The Newburgh-Kingston Caries Fluorine Study*

I. Dental Findings after Three Years of Water Fluoridation

DAVID B. AST, D.D.S., M.P.H., F.A.P.H.A., SIDNEY B. FINN, D.M.D., M.S., AND ISABEL McCAFFREY, M.S.

Director, Bureau of Dental Health; Associate Dentist (Research), Newburgh-Kingston Caries Fluorine Study; and Senior Statistician, Division of Medical Services, New York State Department of Health, Albany, N. Y.

THE caries fluorine hypothesis which states that fluorine has a prophylactic effect on dental caries is supported by extensive epidemiological studies in this country and in other parts of the world.[1-8] These studies were made where potable waters contained fluorine naturally derived from the soil or rocks with which the waters were in contact. Data from animal experimentation and laboratory studies support the conclusions drawn from these investigations.[9-14] These conclusions indicate that there is an inverse relationship between the prevalence of dental caries and fluorine if the fluorine is ingested during the years of tooth development. It is also stated that when approximately 1 p.p.m. fluorine is ingested from natural fluoride containing waters during the years of tooth development we may expect to find about six times as many children showing no dental caries experience, as compared with children using fluoride-free waters; we may also expect to find about a 60 per cent lower dental caries experience rate, and about a 75 per cent decrease in first permanent molar loss. These benefits may be expected without the deleterious effects of mottling which results when higher concentrations of fluorine are present.

The reported studies to date have dealt principally with the mottling and caries prophylactic effects of fluorine when the latter is ingested from potable waters naturally containing fluorides.

In 1943 it was proposed to determine whether we can translate the conclusions derived from the epidemiological studies in fluoride areas to a practical application in fluoride-free areas where the communal water supplies may lend themselves to treatment. This plan proposed to test the caries fluorine hypothesis by increasing the nontoxic concentration of fluorine by adding sodium fluoride to the public drinking water supply of one community and using a comparable fluoride-free community as a control. In 1944 this suggested plan was made a reality when the cities of Newburgh and Kingston in New York State agreed to participate in such a program, as study and control areas respectively. This study was started in June, 1944, when basic dental examinations were begun. On May 2, 1945, sodium fluoride was added to Newburgh's water supply to bring its fluorine content up to 1.0–1.2 p.p.m., while Kingston's water supply remains fluorine-free. It is expected that the study will take 10–12 years to determine adequately the efficacy and safety

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of this caries prophylactic measure.[15-17]

Both cities are situated on the Hudson River about 30 miles apart. Each has a population of approximately 30,000. The climate of both cities is also similar, and their water supplies at the outset of this study were comparable and have remained so, except for the addition of sodium fluoride to Newburgh's supply.

SCOPE OF THIS REPORT

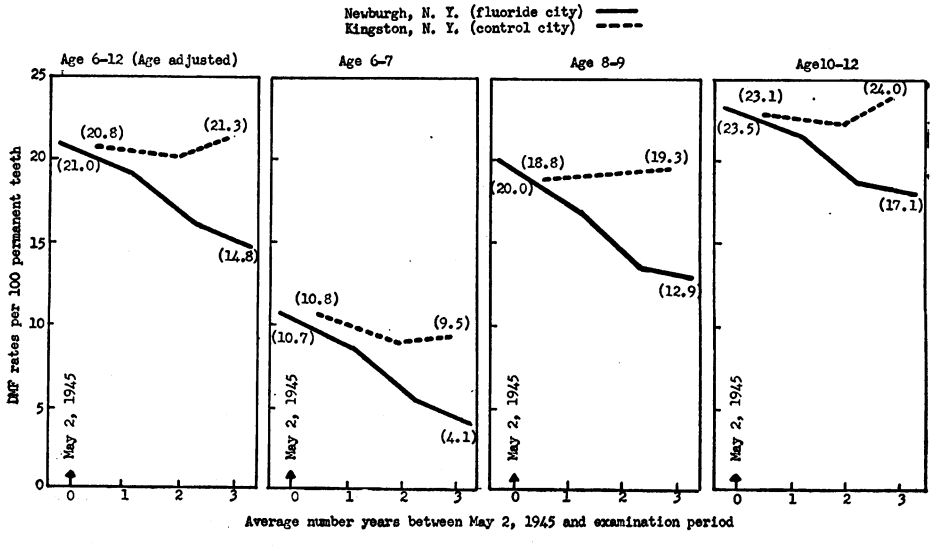
The tabulations and analysis of the data presented here represent a preliminary report based on comparisons of the dental caries experience in permanent teeth of all school children age 6–12 in Newburgh prior to the introduction of sodium fluoride into Newburgh's water supply and in Newburgh and Kingston for the following three years. In this report, in order to determine more accurately the trend, we are considering only those children age 6–12 who were in the original base study and who have had each successive examination until they reach age 12. Also included are new school children who entered the study at age 6 subsequent to the first examination and were present at each of the successive examinations. Thus, this study group will have only those children who we are assuming have had continuous residence in their respective cities. Approximately 3,400 children are included in the Newburgh data and 2,800 children are represented in the Kingston data.

