International Journal of Community Medicine and Public Health
Sharma N et al. Int J Community Med Public Health. 2021 Aug;8(8):4005-4011
http://www.ijcmph.com
pISSN 2394-6032 | eISSN 2394-6040

DOI: https://dx.doi.org/10.18203/2394-6040.ijcmph20213036

Original Research Article

Dental caries and its association with increasing water fluoride concentration in district Rudraprayag, Uttarakhand

Nidhi Sharma[1]*, Vartika Saxena[1], Manisha Naithani[2]

[1]Department of Community Medicine, [2]Department of Biochemistry, AIIMS, Rishikesh, Uttarakhand, India

Received: 04 June 2021
Revised: 15 July 2021
Accepted: 16 July 2021

***Correspondence:**
Dr. Nidhi Sharma,
E-mail: dr.nidhisharma2009@gmail.com

ABSTRACT

Background: Evidence from scientific literature confirms both beneficial and detrimental effects of fluoride on human health with only a narrow range between intakes associated with these effects. The limits of this range have been controversial among researchers since the 1930s. Considering this, the World Health Organization (WHO) permissible limit of fluoride in India has been reduced from 1.5 to 1.0 mg/l in 1998. This study aimed to evaluate the association between increasing water fluoride levels and dental caries prevention on permanent teeth.
Methods: This cross-sectional study involved 1400 children (aged 6–19 years). Caries experience and dental fluorosis were recorded using DMFT/deft and Dean's index respectively. Also, fluoride concentration in drinking water was analyzed. Around 14.4% of children had dental caries with maximum frequency among 9-10 years of age. A significant negative correlation between caries experience and water fluoride level was found ($p<0.05$), with the lowest DMFT scores at the fluoride level of 0.61–2 mg/l and the highest at 0.0–0.3 mg/l. Whereas, high prevalence of dental fluorosis was observed above 0.7 mg/l.
Results: The study revealed that the presence of 0.3-0.7 mg/l fluoride in drinking water reduces dental caries, without an objectionable rise in dental fluorosis.
Conclusions: It can be suggested that fluoride has anticaries property but due to a 'narrow therapeutic window' of 0.3-0.7 mg/l, in a country like India where endemic fluorosis is prevalent, its topical application should be encouraged which is almost equally effective with less systemic adverse effects.

Keywords: Optimum fluoride, Dental caries, Dental fluorosis, Uttarakhand

INTRODUCTION

Dental caries is a chronic and progressive disease of the mineralized tissue of the teeth. Its etiology is multifactorial and is caused by the interaction of tooth substance, certain micro-organisms, and dietary carbohydrates over time, producing acids. Demineralization of the tooth enamel by acid leads to cavitation, impairing its function. It is associated with pain, infection, tooth loss, and reduced quality of life.[1] In children, dental caries may lead to lost school time, as well as problems in eating, speaking, and learning.

Dental caries are a major public health problem according to World Health Organization (WHO) in 2018, globally around 2.4 billion people were suffering from caries of permanent teeth and 486 million children from caries of primary teeth. Dental caries impacting almost half of the world's population (44%).[2] In India, more than 40% of the children suffered from dental caries in both primary and permanent teeth.

Fluoride is said to be caries protective and if the fluoride concentration in drinking water is less than 0.5 mg/l, the risks of dental caries in children may increase.[3,4] On the

other hand, excessive fluoride exposure may lead to harmful health effects such as dental fluorosis and skeletal fluorosis presenting as corroded appearing teeth and bony pain respectively. To prevent adverse effects, WHO has fixed the permissible upper limit of fluoride in drinking water to 1.5 mg/L, and in India limit is reduced to 1 mg/l due to the presence of naturally occurring fluoride in groundwater. But still authorities' opinions on the most effective fluoride therapy for community prevention of tooth decay are mixed; some state fluoride in water is very effective, whereas others see no unusual advantage and prefer topical application strategies.[5,6] Those opposed argue that fluoride in water has no or little cariostatic benefits, may cause serious health problems.[7]

In hilly areas like Rudraprayag, groundwater occurs as localized, disconnected bodies and has a varying range of fluoride concentrations in water. Dental fluorosis can be observed in some localized parts of the district whereas some areas show a high prevalence of dental caries and, absence of fluorosis. The study aims to evaluate the effects of different fluoride concentrations in water (naturally occurring) on the prevention of dental caries and the occurrence of dental fluorosis. Along with this, the association of sociodemographic, oral hygiene practices, food habits, and nutritional status was assessed with dental caries.

