Universidad Europea

GRADUATION PROJECT

Degree in Dentistry

DENTAL FLUOROSIS: UPDATE, REVIEW AND PREVALENCE.

Madrid, academic year 2022/2023

Identification number: 190

ABSTRACT:

Introduction: Dental fluorosis is one of the most increasing dental problems in the world. It is caused by high exposure to fluoride concentrations that result in high porosity and a low mineral content in the enamel. It is a two-sided coin. In the developed world, dental hygiene is at its prime whilst in developing countries the primary cause is untreated water supplies. Therefore, it is important to study the causes, effects and prevalence of dental fluorosis in different countries as well as their associations to other dental diseases as it affects living standards. **Objectives:** This review focuses on the prevalence of dental fluorosis in developing and developed countries with the inclusion of fluoride distribution in water supplies. It also investigates associations to other dental diseases such as caries and periodontal disease. **Materials and methods:** Thirty-four sources found in English language or Spanish were chosen, ranging from 2013-2022, to obtain up-to-date and relevant information. **Results and Discussion:** Developing countries like India and Kenya had a prevalence of >50% of dental fluorosis whilst the developed countries presented low levels of dental fluorosis. The main reason is the untreated water supplies, in the developing countries that comes from boreholes where fluoride concentrations reach up to 5ppm, above the recommended level. Areas with high levels of dental fluorosis had low levels of dental caries and high levels of periodontal disease. **Conclusion:** Water supplies should be investigated and controlled. There should be an increase in awareness of causes and effects of dental fluorosis on the population. The best, optimum level of fluoride intake should be 0.7ppm to achieve the benefits of caries prevention whilst minimizing the risk of fluorosis. More studies need to be done on the relationship between dental fluorosis and periodontal health/disease.

Key words: Dentistry, dental fluorosis, fluoride, caries, developing and developed countries.

RESUMEN:

Introducción: Fluorosis dental es uno de los problemas dentales que es aumentando en el mundo. Está causada por una elevada exposición a concentraciones de flúor que provocan una elevada porosidad y un bajo contenido mineral en el esmalte. Es una moneda de dos caras. En el mundo desarrollado, la higiene dental es óptima, mientras que en los países en desarrollo la causa principal es el suministro de agua no tratada. Por lo tanto, es importante estudiar las causas, los efectos y la prevalencia de la fluorosis dental en diferentes países, así como sus asociaciones con otras enfermedades dentales, ya que afecta al nivel de vida. **Objetivos:** Esta revisión se centra en la prevalencia de la fluorosis dental en los países en vías de desarrollo y desarrollados con la inclusión de la distribución de flúor en los suministros de agua. También investiga las asociaciones con otras enfermedades dentales como la caries y la enfermedad periodontal. **Materiales y métodos:** Se eligieron 34 fuentes encontradas en lengua inglesa o española, comprendidas entre 2013-2022, para obtener información actualizada y relevante**Resultados y discusión:** Los países en desarrollo como India y Kenia tenían una prevalencia de >50% de fluorosis dental mientras que los países desarrollados presentaban bajos niveles de fluorosis dental. La razón principal es el suministro de agua no tratada, que en los países en vías de desarrollo procede de pozos donde las concentraciones de flúor alcanzan hasta 5 ppm, por encima del nivel recomendado. Las zonas con altos niveles de fluorosis dental presentaban bajos niveles de caries dental y altos niveles de enfermedad periodontal. **Conclusiones:** Los suministros de agua deben investigarse y controlarse. Se debería aumentar la concienciación sobre las causas y los efectos de la fluorosis dental en la población. El nivel óptimo de ingesta de flúor debería ser de 0,7-ppm para conseguir los beneficios de la prevención de la caries y minimizar el riesgo de fluorosis. Es necesario realizar más estudios sobre la relación entre la fluorosis dental y la salud/enfermedad periodontal.

Palabras clave: Odontología, fluorosis dental, flúor, caries, países en desarrollo y desarrollados.

TABLE OF CONTENTS:

1. INTRODUCTION:

1.1 Definition:

Dental fluorosis is seen to be one of the most increasing dental health problems around the world. Its prevalence is seen to be high in developing countries where the primary cause is untreated water supplies. Dental fluorosis is a condition that is chronically induced, where exposure to high concentrations of fluoride results in increased porosity and lower mineral content of the enamel. (1) Milder levels of fluorosis are represented by a white parchment on enamel whilst the more severe types appear as brown stains or mottling of enamel. (2)

The development and extent of the fluorosis depends on a series of factors: the dosage, duration and timing of exposure to fluoride. (3) Dental fluorosis is the first sign that represents a toxic effect of fluoride in children. (4) Children whose ages range between 1-4 years are seen to be more susceptible to dental fluorosis as during this time period, their body tissues are at a growing phase. After the age of 8, the prevalence decreases. (3,5)

Figure 1: Severe stage of dental fluorosis seen in a 7-year-old child (6)

1.2 Fluoride:

1.2.1 Chemistry

Fluoride is the ionic form of the element fluorine, which is one of the most reactive elements in the periodic table and is the lightest element from the halogen group. It is proved to be the most electronegative element meaning

it has a powerful tendency to receive a negative charge and in solutions form fluoride ions. (7) In the environment, fluoride is found in various minerals such as rock phosphate, fluorspar, cryolite, mica and hornblende. (8) It is also found in water, atmosphere and food. Fluoride takes over 0.08% of the earth's crust. In an adult, the healthy level of plasma fluoride is 1.5 ml/L.(4)

1.2.2 Sources:

In the environment, fluoride is found in various minerals such as rock phosphate, fluorspar, cryolite, mica and hornblende. (8) It is also found in water, atmosphere, soil and food, having a universal presence on earth. (3)

The 4 main sources of fluoride that increase the likelihood of dental fluorosis are: fluoridated drinking water, topical fluorides (mainly from toothpastes), fluoride supplements and formula prescribed for children. (1)
Water-borne fluoride takes up the largest proportion of the daily intake needed of this element. (3)

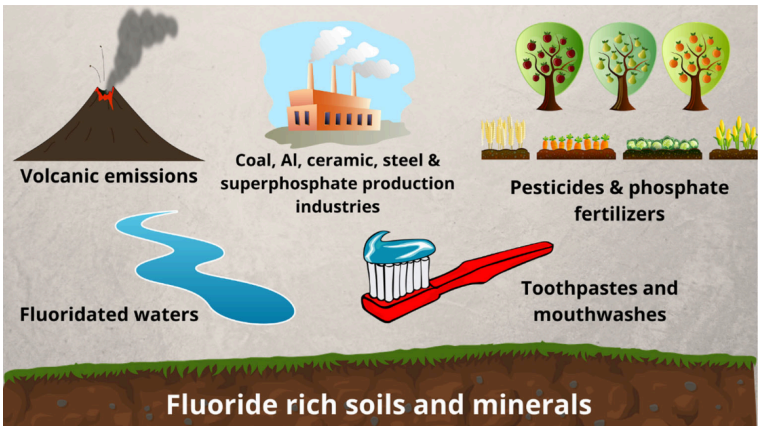


Figure 2: Main sources of fluoride in the environment (8)

Besides the environment and water, there are also other sources of fluoride obtained from foods and beverages, taken in the day to day life that people are not aware about. Fruits and vegetables contain low amounts of fluoride (0.1-0.4 mg kg-1) whilst rice and barley contain high amounts (around 2 mg

kg-1). Meat and fish contain low amounts but the bones of canned fish such as sardines which are consumed contain high amounts of fluoride. People who tend to stick to fish diets have a high exposure to fluoride consumption. Beverages such as tea which is consumed daily in many countries in the world contains high levels of fluoride (up to 400 mg kg-1 in dry weight) (7)

The type of diet influences the amount of dietary fluoride retained in the body. Diets that are high in protein tend to retain more fluoride as compared to a vegetarian diet. This is because they produce acidic urine due to a decrease in the renal excretion resulting in an increase in fluoride retention. Therefore, the effects of being a vegetarian vs a non-vegetarian also affect the level of fluoride in the body. (7)

1.2.3 Recommended level

It is seen that in majority of the artificially fluoridated water, the concentration of fluoride is approximately 1 part per million (ppm) or 1 milligram per liter (mg/L). The world health organization (WHO) has recommended that the maximum limit of fluoride, in the concentration of drinking water, allowed is 1.5 mg/L. (9)

Health services recommend fluoride concentrations in drinking water to be 0.7 mg/L in order to prevent caries and reduce toxic effects of fluoride. (10)

