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Evidence of Dental Fluorosis from the Iron Age Site of Mahurjhari

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Abstract: Human teeth unearthed at the site of Mahurjhari are studied in this work to provide light on the prevalence of dental fluorosis among the megalithic inhabitants of the Vidharbha region. Fluorosis frequencies vary throughout different localities in Mahurjhari, as shown by the available dental data. There are explanations that could be put out for these differences. Since dental signs of fluorosis only formulate when teeth are forming, this may be because the population residing inside the site had access to various water resources, or because the people who are represented in the burial may have relocated to Mahurjhari from nearby locations.

Introduction

Fluorine is the thirteenth most common element in the earth's crust at 600–700 ppm. Fluorine forms inorganic and organic compounds called fluorides. Fluoride is one of the important nutrients in the development and growth of living beings, and it is consumed mostly in inorganic compounds that are present in food and water. Fluorides are present everywhere in nature, in rocks, soil, water, plants, animals, and even air. It makes tooth enamel stronger and more resistant to decay from acid attacks by bacteria and plaque, and acts as a caries-preventing agent. Fluorides work during both the demineralisation and mineralisation processes to strengthen the teeth. In demineralisation, acids present in saliva dissolve the calcium and phosphorous under the tooth's surface, while in the mineralisation process, when saliva is less acidic, it restores the calcium and phosphorous.

Excessive fluoride can have an adverse effect on humans as well as animals, as both of them utilise surrounding natural resources. There are three different forms: skeletal fluorosis, non-skeletal fluorosis and dental fluorosis (Resnick 1995: 3321; Littleton 1999). Prolonged, excessive exposure to fluoride can cause a debilitating bone disease known

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as skeletal fluorosis. Bone changes are observed only in long-standing and severe cases (Møller and Gudjonsson 1932; Shankaran and Gadekar 1964). An abnormal bone may form on any surface, but is particularly apparent in association with the insertions of tendons and ligaments where irregular bony excrescences form. The disease develops insidiously and can be difficult to distinguish from a number of other bone and joint diseases. At the beginning of fluorosis, a person may suffer a variety of symptoms in the absence of any detectable bone changes, including joint pain, joint stiffness, and gastric distress. As with any other toxic substance, individual susceptibility to fluoride varies considerably across the population, and different forms of the disease can take place based on an individual's nutritional status, health status, age, genetics, and exposure to aluminium.

Detection of non-skeletal fluorosis at an early stage is possible by understanding the soft tissue manifestation. In the case of this type of fluorosis, actin and myosin filaments are destroyed, and mitochondria lose their structural integrity, thereby providing evidence of the depletion of muscle energy. The erythrocyte membrane loses its calcium content in the presence of high fluoride.

The third type, dental fluorosis (DF), is easier to identify in comparison to other forms. Tooth discolouration is evident in the form of any change in colour and translucency of the tooth. There are three main types of tooth discolouration: 1. Intrinsic, 2. Extrinsic, and 3. Internalised discolouration (a combination of both). Intrinsic discolouration is caused by dental conditions like caries, trauma, infections, medications, nutritional deficiencies, genetic defects, and hereditary diseases that affecting enamel and dentine.

DF, otherwise known as mottled teeth, brown stain or discolouration of enamel, has been noticed by many scholars since the 1880s (Kuehns 1888; Eager 1901; McKay and Black 1916). Smith et al. (1931) noticed that the prevalence of this type of mottled enamel was directly related to the amount of fluoride in the drinking water. Jolly et al. (1968) observed permanent teeth losing their normal creamy white translucent colour and becoming rough, opaque, and chalky white. Many studies done on primary or deciduous teeth show incidences of fluorosis in the living population (e.g., Smith and Smith 1935; Teotia et al. 1971; Kodali et al. 1994; Warren et al. 1999). It is reported by Greenfield (1990: 438) that fluorosis affecting children whilst still in the womb can cause features such as bowed legs to develop once they start walking.

O'Mullane et al. (2016: 74) mention that the fluoride concentration in teeth reflects the overall availability of fluoride during tooth formation and will vary depending on the time of exposure to and intake of fluoride. The highest fluoride concentrations in enamel are found at the surface and can be around 2000mg/kg in people residing in non-fluoridated regions (representing a 6% replacement of OH^-/F^- in hydroxyapatite) and 3000mg/kg (8% replacement of OH^-/F^-) in fluoridated areas. These concentrations fall sharply after the outermost 10-20 μm of enamel to levels ranging from hundreds of mg/kg to around 50 mg/kg, depending on whether the area is fluoridated or not (Pessan and Buzalaf 2011). Beyond this depth, the fluoride content remains fairly constant up to the enamel-dentine junction, in contrast with bone and dentine, where the accumulation of fluoride continues throughout life. Once human enamel is fully formed, its fluoride concentration can only be permanently altered in subsurface regions as a result of trauma caused, for example, by caries, erosion, or abrasion.

The impact of fluorosis is also determined by factors such as body size, physical activity, food habits (Chari et al. 1974), and variations in atmospheric temperature and humidity (Galagan et al. 1957). In tropical countries like India, daily fluoride intake varies from moderate to high (Arlappa et al. 2013; Saxena and Sewak 2015). According to the Bureau of Indian Standards (BIS), use of drinking water with a high concentration of fluoride in groundwater beyond the permissible limit of 1.5 mg/L is a major health problem in India. Nearly 90% of the rural population of the country uses groundwater for drinking and domestic purposes, and due to excess fluoride in groundwater, a huge rural population is threatened with the health hazards of fluorosis. In the survey of the Central Ground Water Board, Ministry of Water Resources, Government of India (2010), it was observed that in the state of Maharashtra districts like Amravati, Chandrapur, Dhule, Gadchiroli, Gondia, Jalna, Nagpur, Nanded have localized occurrence of fluoride (>1.5mg/L) in groundwater.

DF results in the porosity of the surface and subsurface enamel by which enamel appears opaque. In the clinical features, changes display fine white opaque lines running across the tooth on all parts of the enamel to entirely chalky white teeth. In other cases, the enamel may be so porous (or hypomineralized) that the outer enamel breaks apart post-eruptively and the exposed porous subsurface enamel becomes discoloured (Fejerskov et al. 1990). The effects of fluoride on enamel formation, causing dental fluorosis in humans, are cumulative rather than requiring a specific threshold dose, depending on the total fluoride intake from all sources and the duration of fluoride exposure (Aoba and Fejerskov 2002: 155). The first index to grade dental fluorosis was developed by Dean in 1934, which is known as the Dean's index (Dean 1934). Later, he modified the observations in 1942 (Dean 1942).

The Site of Mahurjhari and the Material Studied

The site of Mahurjhari is situated in the Vidarbha region (long. 79° 30″ E; lat. 21°14″N) of Maharashtra, near Nagpur (Figs. 1-2). The site has been excavated thrice; the first time by Deo for two seasons initially (IAR 1970-71: 24-25, 1971-72: 33-35; Deo 1973). A total of 15 megaliths were excavated, and from those 11 megaliths, human remains were discovered, and the report was published in 1973 (Deo 1973). The site was again excavated by S. B. Deo in 1979 (mentioned in Lukacs 1981). In the years 2003–04, excavation was done by Deccan College under the supervision of R.K. Mohanty (Mohanty 2002, 2003a, 2003b, 2004, 2005a, 2005b: 106-107, 2006, 2008). Altogether, four megaliths (Meg-01, Meg-03, Meg-10, and Meg-28) were excavated. Both single stone circles and double stone circles are found.

