

Relationship Between Fluoride Concentration in Enamel, DMFT Index, and Degree of Fluorosis in a Community Residing in an Area with a High Level of Fluoride

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The DMFT index, degree of fluorosis (DEGF), fluoride concentration in enamel (F), and depth of etch (D) were determined in participants living in an area with a high fluoride level. A statistically significant difference was found between men and women for F and D. A significant correlation was established between F and DEGF and between F and age for men, but not for women.

Dental fluorosis is a condition that has been recognized and reported on since the beginning of the century. McKay observed it in Colorado Springs in 1901¹ and by 1916 it had been connected with decreased caries incidence.² Two years later it was concluded that some element present in the water consumed by people who had mottled teeth was responsible for the staining.³ In 1931, Churchill⁴ suspected a correlation between mottled enamel and fluoride concentration in water. This correlation was confirmed later that year by Smith and Smith,⁵ who experimentally produced mottled enamel in rats by feeding them varying amounts of sodium fluoride.

More recently, the phenomenon of decreased caries experience in areas having a fluoride concentration in water of 1 ppm or more has been well documented.⁶⁻¹³ In addition, Richards et al⁶ and Binder¹⁰ have shown a positive relationship between dental fluorosis and reduced caries incidence. Furthermore, it has been reported that an increase in the concentration of fluoride in the water supply resulted in an increase in

the fluoride concentration in enamel.¹⁴⁻¹⁸

The object of the present study was an attempt to relate these factors, namely fluoride concentration in enamel, caries experience, and the degree of fluorosis in a community residing in an area with a high fluoride level.

Materials and Methods

Since the fluoride concentration of South African waters has been documented,^{19,20} a well-defined geographical area northwest of Johannesburg having an average fluoride concentration in the water greater than 1 ppm could be selected. The African village of Saulspoor, where endemic fluorosis is rampant, was chosen for this study.

Samples of water from subterranean sources such as wells and boreholes, which constituted the main source of drinking water of the population, were collected in plastic containers. The various fluoride concentrations in the water were determined^{21,22} using a fluoride ion combination electrode^a coupled to a digital pH meter.^b

The participants were chosen from pupils who attend one of the high schools in Saulspoor and who had been residing in the area from birth. Their ages ranged from 14 to 23 years and the sample was composed of 41 females and 47 males (Fig 1).

The DMFT index of each participant was determined in good natural light with the use of a mouth mirror and sharp dental probe. The teeth were systematically ex-

^a Orion model 96-09, Orion Research Inc., Cambridge, Mass.

^b Orion model 701, Orion Research Inc., Cambridge, Mass.

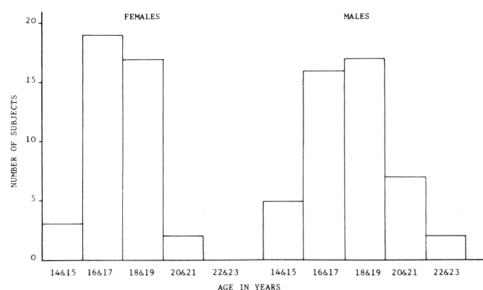


FIG 1.—Age distribution of sample.



FIG 2.—Example of normal teeth. Score = 0.

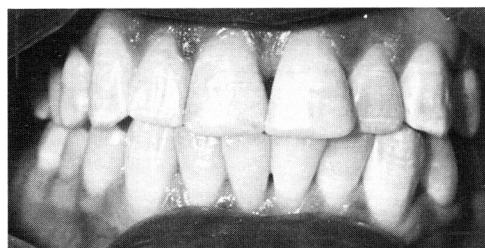


FIG 3.—Example of mild fluorosis. Score = 1.

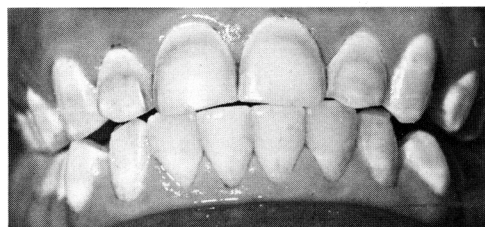


FIG 4.—Example of moderate fluorosis. Score = 2.

aminated and obvious caries noted. Any pit or fissure in which the probe stuck was recorded as carious.²³ Teeth lost as a result of trauma or those congenitally absent were not included in the DMFT index.

The degree of fluorosis (DEGF) for each individual was assessed using Dean's²⁴ classification as a guide. The degree of fluorosis was graded 0 to 3 depending on the extent of the mottling and pitting observed and four classes were devised. The first class comprised normal teeth with no evidence of fluorosis. These were scored as 0 (Fig 2). The second was teeth exhibiting white opaque areas with no brown staining; these were classed as mild and graded as 1 (Fig 3). The third was where extensive white, opaque mottling, irregularly scattered brown staining, and minute pitting occurred; the classification was moderate with a score of 2 (Fig 4). The fourth was widespread brown staining and extensive pitting; these teeth were classed as severe and scored as 3 (Fig 5).

