The Prevalence and Associated Risk Indicators of Dental Fluorosis in China: Results from the 4th National Oral Health Survey

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Objective: *To explore the prevalence and associated risk indicators of dental fluorosis in the mainland of China.*

Methods: *Data for this study was obtained from the 4th National Oral Health Survey in China, conducted from 2015 to 2016. The sample population was 12-year-old school students. Study participants were selected using a multi-stage, stratified random sample selection procedure using a sampling frame compiled from geographical distribution of China. The level of dental fluorosis was determined using the Dean index recommended by the World Health Organization (WHO). A structured questionnaire was distributed to all the subjects in schools. Participants completed a questionnaire with assistance from staff. A bivariate analysis was performed using the chi-square test. Logistic regression was performed to evaluate the association between dental fluorosis and the independent variables.*

Results: *A total of 27,495 students were evaluated, of which 13,650 (49.6%) were male. Overall, dental fluorosis was found in 13.4% of participants; 6.3% had very mild fluorosis, 4.3% had mild fluorosis, 2.3% had moderate fluorosis, and 0.5% had severe fluorosis. The community fluorosis index was 0.28. In the final logistic regression model students from rural areas (RR:1.582, 95%CI 1.473-1.700), students whose fathers had low education (RR:1.429, 95%CI 1.230-1.661 & 1.184, 95%CI 1.026-1.365), and those students with sibling (RR:1.537, 95%CI 1.414-1.671) were more significantly associated with dental fluorosis.*

Conclusion: *As a whole, China has a low dental fluorosis prevalence. Rural areas were the key places for the prevention of dental fluorosis. More prevention measures should be conducted on the children whose fathers were of lower education and who were not an only child.*

Key words: *dental fluorosis, prevalence, risk indicator, the 4th National Oral Health Survey*
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Fluoride is a natural chemical substance existing in nature. It has been commonly used to prevent and manage dental caries, and is widely accepted as a major factor in the dramatic decline of the disease[1]. However, fluoride is a double-edged sword on oral health. The impact of a long-term high intake of fluoride can have adverse effects on teeth and cause dental fluorosis[2].

Dental fluorosis occurs due to the hypomineralisation of dental enamel caused by the ingestion of excessive fluoride during enamel formation[3]. Severity of dental fluorosis depends on the fluoride dose and the timing and duration of fluoride exposure[4]. Mild dental fluorosis is characterised by an opaque area scattered on the teeth without tooth structure being destroyed. More severe dental fluorosis causes the tooth to lose its normal morphology and is a worse public dental health burden[2].

Over the past few decades, the wide availability of fluoride in many forms has exposed people to higher fluoride doses than strictly needed for preventive purposes. The increased exposure to fluoride has contributed increasingly to dental fluorosis[5,6]. The early maturation stage of enamel development in permanent teeth is a critical stage of susceptibility for dental fluorosis[2]. The associated factors with dental fluorosis were unclear. Fluoride in drinking water is a well-recognised risk factor of dental fluorosis[7]. Non-fluoride factors had an effect on the risk of dental fluorosis[8].

An increasing prevalence of dental fluorosis is reported worldwide. Estimated fluorosis prevalence ranges between 30% and 80% in fluoridated and 10% to 40% in non-fluoridated areas of the US[9]. A recent study from India reported 64.3% of adolescents were detected with dental fluorosis[10]. China is a vast, multiethnic country with a diverse geographical environment. Prevalence of dental fluorosis is variable across the country. There is no clear prevalence, severity and associated factors of dental fluorosis in China.

Therefore, the objective of this study was to explore the prevalence of dental fluorosis in 12-year-old children and the associated factors of dental fluorosis in China at a national level.

Materials and methods

Study sample

Data for this study were obtained from the 4th National Oral Health Survey of China, conducted from 2015 to 2016. The sample population was school pupils aged 12 years old. Sampling covered all 31 provinces, autonomous regions and municipalities of the mainland of China. The sample size was calculated according to the prevalence of dental caries in 12-year-old children in the 3rd National Oral Health Survey in China in 2005, which was reported to be 28.9%. Admissible error of prevalence was set at 15%.

