In this fifth-year study of children exposed to a fluoridated public water supply, it was found that the inhibition of caries is a function of the length of time they were exposed to fluoride prior to the eruption of their teeth.

Dental Caries in Maryland Children After 5 Years of Fluoridation

A. L. RUSSELL, D.D.S., M.P.H., and CARL L. WHITE, A.B.

MARKED inhibition of dental caries after 5 years of fluoridation has been demonstrated in a series of independent studies of school children (*1–8*). This report describes a similar finding in somewhat more minute detail.

The children under study are residents of Prince Georges and Montgomery Counties, Md., immediately adjacent to the District of Columbia. All are white; all were born and have resided continuously in the area, and none has received such caries-preventive treatment as the topical application of fluoride solutions. Characteristics of the population, methods employed, and some of the techniques of analysis have been described in detail in previous publications (*9, 10*). In brief, teeth were examined under adequate light with mirror and explorer by a small and carefully calibrated group of examiners. "Catches" were not counted as carious lesions in the absence of other indications of caries. Examinations have been made yearly since 1952, when the community water was fluoridated. The fifth year results are presented in this paper.

In 1952 the Washington Suburban Sanitary Commission maintained two filtration plants, which supplied the water used by the children in the study. The average daily fluoride content of finished water at one plant was 0.98 ppm during the first year and 0.94 ppm during the second; fluoride content of finished water at the other plant was 0.90 ppm during both years. From January 1954 to January 1957, the average daily determination was 1 ppm fluoride at both plants, with most monthly averages within the range of 0.97 to 1.03 ppm fluoride. Since July 1955, all water has been processed in a single plant. The fluoridating vehicle has been sodium fluosilicate.

Mean numbers of teeth in eruption were virtually the same in 1957 as in 1952. There were 1.2 percent fewer deciduous teeth present and 0.01 percent fewer permanent teeth present in 1957 than would have been expected on the basis of 1952 eruption data.

Total Caries Experience

Differences in total caries experience in the children between 1952 and 1957 are shown in tables 1, 2, and 3 and figures 1 and 2.

Significantly more children were free of caries in deciduous teeth at ages 5 and 6, and significantly more were free of caries in permanent teeth at all ages from 6 through 10, in 1957 than in 1952 (table 1). At 5 and 6 years of age, 87 percent and 49 percent, respectively,

Dr. Russell and Mr. White are with the National Institute of Dental Research, National Institutes of Health, Public Health Service, Bethesda, Md.

Table 1. Proportions of caries-free children at the outset of fluoridation and 5 years later, Montgomery and Prince Georges Counties, Md.[1]

Age last birthday (years)	Numbers examined		Percent caries-free in deciduous dentition		Percent caries-free in permanent dentition	
	1952 (N=1,950)	1957 (N=2,872)	1952	1957	1952	1957
5	60	67	36.7	[2] 68.7	98.3	98.5
6	171	245	26.9	[2] 40.0	81.3	[2] 94.3
7	211	256	22.3	21.9	50.7	[2] 74.2
8	181	251	14.9	16.7	32.6	[2] 53.3
9	223	239	18.4	20.1	19.7	[2] 37.7
10	199	220	33.7	30.9	16.6	[2] 25.5
11	191	157	52.4	54.7	12.6	14.0
12	228	397	77.2	77.3	8.3	7.3
13	233	468	91.0	91.9	6.9	5.3
14	188	446	94.1	93.3	3.7	4.3
15	65	126	100.0	93.7	7.7	3.4

[1] All children are native born and are continuous residents of the area; none has received topical fluoride or other caries-preventive treatment.
[2] Difference significant at the $P=.01$ level.

more children had caries-free deciduous teeth. Differences in permanent teeth ranged upward from 16 percent at the age of 6, with the greatest difference in 9-year-old children. At this age, nearly twice as many children with caries-free permanent teeth were observed in 1957 as in 1952.