All of the dental examinations in Newburgh and the first series in Kingston were made with mouth mirror and sharp explorer by the same examiner, one of the authors (S.B.F.). The subsequent examinations in Kingston using the same technic were made by two dental hygienists trained (by S.B.F.) in the method of examination and the charting of defects. In both areas the examiners called off the defects which were recorded by a staff clerk on a dental record card designed specifically for this study.

The findings of each tooth were indicated on the chart as caries-free, pit or fissure, which is not counted as a carious defect unless there is visual evidence of

Chart 1

TRENDS IN DMF RATES OF PERMANENT TEETH, 1944-1949



↑ Date sodium fluoride introduced into Newburgh's water supply

TABLE 1

Per cent of Erupted Permanent Teeth with Caries[1] Experience

Children of School Age Examined at Periodic Intervals
Newburgh and Kingston, N. Y., 1944–1949

	Number of permanent teeth erupted				*DMF rate per 100 teeth*				
	Age[2] at each examination				*Age[2] at each examination*			*Total*	
Examination period	*6–7*	*8–9*	*10–12*	*Total*	*6–7*	*8–9*	*10–12*	*Crude*	*Age[3] adj.*
Newburgh									
June, 1944–May, 1945	3,579	7,937	24,586	36,102	10.7	20.0	23.5	21.4	21.0
Apr., 1946–Jan., 1947	3,466	6,746	20,592	30,804	8.9	16.9	21.9	19.4	19.3
Apr., 1947–Feb., 1948	3,533	6,679	16,942	27,154	5.5	13.5	18.7	15.7	16.0
Apr., 1948–Jan., 1949	4,057	6,642	15,645	26,344	4.1	12.9	17.1	14.1	14.8
Kingston									
Sept., 1945–Feb., 1946	3,631	6,904	21,221	31,756	10.8	18.8	23.1	20.8	20.8
Jan., 1947–Oct., 1947	3,534	7,185	18,147	28,866	9.2	19.1	22.4	20.0	20.1
Nov., 1947–Oct., 1948	4,617	6,699	16,317	27,633	9.5	19.3	24.0	20.4	21.3

[1] Caries experience includes teeth decayed, filled or missing (lost subsequent to eruption).
[2] Age at last birthday.
[3] Adjusted according to the age distribution of the permanent tooth population in the 1945–1946 Kingston examinations.

caries or if the explorer sinks into soft dentine, evident caries with involved surface noted, fillings present with surfaces noted, missing and unerupted teeth, and the presence of hypoplasia. There is also space for remarks for any unusual findings.

TREND IN DMF PERMANENT TEETH

The proportion of erupted permanent teeth with evidence of caries experience (decayed, missing, or filled) decreased in each successive examination period in Newburgh, from 21 per 100 before water fluoridation to 14.8 per 100 at the time of the last survey. The DMF rate per 100 teeth in Kingston remained approximately 21 for the three examination periods. The difference of 6.5 DMF per 100 teeth between Newburgh and Kingston at the last examination suggests a 30 per cent improvement in Newburgh. Chart 1 shows that this reduction in prevalence of caries in the permanent teeth in Newburgh as compared with Kingston was evident at each of the age groups.

