



## Relation between Dental Fluorosis and Intelligence Quotient of School Children in Nagpur - A Cross-Sectional Study

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### ABSTRACT

**Background:** Abating controversy over fluoride is rekindling with findings on animals and aborted fetuses confirming excessive fluoride intake during infancy causes irreversible changes in the CNS.

**Aim:** To investigate the effect of excessive fluoride intake on the Intelligence Quotient (IQ) of children in Nagpur.

**Materials and methods:** A cross-sectional descriptive study was conducted among 130 school children aged 9-13 years. Children were categorized using Dean's Fluorosis Index Modified Criteria. Fluid intelligence and visual discrimination were assessed using Raven's Progressive Matrices Test and Seguin Form Board Test respectively.

**Results:** Mean scores for IQ grade was found significantly higher among children without dental fluorosis than with dental fluorosis (p-value 0.043).

**Conclusion:** The current study states that excessive fluoride intake has an effect on IQ and children with fluorosis have low Intelligence Quotient than those without fluorosis.

**KEYWORDS :** Dental fluorosis, IQ, fluoride

### INTRODUCTION

Fluoride is rightly termed as a double-edged sword as it embraces beneficial effects at low concentrations, but excessive exposure can give rise to number of adverse effects.<sup>1</sup>

India lies in geographical fluoride belt which extends from Turkey up to China and Japan through Iraq, Iran and Afghanistan. Fluorosis is endemic in 20 of the 35 states and union territories of Indian Republic.<sup>2</sup> In India, fluorosis was first reported by Shortt et al., in Nellore district of Madras State.<sup>3</sup> An estimated 62 million people, including 6 million children below the age of 14 years, suffer from fluorosis in India, due to consumption of fluoridated water.<sup>4</sup>

The adverse effects of excessive fluoride are irreversible, ranging from mild dental fluorosis to crippling skeletal fluorosis as the level and period of exposure increases.<sup>1</sup> Barring this, there are several reports that have stated that excess fluoride consumption promotes cancer, hip fracture, leads to still birth or birth defects and has detrimental neurological effects.<sup>5</sup>

Recent research on fluoride poisoning has unveiled that excessive fluoride intake can impair the central nervous system. Fluoride has the ability to form lipid soluble complexes which can penetrate the fetal blood brain barrier and accumulate in cerebral tissues before birth thereby affecting intelligence.<sup>6</sup> The negative effect of fluoride on children in the high fluoride area is mainly due to: (i) disruption of proper development in the womb due to the mother's intake of fluoride being passed to the fetus via placenta, or (ii) exposure to a high fluoride environment in

childhood. Either or both of these could lead to neuron damage, developmental difficulties, or neurotransmitter dysfunction.<sup>1,7</sup>

In children, the most delineated effect is on cognitive capacities, particularly intelligence reduction. Children from an area with high prevalence of fluorosis were found to have five times higher odds of developing low IQ than those who lived in a nonfluorosis area or a slight fluorosis area.<sup>7</sup>

Intelligence has been explained in many different ways including such as abstract thought, understanding, self-awareness, communication, reasoning, learning, having emotional knowledge, retaining, planning, and problem solving. An intelligence quotient, or IQ, is a score procured from one of several standardized tests designed to assess intelligence. IQ scores are employed as predictors of educational achievement, special needs, job performance and income. There is noteworthy connection between a person's degree of intelligence and range of activities, the level of achievement and the depth of understanding possible to him.<sup>8</sup>

An inverse association between fluoride exposure and intelligence was found in a meta-analysis performed in China to review studies on fluoride and IQ between 1988 and 2008.<sup>9</sup>

In the light of the above reports, we aimed at investigating the effect of excessive fluoride intake on the Intelligence Quotient (IQ) of children by looking at the Intelligence Quotient (IQ) scores and dental fluorosis status of the children in Waghdara.

