fluoride. The fluoride tablets are not available locally for use in Bahrain. The available fluoride mouthrinse brands in the region contain 225ppm of fluoride, and are recommended for once daily use, in addition to brushing with a fluoridated toothpaste. The highest concentration of 450ppm is present only in one particular product in Bahrain.

Fluoride varnishes contain 22,600ppm of fluoride and the gels contain 12,300ppm of fluoride. [24] Both these products are available for professional application by dentists. During varnish application, the clinician is advised to use a thin cotton tip applicator to apply 0.3–0.5ml of varnish directly on the surface of the teeth. The application time is about 1–4 minutes. [25, 26] They can be applied up to 4 times annually. [27] Fluoride gels are either self-applied or professionally applied using foam trays from once a year to several times. The gel in the tray is placed in the mouth and kept in place for about 4 minutes. [27] It is common for young children to accidently ingest fluoride in any of the forms mentioned above. [28] Fluoride supplements are generally not recommended for children less than 2 years of age, due to increased risk of fluorosis. [28] Accidental ingestion or inappropriate use of these agents by dental professionals are a source of extrinsic fluoride.

DIFFERENTIAL DIAGNOSIS AND COMMON CLINICAL PRESENTATION OF DENTAL FLUOROSIS IN BAHRAIN

Considering the above-mentioned facts the cause of dental fluorosis in Bahrain can be attributed to:

- Age of fluoride exposure
- Use of tap or well water for drinking and cooking
- Excessive consumption of tea
- Amount of toothpaste and mouthrinse dispensed and accidental swallowing
- Frequency and age of professional application of fluoride

Although it is unfortunate that there is no recent data on the prevalence of dental fluorosis in Bahrain, it is interesting to note that a detailed study was conducted by Judith Littleton in 1987 [27] using similar criteria to those mentioned in Table 1.

The Thylstrup and Fejerskov index and the Dean Index are the most commonly used metrics to assess dental fluorosis. [28] Both indices categorizes dental fluorosis based on clinical appearance, making it possible to identify the mildest to most severe types of the condition with increasing scores. We suggest the use of four major categories that can be easily adapted by clinicians for their assessment. These categories are adopted from Dean’s Index. The classification is presented in Table 1 with clinical photographs representing the type of enamel mottling. This classification is presented to simplify the appropriate treatment guides for these cases. The few other conditions that have similar clinical presentations are described in Table 2.

TABLE 1: CLINICAL PRESENTATION OF DENTAL FLUOROSIS:

Category	Description	Clinical Photograph of patients presented in our clinic
0	normal or translucent enamel	
1 Mild	Slight scattered superficial white/yellow lines or opacities. The white lines run across the surface with accentuated perikymata Subsurface enamel porosity Resistant to caries.	 
2 Moderate	Superficial to deep larger opacities and minute pitting with/without brownish discoloration. Resistant to caries.	 
3 Severe	Severe marked pitting with widespread staining. Deeper layers involved with hypomineralisation. Sometimes leads to enamel breakdown. Caries prone due to increased surface roughness leading to accumulation of plaque.	

The results showed that approximately 50% of the sample in Bronze age, 20% in Iron age and 15% in Islamic ages had dental fluorosis. Out of this only 1/3rd of the sample displayed moderate to severe fluorosis. Enamel mottling was frequently observed in the molar teeth than the anterior teeth. Pitting was more frequently observed in order, in second and third molars, followed by first molars, and less frequent in the anterior teeth. Accentuated lines of perikymata was seen in the anterior teeth. High concentrations of 0.4–1.5 mg/L of fluoride was reported in tap and well water during the study period. This indicates that in this cohort, fluoridated water caused mild to moderate fluorosis in the majority of the studied participants. There is a definite need for more recent data on the pattern of dental fluorosis in Bahrain.