TYPES OF TEETH

The difference in the caries prevalence in the two cities at the last survey periods also was observed for each of the different types of permanent teeth (Table 2).

TABLE 2

Prevalence of Caries[1] According to Type of Tooth

School Children Age 6 to 12 examined in
Newburgh (Apr., 1948–Jan., 1949) and Kingston (Nov., 1947–Oct., 1948)

		DMF rates per 100 teeth (Age adj.[2])		*Difference*	
Type of Tooth	*Age at eruption years*	*Newburgh (Apr., 1948 –Jan., 1949)*	*Kingston (Nov., 1947 –Oct.,1948)*	*Absolute*	*Per cent of Kingston*
1st molars	6–7	48.0	58.7	−10.7	−18.2
Anterior	6–9	4.5	9.9	− 5.4	−54.5
2nd biscuspids	10–12	5.8	9.5	− 3.7	−38.9
1st biscuspids	10–12	2.3	5.6	− 3.3	−58.9
Cuspids	9–12	0.3	1.2	− 0.9	−75.0

[1] Caries experience includes teeth decayed, filled or missing (lost subsequent to eruption).
[2] Adjusted according to the age distribution of the tooth population of each specified type in the 1945-1946 Kingston examination.

TABLE 3

Per cent of Erupted First Molars with Caries[1] Experience

Children of School Age Examined at Periodic Intervals
Newburgh and Kingston, N. Y., 1944–1949

	No. first molars erupted				*DMF rate per 100 first molars*				
	Age[2] at each exam.				*Age[2] at each exam.*			*Total*	
Examination period	*6–7*	*8–9*	*10–12*	*Total*	*6–7*	*8–9*	*10–12*	*Crude*	*Age[3] Adj.*
Newburgh									
June, 1944–May, 1945	1,607	2,369	4,483	8,459	23.3	57.3	76.4	61.0	58.9
Apr., 1946–Jan., 1947	1,552	2,026	3,766	7,344	19.7	51.5	77.9	58.3	58.1
Apr., 1947–Feb., 1948	1,568	2,010	3,093	6,671	12.6	42.6	70.9	48.7	50.3
Apr., 1948–Jan., 1949	1,818	2,055	2,875	6,748	9.1	39.3	68.7	43.7	48.0
Kingston									
Sept., 1945–Feb., 1946	1,641	2,166	3,931	7,738	23.5	53.8	75.1	58.2	58.2
Jan., 1947–Oct., 1947	1,618	2,199	3,379	7,196	19.7	54.3	76.5	57.0	58.0
Nov., 1947–Oct., 1948	2,132	2,066	3,052	7,250	19.8	52.5	78.7	53.9	58.7

[1] Caries experience includes teeth decayed, filled or missing (lost subsequent to eruption).
[2] Age at last birthday.
[3] Adjusted according to the age distribution of the 1st molar tooth population in the 1945–46 Kingston examinations.

The relative sizes of these differences varied considerably, however, according to type of tooth. The prevalence of caries in the first molars was 48.0 per 100 molars in Newburgh, or 18 per cent less than the rate of 58.7 in Kingston. The DMF rates of the incisor teeth which have approximately the same eruption ages as the first molars were 9.9 and 4.5 in Kingston and Newburgh, respectively, or 55 per cent less in Newburgh than in Kingston. A comparison of the relative difference of 18 per cent for the first molars with 55 per cent for the central and lateral incisors shows that artificially fluoridated water had the greatest prophylactic effect during the period of this study on the teeth least often attacked by caries. This also is shown by the inverse relationship between DMF rates and percentage reduction in DMF rates of the cuspids and first and second bicuspids. These observations are in agreement with those previously reported from areas served by naturally fluoridated waters.[2, 3]

The first molars, however, present the major part of the caries problem in grade school children. Approximately 60 per cent of the first molars of the children in the fluoride-free city were carious. This is 6 times the second highest rates of 9.9 and 9.5 per 100 incisors and bicuspid teeth, respectively. Therefore, the prevention of caries in the first molars is of utmost importance in any program for the control of caries in the school age group.

