Urinary Excretion of Fluoride Following Defluoridation of a Water Supply

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PREVIOUS studies have shown that essentially all absorbed fluoride is eliminated in the urine or deposited in skeletal and dental tissues (*1–3*). That all fluoride deposited in the skeleton is not fixed irreversibly is shown by its mobilization following a reduction in fluoride intake (*1*, *3–9*). Brun and his associates (*4*) reported that men who had absorbed fluoride from cryolite dust maintained a high level of fluoride in the urine for as long as 7 years following the period of exposure. Similarly, Largent and Heyroth (*3*) and Largent (*5*) found that urinary excretion of fluoride in excess of the intake continued at a progressively decreasing rate for as long as 2 years after the ingestion of large amounts of fluoride. Blakemore and his co-workers (*6*) observed that in cattle the fluoride content of the urine remained high for some time after they had foraged on pastures contaminated with industrial fluoride dust. Direct evidence of the withdrawal of fluoride from bone has been obtained in cattle (*6*) and in rats (*7–9*).

It was not ascertained by these studies whether or not any factors in association with a reduction in fluoride intake influenced the mobilization of fluoride. It may be surmised, however, that variations in the metabolic activity of skeletal tissue due to age could alter the process. In support of this assumption there is extensive evidence that the degree of skeletal maturation affects the deposition and retention of ions other than fluoride normally present in calcified tissues (*10*).

The purpose of the present study was to investigate the relationship of age to the rate of mobilization of fluoride in a human population group exposed to an excessive amount (8 p.p.m.) of waterborne fluoride.

Organization of the Study

For more than 50 years before defluoridation was begun on March 10, 1952 (*11*), the communal water supply of Bartlett, Tex., contained 8 p.p.m. fluoride. Since this date the fluoride in the water has been maintained at approximately 1 p.p.m.

One hundred and sixteen white males who had used the Bartlett water supply for at least 2 years immediately prior to defluoridation and who were currently drinking Bartlett water composed the study population. Their numerical distribution according to age group, to-

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Table 1. Age distribution of the study group and exposure to 8 p.p.m. fluoride in drinking water

Age group (years)	Number of persons	Number of years of exposure		
		Maximum	Minimum	Mean
7	9	7	7	7
8	7	8	2	6
9	6	9	2	6
10	9	10	4	7
11	4	11	4	9
12	5	12	6	10
13	7	13	2	9
14	3	14	5	11
15	9	15	9	13
16	6	16	7	12
20–29	8	20	5	12
30–39	7	28	4	11
40–49	13	47	8	26
50–59	7	57	4	32
60–69	7	50	4	30
70 and over	9	50	4	34

gether with data relative to duration of exposure to the untreated water, is shown in table 1.

On the day defluoridation was begun (which was, of course, before the defluoridation process had changed the fluoride content of the water supply) and at intervals thereafter during the next 113 weeks, a spot urine specimen was obtained from each person in the study. Aliquots of the specimens were pooled by age groups and analyzed for fluoride by standard procedures (*12*, *13*), with calcium hydroxide (1 gm. per 100 ml. urine) employed as the fluoride fixative.

Results

The mean daily fluoride content of the treated water in Bartlett during the period of observation was 1.32 p.p.m. The average fluoride content for each month is given in table 2.

The urinary fluoride values for each age group appear in table 3, and the means for all children, ages 7 through 16, and all adults, ages 20 and over, are shown in the chart. This division of the study population into children and adults was based on the fact that skeletal maturation is complete by approximately 18 years of age (*14*).

On the day defluoridation was begun, the fluoride content of the urine samples ranged from 5.0 to 9.2 p.p.m. and averaged 6.5 p.p.m. in children and 7.7 p.p.m. in adults. One week later, the water contained 0.7 p.p.m. fluoride, and the mean concentration of urinary fluoride had decreased to 4.9 p.p.m. in children and 5.1 p.p.m. in adults. After 5 weeks the mean urinary fluoride concentration remained unchanged in children but had decreased to 3.9 p.p.m. in adults. No further changes were apparent at the end of 9 weeks and 20 weeks, but the fluoride content of the urine had decreased in both children and adults after 39 weeks. After 113 weeks, the average concentration of fluoride in the urine was 2.2 p.p.m. in children and 2.5 p.p.m. in adults.

Discussion

It has been shown that persons whose drinking water contained 0.5 to 5.1 p.p.m. fluoride excreted fluoride in the urine approximately equal in concentration to that in the drinking water (*15*). On the basis of this evidence, the urine of the Bartlett residents would be expected to contain 1.0–1.5 p.p.m. of fluoride following defluoridation of their drinking water. The fact that the urinary concentrations of fluoride considerably exceeded these expected

Table 2. Average monthly concentrations of fluoride (p.p.m.) in the water supply of Bartlett, Tex., after defluoridation

Year	January	February	March	April	May	June	July	August	September	October	November	December
1952	-------	-------	1. 75	0. 98	1. 08	1. 28	1. 50	1. 46	1. 30	1. 74	1. 41	1. 23
1953	1. 13	1. 08	1. 26	1. 17	1. 09	1. 39	1. 48	2. 13	1. 27	1. 14	1. 30	1. 36
1954	1. 16	1. 43	1. 24	1. 25	1. 06	-------	-------	-------	-------	-------	-------	-------

values agrees with previous reports that urinary excretion of fluoride continued to be high after a marked reduction in the fluoride intake. It also indicates that fluoride is being mobilized from the skeletal tissues of the Bartlett residents.