TABLE 2: DIFFERENTIAL DIAGNOSES OF DENTAL FLUOROSIS:

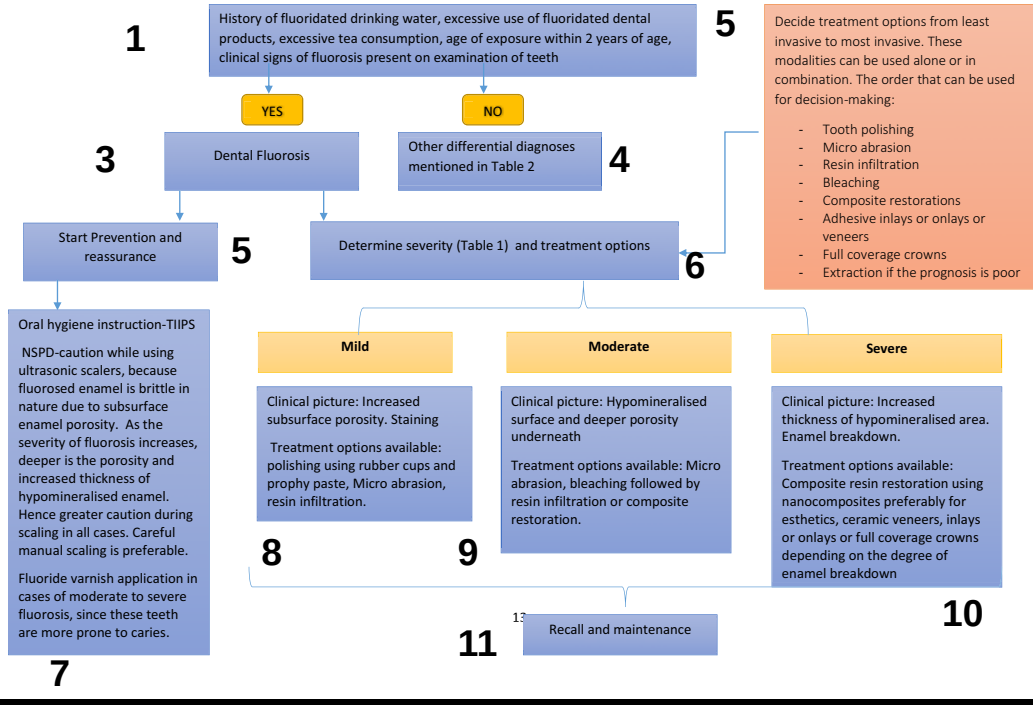
Condition	Mechanism of development	Causes	Clinical presentation and diagnosis	Classification of the disease
Molar Incisor Hypomineralisation (MIH)	Disruption in the amelogenesis process in the early maturation stage or even earlier at the late secretory phase	Systemic factors such as pre-natal or post-natal acute or chronic illness, exposure to environmental pollution during gestation, genetics	White or yellow opacities, post eruptive enamel breakdown involving the first permanent molar and/or incisors. Clinically examine clean, wet teeth. The lesion should be larger than 1mm in diameter. Ask for history of prenatal or post-natal illnesses. The margins of broken down enamel are sharp	**Mathu-Muju and Wright** **Mild MIH**: molars affected, mild/no incisor involvement, no caries, no hypersensitivity **Moderate MIH**: molars and incisors involved, the post-eruptive enamel breakdown limited to one or two surfaces without cuspal involvement, no hypersensitivity **Severe MIH**: post-eruptive enamel breakdown, crown destruction, caries associated with affected enamel, dental sensitivity and aesthetic concerns
Focal Enamel hypoplasia with or without hypomineralisation	Surface defect of the tooth crown that is caused by a disturbance of enamel matrix secretion, defective calcification or improper maturation	Local causes such as infection or trauma to the deciduous teeth leading to damage to the underlying permanent dentition.	Mild brownish discoloration of enamel (hypomineralisation) to severe pitting and irregularity of tooth crown (hypoplasia) depending on the severity of the cause. The margins of broken down enamel are smooth Usually involves single tooth Look for associated history of primary tooth trauma	**Federation Dentaire Internationale** **Pit form** (single/multiple, shallow/deep tiny areas of enamel loss) **Linear form** (grooves or lines of enamel loss <2 mm wide) **Plane form** (areas of partial or complete absence of enamel of a tooth crown)
Environmental/diffuse enamel hypoplasia with or without hypomineralisation	Surface defect of the tooth crown that is caused by a disturbance of enamel matrix secretion, defective calcification or improper maturation	Pre or post-natal illnesses, nutritional deficiencies, smoking in pregnancy, birth injury, congenital syphilis, drugs such as tetracyclines	Mild brownish discoloration of enamel (hypomineralisation) to severe pitting and irregularity of tooth crown (hypoplasia) depending on the severity of the cause. The margins of broken down enamel are smooth Any tooth can be involved depending on the stage of tooth development. Ask for history of prenatal or post-natal illnesses	**Federation Dentaire Internationale** **Pit form** (single/multiple, shallow/deep tiny areas of enamel loss) **Linear form** (grooves or lines of enamel loss <2 mm wide) **Plane form** (areas of partial or complete absence of enamel of a tooth crown)
Hereditary enamel hypoplasia with or without hypomineralisation	Surface defect of the tooth crown that is caused by a disturbance of enamel matrix secretion, defective calcification or improper maturation. More uniform in pattern compared to diffuse type	Genetic causes Amelogenesis imperfect- non syndromic Or associated with syndrome such as Ehler Danlos syndrome, Treacher Collins syndrome	Mild brownish discoloration of enamel (hypomineralisation) to severe pitting and irregularity of tooth crown (hypoplasia) depending on the severity of the cause. The margins of broken down enamel are smooth All teeth in both dentitions are affected and a familial history is often present	**Hypoplastic type:** with defective matrix secretion by the ameloblasts **Hypocalcified type**: where there is defective mineralization of the matrix **Hypomaturation type***:* where enamel crystal growth during maturation is defective due to ineffective enamel protein removal
White spot lesion or initial/incipient caries	Subsurface enamel demineralization caused due to acid attack by cariogenic bacteria.	Dental plaque stagnation due to poor oral hygiene. Frequent sugar consumption	Chalkier, matt or more opaque than the adjacent sound enamel. Enamel breakdown in advanced lesions. Mostly occur in plaque stagnant areas below the contact point, pits and fissures.	**ICDAS*** **Code 1:**First visual change in the enamel **Code 2:**Distinct visual change in the enamel **Code 3:** Localized enamel breakdown