In the earlier report, dealing with human skeletal remains from the site of Mahurjhari, V.V. Rao (1973: 65) mentions some discolouration present in the 1970s excavated material, and there he explains that the colouration is probably due to tobacco or fumigation. It is possible that it may indicate the presence of DF. However, the skeletal collection from that excavation was not available to the present authors for analysis. Kennedy (2003: 51-52) has also mentioned, while summarising Mahurjhari skeletal analysis, “The presence of dental enamel hypoplasia and pronounced femoral curvature suggests that dietary deficiency may have prevailed in this population. Vitamin D deficiency and rickets do not appear to be related to bowing of femora since it is unlikely

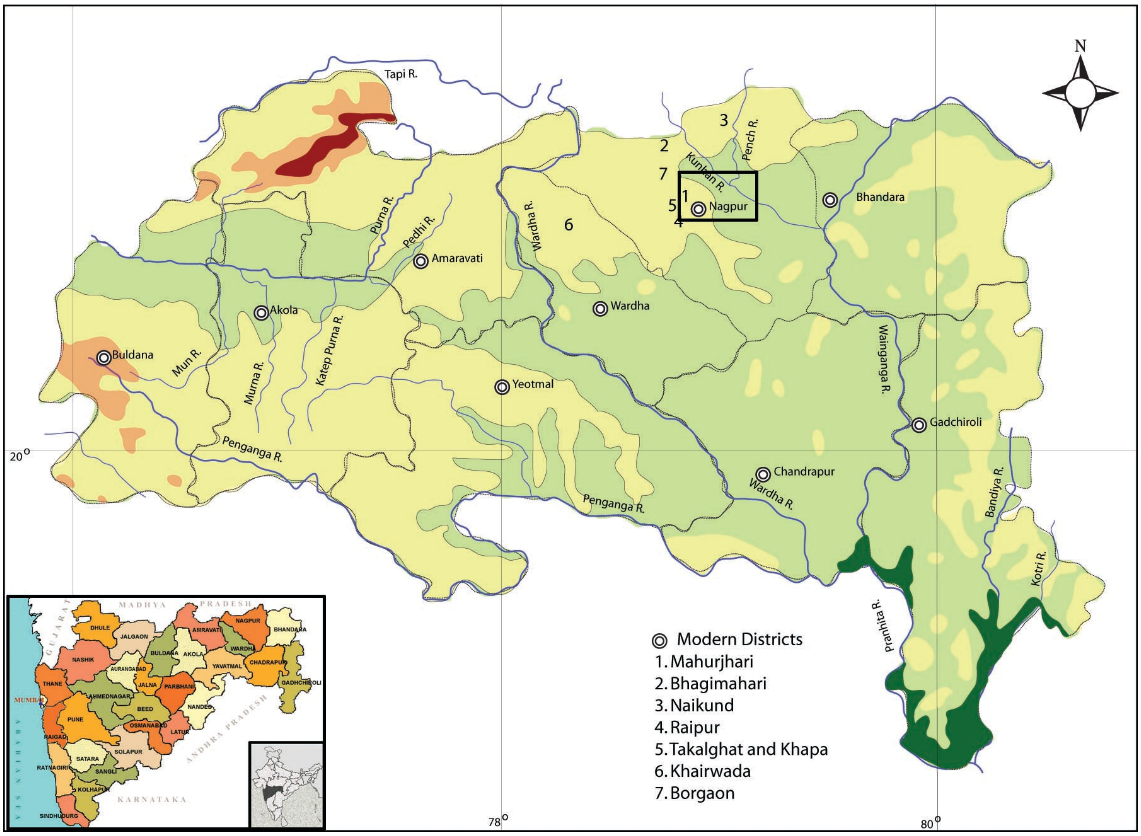

Fig. 1: Map showing the location of the site of Mahurjhari

Fig. 2: Mahurjhari site

that individuals affected were deprived of solar radiation. These indicators of stress are accompanied by the incidences of carious lesions and the attrition of occlusal surfaces of all teeth." This reference suggests that the presence of bowing of the femur might be additional support for the presence of skeletal fluorosis. Therefore, it was interesting to investigate whether DF is present and, if it is, then what its frequency is in the skeletal assemblage.

The total number of teeth considered for the present study is 426 (Table 1), from 49 'individuals'. It is to be noted that the counting of individuals is problematic in Mahujhari as many teeth are found isolated or sometimes one tooth represents an individual. The study involves 213 teeth (212 permanent and 1 deciduous) from the 1979 excavation, out of which Lukacs (1981) studied 196 teeth. Along with this, the study also includes 77 unstudied teeth (69 permanent and 8 deciduous) from the 1979 excavation. From the 2003-2004 excavation (Mohanty 2005), 136 teeth (130 permanent and 6 deciduous) are also included.

The sample represents almost all age groups (Table 2). From the 1979 excavation, there are 16 individuals (5 males, 4 females, 5 uncertain and 2 children) and from the 2003-04 excavation, there are 19 individuals (1 male, 1 female, 6 uncertain, and 11 children). Lukacs's (1981) age and sex determinations for 1979 individuals are considered, and for individuals from the 2003-04 excavation standard methodology of Buikistra and Ubalekar (1994) is used. Age and sex determination were not carried out for the unstudied material from the 1979 excavation as they are isolated findings.

Methodology

There are various methods used by scholars to document the DF, including Thylstrup and Fejerskov Index (1978), Total Surface Index of Fluorosis (TSIF) by Horowitz et al. (1984), Fluorosis Risk Index by Pendrys (1990). The Developmental Defects of Enamel Index was proposed in 1982 by the Commission on Oral Health, Research and Epidemiology arising from a lack of a well-defined and internationally accepted classification of enamel defects. This index was designed to provide an effective system for recording enamel defects in large studies, but it was too complicated. Later on, the index was modified and simplified by Clarkson and O'Mullane (1989). Other than the above-mentioned methodologies, there are other few new concepts in measuring DF. They are as follows: A Visual Analogue Scale (VAS), Quantitative Light Fluorescence (QLF), and Polarized White Light Images (Abiodun-SolankeIyabo et al. 2014). For this study, the Dean Index (1934, 1942) is used as it is easy to understand, reliable, and precise. It is a universal index accepted by scholars. It is a sensitive index and designed to detect six stages of DF, ranging from early clinical changes to the severe stage (Table 3). The concentration and spread of brown stains on teeth were also considered for scoring purposes. The grading is done as: 0 = Normal, 1 = Questionable, 2 = Very Mild, 3 = Mild, 4 = Moderate, 5 = Severe.