METHODS

Study setting and study population

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

A cross-sectional study was conducted in the Rudraprayag district. The sample size was calculated taking prevalence 28.6%, at 95% confidence level, alpha error at 0.05, and margin of error 10%.[8] The Final sample size came out to be 1,386 which was rounded off to 1400. Data collection was done for a period of 12 months from March 2019 to February 2020. The study was conducted after Institutional Ethics Committee (IEC) approval.

The study used a multi-stage random sampling method. The district has three blocks, 3 Nyaya-panchayats were selected from two smaller blocks and 4 Nyaya-panchayat from one larger block. From each Nyaya-panchayat 3 villages were randomly selected using probability-proportional-to-size (PPS) sampling. Thus, a total of 30 villages were selected and 1400 children belonging to age 6-19 years, who were residents of the district in their first 5 years of life were enrolled for the study. Those children with a history of chronic medical illness (example- renal, hepatic, and endocrine disorders) were not included in the study.

To analyze the pattern of dental caries 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. Consent was taken from the parents/guardians of the children after explaining the procedure and importance of the study. Questionnaires elicited information on participants' sociodemographic status, lifestyle, and food habits.

Dental caries and fluorosis assessment

Dental fluorosis was evaluated using the Dean's index. Dental caries were recorded using the DMFT index and to assess the severity of caries, mean DMFT score, and the proportion of the population having DMFT score >4 was determined.

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 −4 °C until use. The concentrations of F− [mg/L] were 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 the socioeconomic status of families. It is based on per capita monthly income.[9]

Social class income/month

I 7008 and above

II 3504-7007

III 2102-3503

IV 1051-2101

V 1050 and below

Statistical analysis

Data were analyzed by statistical software Statistical package for social sciences (SPSS) version 23, categorical data expressed as frequency and percentage. Fluoride concentrations in water was either categorized or were log10 transformed when used as continuous measures to make their distributions more normal. Chi-square/ Fischer exact test was used to find an association between dental caries and associated risk factors. Those variables found statistically significant and clinically important were included in multiple logistic regression. Regression

analysis was done to find association between water fluoride level and dental caries.

RESULT

Study population characteristic and pattern of dental caries

The socio-demographic characteristics of the study population were summarized in Table 1. Among the total participants, 52.3% (732) were girls, and 47.7% (668) were boys. Most of the families belonged to lower socioeconomic status, BG class 4 (44.1%) with parents having a maximum educational level to grade 10. In the district, springs (46.7%) were the main source of drinking water.

The overall prevalence of dental caries was 14.4% (202) (permanent teeth, DMFT) and 35.3% (495) (primary teeth, deft) of which 3.9% of children had >4 DMFT/deft scores. Dental caries was most frequently observed among children of 9-10 years of age, they attributed around 46.9% among the children having dental caries.

Table 1: Sociodemographic characteristic of study population (n= 1400).

Sociodemographic Characteristic		N (%)
Gender	Male	668 (47.7)
	Female	732 (52.3)
Age Mean (SD)	13.5 (3.6)	
Age group (in years)	6-12	602 (43.0)
	13-19	798 (57.0)
Paternal Education	Illiterate	66 (4.7)
	Primary and High school	1213 (86.7)
	Secondary school and graduation	120 (8.5)
Maternal Education	Illiterate	184 (13.1)
	Primary and High school	1128 (80.6)
	Secondary school and graduation	87 (6.2)
Socioeconomic status	BG class 1	Nil
	BG class 2	137 (9.8)
	BG class 3	369 (26.4)
	BG class 4	617 (44.1)
	BG class 5	277 (19.8)
Oral care practices	Started brushing above 4 years	1107 (79.1)
	Don't brush daily/Sometimes in a week	829 (59.8)
	Use toothpaste as cleaning agent	1345 (96.1)
	Changed their brush in > 1 year	1047 (74.8)
Eating habits	>3 times sweet intake (excluding with meals)	124 (8.8)

Table 2: Factors related to prevalence of dental caries: Logistic regression.

