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Relationship of Fluoride Content in Drinking Water with the Occurrence of Dental Fluorosis in Children

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ABSTRACT

Dental fluorosis remains a significant public health concern in regions where drinking water contains elevated levels of naturally occurring fluoride. This study explores the relationship between fluoride concentration in drinking water and the occurrence of dental fluorosis in children, who are particularly vulnerable during the years of tooth development. Excessive ingestion of fluoride, especially at concentrations exceeding the recommended limit of 1.5 mg/L, disrupts enamel mineralization and leads to varying degrees of fluorosis, ranging from mild opacities to severe brown staining and pitting. The study highlights how environmental factors such as geological composition, groundwater depth, and climatic conditions, along with biological factors like age, nutritional status, and individual susceptibility, influence fluorosis prevalence. Results from previous epidemiological findings consistently show a direct correlation between rising fluoride levels and increased fluorosis severity among children aged 6–14 years. The abstract underscores the importance of regular monitoring of fluoride levels in drinking water, implementing defluoridation techniques, and raising community awareness to mitigate long-term health impacts. Effective interventions, including alternative safe water sources and early dental screening programs, are essential to reduce the burden of dental fluorosis and protect the oral health and well-being of children living in fluoride-endemic regions.

Keywords: *Fluoride Concentration, Dental Fluorosis, Children, Public Health, Enamel Defects.*

I. INTRODUCTION

Fluoride is a naturally occurring element found in rocks, soil, air, and water, and it plays a significant role in dental health. At optimal levels, fluoride strengthens tooth enamel, enhances remineralization, and prevents dental caries. However, excessive fluoride intake, particularly during the critical years of tooth development, can lead to dental fluorosis—an irreversible enamel defect characterized by discoloration, surface roughness, and, in severe cases, pitting of the teeth. The primary source of

IJAMSR

International Journal of Advanced Multidisciplinary Scientific Research (IJAMSR) ISSN:2581-4281

fluoride exposure for most populations is drinking water, especially in rural and semi-arid regions where groundwater is the main supply. Consequently, studying the relationship between fluoride concentration in drinking water and the prevalence of dental fluorosis in children is essential for public health planning and preventive dentistry. Children aged 6 to 12 years are especially vulnerable, as this is the period when permanent teeth are forming and mineralizing.

Prolonged ingestion of water containing fluoride levels above the recommended limit—typically 1.0 mg/L according to WHO guidelines—can interfere with enamel matrix formation. The severity of dental fluorosis depends not only on fluoride concentration but also on the duration of exposure, nutritional status, climate, and individual susceptibility. Hot climates, for example, are associated with increased water intake, thereby increasing total fluoride exposure even at moderate concentrations. In many regions of India, Africa, China, Mexico, and parts of the Middle East, natural fluoride levels in groundwater exceed safe limits, contributing to a high incidence of dental fluorosis in children. In countries like India, states such as Rajasthan, Gujarat, Andhra Pradesh, and Uttar Pradesh report fluoride concentrations as high as 4–10 mg/L in some groundwater sources. The resulting health burden affects children's oral health, self-esteem, and overall quality of life.

Discoloration and enamel defects often become socially and psychologically distressing, particularly for adolescents. Understanding the relationship between fluoride content in drinking water and dental fluorosis involves assessing multiple environmental, biological, and socio-economic factors. Environmental factors include geological composition, water source depth, and aquifer characteristics. Biological factors include individual differences in fluoride metabolism, age, genetic predisposition, and dietary patterns—such as calcium and vitamin D intake, which influence fluoride absorption. Socio-economic factors include access to safe drinking water, awareness about fluoride toxicity, availability of defluoridation techniques, and health-seeking behavior.Research in the past two decades has consistently shown a positive correlation between high fluoride levels in drinking water and increased prevalence of dental fluorosis. Several epidemiological studies have reported that children consuming water with fluoride levels above 1.5 mg/L show significantly higher fluorosis scores on Dean's Index and the Thylstrup–Fejerskov Index (TFI).