1.2.4 Distribution in water:

Water that contains high levels of fluoride usually occurs in extensive geographical belts. They are usually associated with volcanic rocks, granite rocks and marine sediments in mountainous regions. Common areas involved with high volcanic activity follow the East African rift system: Jordan, Ethiopia, Kenya, Sudan and Tanzania. Areas with high volcanic activity tend to have high concentrations of fluoride in the groundwater. (7)

Ground water supplies 40% irrigation water and 50% of drinking water to the world. It contains natural amounts of fluoride which are found in uncontrolled, high concentrations in around 25 countries in the world. Over 200 million people from these countries suffer fluorosis due to this. (10)

Community water fluoridation is a public health measure set to prevent caries in a population, having a cost-effective method by addition of fluoride in drinking water. The level supplied ranges from 0.7 to 1.0 ppm depending on the time of the year. However, as temperatures rise, the amount of water intake also increases thus requiring a reduction in the amount of fluoride supplied in water. Fluoridated water is seen to be responsible for dental fluorosis directly and indirectly. (11,1)

1.2.5 Use in prevention of caries

In the dental world, fluoride can be viewed as a two-sided coin. On one side, it is a very important agent in reducing the severity and prevalence of dental caries by inhibiting the cavitation process whilst on the other, it gives rise to side effects that cause an impairment in both the skeletal and dental development. (12)

Fluoride, with a concentration of 0.7-1.2ppm, in water supplies is seen to reduce caries in permanent teeth by 50-60% because it inhibits bacterial enzymes at low concentrations, preventing demineralization whilst at the same time aiding in remineralization. (4)

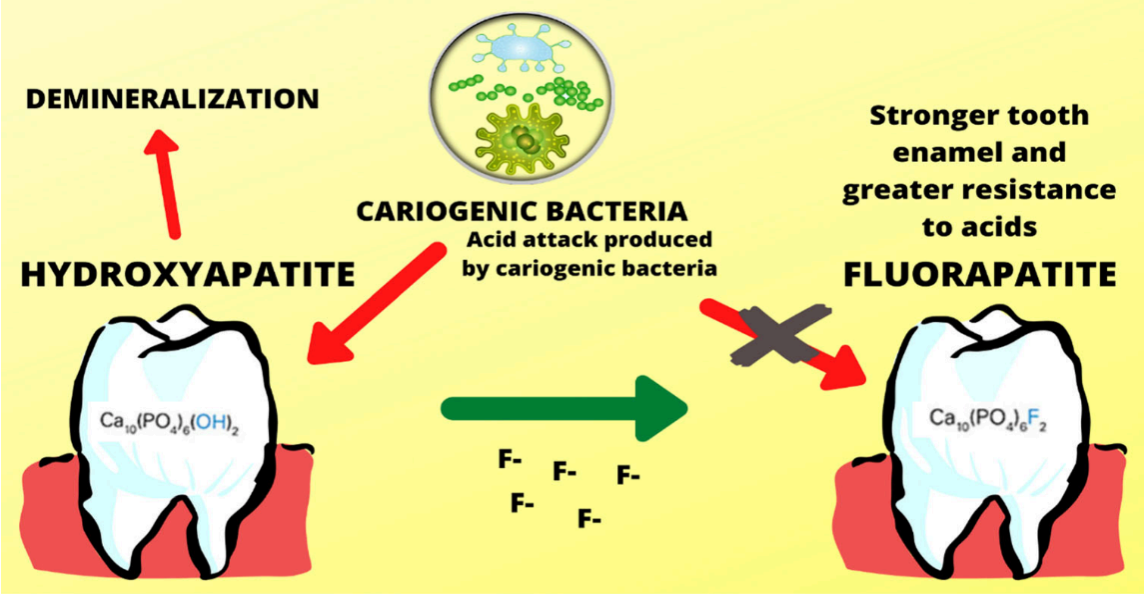


Figure 3: Fluoride effects on the enamel (8)

There are two ways fluoride is used to prevent caries in a community based level: systemic exposure and topical exposure. In regards to systemic exposure, there are 3 ways of providing fluoride to the communities:

i. Milk fluoridation- cost-effective program especially if done through school programs.
ii. Addition of fluoride to salt
iii. Fluoridation of water supplies like drinking water which is seen to be beneficial to people who cannot be a part of other preventive programs and often have high health risks.

In terms of topical exposure, the most preventive measure is brushing twice a day with toothpastes containing 1000–1500 µg/g (ppm) of fluoride. (12)

Other preventive topical methods in young children are taken care of by a health care professional. These include: applying 5% of sodium fluoride varnish every 3-6 months, thixotropic gels where acidulated phosphate fluoride (APF) is used at 1.23% and sodium fluoride (NaF) at 2.0% in gel or an annual application of 38% silver diamine fluoride solution. (SDF)

a) The sodium fluoride varnish helps in preventing development of caries in primary teeth and remineralizing early enamel lesions. Can be used on children under 6-7 years.

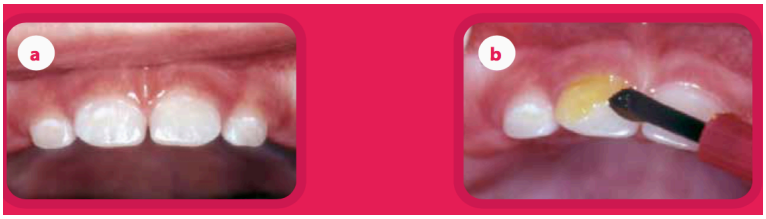


Figure 4: Application of fluoride varnish on an active enamel lesion of childhood caries in anterior teeth. (12)

b) APF at 1.23% and NaF at 2% are used for high incidences of caries and cannot be used for children under 6 years of age. It is done after every 4-6 months. Patient cannot eat or drink for 30 mins after the treatment.

Figure 5: Application of APF gel using a tray (13)

c) The 38% SDF solution arrests the progression of the already cavitated carious lesions in primary teeth as well as hardening the lesions.

Figure 6: Application of SDF on a cavitated lesion on the upper incisors. (12)

Figure 7: Result of SDF application after 2 weeks (12)

1.3 Epidemiology and epidemiological indexes of dental fluorosis

As seen previously, fluoride is present in different levels in the atmosphere, water-borne fluoride being the one most consumed. Fluorosis is an endemic worldwide problem. Various regions have reported dental fluorosis, these regions are: Kenya, India, Brazil, Pakistan, China, Saudi-Arabia.

In India, about 19 states present high incidences of dental fluorosis because the country has high levels of fluoride in its drinking water sources.

Dean and evolve concluded that there is a link between excess fluoride in drinking water and dental fluorosis. (3) Dean's index was introduced as a way of classifying dental fluorosis and it is widely used. (5)

<u>Deans epidemiological index:</u>

0. Enamel is normal and (translucent and smooth)
1. Questionable: white flecks/spots on enamel
2. Mild: opaque areas mostly on tooth surface
3. Moderate and severe: pitting and brown stains on the tooth
4. Corroded appearance of the tooth.

Another epidemiological index commonly used as an alternative is the Thylstrup Fejerskov index because it consists of more categories related to severe dental fluorosis. This index is as follows: (14)

Thylstrup Fejerskov index:

0. Normal enamel after drying with air
1. Perikymata: white, narrow lines
2. More detailed lines of opacity following the perikyamata. Opacity of less than 2mm
3. Cloudy and irregular areas that are opaque
4. Total surface appears chalky white
5. Total surface opaque mostly at the pits but less than 2mm in diameter
6. Pits are arranged in bands less than 2mm whilst confluent areas show loss of enamel of less than 3mm. Marked attrition is present.
7. Changes in morphology due to the marked attrition and merging of pits. In irregular areas that take up less than ½ of the tooth's surface, there is outermost loss of enamel
8. In irregular areas that take up more than ½ of the tooth's surface, there is outermost loss of enamel
9. Loss in main part of enamel + changes in anatomy of the surface

Besides the fluoride found in water, there are other factors influencing dental fluorosis. These are, dental products, temperature, altitude and diet and nutrition. Observations have been made where small children swallow more fluoride from toothpastes which is a big risk factor for dental fluorosis and can cause nausea, stomach pain, which are symptoms of acute fluoride toxicity. (3) Dental fluorosis occurs equally in both genders and can occur in both primary and permanent dentition.

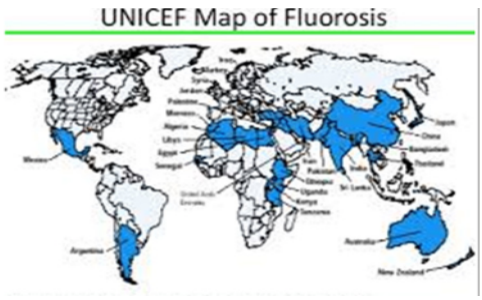


Figure 8: Dental fluorosis seen worldwide (3)

1.4 Characteristics of dental fluorosis

It is characterized by presence of brown discoloration of the teeth with mottled or pitted enamel and white, bilateral striations with stained plaque.