FIRST MOLARS

The DMF rates for the first molars in the last survey were 48.0 and 58.7 per 100 first molars in Newburgh and the control city, respectively, or an absolute reduction of 10.7 DMF per 100 molars during the 3 examination periods covered in this report (Table 3). This represents a relative saving of 18 per cent.

It is of interest to note that the trend in the DMF rates of the first molars was the same in Newburgh and Kingston during the first post-fluorine year of the study period (Chart 2). This suggests that there was little, if any, benefit to the first molars during the first year of water fluoridation. There was a notable departure from this trend in Newburgh, however, in the second and third years of water fluoridation with the result that there were 10.7 less DMF per 100 first molars in Newburgh than in Kingston in the last examination period.

Chart 2

TRENDS IN DMF RATES OF FIRST MOLARS OF SCHOOL CHILDREN 6 TO 12 YEARS OF AGE

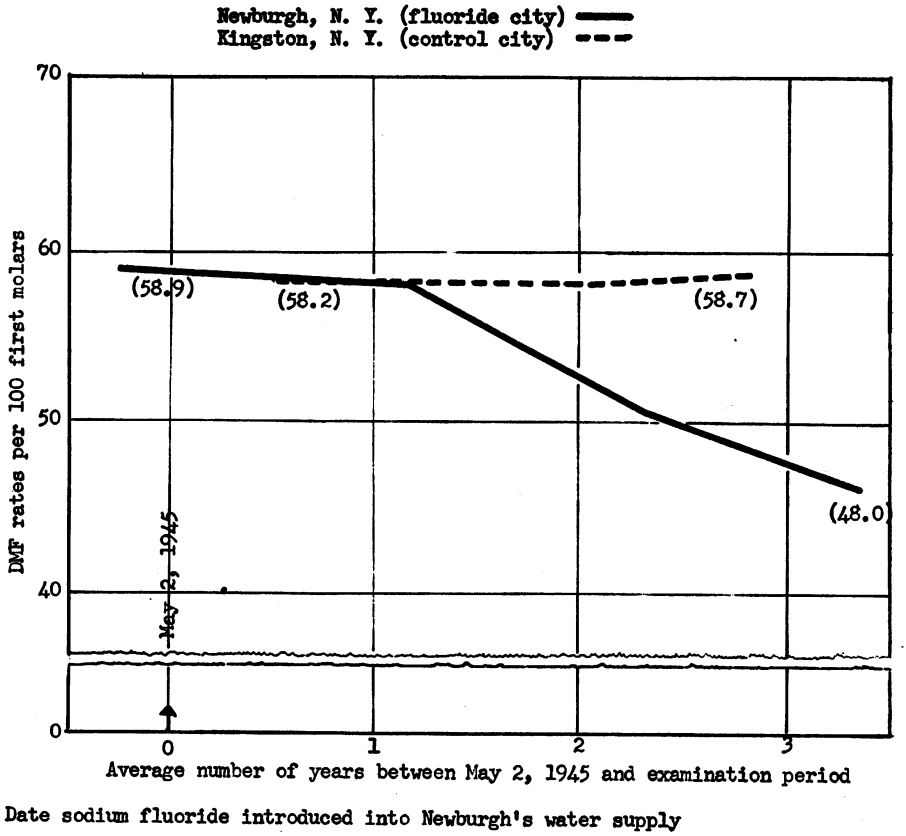


TABLE 4

Per cent of Erupted First Molars with Caries [1] Experience

Children at School Age Examined at Periodic Intervals
Newburgh and Kingston, N. Y., 1944–1949