Moreover, chronic exposure beginning at infancy greatly amplifies the severity. The progression from mild white opacities to severe brown stains and enamel pitting reflects both the fluoride concentration and the duration of exposure. Understanding this relationship is not just academically important but also crucial for community health policy. Identification of high-fluoride areas enables early intervention through de-fluoridation technologies, provision of alternative water sources, and public awareness programs. Techniques such as the Nalgonda technique, activated alumina filtration, and community RO plants have been widely recommended in high-risk regions. School-based dental screening also plays a vital role in early detection and management. Thus, evaluating how fluoride content in drinking water influences the occurrence of dental fluorosis in children helps guide preventive strategies, informs public health decision-making, and contributes to improving the quality of life of affected communities. It remains an important area of research for environmental scientists, dentists, pediatricians, and policy-makers.

IJAMSR

International Journal of Advanced Multidisciplinary Scientific Research (IJAMSR) ISSN:2581-4281

II. REVIEW OF LITERATURE

Pandora, Imelda et al., (2024) when teeth are still developing, consuming too much fluoride can cause dental fluorosis. The fluoride in water, whether naturally occurring or artificially added, is a common source of this high fluoride intake. When fluorosis happens, it can discolour teeth. This discoloration can look like brown stains or yellow spots that spread unevenly over the teeth's surface and make them look less than attractive. The goal of this study is to identify the factors that contribute to dental fluorosis in children and adolescents (aged 6–15) and to establish a correlation between water fluoridation and this condition. The researchers in this study used databases like PubMed and Google Scholar to look for articles published in the last twelve years that dealt with the same topic. We found ten studies. The study's design and conduct were flawed because of its low response rate and its failure to properly identify and address potential confounding factors. Variations in sample sizes, water fluoridation concentrations, indices employed, and target populations contributed to the imprecision of the statistical data collection. Regardless of severity, ten trials demonstrated dental fluorosis. Fluoride levels in drinking water have been rising, and with them, the number of cases of dental fluorosis. Within the range of 0.6-1 ppm, you can find fluorine in potable water.

Kannan, S Karthiga (2017) the healthy growth and resistance to cavities of enamel rely heavily on fluoride. Enamel hypoplasia, however, occurs at fluoride levels more than 1 PPM. This research is to determine the frequency of dental caries and fluorosis among schoolchildren in the Al-Zulfi and Majmaah areas of the Saudi province of Riyadh, as well as to estimate the fluoride level in the drinking water in these localities. The study involved the analysis of drinking water samples from the study area; the organization of screening camps for schoolchildren aged 7 to 15, and the inclusion of 157 children using simple random sampling. We made sure to get the parents' written consent. We used SPSS version 21 to do the statistical analysis on the data we gathered. Fluorosis was diagnosed in 39 children (24.8%) and the fluoride level in the drinking water sample ranged from 0.56 PPM to 0.09 PPM. In the primary dentition, 9 (23%) showed signs of fluorosis, while in the permanent dentition, 30 (76.9%) showed signs. Total caries in permanent teeth average 1.87, whereas primary teeth average 2.35. Dental cavities were more common in the study location and the water supply lacked the ideal amount of fluoride. Dental fluorosis may be caused by different dietary fluoride sources, though. This study emphasizes the need of keeping fluoride levels in drinking water at an optimal level and keeping an eye on how much fluoride people consume through other food sources.

Rathore, S. et al., (2017) the frequency and intensity of fluorosis in children's teeth as a function of various fluoride concentrations in the water supply in the Jodhpur district of Rajasthan. In order to measure dental fluorosis, 1029 youngsters, ranging in age from 8 to 14, were polled. Using a relevant questionnaire that had been pre-tested, we obtained demographic information. Using Dean's Index, we documented the existence and severity. The four groups with varying levels of fluoride in the water supply were the subjects of the study. Using an ion-specific electrode (the Thermo Scientific Orion Star A329, USA), we were able to determine the amount of fluoride in the water supply. In the boari block of the Jodhpur district in Rajasthan, the concentration of fluoride in the drinking water varied between 0.8 and 10 parts per million. Out of 254 participants, 95 (37.40%) had dental fluorosis in category I (<0.8 ppm), 112 (44.09%) in category II (1.2-1.6 ppm), 120 (47.24%) in category III (2.8 ppm), and 169 (61.6%) in category IV (4-10 ppm). The prevalence of fluorosis varied according to the different levels of