The labial surfaces of the maxillary central incisors of each individual were cleaned with pumice and a slowly rotating rubber cup. Enamel biopsy specimens were taken from the middle third of these teeth, using a modification²⁵ of the acid etch technique developed by Hotz, Mühlemann, and Schait.²⁶ The fluoride concentrations in the enamel samples were determined with a fluoride ion combination electrode coupled to a digital pH meter and the calcium concentrations in the samples were determined by atomic absorption spectroscopy.^c The concentration of fluoride in enamel as parts per million and the depth of etch in micrometers were calculated for each tooth.²⁵

The results were statistically analyzed. Student's *t* test was used to establish whether there was a statistically significant difference between the fluoride concentration in

^c Zeiss Model PMQ11 with flame attachment FA2, Carl Zeiss, Oberkochen/Württ, Ger.



FIG 5.—Example of severe fluorosis. Score = 3.

TABLE 1
FLUORIDE CONCENTRATIONS OF SAULSPOORT
DRINKING WATER

Water Sample	ppm F
1	6.16
2	4.42
3	3.60
4	0.40
5	3.56
6	4.42
7	1.86
8	1.00
9	0.96
10	0.64
11	1.12
12	0.93

enamel for the left and right incisors (FL, FR) and was similarly applied in the case of depth of etch (DL, DR). As no significant differences were found, two new parameters were created for each individual. These were fluoride concentration in enamel (F) and depth of etch (D), each being respectively equal to $\frac{FL + FR}{2}$ and $\frac{DL + DR}{2}$.

The differences between the male and female participants for the four parameters—F, D, DMFT index, and DEGF—were tested using Student's *t* test.

Treating the male and female sample separately, the relationship between all pairs of variables was tested by computing the Pearson (product moment) correlation coefficient. Spearman's correlation coefficient was also computed in the case of the nonparametric data, for example, DMFT index and DEGF.

TABLE 2
MEANS OF FOUR PARAMETERS MEASURED FOR
EACH SEX

Parameter	Mean Value	
	Males	Females
Enamel fluoride concentration (ppm) ± SD	1,762 ± 1,598	1,159 ± 890
Depth of etch (µm) ± SD	9.6 ± 1.0	9.0 ± 1.0
DMFT index ± SD	1.2 ± 2.8	0.8 ± 1.6
Degree of fluorosis ± SD	2.0 ± 1.1	1.8 ± 1.1

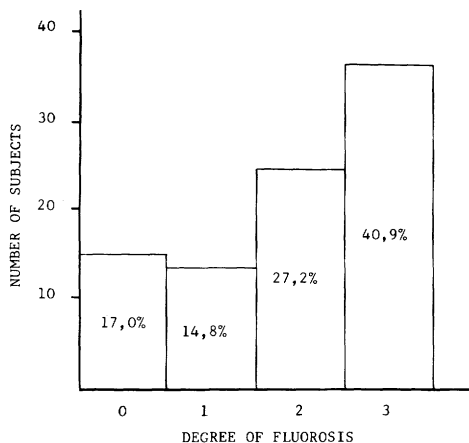


FIG 6.—Distribution of degree of fluorosis. Percentage of sample in each class is indicated.

Results

The fluoride concentration of the water samples ranged between 0.4 and 6.0 ppm (Table 1).

The mean values of the four parameters measured are shown in Table 2.

Of the total sample, 83% exhibited clinical signs of dental fluorosis (Fig 6) and 59% were cariesfree (DMFT index = 0) (Fig 7).

t tests between the male and female participants for each parameter indicated a statistically significant difference for the parameters F (*P* = 0.015) and D (*P* = 0.002) but not for the DMFT index and DEGF. Using Spearman's correlation coefficient, a significant positive correlation was indicated between F and DEGF (*r* = -0.38) for the male sample. The Pearson (product moment) correlation coefficient gave a significant negative correlation between F and age (*r* = -0.40), again for the male sample.

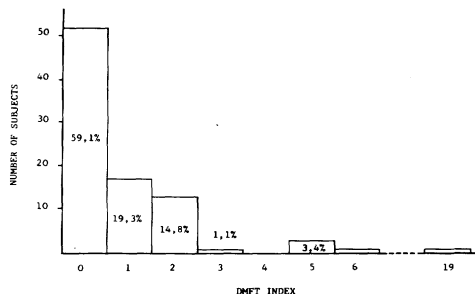


FIG 7.—Distribution of DMFT index. Percentage of sample in each class is indicated.

These correlations could not be shown for the female sample.

Discussion

Climate considerably influences the concentration of fluoride in water.²⁷ After a drought, the fluoride content increases whereas after heavy rains, the content decreases owing to dilution. The water samples from Saulspoord were collected at the end of an exceptionally heavy summer rainfall season. Had these samples been collected during the dry season, higher fluoride concentrations would probably have been found. This would better account for the extent of fluorosis in the area. In addition, although some water was hand pumped directly from the subterranean source, other water was pumped into and collected in open concrete tanks in which the water was even further diluted by rain. This factor could, in part, be the cause for the variations in concentrations of fluoride in the various water sources (Table 1).