It can also be present in the dentin of permanent teeth which is seen histopathologically. There is an increase in the formation of interglobular dentin and an emphasis in the incremental lines of von Ebner.

In its clinical presentation, it is very severe in second permanent molars and premolars and less severe in the permanent mandibular incisors and first molars. The severity also depends on enamel thickness. The thicker the enamel, the more sever the fluorosis and is represented by snowy incisal edged and cusp tips. (5)
At the age of 24 months, mineralization of permanent incisors occurs whilst that of permanent second molars and premolars occurs by 6-7 years. The later the tooth undergoes mineralization, the more severe and prevalent is the dental fluorosis. This explains why the incisors and first molars are the least affected unlike the second molars and premolars which are the most. (4)

1.5 Complications of dental fluorosis:

Dental fluorosis is not only an aesthetic problem but it also leads to severe health conditions. Children with fluorosis tend to suffer from decreased metabolism in bones, magnesium deficiency and a delay in the somatic development.
In adults, most are diagnoses with kidney stones, thyroid disorders, osteoporosis in long bones. In addition to the health problems it comes with, dental fluorosis also results in a decrease in the person's self-esteem and self-confidence, erasing the smile seen in youngsters. (15)

In severe forms of dental fluorosis, structural integrity of dentin and enamel is jeopardized therefore increasing the likelihood dentin hypersensitivity, caries, tooth wear and discoloration. Longevity, function and aesthetics of the teeth affected are compromised and at times some patients with dental fluorosis could also suffer from skeletal fluorosis. (14)

1.6 Pathogenesis of dental fluorosis

Ameloblasts are the specialized epithelial cells that produce enamel as their function is to secrete proteins during the secretory stage that allows growth of a hydroxyl-apatite rod. Ameloblasts cause the enamel rods to grow in length during the secretory stage and in the maturation stage they remove the proteins to allow the rods to thicken in size. During the secretory stage of enamel formation, the risk of fluorosis due to exposure is the lowest. It is the highest when there is exposure during the secretory and maturation stage. Exposure to fluoride causes formation of hypomineralized enamel by the ameloblasts. The porosity can extend to the dentino-enamel junction in severe cases resulting in dental fluorosis. (3)

Proteoglycans and glycosaminoglycans are important in the mineralization of teeth. Fluoride inhibits interaction of the ground substance with the mineral phase because it competes with the binding sites of calcium preventing glycosaminoglycans from binding to the hydroxyapatite. (4)

1.7 Diagnosis of dental fluorosis

1.7.1 Diagnosis

Fluoride intake during the formation of enamel results in a variety of changes of the enamel, depending on the amount of fluoride taken in during the tooth formation period. The changes vary from fine white lines to a chalky appearance which then becomes opaque with more ingestion of fluoride, breaking down after eruption of the tooth. (4)

Diagnosis is very important as dental fluorosis can be confused with other disorders such as molar-incisor hypomineralization, amelogenesis imperfecta, tetracycline staining, turner syndrome and dental problems arising from celiac disease. (14)

When a clear diagnosis is made, the teeth need to be dry and viewed under good lighting.

Dental fluorosis has different levels of severity which are:

i. Mild fluorosis

This first sign of dental fluorosis presents white striae along the surface of the enamel and it is considered as the "snow cap phenomenon" because the cusp tips, marginal edges and incisal edges are opaque. These white lines run along the transverse ridges found on the tooth's surface (perikymata) which correspond to striae of Retzius (the incremental lines in the enamel).

As affectation increases, the lines become wider and at times fusion of the lines occur, producing cloudy white areas on the surface.

Figure 9: mild form of dental fluorosis (16)

ii. Moderate fluorosis:

Tooth surface presents cloudy white areas with presence of perikymata lines in between. There is also discoloration of the superficial enamel and with time, it causes damage of the surface. The tooth eventually loses its transparency and becomes chalky white.

Figure 10: Moderate form of dental fluorosis (16)

iii. Severe fluorosis:

There is affectation of the pits which merge and form horizontal bands across the tooth's surface. Accumulation of these result in large areas that are corroded.

Severe fluorosis represents a complete loss of the enamel surface and the tooth has a dark brown color. The enamel here is poorly mineralized as it contains more proteins and less minerals as compared to normal, healthy enamel.

Teeth with mild fluorosis can resist dental decay because of high levels of fluoride. However, teeth with severe fluorosis are highly susceptible to dental decay because they have lost their outer protective layer and have an uneven surface.

Figure 11: Severe form of fluorosis (16)

1.7.2 Risk of misdiagnosis:

There has been a frequent occurrence in the misdiagnosis of non-fluoride induced enamel defects. These types of defects are caused by two types of factors: local and systemic. The local factors that are the most important are periapical osteitis of the primary dentition and traumatic injuries. On the other hand, the systemic factors include a variety of conditions like chromosomal anomalies, nutritional deficiencies, nephropathies, intoxications, liver disease, infectious diseases and metabolic errors.

Enamel defects have a multifactorial cause therefore making it difficult to determine the specific cause of it. Looking at it from a clinical point, these defects are known as hypoplasia and diffused and demarked opacities.

As we have seen before, the diffused and demarked opacities come from a disturbance in the amelogenesis during the maturation stage whilst the hypoplasia is produces from a disturbance in the secretory stage. Enamel defects showing similarities in their presentation could have been produced by different causative factors.

Amelogenesis imperfecta is a perfect example that causes enamel defects which are most likely mistaken for enamel fluorosis. The three variants of amelogenesis imperfecta produce enamel defects similar to that of fluorosis. The hypoplasic lesions have a reduced quantity in enamel presenting pits and grooves on the surface, the hypocalcified lesions look pigmented and the enamel is soft and breakable and the hypomaturation lesions have an opaque and porous enamel. (8)

1.7.3 Important factors in the diagnosis:

In order to prevent the risk of misdiagnosis of dental fluorosis, a follow up plan should be created for the patient, especially from an early age such as 6 years old when the teeth are in the process of developing so as to detect any defects.

When diagnosing a person with dental fluorosis, it is important to focus on a few factors such as the level of fluoride in the supply of water. For the correct diagnosis,

it is very critical to know the fluoride concentration in tap water. Once this has been discovered, it is important to then know the oral hygiene of the person. Those with poor oral hygiene have damage to their teeth caused by cariogenic bacteria and not due to fluoride. Besides the oral hygiene, other factors which are related to health should be taken in to consideration. The consumption of tea is a factor that should also be considered as tea has a high absorption capacity and there have been studies that have shown a positive correlation between the consumption of tea and dental fluorosis. Lastly, the region of the patient, nutritional status and socioeconomic level should be considered because these are linked to both dental fluorosis and other dental defects. (8)

The table below will emphasize on the importance of considering key factors when diagnosing dental fluorosis as the chances of misdiagnosis can be high.

	FACTORS				POSSIBLE CAUSE
	High fluoride in tap water supply	Good Oral hygiene	Events that are health-related	High consumption of tea	
1.	No	No	No	No	Caries
2.	No	No	Yes	No	Caries OR Developmental enamel defects
3.	Yes	Yes	No	Yes	Dental fluorosis
4.	Yes	No	Yes	No	Developmental enamel defects
5.	Yes	Yes	Yes	Yes	Dental fluorosis OR Developmental enamel defects

1.8 Management and treatment of dental fluorosis:

When it comes to the treatment of dental fluorosis, it depends on the level of severity. It is also very crucial to examine and analyze the fluorosis index beforehand to determine the best treatment approach. (5)

The best preventive measure of dental fluorosis is controlling the amount of fluoride consumed. (1)

The best preventive methods of preventing fluorosis are (4):

- The toothpaste that children use should be a pea sized amount
- Children below the age of 6 should have parental supervision when brushing their teeth to avoid swallowing of toothpaste
- The formulas that babies use should contain water free of fluoride
- Fluoride products for children should be kept out of reach
- The availability of fluoride supplements should only be given when needed depending on other factors such as diet, drinking water and so on.
- Mouth washes containing high amounts of fluoride should only be prescribed by a medical professional

If the person is beyond the preventive stage, there is a variety of treatments depending on the severity of the fluorosis.

For mild cases of fluorosis, sometimes, no treatment is necessary. The main reason that patients opt for treatment is for aesthetic results. Dental bleaching, using the correct concentrations of hydrogen peroxide and micro abrasion can be done on dentition with mild fluorosis.