IJAMSR

International Journal of Advanced Multidisciplinary Scientific Research (IJAMSR) ISSN:2581-4281

fluoride concentration in the drinking water. Out of 1029 youngsters surveyed, 496 (or 48.20%) had dental fluorosis. People living in areas with highly fluoridated water had the highest prevalence of dental fluorosis in children. Elevated levels of fluoride in drinking water were associated with an increase in the incidence and severity of dental fluorosis. That is why there is a strong correlation between the amount of fluoride in drinking water and the frequency of dental fluorosis. The prevalence of dental fluorosis in youngsters is significantly correlated with rising fluoride levels.

Shanthi, M et al., (2014) the current research set out to determine whether there was a correlation between the fluoride (F) levels in the water supply, dental fluorosis, and dental caries in a sample of 9–12 year olds from the Nelakondapally Mandal in the Khammam region of Andhra Pradesh. One thousand fifty students, ranging in age from nine to twelve, were chosen at random from stratified sampling to participate in a cross-sectional analytical study. The participants came from various regions with varying concentrations of naturally occurring F in their drinking water. Using World Health Organization (WHO) basic survey procedures, the children's teeth were examined for fluorosis. The child's general dental health was evaluated using the decayed missing filled teeth (DMFT)/dmft index. The following statistical tests were used: Z-test, ANOVA, Chi-square, standard deviation, standard error, and mean. The current investigation found that 74.9% of the population had fluorosis. Bore well water users had the greatest incidence of dental fluorosis in children. About 56.5% of the people in the study had cavities. Optimal F area children had the lowest caries prevalence and mean DMFT/dmft scores, whereas suboptimal F area children had the highest. Nelakondapally Mandal in the Khammam district has moderate fluorosis prevalence and significant caries prevalence in areas below the ideal F zones.

III. RESEARCH METHODOLOGY

Study Design

The present study adopted a cross-sectional descriptive research design.

Sampling Technique

A convenient sampling technique was adopted.

Sample

A total of 160 children, aged 6–14 years and belonging to rural regions of Jabalpur district, attending the Dental OPD at Government Medical College, Jabalpur, were included in the study. Each child/parent completed a self-assessment questionnaire. Samples of drinking water from wells, bore wells (pressure pump), and bore wells (hand pump) were collected in clean polyethylene bottles.

Data Collection Procedure

Before initiating the study, the selection of the survey area was performed based on the geological mapping data indicating regions with variable groundwater fluoride levels. Dental examination was carried out using a mouth mirror and probe under natural daylight. Dental fluorosis was assessed using Dean’s Fluorosis Index.

IJAMSR

International Journal of Advanced Multidisciplinary Scientific Research (IJAMSR) ISSN:2581-4281

Statistical Analysis

Fluoride concentration in the water samples was estimated using an ion-selective electrode at the Water Quality Testing Laboratory under the Public Health Engineering Department, Jabalpur. The collected data were statistically analyzed using the chi-square test.

IV. DATA ANALYSIS AND INTERPRETATION

Table 1: Age-Wise Distribution of Dental Fluorosis

Age (Yrs.)	Dental Fluorosis Present (%)	Dental Fluorosis Absent (%)
9	92.0	8.0
10	88.0	12.0
11	74.0	26.0
12	91.0	9.0
13–14	84.0	16.0