Associated factors	Caries present n (%)	Caries absent n (%)	P value	Adjusted odds (CI 95%)	P value
Total participants	202 (14.4)	1198 (85.6)			
Sex					
Male (668)	105 (15.7)	563 (84.3)	0.189		
Female (732)	97 (13.3)	635 (86.7)			
Age (years)					
≤12 (602)	198 (32.9)	404 (67.1)	0.000	1	0.000
>12 (798)	4 (0.5)	794 (99.5)		0.097 (0.06-0.16)	
Paternal qualification					
Grade 10th and below (1279)	180 (14.1)	1099 (85.9)	0.219		
Above grade 10th (121)	22 (18.2)	99 (81.8)			
Maternal qualification					
Grade 10th and below (1312)	183 (13.9)	1129 (86.1)	0.048	1	0.758

Continued.

Associated factors	Caries present n (%)	Caries absent n (%)	P value	Adjusted odds (CI 95%)	P value
Above class 10th (88)	19 (21.6)	69 (78.4)		1.20 (0.60-2.00)	
Socioeconomic status					
Class 4 and 5 (894)	128 (14.3)	766 (85.7)	0.875		
Class 3 and Above (506)	74 (14.6)	432 (85.4)			
Frequency of brushing					
Daily (571)	68 (11.9)	503 (88.1)	0.026	1	0.388
Sometimes (829)	134 (16.2)	695 (83.8)		1.17 (0.82-1.7)	
Frequency of changing brush					
≤1 year (348)	57 (16.4)	291 (83.6)	0.333		
>1 year (1047)	145 (13.8)	902 (86.2)			
Type of diet					
Vegetarian (99)	14 (14.1)	85 (85.9)	0.933		
Non vegetarian (1301)	188 (14.5)	1113 (85.5)			
Staple food					
Wheat (1233)	187 (15.2)	1046 (84.8)	0.031	1	0.332
Rice (107)	13 (12.1)	94 (87.9)		0.76 (0.43-1.32)	
Others (60)	2 (3.3)	58 (96.7)			
Frequency of sweet intake					
≤3 times/day (1276)	169 (13.2)	1107 (86.8)	0.000	1	0.000
>3 times/day (124)	33 (26.6)	91 (73.4)		3.7 (2.06-6.52)	
Accessibility of health care facility					
≤1 hour (118)	12 (10.2)	106 (89.8)	0.325		
>1 hour (1280)	190 (14.8)	1090 (85.2)			
Water fluoride level					
≤1mg/L (1237)	192 (15.5)	1045 (84.5)	0.001	1	0.002
Above 1mg/L (163)	10 (6.1)	153 (93.9)		0.58 (0.41-0.82)	
Enamel fluorosis					
Absent (1133)	179 (15.8)	954 (84.2)	0.003		
Present (267)	23 (8.6)	244 (91.4)			

Table 3: Pattern of dental caries with increasing water fluoride concentration.

Water Fluoride concentration (mg/l)	Dental caries n (%)	P value	Odds Ratio (CI 95%)	Severity of dental caries (DMFT >4) n (%)	P value
0 – 0.3 (417)	96 (23.0)	0.000	1	28 (6.7)	0.001
0.31 – 0.6 (538)	65 (12.1)	0.000	0.46 (0.32-0.65)	12 (2.2)	
0.61 – 1 (282)	31 (11.0)	0.000	0.41 (0.27-0.64)	12 (4.3)	
Above 1 (163)	10 (6.1)	0.000	0.21 (0.11-0.43)	2 (1.2)	
Log water fluoride concentration	202 (14.4)	0.001			0.174

Table 4: Association of dental caries and dental fluorosis.