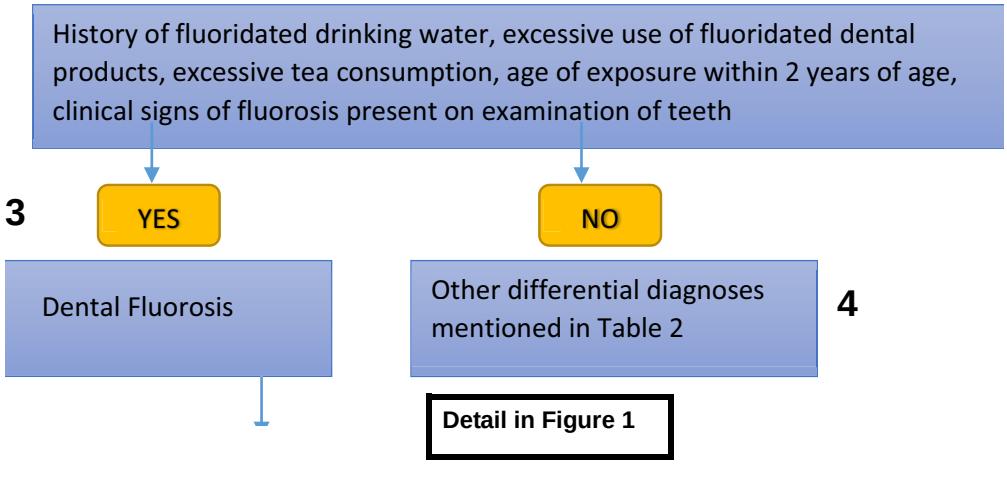
*ICDAS- International Caries Detection and Assessment system.