Observations

All the teeth were observed with our naked eyes and discolouration was recorded according to the location on the tooth. The sample was cleaned with plain water, air-

Table 1: List of dental sample used for the present study

MHR 1978-1979				Unstudied MHR 1978-1979				MHR 2003-2004			
Sp. No.	**Jaws**		**Total**	**Sp. No.**	**Jaws**		**Total**	**Sp. No.**	**Jaws**		**Total**
MHR1	U	13	P-29	MHR, Meg No-1	U	8	P-8	2003/Meg10/Individual 1/ F?/ 20±1 y	U	16	31
M/18-22y	L	16			L	7	d-7		L	15	
MHR2	U	2	P-16	MHR MISC. (Kept with 2a)	U	2	P-8	2003/Meg10/Individual 2/ M/18-25 y	U	12	21
M/30±5y	L	14			L	6			L	9	
MHR2a	U	2	P-4	MHR, Meg No- 3, 203	U	1	P-1	2003/Meg10/Individual 3/ U/18 -20 y	U	7	13
Adult	L	2			L				L	6	
MHR3	U	15	P-23	MHR, Meg No-3, 379	U	9	P-10	2003/Meg10/Individual 4/U/ Around 20 y	U	5	13
U/18-22y	L	8			L	1			L	8	
MHR3a	U	10	P-18	MHR, Meg No-3,388	U	0	P-4	Meg10/Misc. 1/U/10-12 y	U	0	2
12-15 y	L	8			L	4			L	2	
MHR4	U	1	P-8	MHR, Meg No-3,290	U	0	P-1	Meg10/Misc. 2/Around 2 y	U	2	d-2
M?/adult	L	7			L	1			L	0	
MHR5	U	2	P-7	MHR, Meg No-4	U	9	P-12	Meg10/Misc. 3/Around 9 y	U	0	1
M?/adult	L	5			L	3			L	1	
MHR6	U	6	P-10	MHR, Meg No-8	U	1	P-13#	Meg10/Misc. 4/	U	1	7
F?/18-22y	L	4			L	7		5- 6 y	L	6	

(Table 1 Continued…)

(Table 1 Continued…)

MHR 1978-1979				Unstudied MHR 1978-1979				MHR 2003-2004			
Sp. No.	Jaws		Total	Sp. No.	Jaws		Total	Sp. No.	Jaws		Total
MHR6a	U	10	P-16	*1st Individual	L	1		Meg 10/SE 1/	U	P-1	P-2
F?/16-20y	L	6						6-7 y		d-2	d-3
									L	P-1	
										d-1	
MHR7	U	8	P-22	*2nd Individual	L	3		Meg 10/SE 2/	U	P-2	P-2
F?/18-22y	L	14						6-7 y		d-1	d-1
									L	0	
MHR8a	U	7	P-11	*3rd Individual	L	1		Meg 10/SE 5/	U	0	2
F?/17-20y	L	4						11- 12 y	L	2	
MHR8b	U	3	P-2	MHR, Meg No-9	U	0	P-1	Meg 10/NE 2/	U	0	1
Subadult	L	0	d-1		L	1		5-6 y	L	1	
MHR9	U	10	P-15	MHR, Meg No-10	U	2	P-2	Meg 10/NE 3/	U	1	3
M/24–30y	L	5			L	0		7- 8 y	L	2	
MHR10	U	0	P-5	MHR, Meg No-11	U	3	P-9	Meg 10/Outside (2004)/ Around 18 y	U	2	12
U/adult	L	5			L	7	d-1		L	10	
MHR11	U	7	P-17					Meg 1/SE 1/Around 15 y	U	3	7
U/25–30y	L	10							L	4	
MHR13	U	4	P-9					Meg 3/NW 1/	U	0	1
U/18-22 y	L	5						5-8 y	L	1	

(Table 1 Continued…)

(Table 1 Continued…)

MHR 1978-1979			**Unstudied MHR 1978-1979**			**MHR 2003-2004**			
Sp. No.	**Jaws**	**Total**	**Sp. No.**	**Jaws**	**Total**	**Sp. No.**	**Jaws**		**Total**
						Meg 3/SW 2/U/20-25 y	U	4	6
							L	2	
						Meg 3/NE 5/	U	0	3
						17-25 y	L	3	
						Meg 28/Central pit/U/ Around 25 y	U	1	3
							L	2	
Total		P-212			P-69				P-130
		d-1			d-8				d-6
Total sample size			P:212+69+130 d:1+8+6	411 15		Total: 426			

P: permanent; d: deciduous; # number of teeth including *individual 8a+b+c from unstudied material

Table 2: Demographic distribution of sample

1979 (16 individuals)	**2003-04 (19 individuals)**
M: 5 F: 4 U: 5 **Child** 12-15: 1 **Sub adult**: 1	M:1 F: 1 U: 6 **Sub adults: 11** 0-2y: 1 5-10y: 7 10-12y: 2 12- 15y: 1
Adult: 4 (out of that 2 are probably M) **Young adult**: M: 1 F: 4 U: 2 **Middle aged**: M: 2 F: 0 U: 1	**Adult**: 0 **Young adult** M: 1 F: 1 U: 6

dried, and then observed. The colour and nature of the discolouration are considered while recording. The entire tooth surface is observed. The discolouration is recorded as plain, pinprick size, partial, and on the complete surface. The colour is noticed as faint, dark orange, brown, and whitish patch. If the tooth is not displaying discolouration, it has been noted as 0. There are certain teeth that do not show any discolouration but have a whitish patch on them, or are sometimes labelled as 'bad quality enamel' indicating the enamel surface is not glossy as usually seen and has a rough and whitish appearance. The tables are divided into maxillary and mandibular dentition.

There are a total of 213 teeth, out of which one tooth is deciduous and the rest 212 teeth are permanent. Tables 4 and 5 exhibit fluorosis grading that was given to each individual tooth from the 1978-1979 excavations. From a total of 100 maxillary teeth, 46 teeth (46.00%) showed evidence of DF, and out of 108 mandibular teeth, 36 teeth (33.33%) showed DF. Five teeth were broken and hence not included in the observation table. There is no fluorosis found in three individuals: MHR8a, MHR9, and MHR10. Other individuals show some kind of discolouration on their teeth. Maxillary teeth are more affected than mandibular teeth. It is also to be considered that the total number of teeth varies for each individual; they are not a complete set of teeth. One of the major limitations is that for many individuals, only one tooth is present and it has fluorosis, and, as a result, the result shows 100% fluorosis for that individual. This creates an error in the documentation. Fig. 3 shows individual-wise distribution of fluorosis.

Tables 6 and 7 describe unstudied teeth from MHR's 1978-1979 excavation. There are a total of 77 teeth, out of which 8 are deciduous teeth and the remaining 69 are permanent teeth. There are total 37 maxillary teeth out of which 17 (45.95%) and out of 37 mandibular teeth 8 (21.62%) show DF. Three teeth were broken and hence not

Table 3: Dean Index used for grading dental fluorosis

Classification	Dean's Index	Illustration
Normal Grade 0	The enamel is translucent semi vitriform type of structure, smooth and presents a glossy appearance	
Questionable Grade 1	Borderline between Normal and Very Mild Fluorosis. Normal enamel, but translucency is varied by a few white flecks or occasional white spots	
Very Mild Grade 2	Small opaque, paper-white areas scattered irregularly over the labial and buccal surface of teeth involving less than 25% of the tooth surface. Summits of the cusps of bicuspids and second molars are commonly affected	
Mild Grade 3	The Opaque white area in the enamel of the tooth covering less than 50% of the tooth surface	 
Moderate Grade 4	Entire tooth surface affected, those which are subjected to attrition show marked stain. Brown stains are a frequent feature	 
Severe Grade 5	All enamel surfaces is affected, deep brown or black areas, corrosion type of mottled enamel. Stains are widespread	 

included in the observation table. There is no fluorosis found in four individuals: Meg 3 No-203, Meg 3 No-388, Meg 3 No-290 and Meg 10 No-415. Other individuals show some kind of discolouration on their teeth. Maxillary teeth are more affected than mandibular teeth. In Meg No-1, there are both deciduous teeth as well as permanent teeth present, and in this individual, the deciduous teeth show the sign of fluorosis.