Study participants were selected using a multi-stage, stratified random sample selection procedure with a sampling frame compiled from the geographical distribution of China. Firstly, two city districts and two counties were randomly selected from each province. Secondly, three schools were randomly selected from each district and county. Thirdly, 80 12-year-old students were selected from each school at random. If the student number in the selected school was insufficient, the remaining students were selected from the nearest schools. Informed written consent from each student was obtained. The study was approved by the ethical committee of Chinese Stomatological Association (Approval no. 2014-003).

Clinical examination

The clinical examination was performed by 31 trained groups accordingly in 31 provinces, autonomous regions and municipalities in the mainland of China. Each trained group had three examiners. All the examiners received pilot group training before formal clinical examination. Duplicated examinations were conducted for 10% of the study subjects to monitor the reliability of the diagnoses and the data were used for the calculation of inter-examiner agreement. The average of Kappa values was 0.81.

Dental fluorosis was recorded by the Dean's index, which is recommended by the WHO[11]. The Dean index was recorded as: 0 (normal), 0.5 (questionable), 1 (very mild), 2 (mild), 3 (moderate), and 4 (severe). This assessment is based on visual examination. Clinical examinations were carried out using a flat dental mirror in daylight. Teeth were not dried prior to the administration of the index. The labial/buccal surfaces of all erupted permanent teeth were assessed.

The two teeth with the worst dental fluorosis score were recorded for the person-level score. If the scores of the two teeth were the same, the score was recorded as the person's Dean's index. If the scores of the two teeth were different, the score of the less affected tooth of the two was recorded as the person's Dean's index[12].

Questionnaire examination

A structured questionnaire was distributed to all the subjects in schools. Participants completed an on-the-spot questionnaire with assistance from staff. The questionnaire mainly collected information on the child's social, demographic, and behavioural status using a series of close-ended questions. The staff reviewed the questionnaire when it was handed in and asked students to fill in answers if there were any missing.

Statistical analysis

Data processing and statistical analysis was performed using the SPSS 21.0. The dependent variable was dental fluorosis. Thus, those children who has not dental fluorosis record were excluded from this analysis. To verify associations between fluorosis prevalence and the researched variables, a chi-square statistical test or Fisher's exact test and $P < 0.05$ was set as statistical significance. Logistic regression was performed to evaluate the association between dental fluorosis and the independent variables.

Results

A total of 27,495 students were enrolled to evaluate dental fluorosis excluding missing data and unrecorded data. The response rate was 98.8%. Overall, dental fluorosis was found in 13.4% of participants, of which, 6.3% had very mild fluorosis, 4.3% had mild fluorosis, 2.3% had moderate fluorosis, and 0.5% had severe fluorosis (Fig 1). The national percentage of moderate/severe fluorosis was 2.8%. The national community fluorosis index (CFI) value was 0.28.

Results showed different prevalence among provinces in China. The range of dental fluorosis prevalence was from 0 to 51.6%. Guizhou Province and Tianjing city had 51.6% and 45.1% dental fluorosis prevalence respectively – the top two most seriously affected areas in China. Seven provinces had dental fluorosis prevalence above 20%. Most of the provinces were lower than the national dental fluorosis prevalence level. Thirteen provinces had fluorosis prevalence below 5% (Table 1).

Table 2 shows the results of the subjects' sociodemographic background factors with dental fluorosis. The most serious prevalence in China was 16.5% in rural areas, while the least was 9.1% from student's fathers education > 12 years. This was the same with the distribution of the CFI value. There was no difference in dental fluorosis prevalence according to gender.

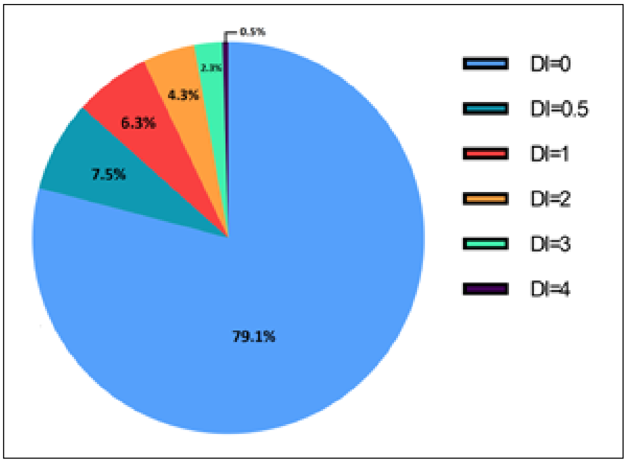

Fig 1 The distribution of dean index in 12-year-old students in the mainland of China.