Mean numbers of deciduous and permanent teeth with caries experience (the def and DMF means, respectively) are shown in table 2 for each age group in each of the study years. In 1957, fewer def teeth per child were found in children up through the age of 7 years and fewer DMF teeth per child in all age groups, than in 1952. Differences were significant in deciduous teeth for children 5 and 6 years of age and in permanent teeth for children aged 6–11 years. Data for the 2 years are compared in figure 1.

The incidence of new carious permanent teeth for each age-cohort over the period of observation is pictured in figure 2. Children who were 10 years old in 1952, for example, had an average of 3.09 DMF teeth; at the age of 15 years, 5 years later, the average had risen to 8.14, a mean increment of 1.01 new DMF teeth per child per year. For children 9 years of age and younger, the incidence is shown from a zero point at the age of 5 years, the time at which permanent teeth begin to erupt. If a straight edge is laid along each of

Figure 1. Mean numbers of deciduous and permanent teeth with caries in native-born children of Montgomery and Prince Georges Counties, Md., 1952 and 1957.

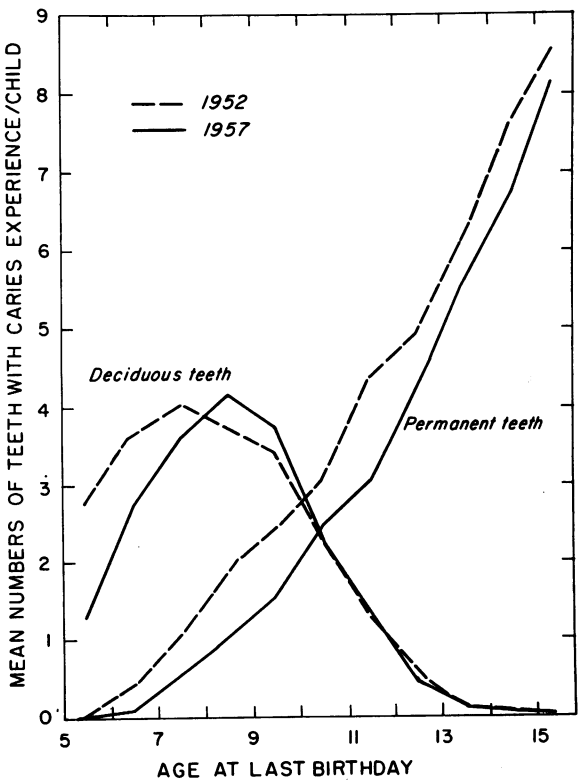


Figure 2. Increase in mean numbers of decayed, missing, or filled teeth in native-born children of Montgomery and Prince Georges Counties, Md., by age groups.

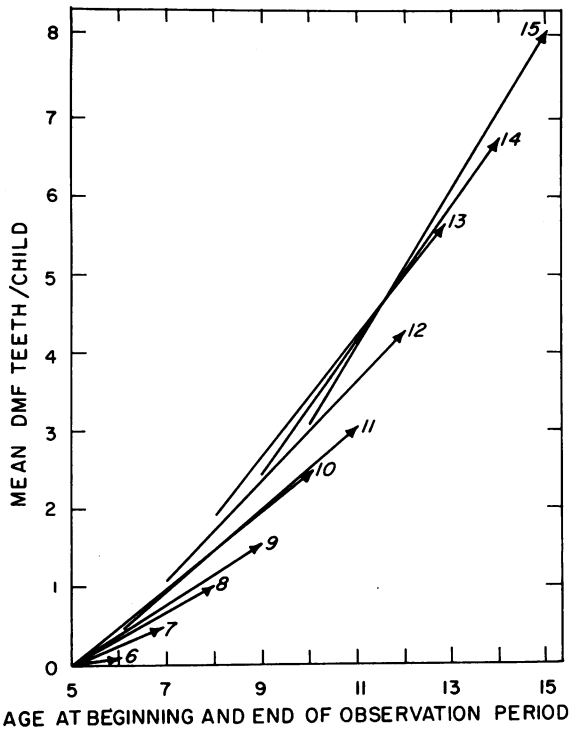


Table 2. Mean numbers of def [1] deciduous and DMF [2] permanent teeth at the outset of fluoridation and 5 years later, Montgomery and Prince Georges Counties, Md.[3]