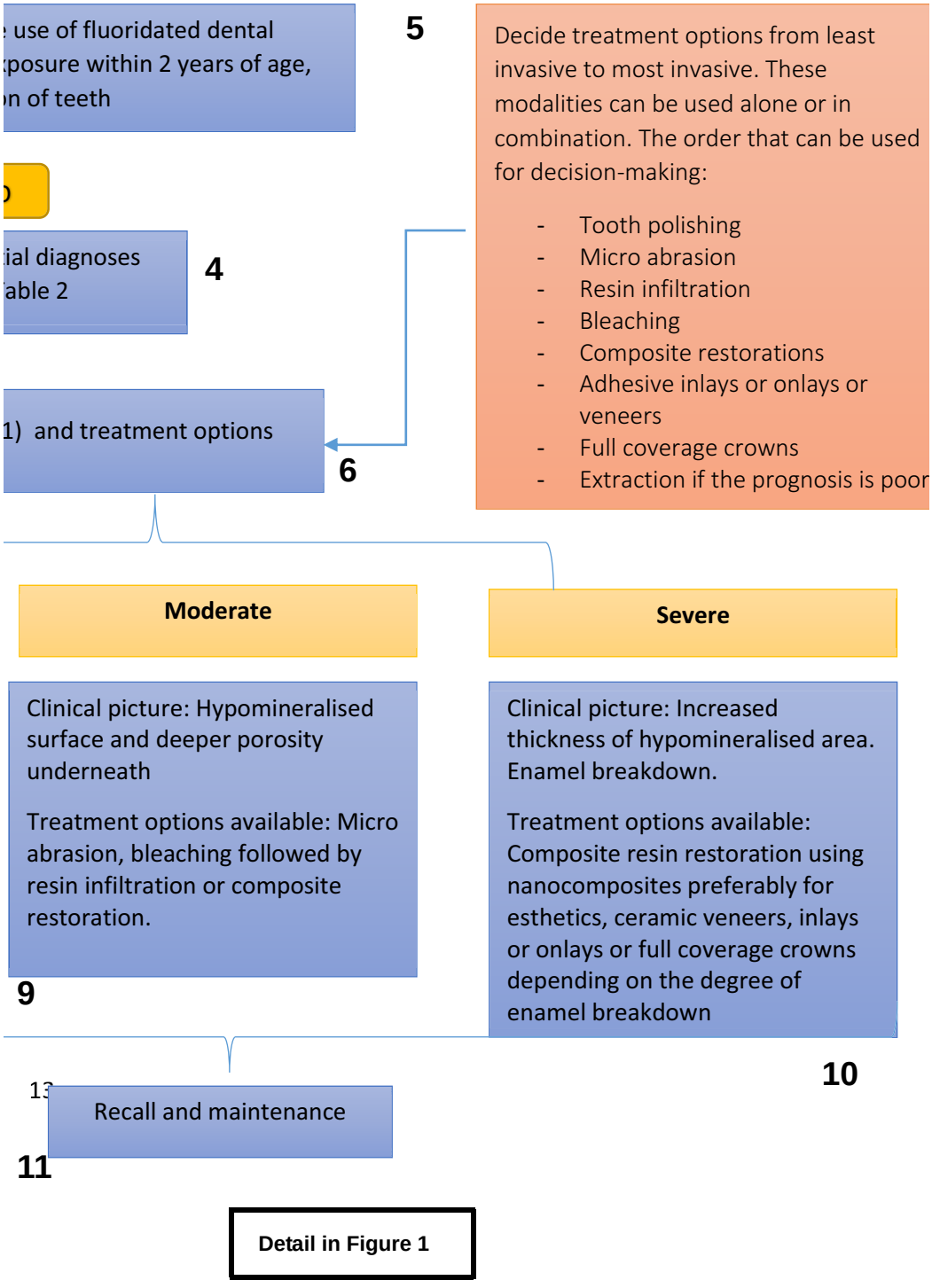
MANAGEMENT OPTION FOR DENTAL FLUOROSIS

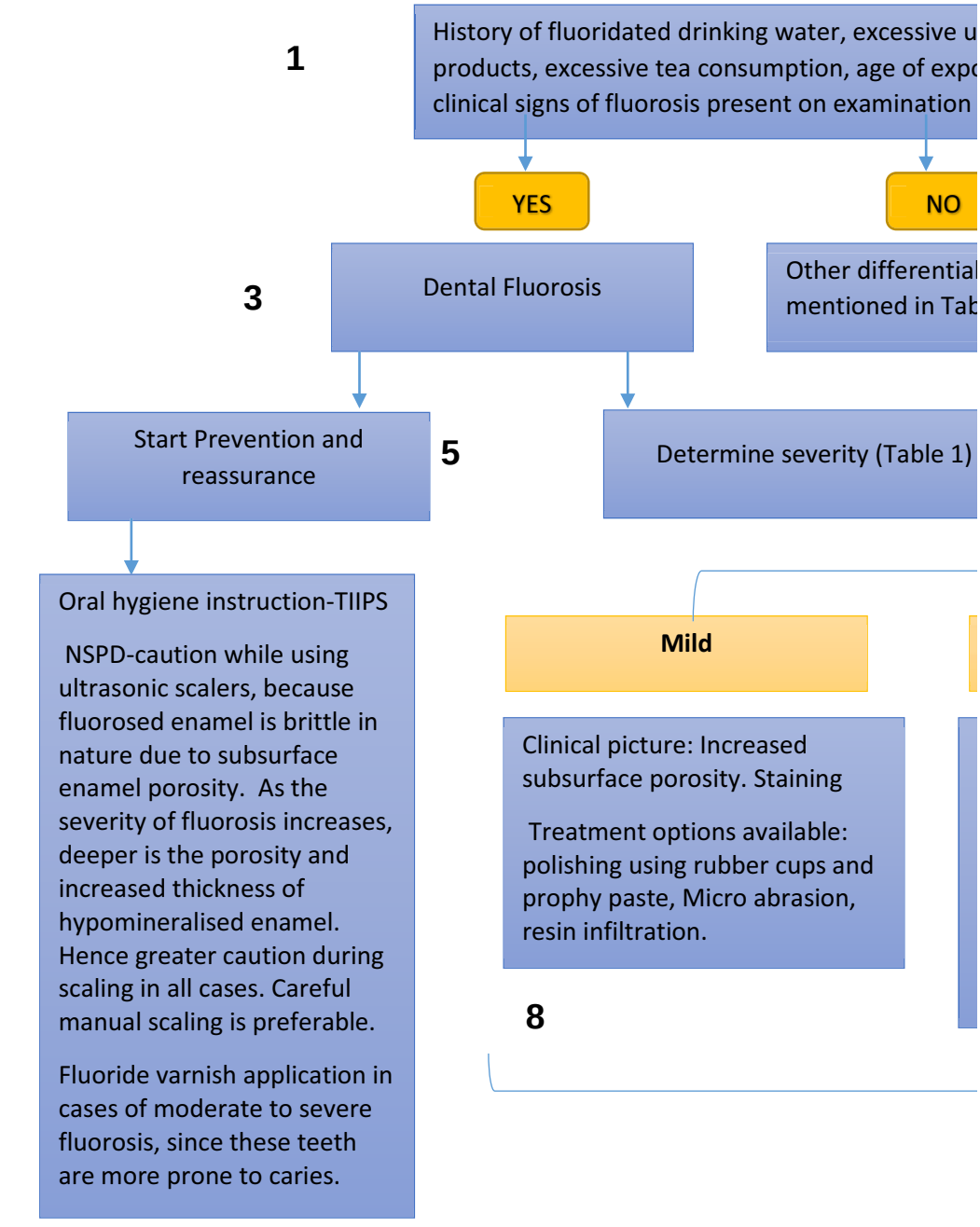
The management of dental fluorosis is dependent upon the esthetic requirements of the patient, severity of the condition and other concomitant factors such as presence of dental caries, sensitivity and oral hygiene status of the patient. It is preferable to begin with the least invasive option that prevents any kind of damage to the existing tooth structure. Based on the factors mentioned, a decision tree is presented in Figure 1 that helps dentist decide on the best treatment option that can be provided for the patient. Preventive strategies should play a key role in the management action plan. The decision tree can be individualized to particular patient needs.

FIGURE 1: DECISION TREE FOR MANAGEMENT OF DENTAL FLUOROSIS:









CASE REPORT

Presenting complaint and history:

A 11-year-old male patient reported with his father to the Ministry of Health primary care dental clinic, with a chief complaint of brown discoloration of teeth. The history revealed that his primary teeth were severely discolored as well. His father noticed that the permanent teeth erupted with mild discoloration. The discoloration worsened with age. The patient is a migrant from Yemen, which has a fluoridated ground water content of 2.3–2.4mg/L. He migrated two years ago. The patient used tap water for drinking; however, after his relocation he has been using bottled water. Diet history reveals increased frequency of consumption of sugars. The patient used fluoridated toothpaste containing 1000ppm of fluoride from when he was 1 years old.