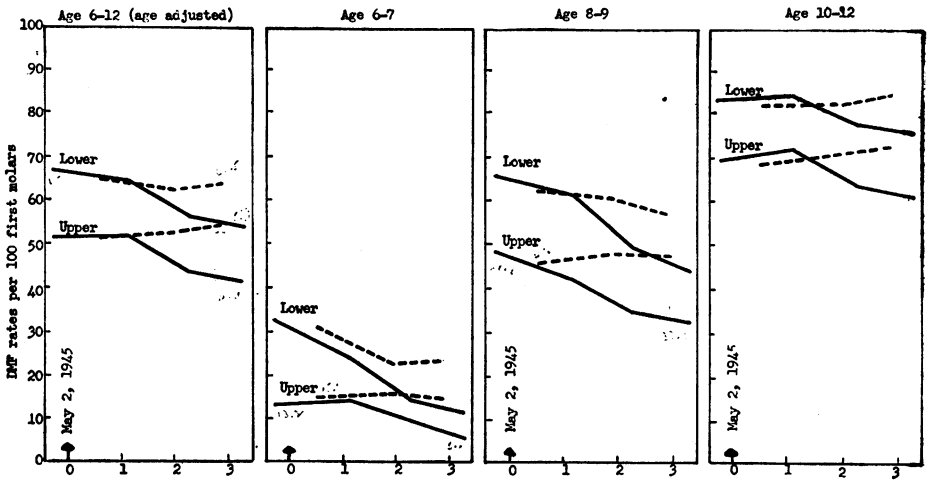
City and examination period	DMF rate per 100 first molars: Upper, Age [2] at each examination 6–7	Upper, Age [2] at each examination 8–9	Upper, Age [2] at each examination 10–12	Upper, Total Crude	Upper, Total Age [3] Adj.	Lower, Age [2] at each examination 6–7	Lower, Age [2] at each examination 8–9	Lower, Age [2] at each examination 10–12	Lower, Total Crude	Lower, Total Age [3] Adj.
Newburgh										
June, 1944–May, 1945	13.2	48.8	69.7	53.2	51.0	33.1	65.8	83.1	68.6	66.7
Apr., 1946–Jan., 1947	15.0	41.9	71.7	51.7	51.3	24.2	61.0	84.1	64.9	64.7
Apr., 1947–Feb., 1948	9.9	35.6	63.7	42.7	44.3	15.3	49.6	78.2	54.6	56.3
Apr., 1948–Jan., 1949	5.8	33.9	61.0	38.1	42.1	12.2	44.7	76.4	49.2	53.9
Kingston										
Sept., 1945–Feb., 1946	15.1	45.8	68.6	51.1	51.1	31.5	61.7	81.5	65.2	65.2
Jan., 1947–Oct., 1947	16.4	48.3	71.2	51.9	53.1	23.1	60.3	81.9	62.1	62.8
Nov., 1947–Oct., 1948	15.8	47.9	72.9	49.1	54.0	23.7	57.1	84.5	58.7	63.5

[1] Caries experience includes teeth decayed, filled or missing (lost subsequent to eruption).
[2] Age at last birthday.
[3] Adjusted according to the age distribution of the 1st molar tooth population in the 1945–1946 Kingston examinations.

Chart 3

TRENDS IN DMF RATES OF UPPER AND LOWER FIRST MOLARS, 1944-1949

Newburgh, N. Y. (fluoride city) ——
Kingston, N. Y. (control city) - - - -



Both the prevalence of caries and the prophylactic effect of fluorine were different for the upper and lower first molars considered separately in the period covered by this report. At the initial examinations the prevalence rate in both cities was approximately 50 DMF per 100 upper first molars and 65 per 100 in the lower jaw (Table 4). In the last examination there was a decrease in Newburgh, as compared with Kingston, of 12 per 100 DMF upper first molars and 10 per 100 in the lower molars. The relative differences are 22 per cent in the upper and 15 per cent in the lower first molars. The relative difference in Newburgh as compared with Kingston was consistently larger in the upper first molars than in the lower first molars at each age (Chart 3).

Examining these data for the different age groups we note that in the upper jaw there is a difference of 10 per 100 DMF first molars at ages 6–7 in Newburgh as compared with Kingston with a relative decrease of 63 per cent. In the lower first molars this difference is 12 per 100 with a relative decrease of 49 per cent. At 8–9 years of age the difference for upper first molars is 14 per 100 with a relative decrease of 29 per cent while in the lower jaw it is 12 per 100 with a relative decrease of 22 per cent.