Age last birthday (years)	Mean numbers of def deciduous teeth		Mean numbers of DMF permanent teeth	
	1952	1957	1952	1957
5	2. 77	[4] 1. 30	0. 03	0. 00
6	3. 67	[4] 2. 76	. 41	[4] . 10
7	4. 04	3. 68	1. 09	[4] . 54
8	3. 78	4. 19	1. 90	[4] 1. 05
9	3. 43	3. 74	2. 42	[4] 1. 59
10	2. 30	2. 31	3. 09	[4] 2. 49
11	1. 29	1. 36	4. 39	[4] 3. 04
12	. 47	. 48	4. 96	4. 28
13	. 16	. 14	6. 15	5. 64
14	. 07	. 07	7. 66	6. 73
15	. 00	. 06	8. 57	8. 14

[1] Decayed, extraction indicated, or filled.
[2] Decayed, missing, or filled.
[3] All children are native born and are continuous residents of the area; none has received topical fluoride or other caries-preventive treatment.
[4] Difference significant at the $P=.01$ level.

Table 3. Expected and observed incidence of new DMF [1] teeth in children using fluoridated water between 1952 and 1957, Montgomery and Prince Georges Counties, Md.

Age interval (years)	Age at time of fluoridation	Incidence of new DMF teeth per child per year	
		Expected [2]	Observed
10–15	10	1. 10	1. 01
9–14	9	1. 05	. 86
8–13	8	. 85	. 75
7–12	7	. 77	. 64
6–11	6	. 80	. 53
5–10	5	. 62	. 50
5–9	4	. 60	. 40
5–8	3	. 63	. 35
5–7	2	. 55	. 27
5–6	1	. 41	. 10

[1] Decayed, missing, or filled.
[2] If 1952 rates had remained unchanged.

these incidence slopes in succession, it will be noted that the rate of caries increase is successively lower in each younger age group (see also table 3).

Mortality rates for permanent teeth were importantly lower in 1957 than in 1952, showing an overall decline at ages 6–13 of about 45 percent. But this change cannot be ascribed wholly to fluoridation, since a school dental health program was begun in the larger county shortly after the study began, and children examined in 1957 had, on the average, about one-third more filled teeth than were seen in children of the same ages in 1952. Filled teeth comprised 44.8 percent of the total number of DMF teeth in 1952 and 66.5 percent of the total number of DMF teeth in 1957.

Permanent First Molars

In the 2 years under consideration, most of the DMF teeth observed in children through 10 years of age were permanent first molars. Considerably fewer DMF first molars were found in 1957 than in 1952, with the differences generally related to the age of the children at the time of fluoridation. Table 4 shows the numbers of DMF permanent first molars which would have been counted in 1957 had the 1952 attack rates remained unchanged; these numbers are compared with the actual numbers seen in children aged 5–12 years.

Table 4. Expected and observed numbers of carious first permanent molars in native-born children of Montgomery and Prince Georges Counties, Md., 1957

Age group (years)	Age at time of fluoridation	Number of children (N=1,832)	Carious first molars expected [1] (Σ=3,529)	Carious first molars observed (Σ=2,820)	Difference (percent)
5	<1	67	2	0	−100.0
6	1+	245	100	25	[2] −75.0
7	2+	256	277	138	[2] −50.2
8	3+	251	471	263	[2] −44.2
9	4+	239	523	368	[2] −29.6
10	5+	220	572	413	[2] −27.8
11	6+	157	449	404	−10.0
12	7+	397	1,135	1,209	+6.5

[1] If 1952 caries attack rates had remained unchanged.
[2] Difference significant at the $P=.01$ level.