For moderate cases, composite resin fillings or aesthetic laminated veneers can be used. And for severe cases, prosthetic crowns may be the only option for long term survival. (1,16)

1.9 Prevalence of dental fluorosis:

Dental fluorosis is a worldwide endemic problem occurring mostly in developing countries. It is seen in various regions of the world such as Africa (Ethiopia, Tanzania, Kenya), India, China, Pakistan and Brazil. The main reason for high incidences of dental fluorosis in these areas is because of the presence of untreated water supplies and some geographical areas such as the East African rift valley with high, unstable amounts of fluoride in the groundwater.

1.9.1 In developed countries:

In developed countries, such as the United Kingdom, America, countries in the European union and Australia, a system of water fluoridation is used as a method of preventing caries. From our basic knowledge, too much fluoride results in dental fluorosis. However, these countries follow the WHO limit of 1.5 mg/L of fluoride therefore avoiding the problem of dental fluorosis. (9)

(i) USA:

In the USA, a recent report was done by the national center of health statistics showing us that data collected from two decades ago (2001-2004) that showed an increase in the prevalence of dental fluorosis was in fact incorrect. It states that fluorosis cannot happen due to the fluoridated water especially because the levels of fluoride in water are 0.7 mg/L.

The reason for this error was the inability of the examiner to distinguish between defects of the enamel and dental fluorosis. To prove this, a study was done in North Carolina in a population of 7700 children where there were more than 7 out of 10 children with no fluorosis and from the study, only 3.7% had fluorosis which was mild or moderate. (17)

(ii) ***China:***

In china, a study was done in a group of students and the prevalence of dental fluorosis was not too high, it was 13.4%. It is seen that in different regions, the prevalence changes. For example, in Guizhou province, the

prevalence is higher. This is because of pollution from coal burning which releases fluoride. In addition, rural areas get water from springs and wells that have a fluoride concentration higher than 1 ppm. (18)

1.9.2 In developing countries:

(I) India:

Since 2017, it is seen that there have been 62 million residents of India that have been affected by dental fluorosis due to consumption of fluoride higher than 3ppm through community water supplies. (4)

India contains many states that have groundwater containing concentrations of fluoride ranging from 0.532-8.802 ppm. The Rhotak district of Haryana in India is referred to as a high endemic area of dental fluorosis due to its high fluoride concentration in water. A study was done there in children and it showed that 51.9% of them had dental fluorosis. Different areas were also observed and it was seen that the higher the fluoride content in water, the higher the percentage of dental fluorosis and lower caries. (19)

(ii) Pakistan:

In Pakistan, the prevalence is not as high compared to other countries because 84% of the water supplies have fluoride levels less than 0.7ppm. From a group of children aged 12-15, the prevalence of fluorosis was 18.821%. (20)

(iii) Saudi Arabia:

In Saudi Arabia, the prevalence of dental fluorosis in children in the southern region was 20.43% whilst that in Najran was 59.72% showing that it varies in the different regions. One of the reasons for the high prevalence is that some of the population drink from well water which is untreated. Therefore, it is recommended to drink water from public supplies or companies where the

fluoride concentrations in the filtered water is in the recommended limit. Also, the people of Saudi Arabia drink a lot of Gahwa which is their local tea that is high in fluoride. (21)

(iv) Kenya:

In Juju, Kenya, the prevalence of dental fluorosis in children aged 12-15 was 50.1% and it was seen that the more severe the fluorosis, the higher the risk of gingivitis. This age group was picked because permanent teeth have erupted and most post eruptive changes of fluorosis occur. The main source of water is from the borehole which is untreated and this water is used for both cooking and drinking. (22)

(vi) Brazil and Uruguay:

In rural communities in the northern part of brazil, the water supply contains residual amounts of fluoride. The prevalence of dental fluorosis was 36.9% in areas where fluoride in water was <0.7ppm and 43.4% in areas containing >0.7ppm of fluoride in water. This was done in children aged between 6-12, Brazil is a very hot area meaning there is increased consumption of water containing traces of fluoride resulting in dental fluorosis. (23)

In Uruguay, the prevalence of dental fluorosis in 12 year olds was 45%. However, it is different from other countries because it does not have fluoridation of water besides for a few places that contain natural occurring fluoride in water. Instead, the children were exposed to other sources of fluoride such as toothpastes, fluoride supplements and mostly used in Uruguay, fluoridated salt. (24)

2. Relationship of other dental diseases and dental fluorosis:

Dental fluorosis is seen to be associated with some of the following dental diseases: caries, periodontal diseases and Molar-Incisor hypomineralization (MIH).

2.1 Dental caries and dental fluorosis:

Dental caries, also known as tooth decay is a disease that affects both primary and permanent teeth of people of all ages including the young children. It is the destruction of a tooth surface due to the acids formed by the bacteria found in plaque. In a favorable environment or under normal conditions, the demineralization (loss of calcium) is compensated by remineralization (uptake of calcium). However, under unfavorable conditions, the remineralization does not neutralize the demineralization resulting in caries. (12)

Figure 12: an example of early childhood caries (12)

Fluoride is very important in the reduction of the prevalence of dental caries. Its use is strongly supported by the world health organization (WHO) (12)

Studies were carried out and it showed us that areas which had higher levels of fluoride in their water presented higher dental fluorosis but the prevalence of caries reduced. An example is in the Rohtak district in Haryana, India which consists of many villages exposed to different fluoride concentrations in water. Balab a village with low fluoride (< 0.7ppm) had a prevalence of dental fluorosis of 0.62 and the mean DMFT WAS 1.90 whilst Tatuli, a village with high fluoride

concentrations (1.5-4ppm) had a prevalence of fluorosis of 1.83 and a mean DMFT of 0.95. (18)

DMFT is a universal, well known and used index to measure the prevalence of caries.

Besides fluoride in water, the intake of fluoride through toothpastes must be controlled in a way that is beneficial to prevent caries as well as prevent fluorosis. Below is a table showing the recommended fluoride in toothpastes in children. For children that have high risk of caries according to the caries risk assessment should use toothpastes containing > 1000 ppm of fluoride. (11)

AGE OF CHILD	FLUORIDE CONCENTRATION (ppm)	AMOUNT OF TOOTHPASTE (SIZE)
Up to 2 years	1000	Rice grain
2-6 years	1000	Pea-sized
>6 years	1450	Length of the head of the brush

2.2 Periodontal status and dental fluorosis:

Periodontal diseases are a major health problem alongside caries in the world. Periodontitis is the cause of most of the teeth loss in adults all over the world and most teenagers and children show signs of gingivitis.

The effect of fluoride on caries is very well established, however its effect on periodontal diseases still needs to be studied in depth.

Many studies show no difference in the prevalence of periodontal diseases in non-fluorosis and fluorosis areas however some show a positive correlation between fluorosis and periodontal status (25)

Periodontal status is measured using the CPI index. The indicators involved are periodontal pockets, bleeding and calculus. In a study done in Juju Kenya, there

was a positive association between fluorosis and periodontal status where the prevalence of gingivitis was 75.6% (21)

This association was explained by the fact that the loss of tooth structure and pitted enamel caused by the dental fluorosis could have resulted in plaque retention and the difficulty of maintaining an adequate oral hygiene. (21)

Other studies showed that gingivitis was present in moderate and severe fluorosis. (26)

Figure 13: Severe dental fluorosis with presence of plaque accumulation on the enamel surface (26)

2.3 Molar-Incisor Hypomineralization (MIH) and dental fluorosis:

MIH is of a systemic origin and is a single entity where there is enamel hypomineralization in one or more permanent molars and at times present on the upper and lower permanent incisors. It is a qualitative defect with no reduction in the thickness of enamel just white, brown or yellow opacities found on the incisal and mid-coronal areas of the tooth. In severe cases, there is destruction of the crown because of the fragile enamel.

MIH can also affect temporary dentition mostly the canines and second molars. This condition is referred to as deciduous molar hypomineralization. (27)

Figure 14: MIH of second degree on the permanent maxillary incisor (27)

Studies were done to see the relationship between MIH and dental fluorosis. Balmer stated that fluoride could be a protective factor for MIH whilst Koch said that MIH was not related to the intake of fluoride. However recent studies show that dental fluorosis and MIH compete. Dental fluorosis affects the second permanent molars and premolars more whilst MIH affects the first permanent molars.

From findings that were carried out, the frequency and severity of MIH seems to be lower in the presence of dental fluorosis. (28)

3. JUSTIFICATION AND STATE OF THE ART:

Reviewing the prevalence of dental fluorosis amongst developing and developed countries helps give us a clear picture on the causes that bring such differences. As we have seen, dental fluorosis is a two-sided coin where dental hygiene is at its prime in developed countries whilst developing countries suffer from higher levels of fluorosis. This study emphasizes on the effects of untreated water supply on the population and how they are the number one major cause in dental fluorosis. From this study, we are also able to see the association of dental fluorosis with other dental diseases such as caries or periodontal diseases. This information can be used to promote awareness in countries that lack education regarding the maximum fluoride concentration recommended and the amount of fluoride in everyday products such as the water we drink, toothpastes used, teas and many more. In addition, strategies can be formed to ensure that other dental diseases such as caries do not occur when reducing the fluoride concentrations in places that require this.

