ORIGINAL ARTICLE

Prevalence of dental Fluorosis and its epidemiological determinants in a Hilly state of India- A Cross-Sectional Study

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Abstract

Background: From a human health perspective, fluorine acts as a double-edged sword as its deficiency leads to dental caries, while excess fluorine intake is associated with the development of fluorosis (dental and skeletal). **Aims and Objectives:** This study was conducted with the aim of assessing the prevalence of dental fluorosis associated with different water fluoride concentrations (naturally occurring sources). Additionally, sociodemographic, lifestyle and anthropometric measurements were analyzed to determine their association with the prevalence of dental fluorosis. **Methodology:** A cross-sectional study was conducted for 12 months in children aged 6-19 years in the Rudraprayag district of Uttarakhand. The fluorosis assessment was done as per Dean's index. The sample size was 1400. Data was collected using a predesigned, pretested, semi-structured questionnaire by personal interview method. A p-value of < 0.05 was considered statistically significant. **Results:** Overall prevalence of dental fluorosis was 19.1% (267/1400). Surprisingly, 39% of these cases of fluorosis were drinking water within normal fluoride range (0.5 mg/l- 1.0 mg/l). Only 4 villages out of thirty reported having more than 1 mg/l fluoride content in the drinking water. The children of higher socioeconomic status, class 2 and above, had 1.78 times more chances of being affected by fluorosis than children of lower socioeconomic status (p = 0.015, 1.78 (1.12 - 2.83)). Dental fluorosis was twice more common among stunted children (p = 0.011, 2.08 (1.16 – 3.73)). **Conclusion:** For the first time, this study reported the occurrence of dental fluorosis in Uttarakhand. Fluorosis was reported even if water fluoride concentration was below 1mg/liter may be due to high altitude of the region.

Keywords

Fluorosis; Public Health; Children; Dental Health

Introduction

Fluorine is the 13th most common element in the earth's crust and is widely distributed in forms such as fluorspar (CaF_2), cryolite (Na_3AlF_6), and fluorapatite ($Ca_5(PO_4)_3$). These forms of fluorine are water soluble; therefore, higher water fluoride levels are observed in areas where groundwater interacts with fluoride-containing rocks at the time of percolation. (1)

From a human health perspective, fluorine acts as a double-edged sword as its deficiency leads to dental caries, while excess fluorine intake is associated with the development of fluorosis (dental and skeletal).

The World Health Organization (WHO) has recommended fluorine intake in drinking water at levels between 0.5 and 1.5 mg/l, which provides protection against dental caries. (2) However, higher concentrations of fluorine (> 1.5 mg/L) in water may lead to dental or skeletal fluorosis depending on different factors such as intensity and duration of exposure. Other sources of exposure to fluorine intake include milk, meat, (3) fluoride-containing toothpaste, tobacco, tea, (4) fluoridated salt, (5) etc.

Excessive consumption of fluorides for an extended period in various forms results in deleterious effects on different body tissues, such as teeth leading to dental fluorosis. It is characterized by staining and pitting of teeth and, in more severe cases, brown discoloration and disfigurement of teeth, presenting a corroded-looking appearance. (6) Dental fluorosis has become a global problem with increasing prevalence in many countries. (7) It is endemic in at least 25 countries globally, with India being among the worst affected countries, influencing the lives of around 60 million people nationwide. (8,9) Out of these, 6 million are children under the age of 14 years. Many Indians rely on groundwater for drinking purposes, and water in many places is rich in fluoride.

Uttarakhand is a state in northern India with difficult geographical terrain and climatic conditions. There are a total of 13 districts; Rudraprayag is situated in the upper Himalayan region of the state. This predominantly hilly state has poor road connectivity, and small scattered settlements; all of these factors contribute to problems with access to health services. In 2009 Central Ground Water Board has reported high fluoride level (>1.5 mg/l) in few villages of Rudraprayag, and there have been some complaints from villagers that their children are facing frequent dental problems, although there has been no previous report of dental fluorosis from the area. Therefore, this study was planned to assess the prevalence of dental fluorosis along with its associated epidemiological determinants in district Rudraprayag.

Material & Methods

Study setting and study population: Rudraprayag district lies in the northwest direction of Uttarakhand and is situated in the Himalayas. There are 688 villages, and the district's total population is around 242,285, of which around 40,000 (children 6-19 years of age) constitute the study population.