In table 5, caries attack rates for permanent first molars computed from the 1952 data are compared with attack rates actually observed during this fifth year of fluoridation in those children aged 6–12 years who were examined in 1956 and reexamined in 1957. Though more caries-free first molars were present in children of each age group in 1957, these teeth were decaying at approximately the 1952 rates in children who were 4 years of age or older at the time of fluoridation. In children 3 years of age or younger at the time of fluoridation, attack rates were sharply and significantly lower than those seen in 1952.

In general, attack rates in mandibular first molars were more severe than attack rates in maxillary first molars, but both tended to follow the same patterns with age.

Older Children

Children 12 years old or older have been slower to exhibit a caries-inhibitory effect following fluoridation than younger children, when comparisons are based on lifetime caries experience. The incidence of new DMF teeth in children aged 13 or 14 years at the end of the third year of fluoridation in these Maryland counties has been reported in an earlier paper (*10*). At the time of fluoridation those children were 10 or 11 years old. No decrease in the incidence of caries was evident in that group during the 1954–55 year.

Table 5. Caries attack rates in first permanent molars, 1956–57, the fifth year of fluoridation, native-born children of Montgomery and Prince Georges Counties, Md.

Age last birthday (years)	Expected [1]		Observed in children examined in 1956 and again in 1957			
	Mean teeth at risk [2]	Attack rate [3]	Number of children	Mean teeth at risk [2]	Attack rate [3]	Age at time of fluoridation
6	2.733	13.8	37	2.756	[4] 2.9	1+
7	3.335	20.1	192	3.945	[4] 8.4	2+
8	2.897	27.5	180	3.236	[4] 13.0	3+
9	2.121	14.6	186	3.022	18.0	4+
10	1.812	22.6	176	2.171	24.1	5+
11	1.402	18.6	116	1.922	22.9	6+
12	1.089	0.1	121	1.248	30.4	7+

[1] Computed from 1952 data.
[2] Number of teeth per child that were caries-free at the beginning of the year and those that erupted during the year.
[3] Percentage of teeth becoming carious during the year.
[4] Difference significant at the $P=.01$ level.

Table 6. Mean numbers of DMF [1] permanent teeth in 653 boys and girls 13 or 14 years of age at the beginning and end of the fifth year of fluoridation (1956–57), Montgomery and Prince Georges Counties, Md.

Type of tooth	Mean numbers of DMF teeth			
	Start of year		End of year	
	Expected [2]	Observed	Expected [2]	Observed
Maxillary				
Central incisor	0. 43	[3] 0. 30 ± 0. 025	0. 49	[3] 0. 39 ± 0. 028
Lateral incisor	. 43	[3] . 33 ± . 025	. 51	[3] . 40 ± . 027
Cuspid	. 04	[3] . 01 ± . 005	. 07	[3] . 02 ± . 006
First bicuspid	. 14	. 14 ± . 016	. 26	[3] . 19 ± . 019
Second bicuspid	. 14	. 11 ± . 014	. 24	[3] . 19 ± . 019
First molar	1. 36	[3] 1. 50 ± . 030	1. 50	[3] 1. 66 ± . 027
Second molar	. 40	[3] . 22 ± . 022	. 70	[3] . 43 ± . 028
All maxillary teeth	2. 93	2. 61	3. 78	3. 29
Mandibular				
Central incisor	0. 07	0. 08 ± 0. 015	0. 07	0. 11 ± 0. 017
Lateral incisor	. 07	. 06 ± . 012	. 08	. 08 ± . 014
Cuspid	. 01	. 01 ± . 005	. 02	. 02 ± . 007
First bicuspid	. 04	. 03 ± . 008	. 09	[3] . 05 ± . 010
Second bicuspid	. 14	. 11 ± . 016	. 23	[3] . 17 ± . 018
First molar	1. 62	1. 64 ± . 028	1. 67	[3] 1. 73 ± . 024
Second molar	. 73	[3] . 43 ± . 029	1. 07	[3] . 73 ± . 034
All mandibular teeth	2. 68	2. 36	3. 22	2. 87
All teeth	5. 61	[3] 4. 97 ± . 129	7. 00	[3] 6. 16 ± . 147

[1] Decayed, missing, or filled.
[2] If rates observed in 1952 had remained unchanged.
[3] Difference significant at the $P = .01$ level.