Enamel fluorosis	Dental caries n (%)	P value	Odds Ratio (CI 95%)	Severity of dental caries (DMFT >4) n (%)	P value
Absent to questionable (1160)	184 (15.9)	0.002	9.24 (2.26-37.80)	49 (4.2)	0.110
Very mild to mild (140)	16 (11.4)	0.016	6.32 (1.42-28.16)	5 (3.6)	
Moderate to severe (100)	2 (2.0)	0.004	1	0 (0)	

Table 2 shows, there were no significant differences in the prevalence and severity of dental caries among the boys and girls (p=0.189), and even socioeconomic status was not associated with dental caries. Prevalence of caries prevalence was less among the participants who brush daily (11.9) as compared to children who brush sometimes in a week (16.2). The frequency of caries was 10 times more among ≤12 years children as compared to children above 12 years. The children taking sweets more than three times a day between the meals were almost 4 times more affected by dental caries as compared to children with less frequent sweet intake [p=0.000, 3.7 (2.06 – 6.52)].

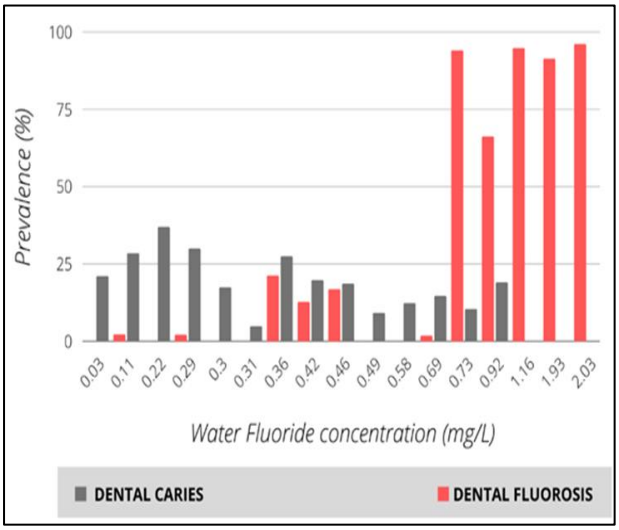

Figure 1: Pattern of prevalence of dental caries and dental fluorosis with increasing water fluoride level.

Dental caries and water fluoride concentrations

Table 3, shows a negative association between water fluoride levels and the prevalence of dental caries [H= 13.96(2), p=0.001]. Children drinking water with 0.61-1 mg/l of fluoride, on average have 41% less chances of having dental caries as compared to children consuming water with <0.3 mg/l fluoride [OR =0.41(0.27-0.64), p=0.00] and these were further reduced to 21% when fluoride concentration in water increased to >1 mg/l. Moreover, as the fluoride concentration in water increased, the severity of dental caries (children with DMFT >4) decreased [r=16.18, (p=0.001)].

Dental caries and dental fluorosis

Table 4, shows children with enamel fluorosis had 50% less chances of having dental caries as compared to children without fluorosis [p=0.003 OR=0.5(0.32-0.80)]. Whereas as the severity of dental caries did not show any association with fluorosis.

DISCUSSION

In this district representative sample of Rudraprayag children and adolescents, increasing fluoride concentration in drinking water was associated with significantly lower levels of dental caries experience. Children exposed to fluoride concentration >0.6 mg/l have 50% chances of having dental caries as compared to children drinking water with <0.6 mg/l of fluoride. The study revealed as the fluoride concentration in drinking water increased the prevalence and severity of dental caries decreased. Besides fluoride concentration, some other factors also significantly influenced the pattern of dental caries among the children.