Study design and sample size calculation: A cross-sectional study was conducted in the Rudraprayag district. The sample size was calculated, taking a prevalence of 28.6% at a 95% confidence level, an alpha error of 0.05, and a margin of error of 12%. (10) A design effect of 2 was also considered, and the final sample size came out to be 1,386, rounded off to 1400.

Study duration: Data collection was done for a period of 12 months.

Strategy for data collection: The study used a multi-stage random sampling method. The district has three blocks and 27 Nyaya panchayats. Almost one-third i.e., 10 Nyaya panchayats were selected for the study. 3 Nyaya – panchayats were selected from two smaller blocks, and 4 Nyaya-panchayats from one larger block. From each Nyaya-panchayat, three villages were randomly selected. Thus, a total of 30 villages were selected. Further using probability-proportional-to-size (PPS) sampling fourteen hundred children aged 6 – 19 years who were residents of the district in their first five years of life were enrolled for the study. Those children with a history of chronic medical illness (for example- renal, hepatic, and endocrine disorders) were not included in the study.

Ethical issues and Informed consent: Assent of children (more than 7 years) and consent of parents was obtained before data collection. The study was conducted after approval from the Institutional Ethics Committee (IEC).

Data collection: Data was collected using a predesigned, pretested, semi-structured questionnaire by personal interview method. Along with this, the oral examination of children was done in the presence of parents/guardians.

The study tool included questions related to participants' sociodemographic status, lifestyle, and food habits.

Dental fluorosis assessment : Dental fluorosis was evaluated using the Dean's index, as follows –

Dean's Index Code – 0 (Normal) – The enamel represents the usual translucent semi-vitriform type of structure. The surface is smooth, glossy and usually pale creamy white in colour.

Dean's Index Code – 1 (Questionable) – The enamel discloses slight aberrations from the translucency of normal enamel, ranging from a few white flecks to occasional white spots.

Dean's Index Code – 2 (Very Mild) – Small, opaque, paper white areas scattered irregularly over the tooth but not involving as much as approximately 25 per cent of the tooth surface.

Dean's Index Code – 3 (Mild) – The white opaque areas in the enamel of the teeth are more extensive but do involve as much as 50 percent of the tooth.

Dean's Index Code – 4 (Moderate) – All enamel surfaces of the teeth are affected and surfaces subject to attrition show wear. Brown stains are frequently a disfiguring feature.

Dean's Index Code – 5 (Severe) – All enamel surfaces are affected, and hypoplasia is so marked that the general form of the tooth may be affected. The major diagnostic sign of this classification is discrete or confluent pitting. Brown stains are widespread, and teeth often present a corroded-like appearance.

Fluoride estimation in water sample: Water samples were collected randomly from 3 different water sources in each selected village. So, a total of 90 water samples were collected and analyzed. All samples were stored in sterile polypropylene containers at room temperature until use. The concentration of fluoride (mg/L) was measured by the ion-selective electrode (Orion company A324pH benchtop model) using the EPA – approved ISE test procedures.

Socioeconomic status assessment: The modified BG Prasad scale was used to measure families' socioeconomic status. It is based on per capita monthly income. (11)

Anthropometric measurements:

Weight: Participants' body weight was measured with a weighing scale manufactured by Krups with the least count of 100 grams. The WHO Anthro-plus program was used to calculate the age –and sex – specific Z scores for weight. (12), Following indicators were used to assess the nutritional status-

Underweight for age and sex, BMI-for-age Z (BMIAZ) score – 2.0 SD to – 3.0 SD.

Severe underweight for age and sex, BMI -for-age Z (BMIAZ) score <-3.0 SD.

Overweight for age and sex, Z (BMIAZ) score > +1 SD.

Normal – 2 SD ≤ z ≤+1 SD.

Height: Height was measured by portable stadiometer manufactured by Thermocare, India, with least count of 1 cm. The WHO Anthro-plus program was used to calculate the age- and sex-specific Z scores for height. (12) Following indicators were used for defining stunting-

(1) Low height-for-age and sex (stunting), - 3 SD ≤ height-for-age Z (HAZ) score < − 2.0 SD; and

(2) Severe stunning, height-for-age, and sex, HAZ score < − 3.0 SD.