**MATERIALS AND METHODS**

A descriptive cross-sectional study was conducted among 9 to 13 year old school children living in Waghdara, Hingna, Nagpur, India, during July 2018. Waghdara is a small village in Yavatman district of Vidharbha, Maharashtra situated from Nagpur at a distance of 140 kms. According to 2011 census, it has a total population of 18000, of which 55% are male and 45% female with 80% literacy rate. Atram H et al (2017) has confirmed a high prevalence of dental fluorosis in Waghdara.<sup>2</sup>

The study protocol was approved by the Institutional Ethical Committee. Informed consent was acquired from the parents and school authorities and assent was obtained from children.

A total of 130 children with normal birth history and similar socio-economic status were selected through stratified random sampling and enrolled in the study. Child with history of trauma to the head or other neurological disorder, any congenital or acquired diseases affecting intelligence and severe extrinsic stains on their teeth due to which assessment of dental fluorosis status was not possible were excluded from the study. Out of these 130 children, 65 were with dental fluorosis and 65 without dental fluorosis. Though, residing in the same area, these variations can be attributed to differences in water fluoride level during the development of their permanent teeth.

**Study Tools:**

Data was collected by clinical examination for assessment of dental fluorosis using Dean's Fluorosis Index Modified Criteria<sup>10</sup> and the IQ levels were tested by means of the Raven's Standard Progressive Matrices (1992 Edition)<sup>11</sup> and Seguin Form Board Test. A self-administered questionnaire proforma was attached consisting of personal information.

**Clinical examination for the assessment of dental fluorosis:**

The assessment of severity and grades of dental fluorosis was done in accordance with the Dean's Fluorosis Index Modified Criteria "1942" given by Trendley H Dean (Table 1). The scores were given to individuals after examining all the teeth present. Recording was based on the two most affected teeth. However, if the two teeth were not equally affected, the score for the less affected tooth was recorded. When teeth were being scored, examination was done starting from the higher end of the index "severe" and each score was eliminated until the final condition was reached. In case of doubt, the lower score was recorded.<sup>10</sup>

**Table 1:** Criterion for Dean's Fluorosis Index Modified Criteria

Fluorosis level	Score
Normal	0
Questionable	0.5
Very mild	1
Mild	2
Moderate	3
Severe	4

**Assessment of IQ levels:**

Visual discrimination, matching and eye hand coordination was assessed using Seguin Form Board Test.<sup>12</sup> Test materials consisted of ten differently shaped wooden blocks and a large form board with recesses corresponding to these shapes. The testing was administered individually to each child, in compliance with the guidelines and direction of the Seguin form board test manual. IQ testing kit was settled on the table and children were asked to advance one by one and perform the test. While administering the test, these blocks were taken out by the examiner and stacked in three rows in front of the subject who had to put them back

as quickly as he/she could. The children were instructed that they had to be as quick as possible and they would be given three trials. The timing was recorded on a stop watch. The task was repeated three times. Time, in seconds was obtained for each trial by investigator, who seated beside and slightly to the back of the subject to be tested. The total time score of each subject in three trials, their average and the shortest time score were obtained. Retesting was done on 10 children after a day so as to check the reliability of the testing protocol (Kappa=0.8).

Fluid Intelligence was assessed using the Raven's Standard Progressive Matrices 1992 Edition. It's a non verbal questionnaire consisting of sets A, B, C, D & E, each set having 12 questions. The problems contain a matrix of geometrical design, with a part removed. The child has to select the missing cell from six to eight given alternatives. Each child was given a questionnaire and was asked to answer all the questions in the specifically designed answer paper. They were allocated a time limit of 30 min according to specification of the test manual. The results obtained were converted into percentile and then overall score in individual assessment was graded as per the guidelines of Raven's Standard Progressive Matrices manual. (Table 2)