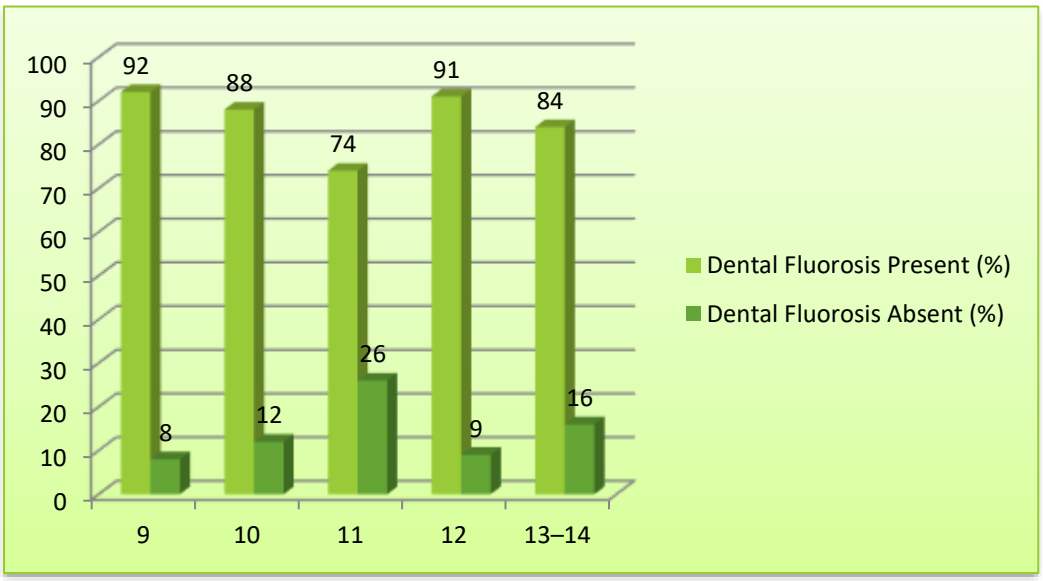

Figure 1: Age-Wise Distribution of Dental Fluorosis

Dental fluorosis is very prevalent across all age groups, according to the age-wise distribution of cases. This suggests that fluoride was widely used throughout the formative years of teeth formation. Children at the age of 9 exhibit the greatest prevalence of fluorosis symptoms (92%), followed by children at the age of 12 at 91%, indicating that exposure to the condition was sustained throughout early infancy. The prevalence is somewhat lower among 11-year-olds (74% affected and 26% unaffected), although it is quite significant among 10-year-olds (88%). A frequency of 84% in children ages 13–14 suggests that fluorosis is still prevalent throughout the preteen and teen years. The pattern shows that dental fluorosis is a major problem in the investigated population as a whole, affecting over 75% of children across all age groups. This emphasizes the need of implementing preventative measures to reduce the danger of fluoride poisoning and of closely monitoring fluoride levels in drinking water.

IJAMSR

International Journal of Advanced Multidisciplinary Scientific Research (IJAMSR) ISSN:2581-4281

Table 2: Association between Years of Residence and Dental Fluorosis among Children

Duration of Residence (Yrs.)	Dental Fluorosis Present (%)	Dental Fluorosis Absent (%)
Up to 9	97.0	3.0
9–10	89.0	11.0
11–12	93.0	7.0
Above 13	81.0	19.0