Intraoral examination (Figure 2)

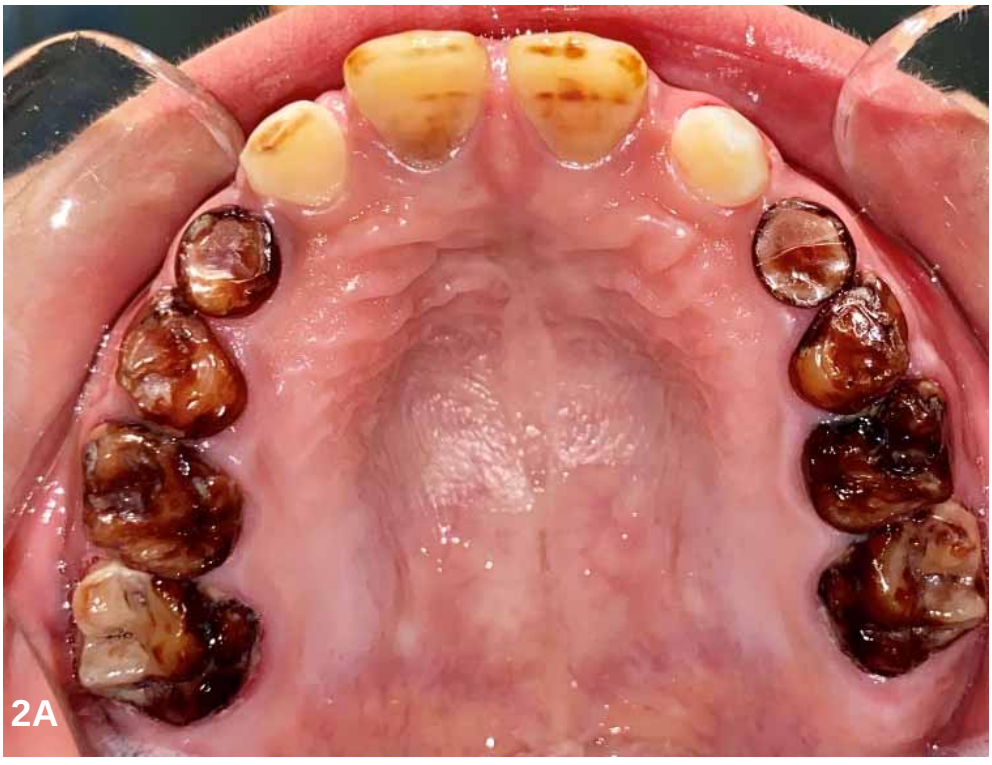
- Dark brown discoloration with irregular cuspal surface in the posterior primary molars and first permanent molar.
- Mild brownish horizontal lines and discoloration was seen in the anterior tooth
- Retained primary teeth #71 #81
- Multiple carious lesions in the molars primarily.
- On radiographic examination, we noticed congenitally missing #41, #31.
- The bleeding on probing was 45.4% and the plaque score was 77.2%.
- The BPE (Basic periodontal examination) reveled a score of 2 for all the quadrants.

Diagnosis and rationale: The possible causes of exposure to fluoride in this patient include drinking high concentration fluoridated water at the early years of age, accidental swallowing of fluoridated toothpaste occasionally considering his age, and clinical presentation of the teeth. A final diagnosis of dental fluorosis was made. The fluorosis was categorized as severe, category 3, based on the description presented in Table 1.

Treatment plan: The preventive phase was initiated as mentioned in the decision tree. Mild scaling was carried out with tooth polishing using rubber cups and prophypaste. Considering the severity of the condition and varying degrees of enamel breakdown, stainless crowns were the treatment of choice for the first permanent molars. This was made after ruling out all the less invasive treatment options mentioned in the decision tree. (Figure 3) Following polishing, the anterior teeth showed mild to moderate improvement in the discoloration. Hence, other invasive modalities were not attempted at this stage. The patient was recalled every three months initially considering the high caries risk status of this patient. The patient was put on a six monthly recall thereafter.

Checklist during recall and maintenance visits:

- Reassess oral hygiene and periodontal health (BPE, Plaque index, BOP, Bleeding index) after 8 to 12 weeks.
- Compliance with dietary advice and Oral hygiene instructions.
- Assess response to preventive measures and condition of restorations.
- Assess the eruption of permanent dentition.
- Assess the stainless steel crowns.
- Assess retained primary teeth.



Figures 2A and 2B. Preoperative photographs. 2A: Upper dentition; 2B: Lower dentition.

Figure 2C. Preoperative photographs. 2C: Anterior view of dentition.