The first molars of the children age 6 and age 7 at the time of the last examination had had an average of 6 and 18 months of exposure to the risk of caries, respectively, during the period of water fluoridation covered by this report. The percentage differences in DMF rates at these ages were approximately 50 per cent as compared with somewhat smaller relative decreases among older children whose first molars had had longer periods of exposure (Table 5). Thus, the greatest protection to the first molars in this study, as well as in studies in natural fluoride areas, appears to have been in the younger age groups nearest to the age of eruption.

The decrease in DMF rates of the first molars of those age 6 at each examination period, as shown in Table 6 and

TABLE 5

Caries Experience (DMF)[1] of First Molars According to Age and Length of Exposure to Fluoridated Water

Newburgh, N. Y. (Apr. 1948–Jan. 1949)
Kingston, N. Y. (Nov. 1947–Oct. 1948)

Average age at examination		Newburgh (fluoride city), Apr., 1948–Jan., 1949				Kingston (control city) Nov. 1947–Oct. 1948	Difference in DMF rates of Newburgh and Kingston	
		Average age on May 2, 1945		Average exposure[2] of erupted teeth to fluoridated water	DMF rate per 100 1st molars	DMF rate per 100 1st molars		
years	months	years	months				Absolute	Per cent of Kingston
6	6	3	2	6 months	6.1	11.9	— 5.8	—48.7
7	6	4	2	18 "	12.3	26.3	—14.0	—53.2
8	6	5	2	30 "	30.9	42.7	—11.8	—27.6
9	6	6	2	40 "	48.5	61.9	—13.4	—21.6
10	6	7	2	40 "	61.2	75.4	—14.2	—18.8
11	6	8	2	40 "	67.2	79.0	—11.8	—14.9
12	6	9	2	40 "	79.7	82.9	— 3.2	— 3.9
Total—Crude rate		—	—	—	43.7	53.9	—10.2	—
Age adj.[3] rate		—	—	—	48.0	58.7	—10.7	—18.2

[1] DMF teeth are those decayed, filled or missing (lost subsequent to eruption).
[2] Based on age 6 as average age at which first molars erupt.
[3] Adjusted to the age distribution of the first molar tooth population in the 1945–46 Kingston examinations.

TABLE 6

Per cent of First Molars with Caries[1] Experience

Children of Ages 6–9 Examined at Periodic Intervals
Newburgh and Kingston, N. Y., 1944–1949

Examination period	DMF rate per 100 first molars Age[2] at each examination			
	6	7	8	9
Newburgh (fluoride city)				
June, 1944–May, 1945	16.2	28.4	45.2	66.3
Apr., 1946–Jan., 1947	11.3	26.5	47.1	55.4
Apr., 1947–Feb., 1948	6.3	16.2	34.1	51.0
Apr., 1948–Jan., 1949	6.1	12.3	30.9	48.5
Kingston (control city)				
Sept., 1945–Feb., 1946	14.6	30.0	48.4	60.7
Jan., 1947–Oct., 1947	11.3	26.7	44.9	63.2
Nov., 1947–Oct., 1948	11.9	26.3	42.7	61.9