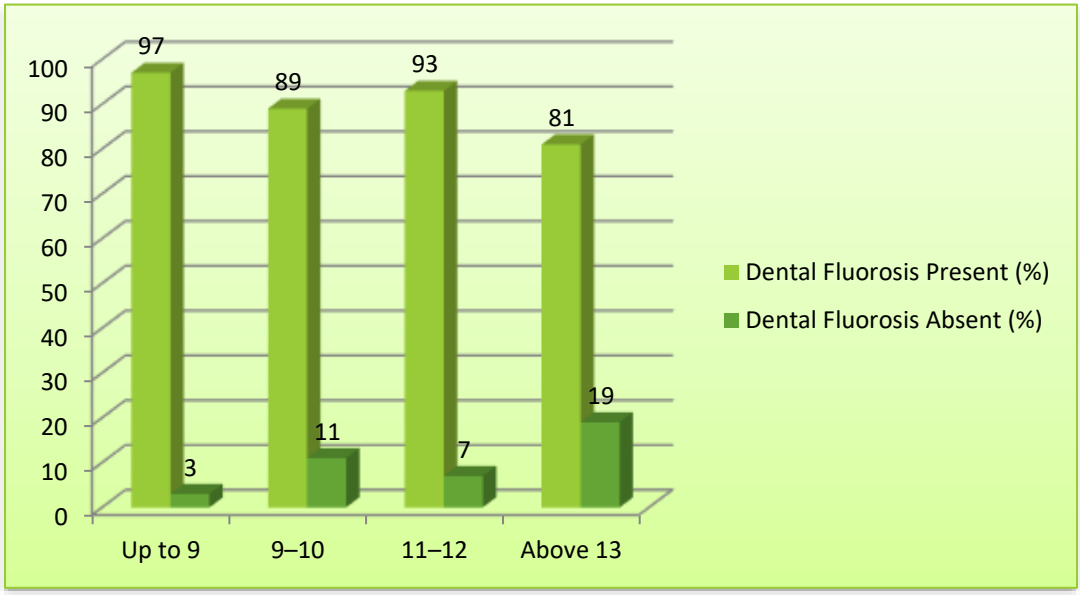

Figure 2: Association between Years of Residence and Dental Fluorosis among Children

Longer exposure to environmental fluoride sources in the community has a substantial impact on the prevalence of fluorosis in children, as shown by the correlation between the length of time a person lives there and the incidence of dental fluorosis. Children's living in the neighborhood for up to nine years had the greatest incidence, at 97%, indicating that exposure occurs early and continues throughout the most important years for tooth development. The fluorosis levels of those who resided in the area for 9-10 years are 89%, which is significantly lower but still excessive. The fact that fluorosis is so common among children who lived there for 11–12 years shows that long-term exposure is still a major concern. Perhaps reflecting differences in exposure, increased knowledge, or changes in water sources over time, the lowest frequency of 81% is shown among children who have lived in the region for more than 13 years. Regardless of these variations, fluorosis is still quite common regardless of how long someone lives in a home. In summary, the findings show that dental fluorosis risk is significantly enhanced with prolonged exposure to water or other sources contaminated with fluoride, highlighting the need for community-wide monitoring and intervention programs.

IJAMSR

International Journal of Advanced Multidisciplinary Scientific Research (IJAMSR) ISSN:2581-4281

Table 3: Association Between Source of Drinking Water at Home and Dental Fluorosis Among Children

Source of Drinking Water	Dental Fluorosis Present (%)	Dental Fluorosis Absent (%)
Well Water	67.0	33.0
Bore Well with Pressure Pump	91.0	9.0
Bore Well with Hand Pump	98.0	2.0