(3) Normal -2 SD ≤ z ≤+2 SD

Data analysis: The collected data was entered into MS-Excel and was analyzed using Statistical Package for Social Sciences (SPSS).

RESULTS

Among the total participants, 52.3% (732) were girls, and 47.7% (668) were boys. The maximum children belonged to the age group of 10-14 years. Most of the families belonged to lower socioeconomic status, BG class 4 44.1% (617) constituting a significant proportion. (Table 1)

In the present study, the overall prevalence of dental fluorosis (as per Dean's Index) was found to be 19.1% (267), of which 18% of children were affected by severe dental fluorosis. (Table 2)

Water samples (90) collected from different parts of the district showed varying fluoride concentrations. It ranged from as low as 0.03 ppm to 2.03 ppm in some places. Out of which, 13.3% (12) samples had fluoride concentration above permissible limit (>1 ppm). Water fluoride concentration showed a significant positive association with the prevalence of dental fluorosis among the study participants. In the places with <0.7 ppm fluoride in drinking water, only 1% of children were affected by fluorosis, whereas at >1 ppm fluoride, about 92% (150) of children suffered from dental fluorosis ($p < 0.001$). (Table 3 and Figure 1,2 and 3)

As can be seen from Table 4, fluorosis was frequently observed among children 12-16 years of age. There were no significant differences in the prevalence and severity of dental fluorosis among the boys and girls (p = 0.68). The children belonging to higher socioeconomic status, class 2, were more frequently affected by fluorosis (25.5% (35)) than the children of lower socioeconomic status (14.8% (132)). Eating habits and source of water were found to be significantly associated with the presence of fluorosis (p < 0.001).

Stunning (27.7% (74)) and severe stunning (11.6% (31)) were more frequent in children affected by fluorosis as compared to children with the absence of fluorosis with (14.9% (169)) and (5.3% (60)) of children stunned and severely stunted respectively. Moreover, as the severity of fluorosis increased, the extent of stunting also increased. Among the children with the absence of fluorosis, only 14.9% were stunted. It increased to 17.9% in children affected by mild fluorosis, but as the severity of fluorosis increased, there was a sharp rise in children suffering from stunting (32.2%). This study also showed no significant difference between the prevalence of dental fluorosis among normal and underweight children (p = 0.147).

Table 5 shows the regression analysis of factors statistically significantly associated with the prevalence of dental fluorosis. It can be seen from the table that the children belonging to higher socioeconomic status, class 2 and above, had 1.78 times more chances of being affected by fluorosis as compared to children of lower socioeconomic status (p = 0.015, 1.78 (1.12 - 2.83)). Stunting was commonly observed in fluorosis-endemic areas, and stunted children had two times more chances of being affected by dental fluorosis (p = 0.011, 2.08 (1.16 – 3.73)).

DISCUSSION

Prevalence of dental fluorosis across the Country

The overall prevalence of dental fluorosis among the children of the district was found to be around 19.1%, with its prevalence ranging from 1.5% to 95.7% in different areas of the district. In the areas where the fluoride concentration in drinking water increased above the permissible limits of 1mg/l, more than 92% of children were affected by dental fluorosis. The fluoride concentration was above the permissible limit in 16.7% of the samples. When compared with other parts of the country, a remarkably high prevalence of fluorosis was recorded in Nalgonda, Arunachal Pradesh (71.5%) (13), and Punjab (82.3-96.3%) (14). At the same time, the Durg district of Chhattisgarh (8.2) (15) and Unnao, Uttar Pradesh (28.6) (10) had a low prevalence of dental fluorosis. This variation in the prevalence of dental fluorosis could be attributed to the levels of fluoride in the water available in the area.

In the district, dental fluorosis among children was even noticed at water fluoride concentration of 0.5 ppm which is much lower than the WHO permissible limit (1 ppm) signifying that at high altitudes fluorosis can occur even at low level of fluoride in drinking water. Similar observation was noted by Al - Omoush et al (16) in Jordan, Ruwaished (higher altitude) had higher incidence and severity of dental fluorosis as compared to Kuraymah (lower altitude) even though their drinking water fluoride levels were less than 0.5 ppm.