There was no apparent correlation of age with urinary excretion of fluoride within either the group 7 through 16 years of age or the group aged 20 years and over. When the mean fluoride values for these two groups are compared, however, it will be noted that during the first 20 weeks the urinary excretion of fluoride decreased somewhat less precipitously in children than in adults. This finding suggests that the degree of mobilization of skeletal fluoride was somewhat greater in children than in adults during this period.

It has been suggested that the withdrawal of fluoride from bone can be attributed to (*a*) exchange phenomena in which fluoride ions on the surface of the apatite crystals exchange with hydroxyl ions in the extracellular fluids and (*b*) to the basic resorption-deposition cycle of the skeleton (*16*). Since this latter process is identified with bone growth and reconstruction, it seems probable that exchange is the principal mechanism concerned in the mobilization of fluoride from the mature skeleton. On this basis the initial rapid decrease in the urinary concentration of fluoride in adults presum-

Fluoride content of water and urine at specified intervals after defluoridation of the water supply in Bartlett, Tex.

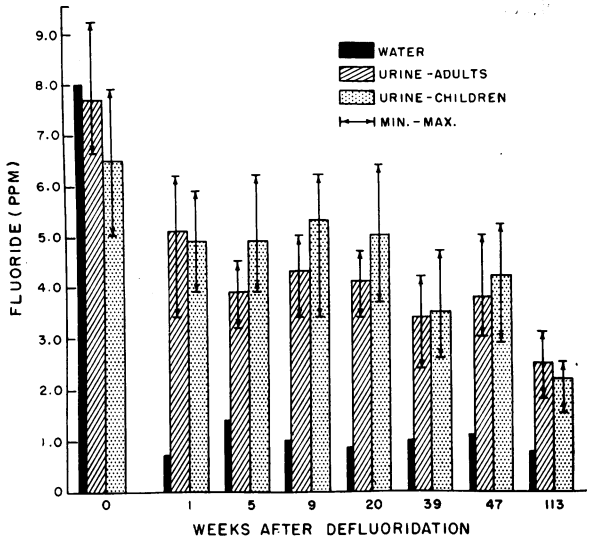

Table 3. Fluoride content of urine (in p.p.m.) for specified age groups after defluoridation of drinking water

Age group (years)	Number of weeks after defluoridation							
	0 (Mar. 10, 1952)	1 (Mar. 17, 1952)	5 (Apr. 14, 1952)	9 (May 15, 1952)	20 (July 25, 1952)	39 (Dec. 9, 1952)	47 (Feb. 4, 1953)	113 (May 11, 1954)
7	6.9	3.9	4.6	5.3	3.9	3.9	4.0	2.5
8	5.5	5.0	4.9	6.2	5.6	2.6	4.8	2.2
9	5.6	4.5	3.9	3.4	4.3	2.9	3.0	2.2
10	6.1	4.3	4.2	4.9	4.8	3.5	4.0	2.1
11	7.2	5.1	5.0	5.4	6.4	3.0	4.2	2.4
12	7.9	5.1	5.0	6.0	4.8	3.5	3.9	2.1
13	6.1	5.2	5.5	5.7	5.3	4.7	5.2	2.0
14	7.7	4.8	6.2	5.2	3.7	4.0	5.0	1.5
15	7.1	5.9	4.8	5.5	5.3	3.2	3.8	2.5
16	5.0	4.7	4.7	5.6	5.7	3.8	3.7	2.1
Average	**6.5**	**4.9**	**4.9**	**5.3**	**5.0**	**3.5**	**4.2**	**2.2**
20–29	6.8	3.4	3.8	4.1	4.0	3.6	3.5	2.7
30–39	8.2	4.4	3.3	3.4	3.7	3.2	3.4	1.8
40–49	9.2	5.7	4.5	5.0	4.7	4.2	----------	2.1
50–59	6.6	5.3	4.4	4.4	4.2	3.8	5.0	2.6
60–69	8.5	5.4	4.1	4.7	3.4	2.4	3.9	2.6
70 and over	7.0	6.2	3.2	3.9	4.5	3.4	3.0	3.1
Average	**7.7**	**5.1**	**3.9**	**4.3**	**4.1**	**3.4**	**3.8**	**2.5**

ably reflects the loss of readily exchangeable, surface-bound fluoride, whereas the somewhat less precipitous drop in children may be the consequence of the progressive liberation of fluoride from bone through resorptive activity.

Summary

The urinary excretion of fluoride was determined in children, ages 7–16 years, and in adults, ages 20 years and older, following the reduction of fluoride in their drinking water from 8 p.p.m. to approximately 1 p.p.m. During a period of 27 months, the concentration of fluoride in urine specimens decreased from 6–8 p.p.m. to approximately 2 p.p.m. The urinary fluoride values during the period were considerably higher than would be expected for a corresponding group with no prior exposure to high levels of fluoride. These values indicate that previously stored fluoride was being mobilized. There was no apparent relation between age and urinary fluoride excretion within either group. However, the extent of mobilization appeared to be greater in children than in adults.

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