DENTAL CARIES IN BROTHERS AND SISTERS OF IMMUNE AND SUSCEPTIBLE CHILDREN[1]

HENRY KLEIN AND CARROLL E. PALMER

INTRODUCTION

SIMILARITIES within families with respect to relative immunity or susceptibility to dental caries have been noted by several investigators. In a study of 325 children and their parents, Day and Sedwick (1) report that the parents of children with extensive caries showed an average loss of two permanent teeth more than the parents of children with low levels of caries. Bunting (2) states that "inherited or inherent individual characteristics, in a small percentage of cases, are more important determinant factors in caries susceptibility than ordinary dietary considerations." Kappes (3) has reported that among the parents of fifty children with "good teeth" two parents had "poor teeth" and nine had "good teeth," while among the parents of fifty children with "poor teeth" thirteen had "poor teeth" and two had "good teeth." Detlefsen (4) has observed that the extent of caries in the first permanent molars appears to have a small but appreciable genetic background. In a discussion of the problem of clinical control of dental caries, Kugelmass (5) points out that "hereditary predisposition to caries susceptibility or immunity appears evident in some children." Further data on familial resemblances in caries in the brothers and sisters of immune and susceptible children are given in a recent paper by Miller and Crombie (6).

Detailed analyses of the constitution of the caries problem in large population groups would appear to warrant further study of the relation between familial factors and relative susceptibility to caries. Accordingly, an investigation of this relationship was de-

[1] From the Division of Public Health Methods, National Institute of Health, Bethesda, Maryland. The present paper was published in a slightly different form in *Public Health Reports*, August 5, 1938, 53, p. 1353.

veloped as one of a series of studies on dental caries in grade school children (7), (8), (9), (10), (11), (12), (13), (14), (15). The present paper is concerned largely with a description of the dental status of the brothers and sisters of one group of children designated as "caries immunes" and those of another group designated as "caries susceptibles." Analysis of the data furnishes quantitative evidence which indicates that significantly less caries is found in the deciduous and in the permanent teeth of the brothers and sisters of the immune group than in those of the caries susceptible group.

MATERIAL AND METHODS

Basic data[2] for the present study were obtained from dental examinations of 4,416 elementary school children who comprised 94 per cent of the entire enrolled grade school population of a small urban community, Hagerstown, Maryland. Records of these examinations contained observations on the number of deciduous and permanent teeth present in the mouth and detailed descriptions of the location and specific surface involvement of the teeth by caries. Carious lesions were those so designated by trained dental officers on the basis of a careful clinical examination with mirror and sharp pointed pig-tail explorer. Pits and fissures in which the explorer caught were itemized separately. For the permanent teeth, caries experience was measured by means of a count of decayed, missing, or filled (DMF)[3] teeth and tooth surfaces. In counting carious tooth surfaces, remaining roots and missing (extracted) permanent teeth were considered equal to five carious surfaces. For the deciduous teeth, an equivalent measure of the total caries experience was not possible, since definite information which would show whether or not a missing deciduous tooth had ever been carious was not available from the data collected. For the deciduous teeth, therefore, caries experience was expressed by means of a count of teeth and

[2] A full description of the manner of collecting these data and a general analysis of the findings are given in reference 7.

[3] For a full discussion of the DMF concept, see reference 16.

tooth surfaces which, at the time of the examination, were actually carious or were filled.

Definitions and the Selection of Immune and Susceptible Children. For purposes of the present analysis, certain children from among the 4,416 examined were selected as "caries immunes" and "caries susceptibles." Immune children were defined as those who at ages ten through fifteen showed *in the permanent teeth* no objective evidence of caries experience (no DMF teeth). Caries susceptible children were defined as those who at age ten had six or more; at age eleven, seven or more; at age twelve, eight or more; at age thirteen, nine or more; and at ages fourteen and fifteen, ten or more DMF teeth.

These criteria are clearly arbitrary, and it is recognized that entirely homogeneous groups were not selected thereby. An important disturbing factor probably arises from the fact that different levels of relative immunity to caries are represented in the immune group. For example, a child fifteen years of age who has no carious permanent teeth may possess a higher level of immunity than a child of ten who, though not having DMF teeth at this age, may develop the disease by the age of fifteen. Similar disturbing factors may be present in the definition of susceptibles, although it seems probable that these are partially obviated by the graduated scale of defining susceptibility in terms of the severity of the disease.