Prevalence of dental fluorosis in rural area was more serious than in urban areas. Students with mothers and fathers with a lower level of education recorded a higher prevalence of dental fluorosis. Only children had less dental fluorosis than those with siblings (Table 2).

In the final logistic regression model, students who lived in rural areas (RR:1.582, 95% CI 1.473-1.700) were more associated with dental fluorosis. In addition, students whose fathers were of low education (RR:1.429, 95% CI 1.230-1.661 & 1.184, 95% CI 1.026-1.365), and students with siblings (RR:1.537, 95% CI 1.414-1.671) were significantly associated with dental fluorosis (Table 3).

Figure 2 gives a detailed description of the association between the Dean index and the dental caries index. Decayed, missing and filled teeth (DMFT)/decayed teeth (DT) were used as dental caries indexes. The children with higher values of DMFT/DT had a higher Dean index. DMFT increased sharply from the 3 to 4 category of the Dean index. A similar tendency was showed in DT with the Dean index.

Discussion

The present study was a national oral health survey in mainland China. China has conducted a national oral health survey every 10 years since 1982 and data from four surveys has been collected to date. This survey is the first national survey including all 31 provinces, autonomous regions and municipalities of mainland China, including all the index age groups recommended by WHO.

Table 1 The prevalence and severity of dental fluorosis in mainland China.

Variables	Fluorosis (%)§	N	Fluorosis Severity (%)						CFI#
			DI = 0 Sound	DI = 0.5 Questionable	DI = 1 Very mild	DI = 2 Mild	DI = 3 Moderate	DI = 4 Severe	
Guizhou	51.6	857	33.5	14.9	27.3	17.2	6.3	0.8	0.91
Tianjin	45.1	941	37.8	17.1	14.3	18.5	10.7	1.5	0.98
Tibet	40.3	927	39.2	20.5	17.6	14.5	7.0	1.3	0.83
Shanxi	38.5	868	43.4	18.1	13.1	10.6	7.9	6.8	0.94
Jilin	29.9	889	62.1	8.0	6.6	10.9	9.3	3.0	0.73
Sichuan	27.1	923	60.0	12.9	20.5	5.5	0.8	0.3	0.42
Gansu	24.4	928	53.6	22.1	9.6	10.5	3.7	0.6	0.11
Ningxia	16.8	849	66.0	17.2	7.8	6.2	2.8	0.0	0.37
Henan	16.6	915	78.3	5.1	6.3	3.8	6.1	0.3	0.36
Heilongjiang	15.8	901	74.8	9.4	6.5	6.4	2.8	0.0	0.32
Hebei	15.7	893	73.2	11.1	8.6	4.1	2.5	0.4	0.32
Shandong	13.8	933	74.4	11.8	11.6	2.1	0.0	0.1	0.20
Shaanxi	13.8	849	79.9	6.4	6.4	4.0	3.2	0.2	0.28
Zhejiang	10.2	879	85.7	4.1	5.2	3.8	1.0	0.2	0.19
Xinjiang	10.1	982	83.8	6.1	6.9	2.5	0.6	0.0	0.17
Jiangsu	8.2	905	87.7	4.1	4.5	2.9	0.7	0.1	0.15
Qinghai	7.4	824	74.9	17.7	4.6	2.2	0.5	0.1	0.20
Shanghai	6.6	942	88.4	5.0	3.9	1.6	1.1	0.0	0.13
Guangdong	4.2	946	92.7	3.1	2.9	0.6	0.7	0.0	0.08
Liaoning	3.5	762	95.1	1.3	2.5	0.8	0.3	0.0	0.06
Beijing	2.1	958	97.6	0.3	1.0	0.5	0.1	0.4	0.04
Fujian	1.9	913	92.6	5.6	1.3	0.2	0.3	0.0	0.06
Anhui	1.8	965	95.8	2.5	1.1	0.6	0.0	0.0	0.04
Inner Mongolia	1.6	793	97.1	1.3	0.9	0.6	0.0	0.1	0.03
Hunan	1.3	905	97.0	1.7	0.8	0.4	0.1	0.0	0.03
Yunnan	1.0	814	97.1	2.0	0.5	0.2	0.2	0.0	0.03
Jiangxi	0.4	923	99.2	0.3	0.4	0.0	0.0	0.0	0.01
Chongqing	0.3	941	99.1	0.5	0.1	0.1	0.1	0.0	0.01
Guangxi	0.1	897	99.9	0.0	0.1	0.0	0.0	0.0	0.00
Hainan	0.0	600	100.0	0.0	0.0	0.0	0.0	0.0	0.00
Hubei	0.0	873	100.0	0.0	0.0	0.0	0.0	0.0	0.00