4. OBJECTIVES

4.2 General objective:

To review and provide an update in the prevalence of dental fluorosis and its impact on oral-health related quality of life.

4.3 Specific objectives:

a) To investigate the fluoride distribution in water supplies in developing countries and their association with dental fluorosis.

b) To compare the prevalence of dental fluorosis in developing and developed countries

c) To determine if there is a relationship between dental fluorosis and the periodontal status of children

d) To determine if there is an association between dental fluorosis and dental caries.

5. MATERIALS AND METHODS:

This study is a literature review that has been conducted in depth with the help of various international databases such as Medline, PubMed and Cochrane. Most articles have come from Medline.

A literature search was performed in the different databases and only terms related to our study were chosen using descriptors such as MeSh. To add on, we also used Boolean operators “OR” and “AND” for our search equation.

The search equation with the terms used was as follows:

(“dentistry” [MeSh Terms] OR “oral health” [MeSh Terms] AND “fluorides” [MeSh Terms])

(“dental caries” [MeSh Terms] OR “decay” [MeSh Terms] AND “fluorides” [MeSh Terms])

(“fluorosis, dental” [MeSh Terms] AND “water supply” [MeSh Terms])

(“fluorosis, dental [MeSh Terms] AND “developing countries” [MeSh Terms] AND “developed countries [MeSh Terms])

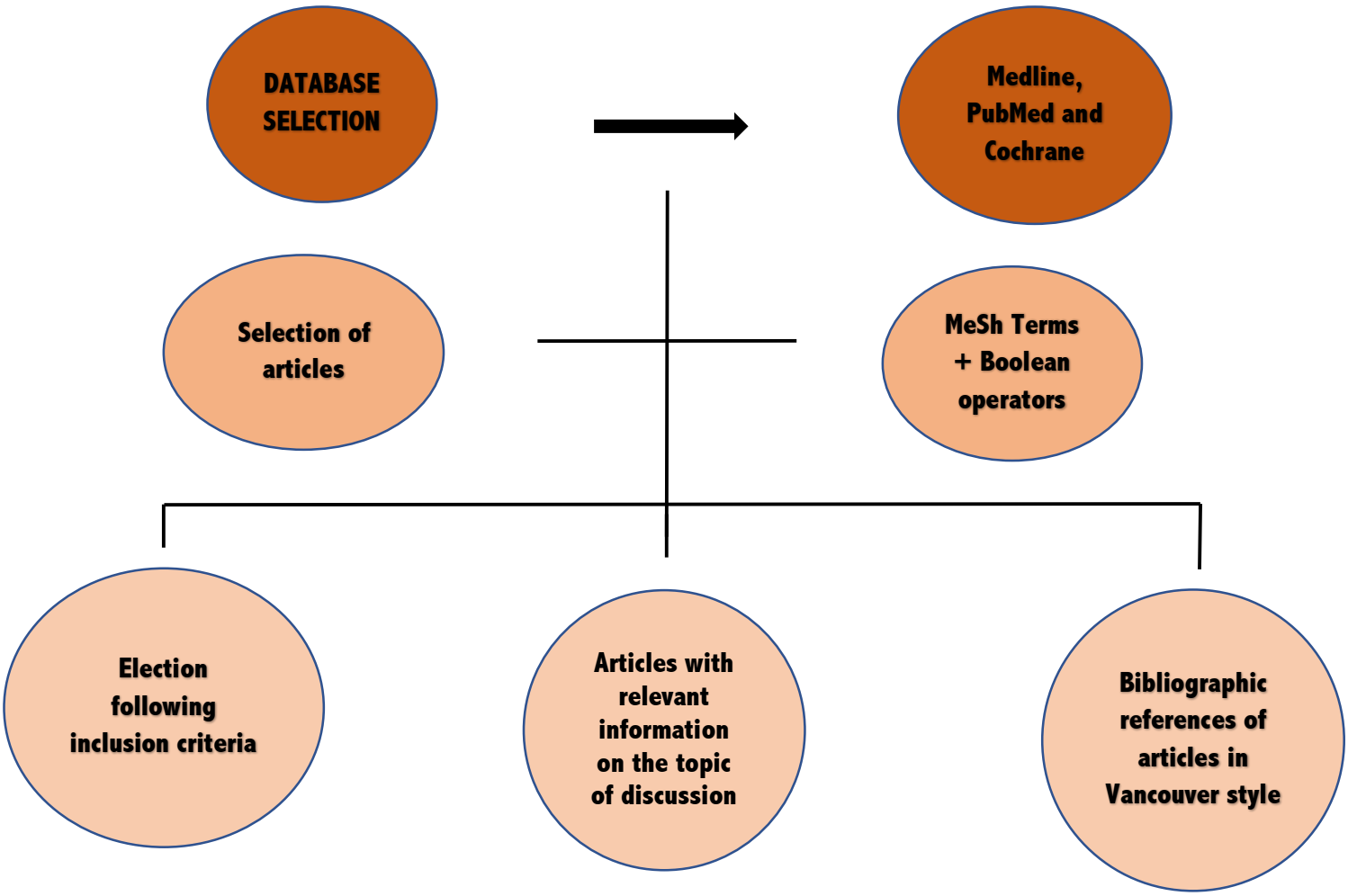
(“epidemiology” [Subheading] AND “prevalence” [MeSh Terms] AND “fluorosis, dental” [MeSh Terms])

(“dental caries” [MeSh Terms] AND “fluorosis, dental”[MeSh Terms])

(“fluorosis, dental”[MeSh Terms] AND “periodontal diseases”[MeSh Terms])

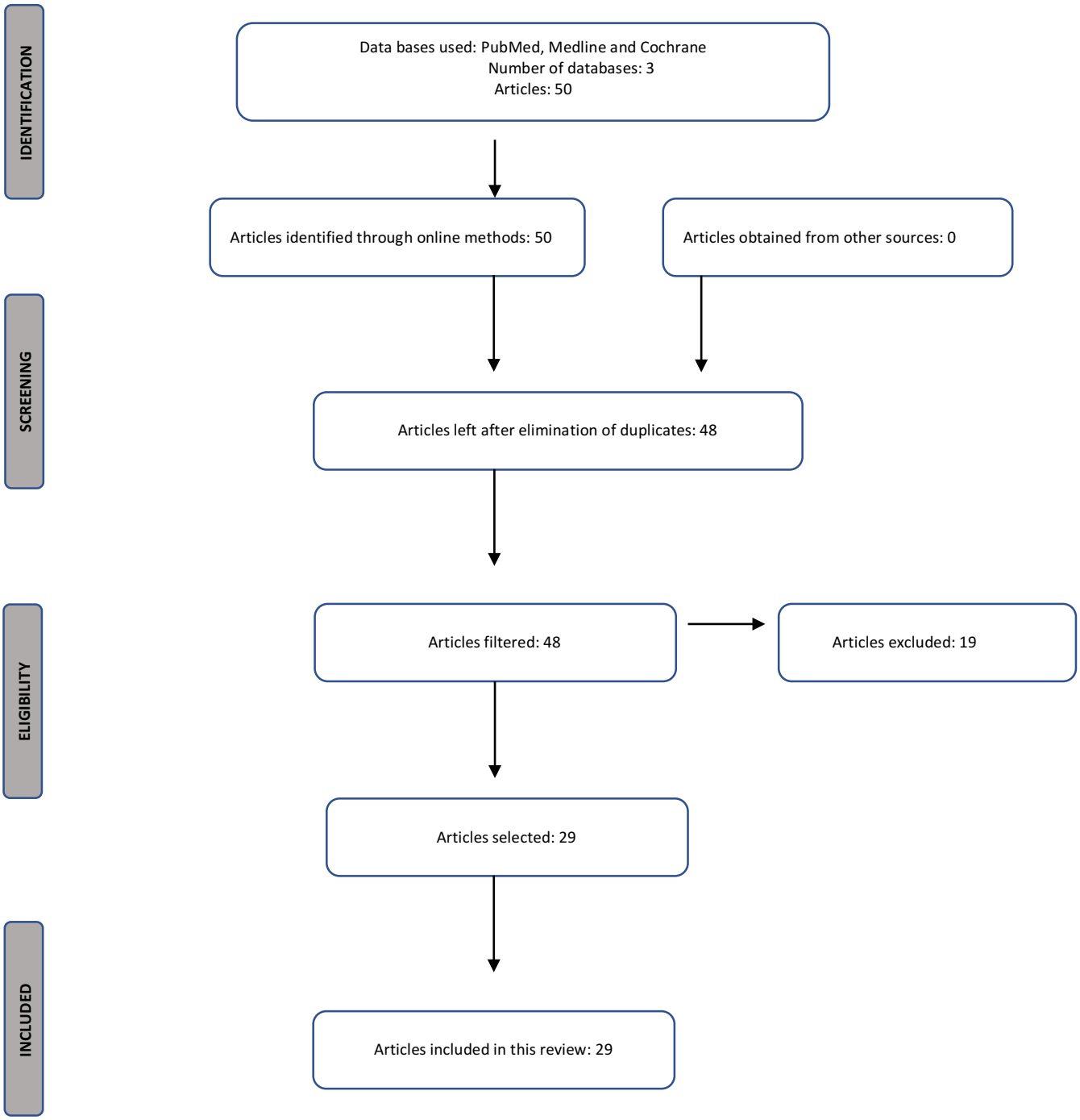
After having selected documents in the database, the inclusion and exclusion criteria was used to select the articles. The articles that were excluded were those that were not in English, limiting our work to articles in the English language. In addition, articles that were related to dental fluorosis on animals or articles solely focused on skeletal fluorosis and not dental were excluded.