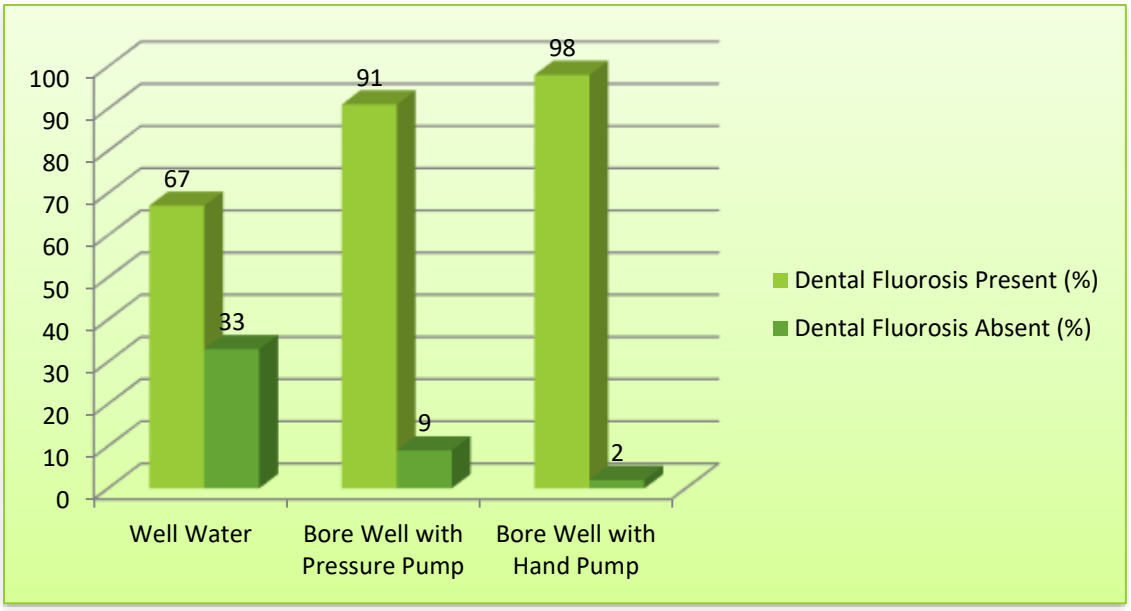

Figure 3: Association Between Source of Drinking Water at Home and Dental Fluorosis Among Children

The correlation between children's dental fluorosis rates and their household water supply shows a robust relationship between water source and fluoride exposure. With a frequency of 98%, children who drink water from bore wells that are pumped by hand are most likely to be drinking water with high levels of fluoride. The next system on the list is bore wells with pressure pumps; in these cases, fluorosis is seen in 91% of the youngsters, indicating that the groundwater that is reached via these systems also contains high amounts of fluoride. On the other hand, fluorosis is far less common among youngsters who drink water from wells (67% vs. 33%). Fluoride levels in groundwater may vary widely depending on the source, with hand-pumped bore well water being the most dangerous. In general, the findings show that the risk of dental fluorosis is much greater in children who use groundwater, especially from bore wells. To reduce fluoride exposure from potentially harmful water sources, it is necessary to conduct targeted water testing, implement defluoridation policies, and raise public awareness.

IJAMSR

International Journal of Advanced Multidisciplinary Scientific Research (IJAMSR) ISSN:2581-4281

Table 4: Impact of Black Tea Intake on the Occurrence of Dental Fluorosis

Black Tea Consumption (in Glass)	Dental Fluorosis Present (%)	Dental Fluorosis Absent (%)
Nil	68	32
1	95	5