§ Having at least one tooth with Dean's fluorosis score 1 or greater, # community fluorosis index

Table 2 Bivariate analysis of associated factors with dental fluorosis in 12-year-old students in the mainland of China.

Variables	Fluorosis (%)§	N	Fluorosis Severity (%)						CFI#	
			DI = 0 Sound	DI = 0.5 Questionable	DI = 1 Very mild	DI = 2 Mild	DI = 3 Moderate	DI = 4 Severe		
Gender										$P = 0.21$
Female	13.1	13,845	79.2	7.7	6.4	4.1	2.1	0.5	0.27	$\chi = 2.5$
Male	13.7	13,650	79.0	7.3	6.3	4.5	2.4	0.5	0.28	
Area										$P < 0.01$
Urban	10.4	14,108	83.3	6.2	5.2	3.4	1.5	0.4	0.21	$\chi = 219.9$
Rural	16.5	13,387	74.6	8.8	7.5	5.3	3.1	0.7	0.35	
Father's education*										$P < 0.001$
> 12 years	9.1	3,999	84.7	6.2	4.6	3.1	1.2	0.3	0.18	$\chi = 123.5$
9-12 years	13.0	14,960	79.7	7.3	6.0	4.2	2.2	0.5	0.27	
≤ 9 years	16.1	8,534	75.4	8.5	7.6	5.0	2.8	0.6	0.33	
Mother's education										$P < 0.001$
> 12 years	9.4	3,842	84.7	5.9	4.7	3.0	1.4	0.3	0.19	$\chi = 107.1$
9-12 years	12.7	13,079	80.3	7.0	6.0	4.1	2.1	0.6	0.26	
≤ 9 years	15.7	10,675	73.3	9.8	8.0	5.4	2.9	0.5	0.32	
Only child **										$P < 0.001$
Yes	9.5	9,893	84.6	5.9	4.7	3.0	1.4	0.4	0.19	$\chi = 211.5$
No	15.6	17,598	76.0	8.4	7.2	5.0	2.7	0.6	0.24	

§ Having at least one tooth with Dean's fluorosis score 1 or greater, # community fluorosis index, * two samples missing, ** four samples missing

Table 3 Multivariate analysis of associated factors with dental fluorosis in 12-year-old students in mainland China.

Variables	β	Standard error	Relative risk	95% confidence interval		*P* value
				Lower limit	Upper limit	
Area						
Rural	0.459	0.037	1.582	1.473	1.700	$P < 0.001$
Urban*						
Father's education						
≤ 9 years	0.357	0.077	1.429	1.230	1.661	$P < 0.001$
9-12 years	0.168	0.073	1.184	1.026	1.365	$P = 0.021$
> 12 years*						
Only child						
No	0.430	0.043	1.537	1.414	1.671	$P < 0.001$
Yes*						

* Reference group

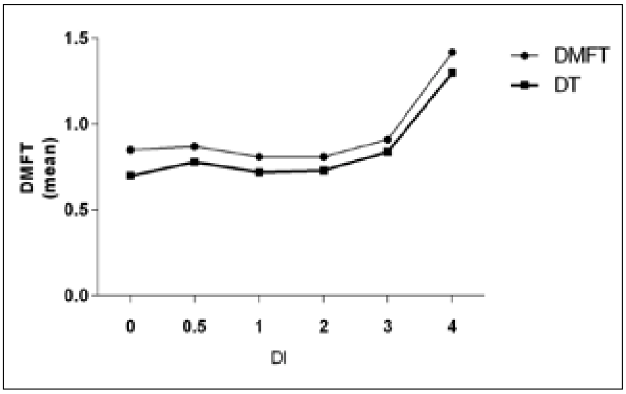

Fig 2 The trend between DMFT/DT and the Dean index in 12-year-old students in the mainland of China.