Of the maxillary dentition representing 13 individuals, 9 show signs of fluorosis. Fig. 4 shows the individual-wise distribution of fluorosis from this series. There are four individuals with only one tooth affected. Out of 9 individuals, the MHR Meg 3 No-379 shows all teeth affected.

Tables 8 and 9 describe teeth from MHR's 2003-2004 excavation. There are a total of 136 teeth, out of which 6 are deciduous and 130 are permanent. Of 58 maxillary teeth, 32 teeth (55.17%) are affected, and from 71 mandibular teeth, 24 teeth (33.80%) are affected.

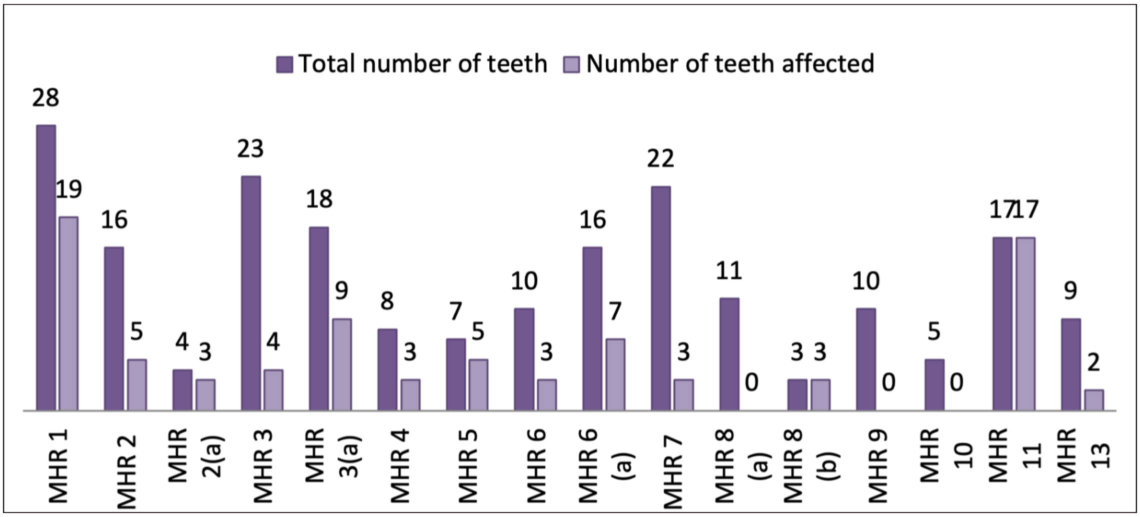

Fig. 3: Individual-wise occurrence of dental fluorosis (1979 samples)

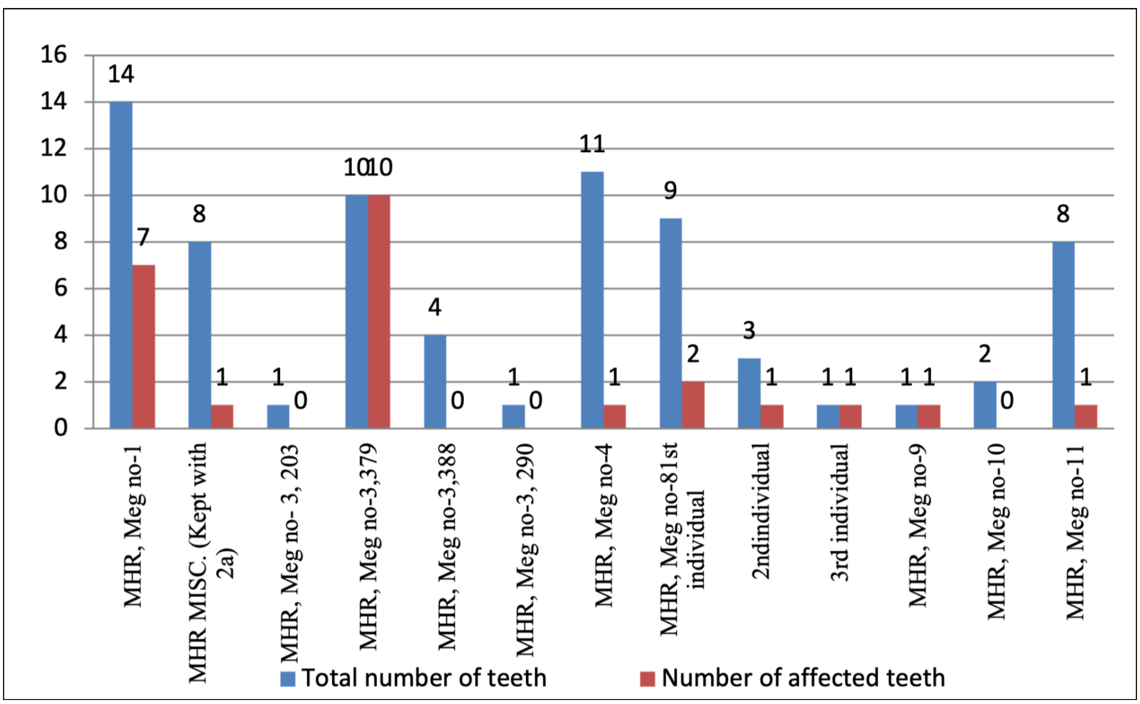

Fig. 4: Individual-wise distribution of fluorosis from 1979 unstudied material

Seven teeth were broken and hence not included in the observation. There was no fluorosis found in three individuals: MHR 2003 Meg 10 Individual 2, MHR 2003 Meg 10 Individual 4, and Meg 10 Miscellaneous 1 (Fig. 5). Other individuals show some kind of discolouration on their teeth. Maxillary teeth are more affected than mandibular teeth.

Hence, a total of 426 teeth were studied for the present work. Of the 426 teeth, 15 were deciduous and the remaining 411 were permanent (Table 10). Out of 195 maxillary teeth, 95 (48.71%) exhibited evidence of fluorosis, and out of 216 mandibular teeth, 68 (31.48%) had fluorosis. Out of 9 maxillary deciduous teeth, 7 are affected, and out of 4 mandibular deciduous teeth, 2 are affected due to fluorosis. It is interesting to see the

Table 4: Dean Scale for teeth from MHR 1978-1979 excavation: Maxillary dentition

Specimen Number	**Tooth Class**															
	I1		**I2**		**C**		**Pm1**		**Pm2**		**M1**		**M2**		**M3**	
	R	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**
MHR1	4	4	2	1	2	1	1	1	0	0	2	1	-	2	-	-
MHR2	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	2
MHR2a	-	-	-	-	-	-	2	-	-	-	-	5	-	-	-	-
MHR3	0	0	-	0	0	0	0	0	0	0	0	2	0	0	0	0
MHR3a	0	4	-	-	4	-	0	3	0	-	2	0	3	1	-	-
MHR4	-	-	-	-	-	0	-	-	-	-	-	-	-	-	-	-
MHR5	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-	4
MHR6	-	-	-	-	-	-	-	-	-	-	1	0	0	2	0	2
MHR6a	-	0	-	2	0	0	1	-	0	-	1	1	-	3	-	5
MHR7	-	-	-	0	-	0	-	-	0	0	0	-	0	2	2	-
MHR8a	-	-	-	-	-	0	0	-	0	-	0	0	0	0	-	-
MHR8b	-	-	3	-	-	-	-	-	-	4	-	-	-	d-1	-	-
MHR9	-	-	-	0	0	0	0	0	0	0	-	0	-	0	0	-
MHR10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MHR11	-	-	3	-	1	-	-	-	-	-	5	-	5	5	4	5
MHR13	-	-	-	0	-	-	-	-	4	-	-	-	0	-	0	-