Similar data for the 653 children examined in 1956 and reexamined in 1957 who were 13 or 14 years of age at the end of the fifth year of fluoridation are shown in table 6. The differences between expected and actual numbers of teeth in eruption, in this group, were negligible; means of 26.33 and 27.38 teeth would have been expected on the basis of 1952 eruption data, and means of 26.24 and 27.35 teeth were actually observed. In 1957 there were slightly but significantly more DMF permanent first molars than had been seen in 1952. Means for the relatively caries-immune mandibular incisors and cuspids were essentially the same. Means for all other tooth types were significantly lower.

Crude incidence data may be computed from table 6. However, because of the greater numbers of teeth at risk, comparison with 1952 findings is more valid when based on attack rates (table 7). In general, the differences between expected attack rates and those observed during this fifth year of fluoride exposure are related to the age of the tooth at the time of fluoridation. Permanent first molars, for example, had been in eruption about 3 years when first exposed to fluoride; the few remaining caries-free first molars were actually becoming carious at a faster rate than would have been predicted from 1952 findings. At the other end of the scale, permanent second molars, which erupted 2 to 3 years after fluoridation began, included significantly fewer carious teeth at the beginning of the year (see table 6), and attack rates during the year were sharply and significantly lower than expected. Attack rates were lower in all teeth erupting after fluoridation, but in only one of the teeth (the maxillary lateral incisor, with the shortest time at risk at that point) which were in eruption before fluoridation began.

Differences between expected and observed caries attack rates (omitting the mandibular incisors, teeth with attack rates too low for va-

Table 7. Expected and actual caries attack rates in 653 boys and girls 13 and 14 years of age during the fifth year of fluoridation, Prince Georges and Montgomery Counties, Md., 1956–57

Type of tooth	Years at risk at start of fluoridation [1]	Mean DMF per child at start of year		Attack rate during year [3]		Total teeth becoming carious in year	
		Expected [2]	Observed	Expected [2]	Observed	Expected [2]	Observed
	Teeth in eruption and at risk of caries prior to fluoridation						
Mandibular central incisor	3.08	0.07	0.08	0	1.2	0	15
Mandibular first molar	2.96	1.62	1.64	12.0	[4] 24.4	28	57
Maxillary first molar	2.86	1.36	1.50	22.5	[4] 31.2	73	101
Maxillary central incisor	2.03	.43	.30	3.8	5.3	42	59
Mandibular lateral incisor	2.01	.07	.06	.4	1.1	5	14
Maxillary lateral incisor	.95	.43	.33	5.2	4.2	55	45
Total	2.32	3.98	3.92	3.9	5.5	203	291
	Teeth erupting after fluoridation						
Mandibular cuspid	−1.06	0.01	0.01	0.5	0.2	7	3
Maxillary first bicuspid	−1.27	.14	.14	6.7	[4] 3.1	81	37
Mandibular first bicuspid	−1.29	.04	.03	2.4	1.0	31	13
Maxillary cuspid	−2.02	.04	.01	1.9	.5	23	6
Maxillary second bicuspid	−2.07	.14	.11	6.0	4.8	71	57
Mandibular second bicuspid	−2.11	.14	.11	5.1	3.1	59	36
Mandibular second molar	−2.57	.73	.43	29.1	[4] 20.3	280	196
Maxillary second molar	−3.22	.40	.22	21.5	[4] 13.3	224	139
Total	−1.95	1.64	1.06	8.3	5.2	776	487

[1] Measured from the median time of eruption to the mean age of the group at the time of fluoridation.
[2] If 1952 rates had remained unchanged.
[3] The percentage of teeth which were free of caries at the beginning of the year, or erupted during that time, which became carious during the year.
[4] Significantly different at the $P=.01$ level.