**Table 2:** Grading Criterion for IQ scores according to Raven's Progressive Matrices manual

Grade I	"Intellectually superior" If a score lies at or above 95 <sup>th</sup> percentile for that age group
Grade II	"Definitely above average" If a score lies at or above the 75 <sup>th</sup> percentile for that age group
Grade III	"Intellectually average" If a score lies between the 25 <sup>th</sup> and 75 <sup>th</sup> percentile for that age group
Grade IV	"Definitely below average" If a score lies at or below the 25 <sup>th</sup> percentile for that age group
Grade V	"Intellectually impaired" If a score lies at or below the 5 <sup>th</sup> percentile for that age group

**Method Of Calibration Of Examiner**

The examination was carried out by a single examiner (investigator herself) and recording was done by another person, who was familiar with the local language and assisted the examiner in recording the details. Calibration of the examiner was done before the study was conducted and in the middle of the study-by doing duplicate examination of 5% (1 in 20) of the total population and intra examiner agreement was assessed with Kappa statistics for dental fluorosis with Kappa levels above 75%.

Statistical analysis was be done by using software SPSS 22.0 version (Statistical Package for Social Sciences) and GraphPad Prism 6.0 version and p<0.05 was considered as level of significance. Descriptive and inferential statistics were performed using Student's paired and unpaired t test.

**RESULTS**

The mean age of the children included in the study was 10.6. It was observed that the mean Seguin form board test average values of children with dental fluorosis (20.62), was significantly higher than the mean values for children without dental fluorosis (17.93). Similarly, it was also noticed that the mean Seguin form board test shortest values of children with dental fluorosis (18.27), which was again significantly higher than the mean values for children without dental fluorosis (15.34). This implies that children without dental fluorosis performed

faster in the test (Table 3).

and shortest values in fluorosis and non-fluorosis group were statistically non-significant (Table 4 and 5).

Gender wise comparison of Seguin form board test average

**Table 3:** Comparison of Seguin form board test average timing and Seguin form board test shortest timing in fluorosis and non fluorosis group

IQ Test		N	Mean	Std. Deviation	Std. Error Mean	t-value	p-value
Seguin form board test average timing	Fluorosis	65	20.62	4.88	0.60	3.32	0.001,S
	Non Fluorosis	65	17.93	4.35	0.53		
Seguin form board test shortest timing	Fluorosis	65	18.27	4.20	0.52	4.11	0.0001,S
	Non Fluorosis	65	15.34	3.90	0.48		

**Table 4:** Gender wise comparison of Seguin form board test average values and Seguin form board test shortest values in fluorosis group.

IQ Test	Gender	N	Mean	Std. Deviation	Std. Error Mean	t-value	p-value
Seguin form board test average values	Male	40	19.94	4.90	0.77	1.43	0.15,NS
	Female	25	21.71	4.75	0.95		
Seguin form board test shortest values	Male	40	17.47	3.86	0.61	1.99	0.05,NS
	Female	25	19.56	4.46	0.89		

**Table 5:** Gender wise comparison of Seguin form board test average values and Seguin form board test shortest values in non fluorosis group

IQ test	Gender	N	Mean	Std. Deviation	Std. Error Mean	t-value	p-value
Seguin form board test average	Male	27	17.05	3.38	0.65	1.37	0.17,NS
	Female	38	18.55	4.87	0.79		
Seguin form board test shortest	Male	27	14.91	3.29	0.63	0.75	0.45,NS
	Female	38	15.65	4.30	0.69		

The comparison of IQ grades in fluorosis and non fluorosis group yielded statistically significant values with majority of children with fluorosis falling under grade V that is "Intellectually impaired" followed by grade IV. (Table 6) The gender wise comparison of IQ grades was found to be

statistically significant with 45% boys and 68% girls with fluorosis falling under the lowest grade. (Table 7) There was no statistically significant difference found between the IQ grades of males and females without fluorosis. (Table 8)