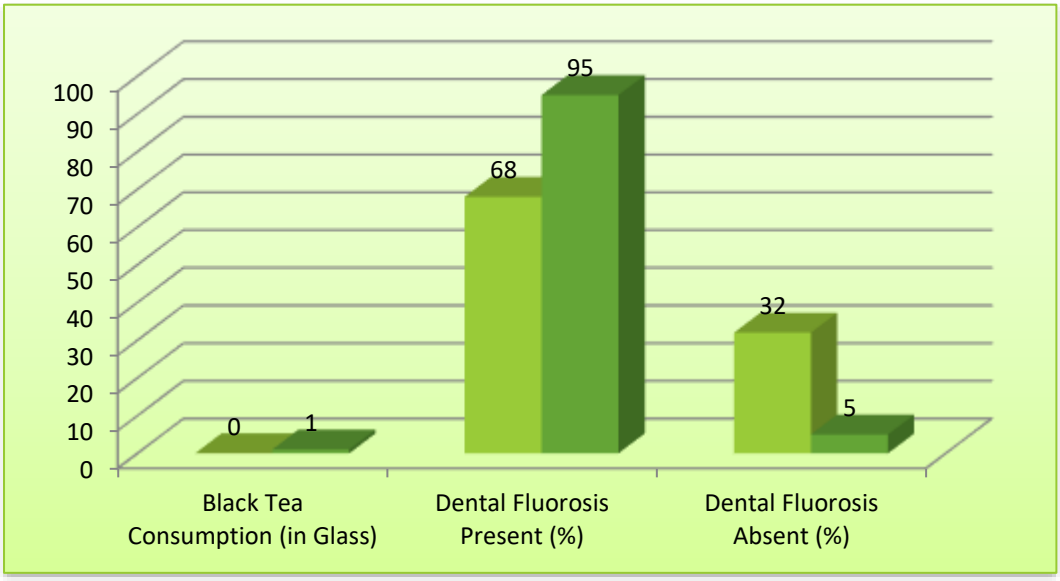

Figure 4: Impact of Black Tea Intake on the Occurrence of Dental Fluorosis

Children who drink black tea are more likely to develop dental fluorosis, according to the statistics in Table 4. The frequency of fluorosis is 68% among those who do not drink black tea, whereas 32% of the population is free of the illness. On the other hand, the frequency of fluorosis is 95% in youngsters who drink one glass of black tea each day, with just 5% remaining unaffected. Since tea leaves absorb a lot of fluoride from the soil, this dramatic spike implies that black tea may be a major source of fluoride consumption. The risk of dental fluorosis seems to be increased even with only one glass of black tea per day, especially when consumed in conjunction with other fluoride-containing background sources like groundwater or fluoridated goods. Children are more likely to develop dental fluorosis if they drink black tea on a regular basis, according to the results. This is an extra source of fluoride in the diet that is typically ignored.

Table 5: Impact of Milk Consumption on the Prevalence of Dental Fluorosis

Milk Consumption (in Glass)	Dental Fluorosis Present (%)	Dental Fluorosis Absent (%)
Nil	93.0	7.0
1	74.0	26.0

IJAMSR

International Journal of Advanced Multidisciplinary Scientific Research (IJAMSR) ISSN:2581-4281

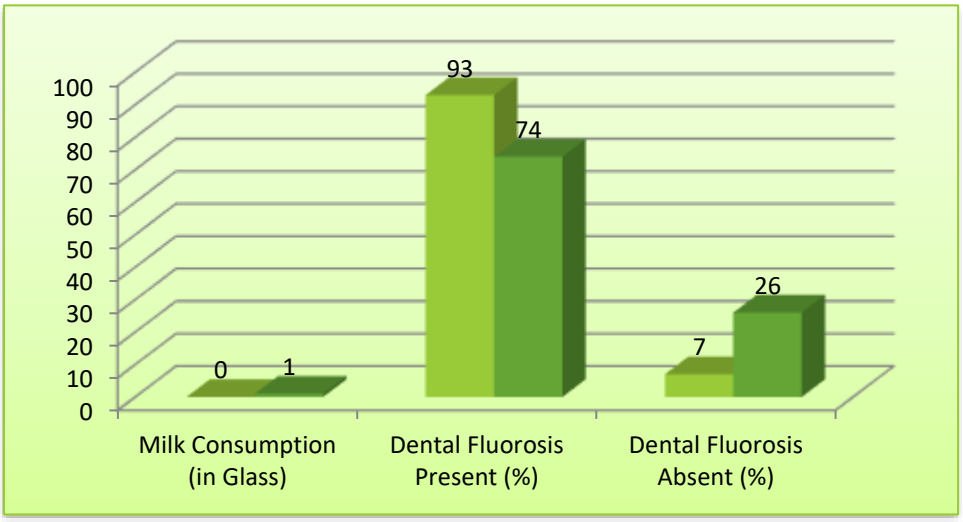

Figure 5: Impact of Milk Consumption on the Prevalence of Dental Fluorosis

A clear correlation between children's milk intake and dental fluorosis prevalence is seen in Table 5. A far greater prevalence of fluorosis (93% vs. 7%) is seen in those who do not drink milk. On the other hand, the prevalence of fluorosis is 74% lower and 26% lower in children who drink one glass of milk daily. This counterintuitive correlation raises the possibility that consuming milk might mitigate the effects of dental fluorosis. The mineral and calcium content of milk may lessen the likelihood of enamel fluorosis during tooth development by reducing the absorption of fluoride in the gastrointestinal system. Healthy enamel production may also be associated with a child's improved nutritional condition, which may be enhanced when they drink milk. Consistent milk drinking may lessen the effects of fluoride exposure and the risk of dental fluorosis, according to the study.