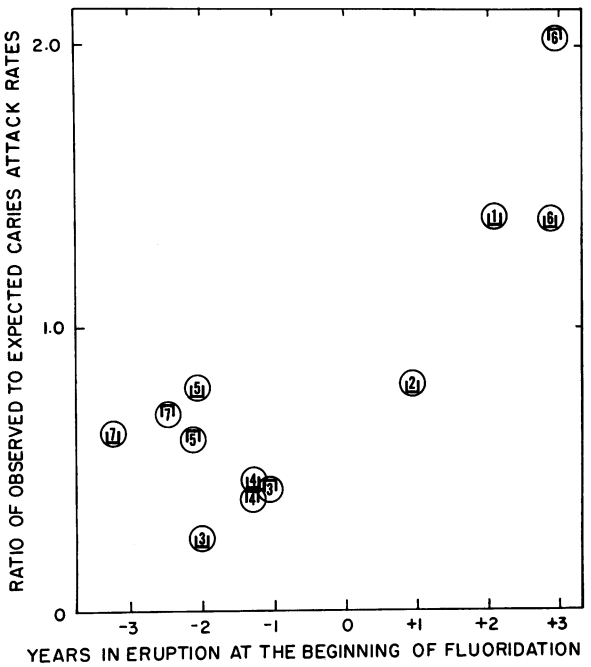
lidity in a sample of this size) are shown in figure 3. In preparing this illustration teeth have been numbered from the midline toward the posterior part of the mouth. A bracket open at the top indicates position in the upper jaw, and a bracket open at the bottom indicates position in the lower jaw. The numeral 3 in a bracket open at the bottom, for example, indicates the mandibular cuspid.

Discussion

So far as the deciduous dentition is concerned, little caries-inhibitory effect is evident in the data for children who were 2 years old or older at the time of fluoridation (7 years old or older in 1957). The most striking difference is shown in children aged 5 years in 1957, whose first waterborne fluoride exposure occurred during the period of calcification, and hence prior to eruption, of these teeth. Six-year-old children showed an intermediate degree of inhibition. Their deciduous teeth were fully calcified, but not in eruption, at the time fluoridation began.

Similarly, the younger the child at the time of fluoridation the greater the degree of caries inhibition in permanent first molars. In older children the greater degree of caries inhibition was seen in those tooth types first exposed to fluoride at the earlier stages in development. The critical point would seem to be the time of eruption. Tooth types with first fluoride exposure essentially coincident with eruption show minimal caries inhibition, and those in eruption 2 to 3 years at the time of fluoridation show no inhibitory effect which can be detected in counts of DMF teeth. In short, at this point (the fifth year of fluoridation) and measured in this way, the degree of caries inhibition in any tooth type seems to be a simple function

Figure 3. Differences between expected caries attack rates and rates observed during the fifth year of fluoridation, by eruption status of teeth, Montgomery and Prince Georges Counties, Md.



of the length of fluoride exposure prior to eruption and the consequent risk of attack by dental caries.

Attack rates for children 13 or 14 years of age were slightly higher than expected during the third year of study (*10*), and they continued to be higher in permanent first molars in children of these ages in this fifth year. These facts suggest that (*a*) the prevalence of caries in this area may have been following an upward trend at the time the study was initiated, or (*b*) there may have been a gradual shift toward more stringent criteria over the course of the six yearly examinations.

Some such shift is inherent in the increased numbers of filled teeth. Bitewing X-ray examination is standard procedure in private dental offices in the area, which means that a proportion of these fillings represented lesions which could not have been detected by mirror and explorer until the following year.

In either event, the effect of such a shift would be toward a slight underestimation of the true magnitude of caries reduction.

Summary and Conclusion

A group of white, native-born children in Prince Georges and Montgomery Counties, Md., has been examined yearly since fluoridation of the community water supply in 1952. Their total caries experience after 5 years of fluoridation and the incidence of caries during the fifth year are compared with data from the baseline examination.

In this group at this time caries inhibition seems to be a simple function of the length of fluoride exposure prior to eruption of teeth and the risk of caries attack.

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