Age: The children above 12 years of age in the district were more frequently affected by dental fluorosis as compared to children of ≤12 years. The intake of water increases with age, which may lead to an increased prevalence of fluorosis among more than 12-year-old children. With age, the frequency of tea intake also increases, and it is considered a significant source of fluoride through diet. Other studies also recorded similar findings. In a cross-sectional study in the Kolar district of Karnataka, Narayanamurthy et al. found that the prevalence of dental fluorosis was significantly associated with increasing age. (17)

Gender: In Rudraprayag, an almost similar prevalence of dental fluorosis was observed among boys and girls, and no significant association of dental fluorosis was observed with gender. A ten-year systematic review and meta-analysis by Akuno et al. (18) also signified that the impact of gender on dental fluorosis epidemiology was found to be inconclusive. However, a study by Narayanamurthy et al. found that fluorosis was more prevalent in females than males and was significantly associated with gender. (17)

Socioeconomic status: The present study established that dental fluorosis was related to the families' socioeconomic status (SES). The prevalence of fluorosis was significantly higher among children from higher SES families. Whereas, in a study conducted by Shekar et al., they found no significant association between dental fluorosis and socioeconomic status. (13) In general, the good brands of toothpaste available in the markets that higher socioeconomic status families prefer are usually fluoridated and repeated brushing of children leads to higher chances of fluoride ingestion through toothpaste. Carbonated beverages and packed snacks with high amounts of black salt also have a considerable amount of fluoride. Children of higher socioeconomic status have easier access to them, leading to additional fluoride intake than children of lower socioeconomic status families. On the other hand, families of lower SES in hilly areas mainly raise cattle like cows and buffalo, goat for their living and agricultural purposes. Thus, milk and milk products are a prominent part of their diet, and they have been reported to protect against fluorosis.

Underweight and Stunting: On analysis of participants' weight, the children in the fluorosis endemic areas frequently had normal weight compared to the control group with the absence of fluorosis. However, this difference was very slight and insignificant. A similar finding was recorded in a study in China, which showed that exposure of school-age children to a low to moderate level of fluoride was positively associated with overweight/obesity. (19) In studies of Brazilian school children from Paraiba (20) and among school students from Delhi (21), BMI was not associated with dental fluorosis.

In our study, we found that children affected by fluorosis had higher prevalence of stunting (27.7%) and severe stunting (11.6%). As severity of fluorosis increased, there was sharp rise in children suffering from stunting (32.2%). In a study conducted by Prasad et al (22) in Karnataka, 21.6% of children were stunted and 8.6% of children were found to be severely stunted. Among severely stunted children, 37.5% and 5.4% were found to have mild and moderate fluorosis respectively while no one had severe fluorosis. They also found that in stunted children, 34.3% and 10% of children had mild and moderate fluorosis respectively.

Conclusion

This study gave very important conclusions –

- The presence of dental fluorosis in Rudraprayag district got confirmed and it is a first report from State of Uttarakhand.
- Increasing prevalence of dental fluorosis among participants was positively associated with the water fluoride content.
- As Rudraprayag is a Himalayan district at high altitude, fluorosis got reported even among those participants drinking water with normal

range of fluoride content as per Bureau of Indian Standards (BIS).

- Stunting and fluorosis were found co-existing.

Recommendation

Regular monitoring of fluoride levels in drinking water sources should be conducted, and appropriate interventions implemented in high-fluoride areas to prevent excessive exposure. Community-based awareness campaigns can be initiated to educate residents about the sources of fluoride exposure and its ill effects. In areas where high fluoride concentrations in groundwater is present, safe drinking water alternatives such as rainwater harvesting, defluoridation, and piped water supply from low-fluoride sources can be promoted.

Limitation of the Study

This study captures data at a single point in time, making it difficult to establish causal association between fluoride exposure and dental fluorosis. Some epidemiological determinants, such as dietary habits and water consumption patterns, rely on self-reported data, which may have introduced recall bias.

Relevance of the Study

This study is relevant as it aids in understanding the impact of fluoride on dental health, guiding prevention and management strategies. It also intends to inform public health policies on safe fluoride levels in groundwater and other sources.

Authors Contribution

All authors have contributed equally.

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Nil

Conflict of Interest

There are no conflicts of interest.

Declaration of Generative AI and AI Assisted Technologies in the writing Process

The authors haven't used any generative AI/AI assisted technologies in the writing process.

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