As we collected articles for our study, we had included articles ranging from the years 2013-2022 except for two articles. One of the two articles which is about the exposure and prevention of fluorosis was published in 2009 whilst the other about fluoride in drinking water was published in 2006. These two articles were chosen as they contained relevant information for this topic.



6. RESULTS:

In this part of the paper, a variety of articles shall be summarized on the prevalence of dental fluorosis in different countries, both developed and developing to see the effects of controlled and uncontrolled fluoride concentrations in water supply on the populations. In addition to this, we will see if there are any associations or correlations of dental fluorosis with other dental diseases such as periodontal diseases and caries.



6.1 Dental fluorosis in developed countries:

REFERENCE	COUNTRY	STUDY SAMPLE	TYPE OF SAMPLE SELECTION	TYPE OF INDEX USED TO MEAUSRE FLUOROSIS	CONTROLLED FLUORIDE IN WATER?	PREVALANCE OF DENTAL FLUOROSIS
Yan Zhou et al. 2018 (18)	China	27,495 12-year-old students 49.6% male and 51.4% female	Multi-stage stratified random sampling	Deans index	Yes except for rural areas such as Ghizou where water from springs contains >1ppm fluoride	**13.4% fluorosis** very mild= 6.3%, mild= 4.3%, moderate= 2.3% and severe= 0.5%
American fluoridation society. 2019 (17)	USA (North Carolina)	7,700 children	Random sampling	Deans index	Yes Contains no more than 0.7 milligrams per liter	**3.7% fluorosis** mild, moderate and severe.

There are two studies under developed countries: one done in china (row 1) and the other done in the USA (row 2). Both studies used randomized samples and deans index to measure the prevalence of dental fluorosis. In china, the prevalence was 13.4% (18) whilst in USA it was 3.7% (17). Both countries presented low levels of dental fluorosis.

6.2 Dental fluorosis in developing countries:

REFERENCE	COUNTRY	STUDY SAMPLE	TYPE OF SAMPLE SELECTION:	INDEX USED TO MEASURE FLUOROSIS	CONTROLLED FLUORIDE IN WATER SUPPLY?	PREVALANCE OF DENTAL FLUOROSIS
Reena Rani, Ruchi Singhal et al. 2022 (19)	India	1262 (6-12-year-old) children males: 615 females: 647	Simple random sampling	Deans index	No, Rohtak district is found in high fluoride belt areas and most villages have a F-concentration of 1.5-4 ppm	**51.90% of dental fluorosis.** Very mild: 13.39%, mild:9.11%, moderate:8.16%, severe: 5.15%
Ashraf S, Khalid MU, Jamil H. 2018 (20)	Pakistan	526 (12-15-year olds) schoolchildren of Gojra	Cross-sectional study: randomized	Deans index	Yes, 84% of water supplies have a low fluoride concentration of 0.7 ppm	**18.44% of fluorosis** very mild:5.13%, mild:3.23%, moderate:1.71%, severe: 0.76%
Das G, Tirth V, Arora S, Algahtani A, Kafeel M, Alqarni AH, et al. 2020 (21)	Saudi Arabia	1150 (ages betwwen 9-50 years) male: 609 female: 541	Cross-sectional study: randomized	Deans index	No, fluoride concentrations ranged between 0.03-3.8ppm with higher concentrations in well water (most consumed)	**20.43% of fluorosis** Mild to moderate in patients drinking well water

Lucy W. Waweru, Harun Kimani, Opinya G. N., Ng'ang'a P. 2015 (22)	Kenya	225 primary school children (12-15 years old)	Descriptive cross-sectional study: randomized sample	Thylstrup and fejerskov Index (TFI)	No, fluoride concentrations range between 0.2-3.6ppm with higher concentrations in bore hole water (most consumed)	**50.7% of fluorosis** TFI 1-4: 41.4% TFI > 5: 8.7%
Fernandes IC, Forte FD, Sampaio FC. 2020 (23)	Brazil	610 school children (6-12-year-old)	Followed an inclusion criteria: 4 permanent molars erupted, any dental malformation not allowed	Thylstrup and fejerskov Index (TFI)	No, fluoride concentrations range between 0.06-1.98ppm	**Group 1 (< 0.7 ppm): 36.9%** **Group 2 (>0.7 ppm): 44.8%**
Angulo M, Cuitiño E, Molina-Frechero N, Emilson C-G.2019 (24)	Uruguay	1544 (12-year-old) school children	Descriptive cross-sectional, explanatory and observational study: randomized sample	Thylstrup and fejerskov Index (TFI)	Yes, however, there is both salt fluoridation and water fluoridation	**45.0% of dental fluorosis** TFI 1-2: 29.3%, TFI 3: 20.9%, TFI 4: 6.7%, TFI 5-9: 2.1%

There are 6 countries viewed under this in which all studies done were cross-sectional studies with the samples randomized except for the study done in Brazil which followed an inclusion criteria where the children needed to have all 4 permanent molars erupted and they should not present any other dental deformation such as MIH etc. Studies done in India, Pakistan and Saudi Arabia used dean's index to measure fluorosis whilst the ones done in Uruguay, Kenya and brazil followed the Thylstrup and fejerskov Index. The country that presented the highest prevalence of dental fluorosis was India with 51.9% (19) whilst the lowest was in Pakistan with 18.44%. (20)

The fluoride concentrations in all the countries listed above except for Pakistan and Uruguay were not controlled in the water supply. Water from boreholes or wells contain high amounts of fluoride and this water is a source of drinking water for countries such as Kenya and Saudi Arabia. In comparison to the developed countries, the developing countries presented a higher prevalence of dental fluorosis.

6.3 Association between caries and dental fluorosis:

REFERENCE	COUNTRY	STUDY SAMPLE	GROUP 1	GROUP 2	INDEXES USED	PREVALANCE OF CARIES	PREVALANCE OF FLUOROSIS
Mohd Nor NA, Chadwick BL, Farnell DJJ, Chestnutt IG. 2018 (29)	Malaysia	1600 9-12-year-old children	Children from a fluoridated area	Children from a non-fluoridated area	Deans index: fluorosis DMFT: caries	Fluoridated area: 9 year olds- **24.6%** 12 year olds- **25.5%** Non-fluoridated area: 9-year-old:**40.2%** 12-year-old: **53.5%**	Fluoridated area: 9 year olds- **31.9%** 12 year olds- **38.4%** Non-fluoridated area: 9 year olds- **6.5%** 12 year olds- **4.7%**
Manisha Vijayran et al. 2014 (25)	India (Haryana state)	2047: 5 and 12-year-old school children	Area 1: Water with fluoride concentration of 3.9ppm	Area 2: Water with fluoride concentration of 5.6 ppm	Deans index: fluorosis DMFT score: caries	Area 1: **76.5%** dental caries Area 2: **36.0%** dental caries	Area 1: **94%** Dental fluorosis Area 2: **84.1%** dental fluorosis

Two studies were reviewed to see if there is any relationship or correlation between dental fluorosis and dental caries. In the first row, the study done in Malaysia, for 12 year olds in the non-fluoridated area, the prevalence of caries was 53.5% whilst dental fluorosis with a dean's index of >2 was 4.7%. In the fluoridated area, the prevalence of caries was lower with 25.5% but the dental fluorosis was higher with 38.4% (29)

In the study carried out in India, 2 areas were examined. Both had high levels of fluoride with area 2 having it at 5.6 ppm, higher than the maximum lethal dose (4 ppm). Fluorosis was high in both however dental caries was higher in area 1 where there were lower fluoride concentrations than area 2. Area 1 had 76.5% of dental caries whilst area 2 had nearly half the prevalence at 36.0% (25).