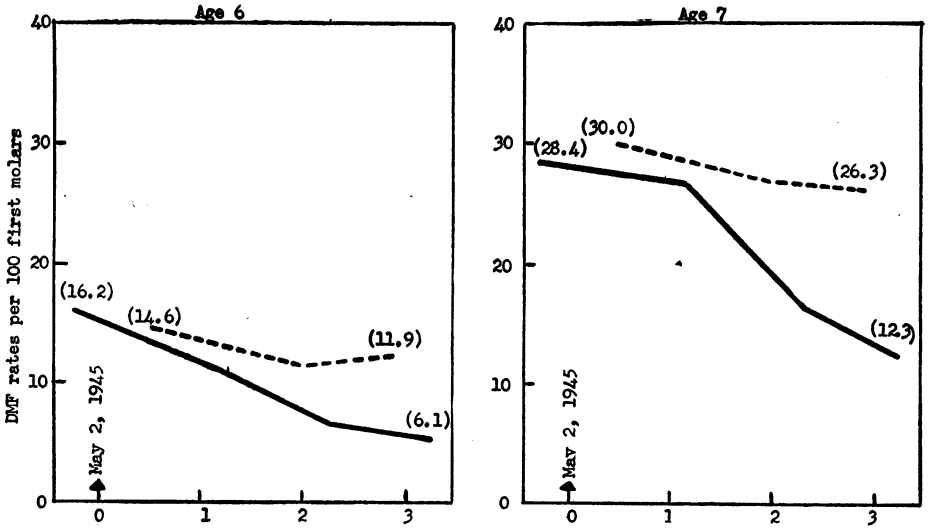
[1] Caries experience includes teeth decayed, filled or missing (lost subsequent to eruption).
[2] Age at last birthday.

Chart 4, suggests some interesting observations concerning the periods when fluorides ingested in potable water may be effective. The first molars examined at each survey supposedly had had the same length of post-eruption exposure to fluorine. Those examined in the last survey, however, had had a longer pre-eruption exposure than those examined in the third survey; similarly, those examined in the third survey had had a longer preëruption exposure than those examined in the second survey. This suggests that the continued downward trend at age 6 in Newburgh is due to the increased length of exposure in the period prior to tooth eruption. This preëruption exposure, however, is estimated to have begun at approximate average ages of 3, 4 and 5 for those age 6 in the fourth, third and second survey periods, respectively, or ages when the crowns of the first molars might be expected to be almost or completely calcified.

The benefits of fluorides ingested in

Chart 4

DMF RATES OF FIRST MOLARS OF SCHOOL CHILDREN
AGES 6 AND 7, 1944 - 1949
Newburgh, N. Y. (fluoride city) ————
Kingston, N. Y. (control city) - - - -



↑ Date sodium fluoride introduced into Newburgh's water supply

potable water during the period of tooth development prior to the completion of calcification have been reported by Dean.[1-3] Other observations reported by Klein and Deatherage have indicated the benefits of fluorides ingested in potable water during the post-eruptive period.[18, 19] Although other explanations cannot be entirely disregarded, the decreases shown in Chart 4 and apparently resulting from exposure to fluorine between the ages of 3 and 6 also may suggest the possibility of some benefit from the ingestion of fluoridated water in the period between calcification of the first molars and eruption.

SUMMARY

1. The DMF rate for permanent teeth shows a consistent downward trend in Newburgh from 21.0 to 14.8 per 100 permanent teeth. This indicates a saving of 6.5 permanent teeth per 100 in Newburgh as compared with a rate of 21.3 per 100 in Kingston at the last examination. This represents a saving of 30 per cent.

2. Among first molars, which account for the major part of the caries problem in children, after three years of fluoride experience, Newburgh's rate was 48.0 DMF per 100 first molars, while Kingston's was 58.7, or a difference of 10.7 DMF per 100 first molars. This represents a saving of 18 per cent in DMF first molars.

3. The greatest benefits are noted in the younger age groups.

4. The differences between Newburgh and Kingston as represented in these data suggest the possibility of benefits from exposure to fluoridated water subsequent to enamel calcification and subsequent to eruption of the first molars.

5. We cannot entirely rule out the possibility of variation in the interpretations of the examiners. The fact that more than one examiner was used might alter the differences between Newburgh and Kingston to some extent. However, the size of the differences in the DMF rates of the two cities is such that it is unlikely that an examiner bias could vitiate them.

6. These data are preliminary and it will be necessary to continue collecting data for the proposed duration of the study, that is, through 1954 to 1956, to obtain additional in-

formation concerning the caries prophylactic value of fluorine.

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Hospital Administration Course

The University of Pittsburgh Graduate School of Public Health has announced courses in hospital administration under a newly appointed Professor, Glidden L. Brooks, M.D., of Philadelphia, who will serve as Coordinator of the Medical Center Hospitals and Clinics.