In this study, the caries prevalence in the 6- to 8-year age group was found to be 47.1%, in the 8- to 12-year age group, it was 25.5% whereas in age groups 12-15 and 15-19 it was reduced to 0.5%. The result from the study revealed that the prevalence of caries decreased as the age advanced. And In the 14- to 17-year age group, it was the least almost nil. The outcomes of this study are in coherence with the results attained by Vaish, who presented a similar trend with prevalence rates of 58.3% in 6- to 8-year age group, 47.7% in 9- to 11-year age group, and 44.3% in 12- to 14-year age group.[10] This decrease in the caries rate with age may be attributed to the fact that there is an improvement in awareness of oral hygiene with age. This is reinforced by the study done by Chu et al. concluding that 44 and 22% of the 6- and 12-year-old children respectively in their study population, had never brushed showing improvement in oral hygiene practices with age.[11] In the present study, the variation in the deft mean [H=130.12(3), p=0.000] and DMFT [H=342.67(3), p=0.000] with the age was found to be very highly significant. The mean deft score declined progressively as the age advanced, whereas no remarkable pattern was observed in the mean DMFT score with age. The decline in the deft values may be due to the reduction in the number of primary teeth with age due to normal exfoliation. Rao et al. also stated a similar tendency with the deft declining (4.53±4.15 in 5- to the 6-year age group to 1.81±1.88 in 11- to 12-year age group).[12]

Eating patterns play an important role in the etiology of dental caries. The addition of refined sugar (sucrose) into the modern diet, especially among children has been related to the increased caries prevalence. For a long, philosophers have been suspecting dietary habits influencing the etiology of caries. The direct association of frequency of sweet, sticky snacks and dental caries incidence has been concluded by Gustaffson (1954) in the Vipehome study. To assess the relationship between the sugar in the diet and dental caries the children were divided into two groups depending upon the total number of sugar exposures/day else along with the three meals i.e. frequently (more than 3 sugar exposures/day), and Occasionally (<3 sugar exposure/day). However, the reliability and validity of such an anamnestic history for assessing the role of diet in the prevalence of caries is uncertain. Despite these issues, an attempt was made to find the relation between sweet consumption and dental caries. Almost 8.8% of children in the study had >3 sugar exposures/day. A considerably higher caries prevalence

was observed in the frequent sweet eating group compared to those who occasionally eat sweets. A significant association was recorded between the frequency of sugar consumption and dental caries. The result of the present study verifies the role of sugar (sucrose) as one of the vital etiological factors which are in coherence with the findings of other studies.[13,14] On the other hand, the prevalence of dental caries among the study population doesn't show any significant association with frequency of brushing and socioeconomic status.

The present study showed a wide variation of fluoride levels in drinking water, ranging from 0.03 to 2.03 ppm. The domestic water source in the hilly area mainly springs. They are the highly weathered and immensely fractured geological system that allows a rapid transit of water through them under gravitational force. Fluoride contamination was commonly observed in the water from the springs situated in areas of fluoride-rich rocks. Fluoride-rich minerals leach out of these rocks and concentrate into the groundwater. Thus the dominating factor leading to fluoride contamination is the lithology and geology of the aquifer that hold groundwater in the subsurface.[15] The inverse relationship between fluoride level and caries experience observed in the present study is recorded in the literature.[16-20] A school-based survey that included 17,599 schoolchildren (aged 6–12 years), found a very high prevalence of caries among children in Yemen. It also recorded an inverse relation between dental caries experience and fluoride levels.

Figure 1 shows that as the water fluoride concentration increased mean prevalence of dental caries gradually decreased. Caries prevalence among the population gradually decreased as the fluoride concentration increased from 0.22 mg/l and decline to almost nil when water fluoride concentration increased above 1 mg/l. On the other hand, at fluoride levels above 0.7 mg/l, as seen in many areas of our study, a high prevalence of dental fluorosis was recorded which leads to structural changes of dental tissues leading to dark brown stains and rough, pitted enamel that is difficult to clean. But at the lower concentration fluoride lends caries protection without causing any esthetic deterioration in teeth appearance.

The mechanisms by which fluoride protects the tooth from caries is being continuously studied for two decades. Different cariogenic bacteria present in the oral cavity metabolize sugars and produce acid leading to demineralization of tooth structure. The tooth structure is mainly composed of hydroxyapatite minerals. Studies explain that fluoride ion fits well in the structure of a hydroxyapatite crystal of dental enamel, much better than the hydroxyl group, and this results in lower solubility of fluoridated apatite when compared with fluoride-free apatite in the acidic environment. Fluoride slows down demineralization by coprecipitating calcium and phosphate ions that dissolve and by enhancing the precipitation of fluoridated apatite even during an acid attack in caries progression. It has also been suggested, that the fluoride ion can disturb the physiology of microbial cells, destroyed the cell membrane resulting in their destruction.[21,22] Thus, fluoride may inhibit tooth decay by 40% to 60%.