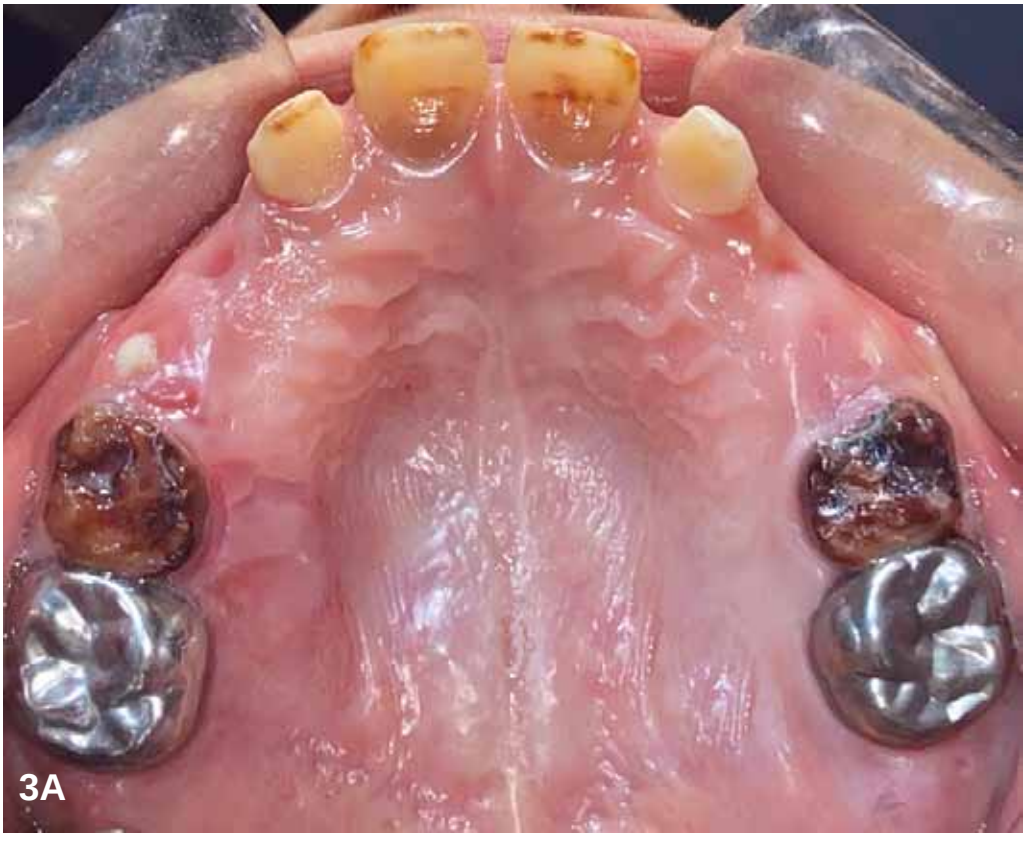


Figure 3A. Postoperative photographs. 3A: Upper dentition.

Figures 3B and 3C. Postoperative photographs.3B: Lower dentition; 3A:Anterior view of dentition.

CONCLUSIONS

The prevention of dental fluorosis can be attempted by educating the patients on the effects of drinking tap/well water in fluoridated areas. Parents should be advised on using bottled water for cooking and drinking. It is important to establish a dental home for every child as soon as the first tooth erupts into the oral cavity. Dentists

should be cautious in using fluoride sources for caries prevention. Information regarding other sources of fluorides such as tea should be included during patient education. The key to prevent development of fluorosis is to prevent the exposure as early in life as possible. The strength of the paper is that all the detailed data regarding fluoride sources are explained particularly from a Bahrainian context. Although the limitation of this review is that the worldwide data regarding prevalence of dental fluorosis is not presented, this is beyond the scope of this paper. The intention is to provide a guide to the clinicians to understand the steps to arrive at the diagnosis of dental fluorosis. This is provided as an example to emphasize to the readers that the data from their specific location is extremely critical to diagnose dental fluorosis. Future research should be conducted in every geographic location to understand the nature of the fluoride sources that are presented in this paper. Prevalence reports are also mandatory for every geographic location to identify potential sources of excessive fluoride. This helps to initiate government policies that can contribute to the use of fluoride in a safe and effective manner.

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