The results showed that the prevalence and severity of dental fluorosis is low in China. Weiner et al[13] compared national data collected in 2001 to 2002 with data from 2011 to 2012 for adolescents in the US. The normal percent was 49.8% in 2001, while the percentage was 31.2% in 2011.They found an continued increase in fluorosis rates in the US. Verma et al reported that a high prevalence of fluorosis was shown in India, with more than 50% having either severe or moderate fluorosis[10]. According to a report by Molina-Frechero et al, Mexico City recorded 59% dental fluorosis[14]. Compared with the 3rd National Oral Health Survey in 2005, there was not too much change in the prevalence and severity of dental fluorosis[15]. The prevalence of dental fluorosis in China was stationary over the past 10 years.

However, different parts of China showed variable dental fluorosis prevalence. Guizhou province had the most dental fluorosis, which was consistent with a previous study[16]. Dental fluorosis in Guizhou province is a coal-burning type of endemic fluorosis. Endemic fluorosis caused by coal burning is a special type of fluorosis in China. Pollution from coal burning is not the only cause of dental fluorosis, but there is also risk of skeletal fluorosis. The government needs to introduce more preventive measures to reduce the coal-burning fluorosis. Besides, nearly half of students in Tianjin city had dental fluorosis. A potential reason for this was fluoride pollution in drinking water, especially in rural areas of Tianjin city[17]. There was very little dental fluorosis found in Hainan and Hunan. This was probably due to the low prevalence and a limited sample size.

Rural areas in China had more serious dental fluorosis than urban areas. Although the difference between rural and urban areas is less nowadays, fluoride pollution is more serious in rural areas than in urban areas[18]. There are many ways in which fluoride can pollute rural area, including underground water, food, and air pollution. Dental fluorosis has a strong association with the amount of fluoride content in drinking water[7]. Drinking water is the prime dietary source of fluorides. In China, the concentration of fluoride in tap water is set lower in urban areas. In rural areas, most areas will use underground water. The concentration of fluoride in underground water is variable and often above 1 part per million. Recently, the Chinese government has implemented water defluoridation projects and improved drinking water quality[19]. But children s are at a high risk of non-carcinogenic hazards from exposure to drinking water with high fluoride levels[18]. Furthermore, people living in rural areas lacked knowledge about the potential damage of fluorides.

The present study found that parents' socioeconomic status was associated with dental fluorosis. A higher socioeconomic status in adolescents meant a decreased risk of dental fluorosis, a fact consistent with a previous study[20]. The link between a better socioeconomic status and better health outcomes has been demonstrated in many reports[21]. Parents of low socioeconomic status were much more likely to lack health knowledge about the potential damage of fluorides and were more likely to live in rural areas where water is from springs or wells[22]. Those students who were 'only' children also showed a lower risk of dental fluorosis, largely due to receiving more attention from their parents. They would get more knowledge about the fluorides, which would keep them away from dental fluorosis.

We also found dental caries was increased with the severity of dental fluorosis. The structure of the teeth suffering dental fluorosis was impaired and more susceptible to dental caries[23].

In conclusion, China has a low prevalence of dental fluorosis as a whole. Rural areas were the key places for the prevention of dental fluorosis. More prevention measures should focus on the children whose fathers were of lower education and those in families with more than one child.

Conflicts of interest

The authors reported no conflicts of interest related to this study.

Author contribution

Dr Yan ZHOU contributed to the data collection, data analysis and preparation of the manuscript; Drs Dong Ru CHEN and Qing Hui ZHI contributed to the data collection and data analysis; Drs Xing WANG, Xi Ping

FENG, Bao Jun TAI, De Yu HU, Bo WANG, Chun Xiao WANG, Shu Guo ZHENG, Xue Nan LIU, Wen Sheng RONG, Wei Jian WANG, Yan SI, and Huan Cai LIN trained the investigators, designed and supervised the survey; Drs Yan SI and Huan Cai LIN contributed to the design of the study, general supervision of the research group, and critically revised the manuscript for important intellectual content.

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