6.4 Association between periodontal status and dental fluorosis:

REFERENCE	COUNTRY	STUDY SAMPLE	INDEXES USED	PREVALANCE OF PERIODONTAL PROBLEMS IN THE PRESENCE OF FLUOROSIS	PREVALANCE OF PERIODONTAL PROBLEMS IN THE ABSENCE OF FLUOROSIS
Lucy W. Waweru, Harun Kimani, Opinya G. N., Ng'ang'a P. 2015 (22)	Kenya	225 primary school children (12-15 years old)	Thylstrup and fejerskov Index (TFI): fluorosis CPI: periodontal status	Population with fluorosis: **50.7%** Prevalence of gingivitis: **75.6%**	Population without fluorosis: **49.3%** Prevalence of gingivitis: **24.4%**
Jaume Miranda-Rius et al. 2020 (26)	Tanzania	581 individuals picked from a public secondary school	Thylstrup and fejerskov Index (TFI): fluorosis Silness & Löe Plaque Index, the Community Periodontal Index: periodontal	CPI less than or equal to 2: **35.61%** with moderate fluorosis CPI > 2: **81.82%** with mild fluorosis	CPI less than or equal to 2: **24.91%** with no fluorosis CPI > 2: **18.18%** with no fluorosis

			status	Plaque index > 50%: **39.87%** with moderate fluorosis	Plaque index >50%: **20.25%**

In the study done by Lucy Waweru et al which took place in Kenya, in the population presenting fluorosis which was 50.7% there was a prevalence of gingivitis of 75.6% whilst in the population without fluorosis, the prevalence of gingivitis was lower with 24.4% (22).

In the study done in Tanzania, the prevalence of gingivitis and plaque was highest in the presence of moderate fluorosis. The prevalence with CPI of above 2 was 81.82% in the presence of fluorosis and 18.18% when there was no fluorosis present. Prevalence of plaque index of >50% was higher in the population with moderate fluorosis than without fluorosis (26)

7. DISCUSSION:

7.1 Developed vs developing countries:

Regarding the developed countries, two major ones were looked at: China and USA. Both countries had low levels of dental fluorosis. North Carolina in USA had a prevalence of 3.7% because the amount of fluoride in the water supply does not exceed more than 0.7 mg/l. (17) In addition to the fact that the water supplies are controlled, there is a lot of awareness regarding the fluoride concentrations in foods, toothpastes and other products that could increase the prevalence of dental fluorosis.

China on the other hand still presented low levels of fluorosis but it was higher than in the USA because there are a few villages in china such as Ghizou, which is found in the rural areas, that gets its water from springs which naturally contain more than 1 ppm of fluoride. Out of the 13.4% of fluorosis, mild fluorosis took a major chunk of it. (6.3 +4.3= 10.3%). (18)

In developed countries, we can therefore say that the prevalence of dental fluorosis is not very high due to the existence of clean water and awareness of the effects of excess fluoride on the body and teeth.

In developing countries, the prevalence of dental fluorosis is high and one of the main causes for this is the untreated drinking water supply. To make matters worse, most of these developing countries are tropic, meaning that they have a hot and dry climate. The hotter the climate, the increase in the consumption of water.

India presented the highest levels of fluorosis with 51.9% because most of the villages obtain drinking water from the ground which contain high levels of fluoride and most of this districts are found along high fluoride belt areas. (19)

The country with the second highest prevalence of dental fluorosis is Kenya with 50.7%. In Kenya, most water comes from boreholes that contain high levels of fluoride between 1ppm-5ppm. (22). Saudi Arabia also has a high prevalence of 20.43% due to the water consumed which is from wells (21).

The two developing countries that have the fluoride concentrations in water controlled were Pakistan and Uruguay. Pakistan presented the lowest prevalence of 18.44% in the developing country section. Since the water there contained fluoride below 0.7 ppm, the reason for the incidence of dental fluorosis was most likely due to excessive ingestion of fluoride containing supplements such as toothpastes, mouthwash rinses or even tea in this case as many people in Pakistan consume big amounts of tea. (20)
Even though in Uruguay, the water supply is controlled, the prevalence of dental fluorosis was high with 45%. This is because in addition to water fluoridation, the country added in salt fluoridation which also has a big effect on fluorosis causing it to increase. (24)

Therefore, for developing countries, the main reason for the high levels of dental fluorosis is the untreated water supplies. Alongside this, excessive consumption of foods and beverages that are high in fluoride concentration, such as tea, have led to an increase in dental fluorosis.

7.2 Dental fluorosis vs caries:

In Malaysia, it was seen that in the fluoridated area or area with 0.7-1.2ppm of fluoride in water, the prevalence of dental fluorosis was 31.9%-38.4% in the 9-12 year olds respectively whilst the prevalence of caries was 24.6%-25.4%. On the other hand, the ones exposed to low fluoride (0.5 ppm) showed a lower prevalence of fluorosis (6.4%-4.7%) and a higher prevalence of dental caries (40.2%-53.5%). (29). In low fluoridated areas, a higher number of missing teeth due to caries was seen because fluoride is one of the major components used to prevent caries. Fluoride helps in the formation of calcium phosphate as well as

increases structural stability and reduces volume of crystal formed. A reduction in these causes teeth to be prone to caries.

A similar result was seen in India where the sample was exposed to two different areas, both containing very high levels of fluoride in water. Dental fluorosis was very high in both as the fluoride was above the recommended level. In area 1, the concentration was 3.9ppm whilst in area 2 it was 5.6ppm. prevalence of caries was 76.5% in area 1 and in area 2 with the higher amount of fluoride, the prevalence of caries was nearly half with 36.0% showing us that fluoride is essential in the prevention of caries (25)

A high amount of fluoride in the water results in a high prevalence of dental fluorosis and a low prevalence of dental caries.

7.3 Dental fluorosis vs periodontal status:

In Kenya, the population that had dental fluorosis presented 75.6% of gingivitis whilst the rest of the population that did not have fluorosis presented 24.4% of gingivitis. The reason for this could be that the pitted and molted enamel present due to fluorosis makes it difficult to maintain good oral hygiene techniques and these surfaces could have resulted in more plaque retention increasing the likelihood of gingivitis. (22)

In Tanzania, the population with moderate fluorosis that presented a plaque index of more than 50% was 39.87% whilst the prevalence in the group that had no fluorosis was 20.25%. The group that had moderate fluorosis had both high plaque index, CPI index and a high prevalence of bleeding during probing. This is because the retentive and rough surfaces of the enamel produced because of fluorosis. As the degree of fluorosis increases, the prevalence of periodontitis also increases. (26)

8. CONCLUSION:

- The main objective was to review and provide an update on the prevalence of dental fluorosis and its impact on oral health related quality of life. It is seen that the prevalence of dental fluorosis in countries where water fluoridation is used in a controlled manner is low which emphasizes on the benefits of fluoridation of water. Other countries with low economic status that are not able to access good oral health, topical fluorides, have untreated water supplies and have lack of knowledge on the effects of fluoride on dental health present a higher prevalence of dental fluorosis. However, as time progresses, awareness has increased and there are many available treatments to prevent dental fluorosis as well as treat the esthetic problems caused by dental fluorosis. These availabilities have improved oral health related quality of life in countries and populations that have access to this and can afford it.

- The fluoride distribution in water supplies had a range in different countries. India for example had a range of 0.532-8.802 ppm, Kenya had a range of 1.7 ppm-2.0ppm. These developing countries presented a big range with concentrations above the recommended level. It was seen that the bigger the range in fluoride concentrations, the higher the prevalence of dental fluorosis as it shows that the water is uncontrolled and untreated. For such countries, implementation of de-fluoridation systems should be put in to place and the water supply should be treated with the fluoride concentration controlled.

- It is seen that the prevalence of dental fluorosis is higher in developing countries than developed. This is because the developed countries have fluoridation systems already installed and there is an increase in the dental health education regarding fluoride and its effects. In developing countries, the main cause is the untreated water supplies. Countries such as India, China and Saudi Arabia present high fluoride concentrations in their water. Implementation of partial de-fluoridation in the borehole water, wells and Springwater should be done. In addition to this, public talks and demonstrations should take place to increase

the awareness of fluorides and the supplements that contain high concentrations such as tea which is highly consumed in these countries.