Table 5: Dean Scale for teeth from MHR 1978-1979 excavation: Mandibular dentition

Specimen Number	**Tooth Class**															
	I1		**I2**		**C**		**Pm1**		**Pm2**		**M1**		**M2**		**M3**	
	R	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**
MHR1	0	0	0	0	0	1	1	0	1	1	-	1	1	1	1	0
MHR2	0	2	-	0	0	0	0	-	0	0	0	0	0	1	0	1
MHR2a	-	-	-	-	-	-	-	-	-	-	-	-	-	2	0	-
MHR3	-	-	-	-	-	4	-	1	-	0	0	0	0	2	-	0
MHR3a	0	0	0	-	0	-	-	-	4	-	0	1	4	-	-	-
MHR4	-	2	-	-	-	-	3	3	-	-	0	0	0	0	-	-
MHR5	-	-	-	-	0	-	0	-	1	-	-	-	5	-	4	-
MHR6	-	-	-	-	-	-	-	-	-	-	0	-	0	0	0	-
MHR6a	-	-	-	-	0	0	-	-	-	-	0	-	0	-	1	0
MHR7	0	0	0	-	-	0	0	0	0	0	0	2	0	0	0	0
MHR8a	-	-	-	-	-	-	-	-	-	-	0	0	0	0	-	-
MHR8b	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MHR9	-	-	-	-	-	0	-	0	-	0	-	0	-	0	-	-
MHR10	-	-	-	-	-	-	-	-	-	-	-	0	-	-	-	-
MHR11	-	-	-	-	-	-	5	1	5	1	5	5	5	5	5	5
MHR13	-	-	-	-	-	-	0	-	-	-	-	0	0	0	0	-

Table 6: Dean Scale for unstudied teeth from MHR 1979: Maxillary dentition

Specimen Number	Tooth Class															
	I1		**I2**		**C**		**Pm1**		**Pm2**		**M1**		**M2**		**M3**	
	R	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**
MHR, Meg No.1	4	5 d1	-	-	-	-	-	-	-	-	0	0 d-1	d-0	-	-	-
MHR MISC. (Kept with 2a)	-	0	-	0	-	-	-	-	-	-	-	-	-	-	-	-
MHR, Meg No.3, 203	-	-	-	-	-	-	-	-	-	-	0	-	-	-	-	-
MHR, Meg No.3, 379	3	-	3	3	3	-	-	1	1	3	3	-	-	-	-	3
MHR, Meg No.3, 388	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MHR, Meg No.3, 290	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MHR, Meg No.4	-	0	0	0	-	0	-	-	0	0	-	-	1	0	0	-
MHR, Meg No.8																
1st individual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
2nd individual	-	-	2	0	0	-	-	-	-	-	-	-	-	-	-	-
3rd individual	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
MHR, Meg No.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MHR, Meg No.10	-	-	-	-	0	-	-	-	-	-	-	-	-	-	-	0
MHR, Meg No.11	-	-	-	-	-	-	-	-	-	-	-	2	-	0	-	-

No.: It is the number assigned to the skeletons by the excavator.

Table 7: Dean Scale for unstudied teeth from MHR 1979: Mandibular dentition

Specimen Number	Tooth Class															
	I1		**I2**		**C**		**Pm1**		**Pm2**		**M1**		**M2**		**M3**	
	R	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**
MHR, Meg No.1	-	-	4	4	-	-	-	-	-	-	d-0	0	d-0	0 d-3	-	-
MHR MISC. (Kept with 2a)	0	-	0	-	0	-	0	-	-	-	-	-	3	-	0	-
MHR, Meg No.3, 203	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MHR, Meg No.3, 379	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	-
MHR, Meg No.3, 388	-	-	-	-	0	-	-	-	0	0	-	0	-	-	-	-
MHR, Meg No.3, 290	-	-	-	-	-	-	-	-	0	-	-	-	-	-	-	-
MHR, Meg No.4	-	-	-	-	0	-	-	-	-	-	-	0	-	-	-	0
MHR, Meg No.8																
1st individual	0	-	1	-	0	-	0	-	1	0	0	-	-	-	0	-
2nd individual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3rd individual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MHR, Meg No.9	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
MHR, Meg No.10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MHR, Meg No.11	-	-	-	-	-	-	0	0	-	-	-	0	0	-	0	0

No.: It is the number assigned to the skeletons by the excavator.

most affected tooth class (Table 9). The maxillary teeth are more affected than the mandibular teeth (Fig. 6). Maxillary molars, incisors, and first premolars are more affected when compared to other teeth. In the mandible, the incisors and second molars are more affected than other teeth. The total percentage of teeth affected by the whole sample is 39.66%.

Discussion

While studying the dental remains from the site of Mahurjhari, many interesting facts could be deduced. These need to be analysed in the context of the relationship between fluorosis and dental caries as well as that of enamel hypoplasia. It is found that the discolouration on teeth is caused by fluorosis and not post-mortem processes or taphonomical activities. If teeth were exposed to fluoride in the soil, post-burial condition, then the discolouration would have been similar to all the teeth. There are a few adolescent individuals with both deciduous teeth as well as permanent teeth having fluorosis (MHR 8b, MHR Meg No-1 and No- 22, Meg 10/SE1, Meg 10/SE2). This demonstrates that those individuals were exposed to fluoride-rich water for an extended period of time.

According to WHO, dental caries is defined as the localised post-eruptive, pathological process of external origin involving softening of the hard tooth tissue and proceeding to the formation of a cavity. Dental caries is caused by the action of acid on the enamel surface. The acid is produced due to sugar consumption, mainly sucrose from food or drinks. This sugar reacts with the bacteria present in the dental plaque on the surface of the tooth. The acid is produced, which results in the loss of calcium and phosphate from the enamel. This process is called demineralisation. The risk of dental caries is higher in areas where the fluoride content of water is lower. Fluoride helps in slowing down the process of demineralisation. It also helps to remineralise the surface, which shows an early sign of phosphate or calcium deficiency. But there is another angle to it, as Levy (2003: 286) suggested, "With more severe form of fluorosis, caries risk increases because of pitting and loss of the outer enamel". A more severe degree of enamel fluorosis is associated with an abnormally high incidence of caries. The high degree of DF causes an increased tendency to caries (Carlsson 1978; Cortes et al. 1996). Dental caries are present in 8 individuals out of 16 from the 1978-1979 excavation. Three individuals show both dental caries and DF on the same tooth. In the unstudied material of 1978-1979, out of 14 individuals, four of them show dental caries but no individual with caries and fluorosis on the same tooth. The 2003-2004 excavation yielded 19 specimens with teeth. Only 2 specimens show signs of dental caries, and two individuals show both dental caries and DF on the same tooth (Fig. 7).