**Table 6:** Comparison of IQ grades in fluorosis and nonfluorosis group

IQ Grade	Fluorosis		Non Fluorosis		χ <sup>2</sup> -value	p-value
	No	%	No	%		
Grade I	0	0	0	0	8.16	0.043,S
Grade II	1	1.54	2	3.08		
Grade III	9	13.85	14	21.54		
Grade IV	20	30.77	30	46.15		
Grade V	35	53.85	19	29.23		
Total	65	100.00	65	100.00		

**Table 7:** Gender wise comparison of IQ grade in fluorosis group

IQ Score	Male		Female		χ <sup>2</sup> -value	p-value
	No	%	No	%		
Grade I	0	0	0	0	6.41	0.011,S
Grade II	1	2.5	0	0		
Grade III	9	22.5	0	0		
Grade IV	12	30	8	32		
Grade V	18	45	17	68		
Total	40	100	25	100		

**Table 8:** Gender wise comparison of IQ grade in non fluorosis group between the IQ grades of males and females without fluorosis. (Table 8)

IQ Score	Male		Female		χ <sup>2</sup> -value	p-value
	No	%	No	%		
Grade I	0	0	0	0	5.43	0.14,NS
Grade II	0	0.00	2	5.26		
Grade III	8	29.63	6	15.79		
Grade IV	9	33.33	21	55.26		
Grade V	10	37.04	9	23.68		
Total	27	100.00	38	100.00		

**DISCUSSION**

The present study was a cross-sectional study conducted on a stratified random sample of 130 school going children selected from Waghdara. Atram H et al found that, the fluoride concentrations of drinking water samples in Waghdara were well within the permissible limits as prescribed by BIS and WHO and hence eliminated drinking

water fluoride as an etiological source of dental fluorosis. Therefore, the mysterious prevalence of fluorosis in Waghdara (11-14 years age group 90%- Males, 76.9%- Females) could be explained by the following reasons. Almost 94.9% of the fluoride released during tea infusions is absorbed by consumers. Cooking food in aluminum vessels with the use of fluoridated water leads to formation of

aluminum fluoride complexes that get absorbed rapidly from intestine resulting in fluoride toxicity. Fluoride will also be present in the soil due to weathering of rocks & if agriculture is carried out in such soil then there is a fair bit of chance that the fluoride is transported through the food chain in our system which can also lead to fluorosis.<sup>2</sup>

The Dean's index was used for examining Dental Fluorosis is simple, reliable and uniform. It is also the recommended index for use when the water fluoride level is below 5 ppm.<sup>13</sup>

IQ has been used to measure intellectual ability for many years and there are many standards for measuring IQ. In the current study, we have used two IQ tests to check various aspects of IQ. Seguin Form Board Test finds application in assessment of general intelligence of children in pre-primary and primary school years. It is used for measuring visual discrimination, matching, eye-hand coordination and cognitive-perceptual abilities in children. Children without dental fluorosis included in the study performed faster in the Seguin Form Board Test as compared to those with dental fluorosis. Seguin form board test average values of children with dental fluorosis (20.62), was significantly higher than the mean values for children without dental fluorosis (17.93). Similarly, it was also noticed that the mean Seguin form board test shortest values of children with dental fluorosis (18.27), which was again significantly higher than the mean values for children without dental fluorosis (15.34). This implies that children without dental fluorosis performed faster in the test and had better visual discrimination, matching, eye-hand co-ordination and cognitive abilities than those with fluorosis. This is in accordance with studies conducted by Nagarajappa R et al (2013)<sup>14</sup> and Asawa K et al (2014).<sup>15</sup>

Gender wise comparison of Seguin form board test average and shortest values in fluorosis and non-fluorosis group were statistically non-significant. Nagarajappa R et al (2013) used the Seguin Form Board Test to assess the intelligence quotient (IQ) level of children from high an low water fluoride areas. Females in their study had lower mean timing scores than males in both the areas but the difference was not statistically significant.<sup>14</sup>