In the "early" years, fluoride intake in the diet in form of tablets, drops were encouraged to utilize its anticaries property. But slowly because of the harmful effects of high dozes of fluoride topical application was encouraged. Initially, fluoride topical applications were given at ages during childhood and adolescence when new teeth erupt. Further research revealed that fluoride interferes positively with the daily cycles of de- and remineralization which shifted the attention to fluoride application methods that could be used daily. And soon effective fluoride toothpaste and dentrifices became the preferred method of providing fluoride for caries protection.[23,24] All in all, the balance between the achievement of maximum protection against dental caries and the risk of development of fluorosis should be taken into consideration.[25]

One of the strengths of our study lies in its large sample size. Besides, the study also took into consideration other factors reportedly associated with caries, such as dietary habits and pattern of sugar intake, oral hygiene practices, dental visits, parents' level of education, and socioeconomic status. Still, some limitations do exist such as no information was recorded about children's exposure to fluoride from other sources, which could act as confounding factors that might affect the dental caries prevalence, duration of the participants' exposure to high fluoride water, or information on the residency period of the participants in each area. Such data could be used to further refine the assessment on the effectiveness of anticaries property of fluoride. Furthermore, longitudinal studies that control for these other confounding factors are needed to confirm the association between water fluoride and dental caries.

CONCLUSION

The study confirms existing evidence of the benefit of fluoride in caries prevention. Caries levels were significantly lower among children in the areas with water containing >0.3 mg/l fluoride than the areas with less water fluoride concentration and as the fluoride concentration increased to 2.03 mg/l caries prevalence reduced to almost nil. On the other hand, drinking water fluoride concentration upto 0.7 mg/l didn't showed any significant dental fluorosis. Thus 0.3-0.7 mg/l range of fluoride imparted best caries prevention with protection against fluorosis. Other important risk factor for dentine caries prevalence dental in the study was frequent sweet consumntion between meals. Whereas, no differences in caries experience due to other variables like gender and socio-economic factors, were noted in the study.

Studies suggest that the mechanism of action of fluoride is mainly topical and mostly post-eruptive. Our study verifies that appropriate use of fluoride may result in a substantial

lifelong benefit to oral health. So, in a country like India which falls in the world's fluorosis endemic belt to avoid aesthetically unattractive levels of fluorosis use of topical fluoride should be encouraged to take advantage