Table 6: Correlation between the Usage of Aluminium Vessels and the Occurrence of Dental Fluorosis

Usage of Aluminium Vessels	Dental Fluorosis Present (%)	Dental Fluorosis Absent (%)
Yes	97.0	3.0
No	53.0	47.0

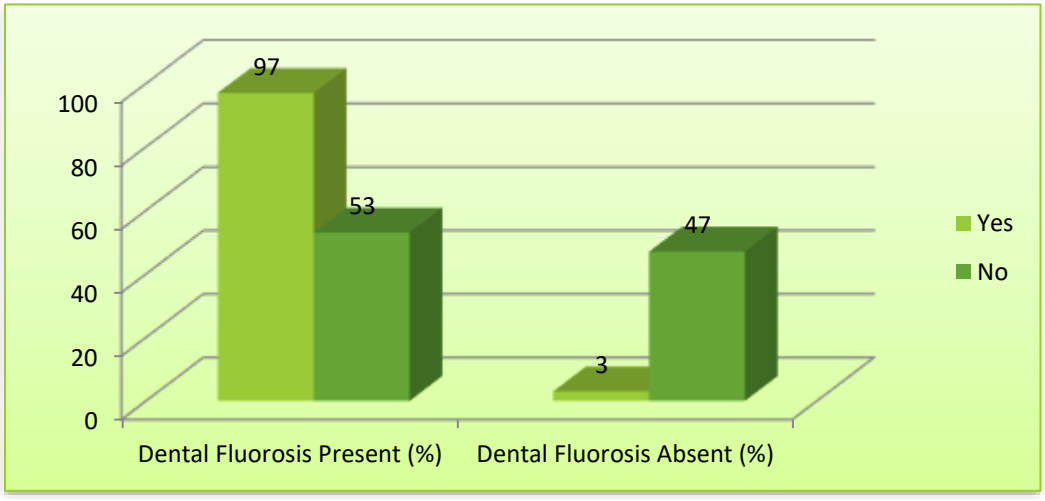

Figure 6: Impact of Aluminium Vessel Usage on Dental Fluorosis Prevalence

IJAMSR

International Journal of Advanced Multidisciplinary Scientific Research (IJAMSR) ISSN:2581-4281

The frequency of dental fluorosis among youngsters is strongly correlated with the usage of aluminium pots for cooking or storing water, according to the data in Table 6. An alarmingly high frequency of fluorosis of 97% has been reported in homes using aluminium containers, with just 3% of youngsters remaining unaffected. The incidence of fluorosis is 53% in families that do not use aluminium vessels, and 47% of children in such households do not have the disease. This notable disparity raises the possibility that aluminium containers enhance the absorption or retention of fluoride in beverages and foods. Fluorosis of the teeth is more likely to occur when aluminium forms complexes with fluoride ions, which may increase the body's bioavailability of fluoride. Groundwater supplies used by households utilizing aluminum may have significant quantities of naturally occurring fluoride, which increases exposure even further. Taken together, the results suggest that aluminum containers might play a significant role in the development of fluorosis, highlighting the need of raising knowledge about safer options like glass or stainless steel cutlery.

V. CONCLUSION

The relationship between fluoride concentration in drinking water and the occurrence of dental fluorosis in children is clear, consistent, and well-supported by research. Excessive fluoride exposure during the tooth-forming years leads to structural and aesthetic defects in enamel, with severity strongly influenced by fluoride levels, duration of exposure, and individual susceptibility. Communities relying on high-fluoride groundwater show significantly greater prevalence of dental fluorosis compared to those with optimal fluoride levels. Children are especially vulnerable due to their developing dentition and higher relative water intake. The findings emphasize the need for continuous monitoring of fluoride levels in drinking water, particularly in regions known for naturally high groundwater fluoride. Implementing safe water supply systems, defluoridation methods, and community education programs can substantially reduce the burden of fluorosis. Preventive strategies should focus on early detection, promoting awareness among parents and caregivers, and encouraging the use of alternative water sources when necessary. Ultimately, understanding and addressing the link between drinking-water fluoride and dental fluorosis is essential for safeguarding children's oral health, improving quality of life, and guiding public health interventions in fluoride-endemic areas.

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IJAMSR

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