There is an interesting relationship between enamel hypoplasia and fluorosis. Enamel hypoplasia is defined as an incomplete or defective formation of the organic enamel matrix of the tooth. In simple words, it is due to a deficiency in enamel formation. There are basically two types of enamel hypoplasia: hereditary and environmental. Various factors responsible for enamel hypoplasia include nutritional or vitamin deficiency, exanthematous diseases (e.g., measles, chickenpox, and scarlet fever), congenital syphilis, hypocalcemia, birth injury, prematurity and local infection or trauma (fluoride). A high level of fluoride is responsible for the worsening of enamel

Table 8: Dean Scale for teeth from MHR 2003-2004 excavation: Maxillary dentition

Specimen Number	**Tooth Class**															
	I1		**I2**		**C**		**Pm1**		**Pm2**		**M1**		**M2**		**M3**	
	R	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**
2003/Meg10/ Individual 1	2	2	0	0	0	0	1	0	1	0	2	2	2	0	2	0
2003/Meg10/ Individual 2	0	-	0	-	0	0	0	0	0	0	0	0	0	-	0	-
2003/Meg10/ Individual 3	0	-	0	5	2	1	-	2	-	-	-	-	4	-	-	-
2003/Meg10/ Individual 4	-	-	-	-	-	-	-	-	-	-	-	0	0	-	0	-
Meg10/Misc. 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Meg10/Misc. 2	-	-	-	-	-	-	-	-	-	-	d-3	d-0	-	-	-	-
Meg10/Misc. 3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Meg10/Misc. 4	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
Meg 10/ SE 1	-	-	-	-	5	-	-	-	-	-	d-5	-	d-5	-	-	-
Meg 10/ SE 2	-	-	-	-	-	-	-	-	-	-	-	4 d-4	5	-	-	-
Meg 10/ SE 5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Meg 10/ NE 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Meg 10/ NE 3	-	-	-	-	-	-	-	-	-	-	-	4	-	-	-	-
Meg 10/ Outside (2004)	4	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-
Meg 1/ SE 1	-	-	-	-	-	-	5	-	-	-	1	5	-	-	-	-
Meg 3/ NW 1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Meg 3/ SW 2	-	-	-	-	4	-	4	-	-	4	-	-	4	-	-	-
Meg 3/ NE 5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Meg 28/ Central pit	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-

hypoplasia. It is present in 5 individuals out of 16 from the 1978-1979 excavation, and three individuals show both enamel hypoplasia and dental fluorosis on the same tooth. In the unstudied material of 1978-1979, out of 14 specimens, five show signs of enamel hypoplasia, and two individuals show both enamel hypoplasia and DF on the same tooth. The 2003-2004 excavation yielded 19 specimens with teeth, out of which five specimens show signs of enamel hypoplasia and three individuals show both enamel hypoplasia and dental fluorosis on the same tooth (Fig. 8).

The ethnographic data shows that the current population consuming well water is tested positive for fluorosis, and those consuming tap water and water from hand pumps have no sign of fluorosis from in and around Mahurjhari. Water samples were tested for all the sources, and the level of fluoride is <0.5 ppm in wells as well as in hand

Table 9: Dean Scale for teeth from MHR 2003-2004 excavation: Mandibular dentition

Specimen Number	**Tooth Class**															
	I1		**I2**		**C**		**Pm1**		**Pm2**		**M1**		**M2**		**M3**	
	R	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**	**R**	**L**
2003/Meg10/ Individual 1	0	0	0	0	0	0	-	0	0	0	0	0	1	0	0	0
2003/Meg10/ Individual 2	0	-	-	-	0	-	-	0	0	0	0	0	0	0	-	-
2003/Meg10/ Individual 3	-	2	-	2	-	0	-	0	0	1	-	-	-	-	-	-
2003/Meg10/ Individual 4	-	-	-	0	-	-	0	0	-	0	-	0	0	0	-	-
Meg10/Misc. 1	-	-	-	-	-	-	-	-	-	-	0	0	-	-	-	-
Meg10/Misc. 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Meg10/Misc. 3	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-
Meg10/Misc. 4	0	0	2	2	-	-	-	-	-	-	5	5	-	-	-	-
Meg 10/ SE 1	-	-	-	-	-	-	-	-	-	-	-	-	-	5 d-5	-	-
Meg 10/ SE 2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Meg 10/ SE 5	-	-	-	-	-	-	-	-	-	-	-	-	3	-	0	-
Meg 10/ NE 2	-	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-
Meg 10/ NE 3	-	-	-	-	2	-	-	-	-	-	-	-	5	-	-	-
Meg 10/ Outside (2004)	-	-	-	-	0	2	0	0	0	0	0	0	2	1	-	-
Meg 1/ SE 1	-	-	-	-	-	-	-	-	-	-	-	0	-	0	4	-
Meg 3/ NW 1	-	-	-	3	-	-	-	-	-	-	-	-	-	-	-	-
Meg 3/ SW 2	-	-	-	-	-	-	4	-	-	-	-	-	4	-	-	-
Meg 3/ NE 5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Meg 28/ Central pit	-	-	-	-	-	-	-	-	-	-	4	-	4	-	-	-

pump water. There is no high concentration of fluoride in any water source. The students who consumed well water live 1.5 km away from the village in a mining area. The parents of these kids have come from the border village of Madhya Pradesh in order to work in the Mahurjhari mining industry. Therefore, these kids probably were exposed to fluoride-rich water during their early years of life, hence they have discolouration present on their teeth. The data from the water resources of Mahurjhari suggests a low-fluoride zone in spite of the fact that fluoride-rich water bodies might be present in the vicinity of the site.

The absence of fluoride content in water resources and the presence of fluorosis on individuals from the burials indicate there was a probability of some population

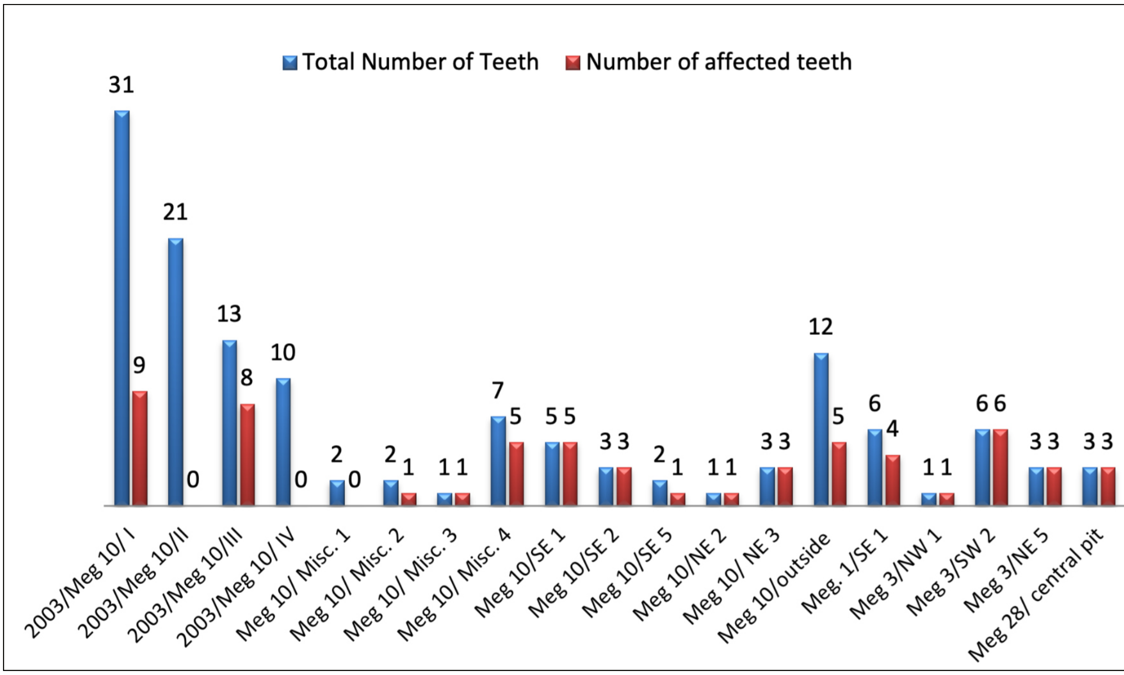

Fig. 5: Individual-wise occurrence of dental fluorosis (2003-04 sample)