Of the children examined, 83% exhibited clinical signs of dental fluorosis (Fig 6). In a similar study done in Austria, Binder¹⁰ reported a 52% incidence of fluorosis in an area having a fluoride level of 3 ppm in the water. Richards et al⁶ working in regions with fluoride concentrations of 1.8 ppm and more in the water, and having a similar mean maximum temperature to Saulspoord, found that 85% of their sample had symptoms of fluorosis of the teeth. In their study, Richards et al⁶ clearly indicated the influence of temperature on the incidence of fluorosis. They showed that, in areas having a similar fluoride concentration in the water, more dental fluorosis occurred where the mean maximum temperature was higher. The mean daily maximum temperature in the Saulspoord area is 25.3 C.²⁸ This warm climate and associated increased water intake may be partly responsible for the high incidence of fluorosis encountered.

In the present study, 59% of the participants were found to be cariesfree (Fig 7). In 1946, Ockerse²⁷ reported that 71% of children with mottled teeth examined through South Africa were cariesfree. In their studies, Richards et al⁶ and Binder¹⁰ reported a cariesfree incidence of 32 and 47%, respectively. A direct comparison of these figures with those obtained in the present investigation should, however, be viewed

with caution since factors such as age, race, socioeconomic group, diet, and climate influence the incidence of caries and fluorosis.^{6,29-33} The diet consumed by the residents of Saulspoord consists largely of whole or lightly milled cereal products and is not deficient in protein.³⁵

Cutress and Malthus,³⁵ Isaac et al,¹⁴ Aasenden et al,¹⁶ and Aasenden, Moreno, and Brudevold³⁶ have all determined the fluoride content in enamel of persons residing in areas with a high fluoride level. However, because of differing experimental procedures such as using whole enamel or analyzing very superficial enamel layers, it is not possible to compare the fluoride concentrations in enamel determined in this study with those found by these workers.

In order to establish whether the results of the male and female samples could be pooled in the case of each of the four parameters, Student's *t* test was used to test for any significant difference between the sexes. A statistically significant difference was found between the male and female participants for F and D. The finding in the case of F was in agreement with those of other studies.^{16,37} In the present study, however, many of the female participants had attempted to remove the unsightly discolored enamel by manual abrasion with sand or ash (Fig 8). Therefore, the differences found between the male and female participants for F and D are more likely to be due to external, physical factors rather than internal genetic ones. Consequently, it was decided to treat the sexes separately in all subsequent statistical tests.

The positive correlation established in this study between F and DEGF is in accordance with Isaac et al's¹⁴ and De Aisenberg and Ubios's³⁸ findings that mottled enamel had a very much higher fluoride concentration than unstained enamel.

It has been repeatedly shown that the fluoride concentration in enamel is highest in

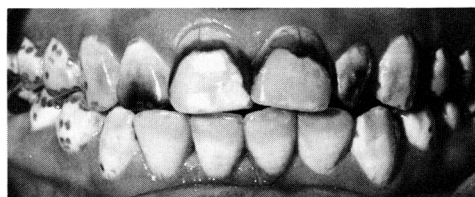


FIG 8.—Example of abrasion of maxillary central incisors in attempt to remove staining.

the outer region and falls steeply from the surface to a plateau in the interior.^{36,39} Because of this very characteristic distribution, only a small amount of wear is required to produce a considerable change in the fluoride concentration of the enamel surface. This would account for the significant negative correlation between F and age established here. The tendency for the level of fluoride concentration in enamel to decrease with age has also been previously demonstrated.^{40,41} The correlation established in this study supports the conclusion made by Weatherall, Hallsworth, and Robinson⁴¹ that the fluoride lost from the outer enamel surface as a result of wear is not restored to an appreciable extent even in areas where the fluoride content of the water supply is high.

The correlations between F and DEFG and F and age could not be shown for the female sample. A possible reason for this may again be the removal of stained enamel by many of the female participants. They would thereby remove the layer of superficial enamel that contains the highest fluoride concentration. This would mask any correlation involving fluoride concentration that could otherwise emerge.

No correlation was found when testing DMFT index against any of the other parameters. This may be accounted for by two factors. First, the whole sample was exposed to high levels of fluoride that would confer a high degree of protection against caries. Second, Retief, Cleaton-Jones, and Walker^{42,43} have reported low caries incidence in a sample of a similar racial and socioeconomic group residing in a nearby fluoride-deficient area. These two factors may explain the low and narrow range of DMFT indexes recorded in the present study (Fig 7). In other ethnic groups where the DMFT index range is greater,⁴² correlation involving the DMFT index may be found.

Conclusions

The object of the present study was an attempt to relate fluoride concentration in enamel, caries experience, and the degree of fluorosis in a community residing in an area with a high level of fluoride. A significant difference was found between the male and female samples for the F and D parameters. A positive correlation was established for the male participants between DEFG and

F, and a negative correlation between age and F. These correlations were not found for the female participants. Because of the low and narrow range of DMFT indexes, no correlation involving this parameter could be established.

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