- There is a negative correlation with periodontal health and fluorosis. As dental fluorosis increases, periodontal health worsens. This is because dental fluorosis results in changes in the structure of the tooth depending on the severity. These changes increase plaque retention. In addition to this, the oral hygiene is poor causing inflammation of gums and easy bleeding when probing. As the severity of fluorosis increases, the prevalence of periodontitis increases. However, more studies need to be done to fully agree with the statement stated above.

- There is a negative correlation between caries and fluorosis. When we increase the amount of fluoride ingestion, the prevalence of dental fluorosis increases whilst the prevalence of caries decreases. The main aim is to achieve a good balance between the prevention of fluorosis and the caries-preventive measures with the use of fluoride. Therefore, the optimum level of fluoride needed to obtain the benefits of caries prevention whilst minimizing the risk of fluorosis is 0.7ppm. Water fluoridation alongside oral health promotion on a global scale can help reduce the risk of dental caries and improve standards of living.

9. BIBLIOGRAPHY/REFERENCES:

1. Abanto, Jenny & Rezende, Karla & Salazar Marocho, Susana & Alves, Fabiana & Celiberti, Paula & Ciamponi, Ana. Dental fluorosis: Exposure, prevention and management. Medicina oral, patología oral y cirugía bucal. 2009. 14.

2. Chankanka O, Levy SM, Warren JJ, Chalmers JM. A literature review of aesthetic perceptions of dental fluorosis and relationships with psychosocial aspects/oral health-related quality of life. Community Dentistry and Oral Epidemiology. 2010;38(2):97–109.

3. Mohanta A. Dental fluorosis- revisited. Biomedical Journal of Scientific & Technical Research. 2018;2(1).

4. Mallishery, Shivani & Sawant, Kashmira & Jain, Mokshi. Fluoride Toxicity: A Review on Dental Fluorosis and Its Prevalence in India. IOSR Journal of Dental and Medical Sciences.2020. 48-53

5. Mani G, Shahroom NSB, Ramakrishnan M. Interventions in management of dental fluorosis, an endemic disease: A systematic review. Journal of Family Medicine and Primary Care. 2019;8(10):3108.

6. Khandare AL, Gourineni SR, Validandi V. Dental fluorosis, nutritional status, kidney damage, and thyroid function along with bone metabolic indicators in school-going children living in fluoride-affected hilly areas of Doda District, Jammu and Kashmir, India. Environmental Monitoring and Assessment. 2017;189(11).

7. J. Fawell, K. Bailey, J. Chilton, E. Dahi, L. Fewtrell and Y. Magara. Fluoride in drinking water. 2006

8. Revelo-Mejía IA, Hardisson A, Rubio C, Gutiérrez ÁJ, Paz S. Dental fluorosis: The risk of misdiagnosis—a review. Biological Trace Element Research. 2020;199(5):1762–70.

9. Sally-Ann Botchey, Jing Ouyang, Sayinthen Vivekanantham. Global Water Fluoridation: What is Holding Us Back? Alternate therapies. 2015. 21(3)

10. Farías P, Estevez-García JA, Onofre-Pardo EN, Pérez-Humara ML, Rojas-Lima E, Álamo-Hernández U, et al. Fluoride exposure through different drinking water sources in a contaminated basin in Guanajuato, Mexico: A deterministic human health risk assessment. International Journal of Environmental Research and Public Health. 2021;18(21):11490.

11. Koberová Ivančaková R, Radochová V, Kovácsová F, Merglová V. Exogenous intake of fluorides in caries prevention: Benefits and risks. Acta Medica (Hradec Kralove, Czech Republic). 2021;64(2):71–6.

12. Ending childhood dental caries: WHO implementation manual. Geneva: World Health Organization; 2019

13. Shah S, Bhaskar V, Venkataraghavan K, Choudhary P, Ganesh M, Trivedi K. Efficacy of silver diamine fluoride as an antibacterial as well as antiplaque agent compared to fluoride varnish and acidulated phosphate fluoride gel: An in vivo study. Indian Journal of Dental Research. 2013;24(5):575.

14. Niazi FC, Pepper T. Dental Fluorosis. StatPearls. 2022

15. Strużycka I, Olszewska A, Bogusławska-Kapała A, Hryhorowicz S, Kaczmarek-Ryś M, Grabarek BO, et al. Assessing fluorosis incidence in areas with low fluoride content in the drinking water, fluorotic enamel architecture, and composition alterations. International Journal of Environmental Research and Public Health. 2022;19(12):7153.

16. Akpata ES. Therapeutic management of dental fluorosis: A critical review of literature. Saudi Journal of Oral Sciences. 2014;1(1):3.

17. Dental fluorosis in the United States. American fluoridation society. 2019

18. Yan Zhou et al. The prevalence and associated risk factors of dental fluorosis in china. The 4th National Oral Health Survey Chin J Dent Res 2018;21(3):205–211

19. Reena Rani, Ruchi Singhal et al. Prevalence of dental fluorosis and dental caries in fluoride endemic areas of Rohtak district, Haryana. Journal of Indian society of periodontics and preventive dentistry. 2022.

20. Ashraf S, Khalid MU, Jamil H. Dental fluorosis. The Professional Medical Journal. 2018;25(02):242–5.

21. Das G, Tirth V, Arora S, Algahtani A, Kafeel M, Alqarni AH, et al. Effect of fluoride concentration in drinking water on dental fluorosis in southwest Saudi Arabia. International Journal of Environmental Research and Public Health. 2020;17(11):3914.

22. Lucy W. Waweru, Harun Kimani, Opinya G. N., Ng'ang'a P. M. Periodontal Status of Children with Dental Fluorosis in Juja, Kenya. American Journal of Medicine and Medical Sciences 2015, 5(1): 7-9

23. Fernandes IC, Forte FD, Sampaio FC. Molar-incisor hypomineralization (MIH), dental fluorosis, and caries in rural areas with different fluoride levels in the drinking water. International Journal of Paediatric Dentistry. 2020;31(4):475–82.

24. Angulo M, Cuitiño E, Molina-Frechero N, Emilson C-G. The association between the prevalence of dental fluorosis and the socio-economic status and area of residence of 12-year-old students in Uruguay. Acta Odontologica Scandinavica. 2019;78(1):26–30.

25. Manuja N, Chaudhary S, Sinha A, Chaitra TR, Vijayran M. Co-relation of body mass index, dental caries and periodontal status with fluorosis in different high fluoridated areas of Haryana State, India. Indian Journal of Dental Research. 2014;25(6):722.

26. Miranda-Rius J, Brunet-Llobet L, Lahor-Soler E, Mrina O, I Mashala E, J Mahande M. Periodontal and dental conditions of a school population in a volcanic region of Tanzania with highly fluoridated community drinking water. African Health Sciences. 2020;20(1):476–87.

27. Sosa-Soto J, Padrón-Covarrubias AI, Márquez-Preciado R, Ruiz-Rodríguez S, Pozos-Guillén A, Pedroza-Uribe IM, et al. Molar incisor hypomineralization (mih): Prevalence and degree of severity in a Mexican pediatric population living in an endemic fluorosis area. Journal of Public Health Dentistry. 2021;82(1):3–10.

28. Restrepo M, Rojas-Gualdrón DF, de Farias AL, Girotto-Bussaneli D, Santos-Pinto L. Association between frequency and severity of dental fluorosis and molar incisor hypomineralization. Journal of Clinical Pediatric Dentistry. 2022;46(1):30–4.

29. Mohd Nor NA, Chadwick BL, Farnell DJJ, Chestnutt IG. The impact of a reduction in fluoride concentration in the Malaysian water supply on the prevalence of fluorosis and dental caries. Community Dent Oral Epidemiol. 2018;46:492–499

30. Casaglia A, Cassini MA, Condò R, Iaculli F, Cerroni L. Dietary fluoride intake by children: When to use a fluoride toothpaste? International Journal of Environmental Research and Public Health. 2021;18(11):5791.

31. Saldarriaga A, Rojas-Gualdrón DF, Restrepo M, Bussaneli DG, Fragelli C, de Cássia Loiola Cordeiro R, et al. Clinical changes in the severity of dental fluorosis: A longitudinal evaluation. BMC Oral Health. 2021;21(1).

32. Macey R, Tickle M, MacKay L, McGrady M, Pretty IA. A comparison of dental fluorosis in adult populations with and without lifetime exposure to water fluoridation. Community Dentistry and Oral Epidemiology. 2018;46(6):608–14.

33. James P, Harding M, Beecher T, Browne D, Cronin M, Guiney H, et al. Impact of reducing water fluoride on dental caries and fluorosis. Journal of Dental Research. 2020;100(5):507–14.

34. Curtis AM, Levy SM, Cavanaugh JE, Warren JJ, Kolker JL, Weber-Gasparoni K. Decline in dental fluorosis severity during adolescence: A cohort study. Journal of Dental Research. 2020;99(4):388–94.