The second IQ test used was the Raven's progressive matrices because the results obtained by it are not affected by the cultural, ethical, linguistic or racial background of the children. It is used in measuring abstract reasoning and regarded as a non-verbal estimate of fluid intelligence. In our study, majority of children with fluorosis fell under grade V (Intellectually impaired) followed by grade IV (Definitely below average). The gender wise comparison of IQ grades were found to be statistically significant with 45% boys and 68% girls with fluorosis falling under the lowest grade. There was no statistically significant difference found between the IQ grades of males and females without fluorosis. The results of our research show that exposure to high levels of fluoride, as also determined by the dental fluorosis status of the child, does have detrimental effect on the mental ability of the child. Although the effect on the IQ of the child does not seem to be affected by the degree of fluorosis, nevertheless there is a correlation between dental fluorosis and the intellectual ability. This is in accordance with studies conducted by Aravind A et al (2016)<sup>16</sup>, Sebastian ST et al (2015)<sup>17</sup>, Khan SA et al (2015)<sup>18</sup>, Seraj B et al (2012)<sup>19</sup>, Shivaprakash PK et al (2011)<sup>20</sup>, Poulesami HR et al (2011)<sup>21</sup>, Eswar P et al (2011)<sup>22</sup>, Sudhir KM et al (2009)<sup>23</sup>

Excess fluoride has been found to be neurotoxic. Animal studies where mice were exposed to drinking water with high concentration of fluoride showed deterioration of learning and memory ability, decreased thickness of

postsynaptic density, increased width of synaptic cleft and higher cholinesterase activity in brain tissue.<sup>24,25</sup> Other animal studies have shown that rats exposed to drinking water with high concentration of fluoride at weaning were found to have elevated fluoride levels in 6 of 7 brain regions and plasma fluoride levels 7 to 42 times higher than those found in control animals.<sup>26</sup> Studies have also reported an increased brain cell apoptosis in offspring rats seen with high fluoride exposure.<sup>27</sup> The neurotoxin, fluoride has also shown to induce S-phase cell cycle arrest and DNA damage in primary cultured rat hippocampal neurons.<sup>28</sup>

Investigations on aborted human fetuses collected from endemic fluorosis area found that accumulation of fluoride in brain tissue causes disruption of certain neurotransmitters and receptors in nerve cells and also increased numerical density of volume of neurons and undifferentiated neuroblasts.<sup>29,30</sup> Evidence also suggests increased activity of alkaline phosphatase in femur and kidney and there is a reduction in number of mitochondria, rough endoplasmic reticulum and free ribosomes in neurons of cerebral cortex.<sup>31</sup>

Once absorbed in the blood through diet, fluoride forms lipid soluble complexes which cross the blood brain barrier to accumulate in the cerebral tissues.<sup>32,33</sup> The penetrated fluoride complexes adversely affect the CNS development by different neurotoxic mechanisms, such as free radical generation, inhibition of anti-oxidants and mitochondrial energy enzymes and inhibition of glutamate transporters.<sup>34</sup>

#### Limitations

In the present study, assessment of the effect of fluoride on child's IQ has been done, but it is possible that some other trace elements like Arsenic, Lead, Iodine may have neurological effects. Thus, further researches are required to investigate the effect of other environmental or geological contaminants on intelligence.

#### CONCLUSION

Fluoride has been advised since a long time as the ideal preventive, therapeutic agent for dental caries. However, like a coin that has two sides, fluoride has both favorable and harmful effects. The comparison on children with and without fluorosis has supported the hypothesis that excess fluoride intake does have an effect on Intelligence Quotient. Children with fluorosis have shown to have lower Intelligence Quotient in both the IQ tests. Therefore, a close monitoring of fluoride levels in local water supplies from areas with endemic fluorosis and implementing public health measures like defluoridation to reduce the fluoride exposure levels in high fluoridated regions seem necessary.

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