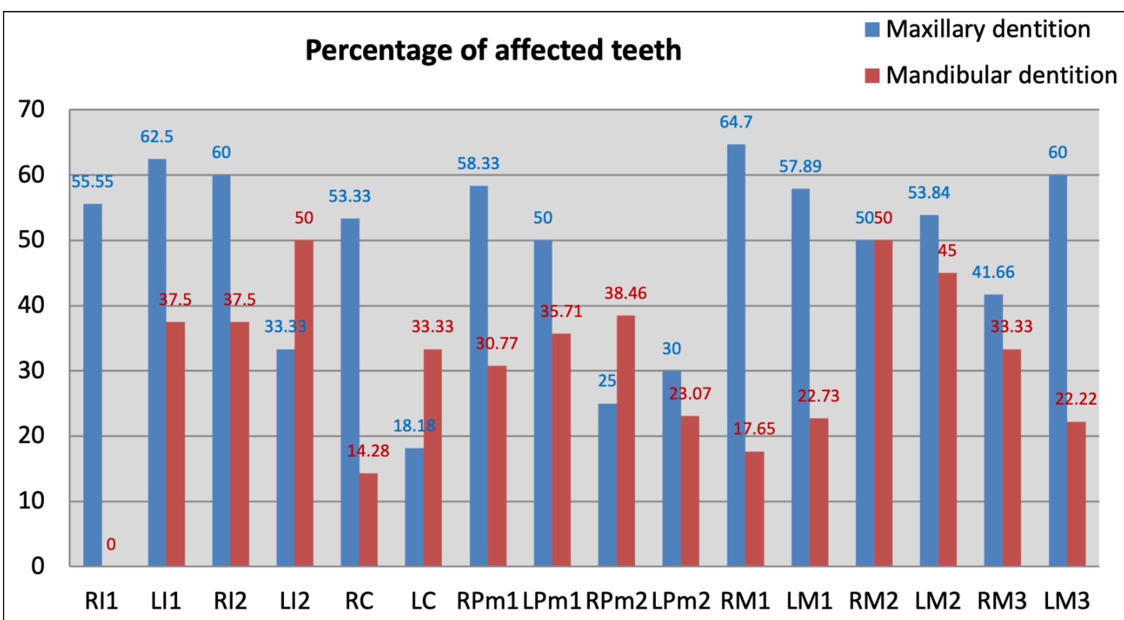

Fig. 6: Relative proportion of affected teeth

Table 10: Distribution of dental fluorosis in each tooth class

	Maxilla			Mandible		
Tooth	**No. of teeth**	**Affected teeth**	**Percentage**	**No. of teeth**	**Affected teeth**	**Percentage**
RI1	9	5	55.55	9	0	0
LI1	8	5	62.50	8	3	37.50
RI2	10	6	60.00	8	3	37.50
LI2	12	4	33.33	8	4	50.00
RC	15	8	53.33	14	2	14.28
LC	11	2	18.18	9	3	33.33
RPm1	12	7	58.33	13	4	30.77
LPm1	8	4	50.00	14	5	35.71
RPm2	12	3	25.00	13	5	38.46
LPm2	10	3	30.00	13	3	23.07
RM1	17	11	64.70	17	3	17.65
LM1	19	11	57.89	22	5	22.73
RM2	16	8	50.00	24	12	50.00
LM2	13	7	53.84	20	9	45.00
RM3	12	5	41.66	15	5	33.33
LM3	10	6	60.00	9	2	22.22
Total	**195**	**95**	**48.71**	**216**	**68**	**31.48**
					Total Teeth	**411**
15 teeth are broken and not considered					**Affected**	**163**
					Percentage	**39.66%**

movement towards Mahurjhari from a fluoride-rich belt from neighbouring areas. This also indicates certain population was getting assimilated with the local population of Mahurjhari. As mentioned in the previous study, the burials were divided into clusters on the basis of their burial goods (Vaidya 2014). Data from the 1978-1979 excavation suggests that individuals with most cases of fluorosis fall into cluster 2, 3, and 7 (Vaidya 2014). According to Vaidya (2014), these clusters are related to the craftsman community. These craftsmen were involved in making horse ornaments and defensive weaponry. There is a strong possibility of specialised craftsmen travelling from one settlement to another for the purpose of economic gain and technological exchange. These craftsmen might be sharing not only kinship ties with people within the settlements but also across settlements for the exchange of economic gains. This can be one of the speculations regarding the identification of the population. The isotopic analysis will further add some information.

Pathology and nutritional patterns show moderate dental caries and stress, indicating a high level of carbohydrates in the diet (Lukacs 1981). On the basis of dental caries, Lukacs suggested that megalithic people from Mahurjhari were agriculturists.