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

REFERENCES

1. Sheiham A. Oral health, general health and quality of life. Vol. 83, Bulletin of the World Health Organization. World Health Organization. 2005. http://www.who. Accessed on 19th March, 2021.
2. FDI World Dental Federation. Facts, Figures and Stats, Oral disease: 10 key facts. 2012. https://www.fdiworlddental.org/oral-health/ask-the-dentist/facts-figures-and-stats. Accessed on 19th March, 2021.
3. Aslani H, Zarei M, Taghipour H, Khashabi E, Ghanbari H, Ejlali A. Monitoring, mapping and health risk assessment of fluoride in drinking water supplies in rural areas of Maku and Poldasht, Iran. Environ Geochem Health. 2019;41(5):2281-94.
4. Kirkeskov L, Kristiansen E, Bøggild H, Von Platen-Hallermund F, Sckerl H, Carlsen A, et al. The association between fluoride in drinking water and dental caries in Danish children. Linking data from health registers, environmental registers and administrative registers. Community Dent Oral Epidemol. 2010;38(3):206-12.
5. Yeung CA. A systematic review on the efficacy and safety of fluoridation [Internet]. Vol. 9, Evidence-Based Dentistry. Evid Based Dent. 2008;39-43.
6. The ethics of water fluoridation. 2019. https://pubmed.ncbi.nlm.nih.gov/11253350/. Accessed on 19th March, 2021.
7. Cross DW, Carton RJ. Fluoridation: A Violation of Medical Ethics and Human Rights. Int J Occup Environ Health. 2003;9(1):24-9.
8. Srivastava AK, Singh A, Yadav S, Mathur A. Research Article Endemic Dental and Skeletal Fluorosis: Effects of High Ground Water Fluoride in some North Indian Villages. Int J Oral Maxillofac Pathol. 2011;2(2):7-12.
9. Pandey VK, Aggarwal P, Kakkar R. Modified BG prasad socio-economic classification, update - 2019. Indian J Community Heal. 2019;31(1):123-5.
10. Prevalence of caries among tribal school children in Phulbani district, Orissa. 2021. Available at: https://pubmed.ncbi.nlm.nih.gov/6590628/. Accessed on 19th March, 2021.
11. Chu CH, Wong AWY, Lo ECM, Courtel F. Oral health status and behaviours of children in rural districts of Cambodia. Int Dent J. 2008;58(1):15-22.
12. SS Rao, P V. Prevalence of dental caries among school-going children in South India. Int J Med Sci Public Heal. 2016;5(4):700.
13. Viswanath D, Sabu N. Prevalence of dental caries, the effect of sugar intake and tooth brushing practices in children aged 5-11 years in Bangalore North. SRM J Res Dent Sci. 2014;;5(3):155.
14. Touger-Decker R, van Loveren C. Sugars and dental caries. The American journal of clinical nutrition. Am J Clin Nutr. 2003;78.
15. Chowdhury A, Adak MK, Mukherjee A, Dhak P, Khatun J, Dhak D. A critical review on geochemical and geological aspects of fluoride belts, fluorosis and natural materials and other sources for alternatives to fluoride exposure. J Hydrol. 2019;574:333-59.
16. Skórka-Majewicz M, Goschorska M, Żwierełło W, Baranowska-Bosiacka I, Styburski D, Kapczuk P, et al. Effect of fluoride on endocrine tissues and their secretory functions -- review. Chemosphere. 2020;260.
17. Ramezani G, Valaie N, Rakhshan V. The effect of water fluoride concentration on dental caries and fluorosis in five Iran provinces: A multi-center two-phase study. Dent Res J (Isfahan). 2015;12(1):31-7.
18. Petersen PE, Ogawa H. Prevention of dental caries through the use of fl uoride-the WHO approach. Community Dent Health. 2016;33:66-8.
19. Al-Akwa AA, Al-Maweri SA. Dental caries prevalence and its association with fluoride level in drinking water in Sana'a, Yemen. Eur J Dent. 2018;12(1):15-20.
20. Nor NAM, Chadwick BL, Farnell D, Chestnutt IG. The prevalence of enamel and dentine caries lesions and their determinant factors among children living in fluoridated and non-fluoridated areas. Community Dent Health. 2019;36(3):229-36.
21. Cate JM, Buzalaf MAR. Fluoride Mode of Action: Once There Was an Observant Dentist. J Dent Res. 2019;98(7):725-30.
22. Goldberg M. Central Fluorides in Dental Tissues: Caries Prevention and Fluorosis. JSM Dent. 2020;8(1):1123.
23. Article R. The Untold Story of Fluoridation : Revisiting the Changing Perspectives. 2018;121-7.
24. Fluoride in dentistry (Book, 1996) [WorldCat.org]. https://www.worldcat.org/title/fluoride-in-dentistry/oclc/36126959. Accessed on 19th March, 2021.
25. Hosur MB, Puranik RS, Vanaki S, Puranik SR. Study of thyroid hormones free triiodothyronine (FT3), free thyroxine (FT4) and thyroid stimulating hormone (TSH) in subjects with dental fluorosis. Eur J Dent. 2012;6(2):184-90.

Cite this article as: Sharma N, Saxena V, Naithani M. Dental caries and its association with increasing water fluoride concentration in district Rudraprayag, Uttarakhand. Int J Community Med Public Health 2021;8:4005-11.