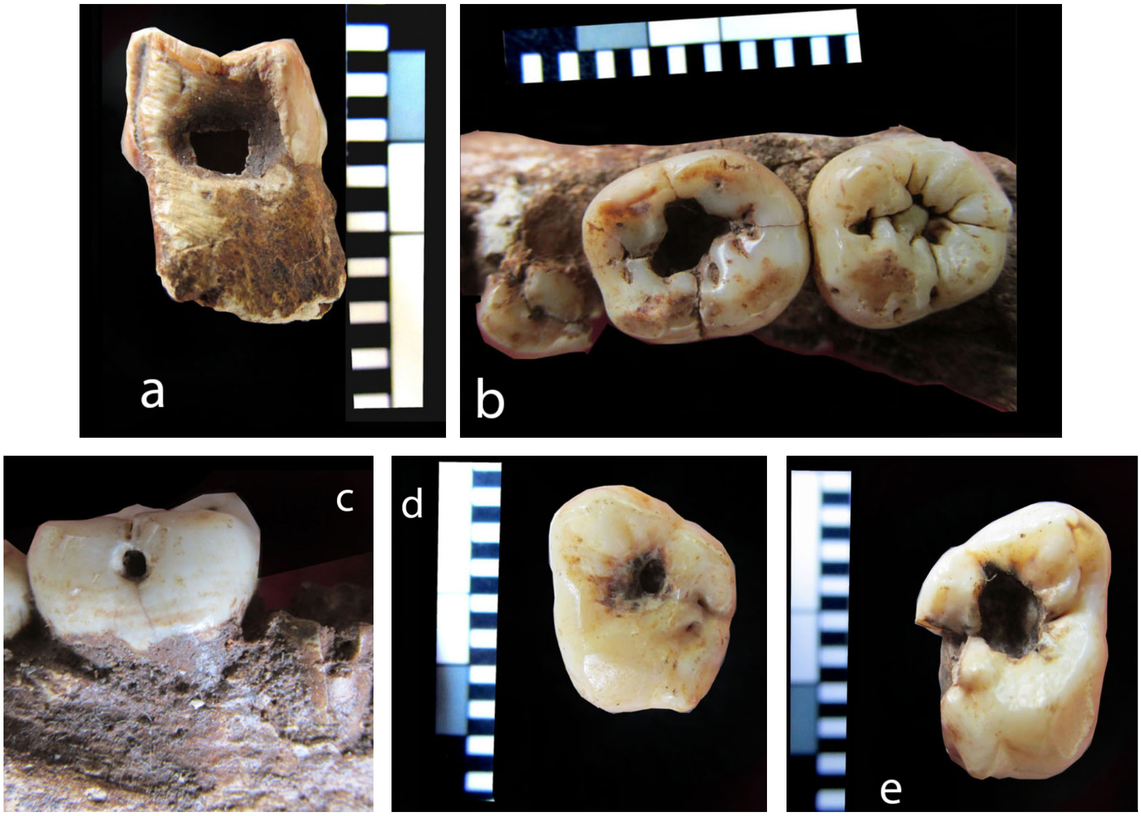

Fig. 7: Examples of dental caries and fluorosis co-occurrence. a: MHR-2003, Meg-10, Q-SE, Dig-6, SE-1 Maxillary Rdm1; b: MHR-1 (1978-79), Mandibular LM1; c: MHR-1 (1978-79), Mandibular RM1; d: MHR-6 (1978-79), Maxillary LM3; e: MHR-6, (1978-79) Maxillary RM3

There is evidence of double cropping recovered from other megalithic habitation sites like Bhagimohari, i.e., harvested during both the rainy and winter seasons (Kajale 1989). The discovery of settlement at Mahurjhari (Mohanty 2005) and also finding an Early Iron Age bead manufacturing locality indicates the presence of long-term settlement as well as craft production. This suggests the possibility of people from other settlements coming to Mahurjhari and settling for economic activities.

Looking at the distribution pattern of megalithic habitation sites in Nagpur district, it shows that the distance between two settlements is not more than 15 km (Deo 1973). In some cases, it has been noticed that habitations are quite close by, that is, around 7 to 8 km (Vaidya 2014, 2016). As discussed above, these settlements might be involved in the inter-site transport network. There is the possibility of more than one settlement using a common burial ground or various burial localities in a shared geographical unit, e.g., Mahurjhari, Junapani, Lava, Dugdhamna (Vaidya 2014). The presence of both individuals with and without fluorosis clearly suggests movements or mixing of populations within settlements. Therefore, based on the present study, it may be possible to understand population movement in the Iron Age context using DF findings.

The present paper provides a window for understanding the presence of DF in the megalithic population of the Vidharbha region. It shows that the population was getting

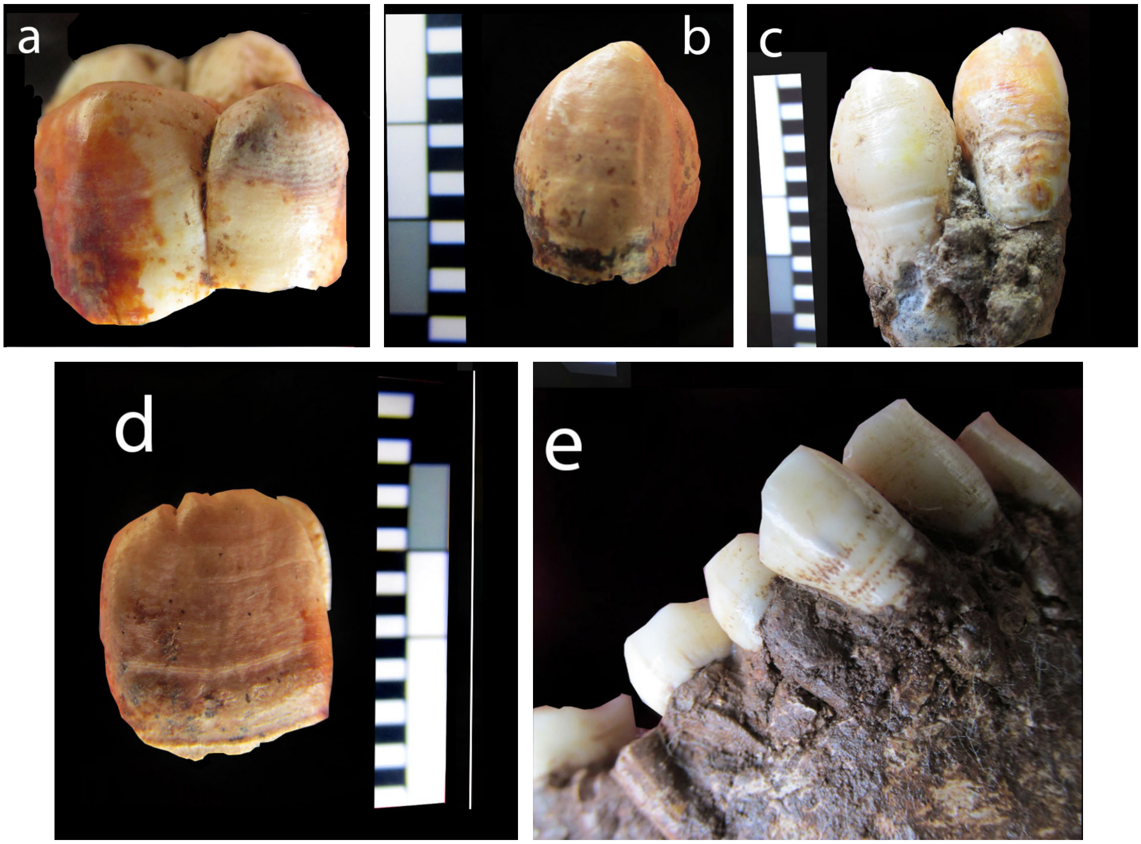

Fig. 8: Examples of enamel hypoplasia and fluorosis co-occurrence. a: MHR-2004, Meg-1, Loc-A, Q-SE, Dig-7, Maxillary RM1; b: MHR-2003, Meg-10, Q-SE, Dig-6, SE-1, Maxillary RC; c: MHR-2003, Meg-3, Individual 3, Maxillary LI2, LC; d: MHR-1979, Meg-1, No-22, Q-SE Maxillary LI1; e: MHR-1 (1978-79), Mandibular RC

exposed to DF. It is difficult to understand the presence of skeletal fluorosis, which is the result of exposure to high fluorine owing to the fragmentary nature of bones. However, the populations represented in different megaliths express the existence and extension of the problem. As seen in the present sample, the dental data from different localities within Mahurjhari shows differences in fluorosis frequencies. Many hypotheses can be forwarded regarding these discrepancies. One of the reasons could be that the population living within the site had access to different water resources or the people who are represented in the burial might have migrated to Mahurjahri from surrounding areas as the dental indicators of fluorosis only formulate when the teeth are developing. This is quite possible as the megalithic populations were mainly engaged in pastoral activities and therefore, required to move from one place to another.

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