In connection with a discussion of the comparability of the immune and susceptible children, it is necessary at this point to mention the unexpected finding of significant differences in the populations of teeth in the two groups of children. In brief, this consisted of the finding of a greater average number of erupted permanent teeth in the susceptibles than in the immunes and, as a direct corollary, a smaller average number of deciduous teeth present in the mouths of the susceptibles than in the mouths of the immunes. The full significance of this observation is not immediately apparent and requires additional study. In explanation, how-

ever, it may be mentioned that the method of designating the immunes and the susceptibles probably accounts, in part, for the differences, since children selected as susceptibles were required to have a specified minimum number of DMF teeth, and those selected as immunes no DMF teeth.

By these criteria, children with larger numbers of erupted permanent teeth may tend to fall into the susceptible group; those with smaller numbers of erupted teeth may tend to fall into the immune group. A specific mechanism which might bring about this differential selection may be illustrated as follows: If the teeth of a particular child tend to erupt at an early age, these teeth will have been exposed to the environment of the mouth longer, at the same chronological age, than will be those of a child whose teeth tend to erupt at a relatively late age. Since attack by dental caries is related to the length of time the teeth are exposed in the mouth, children whose teeth erupt early may be expected to show, at the same chronological age, more caries than children whose teeth erupt late. The selection of susceptible children (those having a specified minimum number of DMF permanent teeth) may tend to pick out individuals who are "early eruptors";[4] immune children, on the other hand, may tend to be "late eruptors." The presence of relatively more early eruptors in the susceptible group and relatively more late eruptors in the immune group may be the factor which accounts for the finding of more erupted permanent teeth in the former than in the latter group of children. As just indicated, however, the full significance of this finding is not clear at the present time. Nevertheless, its possible implications must be borne in mind in studies on the relative immunity and susceptibility of children to dental caries.[5]

[4] "Early eruptors" may be expected to have, at comparable ages, more permanent teeth erupted than "late eruptors."

[5] In order to compare the caries experience of two groups of children of the same chronological age, one group having significantly more permanent teeth erupted than the other, it would appear to be necessary to take account of the fact that the teeth of one group have

(Continued on page 71)

Of the grade school pupils examined, 357 children were designated as caries immune and 270 as caries susceptible by means of the criteria previously described. Since nearly all of the children of elementary school age in the community were examined, dental records for essentially all of the brothers and sisters (of school age) of these immune and susceptible children were available for study. Some of the caries immunes and caries susceptibles themselves fell within the brother-sister group. Two such immunes were observed in each of twenty-seven families, and two such susceptibles were observed in each of thirteen families; three immunes were found in each of two families and three susceptibles in three families; four immunes were observed in one family. In two families, one immune and one susceptible were found per family.

Selection of Brothers and Sisters of Immune and Susceptible Children. In the material under analysis, the families fall into two major groups: (a) those in which only one immune or susceptible child was observed, and (b) those in which there were observed more than one immune or more than one susceptible child. In the first group of families, all children examined, except the immune or susceptible child, were placed in the brother-sister group. In the second group, the older or eldest immune or susceptible child was selected as the index case, and the other children, regardless of their relative immunity or susceptibility, were grouped within the brother-sister class. For the two families in which both an immune and a susceptible were found, the immune child was counted among the brothers and sisters of the susceptibles in one family, and the susceptible child was counted among the brothers and sisters of the immunes in the other family.

Index Cases and the Brother-Sister Class. By means of the procedures and criteria discussed in the preceding sections, two special

been exposed to the environment of the mouth for a longer period of time than the teeth of the other group. One method of taking account of this factor involves the expression of caries experience in terms of "posteruptive tooth age." An application of this method will be found in a later section of this paper.

classes of children were obtained: First, a group of 184 immune and a group of 117 susceptible *propositi or index cases;* second, a special class composed of a group of 306 brothers and sisters of immune index cases and a group of 182 brothers and sisters of susceptible index cases. Among the 306 brothers and sisters of immunes, there were included, by the method used for designating the brother-sister class, thirty-four children who meet the criteria for immunes and one who meets the criteria for the susceptibles. Among the 182 brothers and sisters of susceptibles, nineteen children meet the criteria of susceptibles and one child meets the criteria of immunes.

Since each index case represents a family containing one or more immune or susceptible children, it may be noted that 184 "caries immune families" and 117 "caries susceptible families" constitute the number of different family groups from which the children are drawn. The age and sex distributions of the 301 index cases through which these families were selected, as well as the distributions for their 488 brothers and sisters are given in Table 1.

FINDINGS

Caries Immunes and Caries Susceptibles Within the Same Family. Preliminary to the presentation of findings on the dental status of the brothers and sisters of the immune and susceptible index cases, information of some significance regarding one aspect of the familial characteristic of caries can be derived from a study of the distribution of caries immunes and caries susceptibles within families. Thus, the fact may be derived from the material presented previously that two or more immunes were found in thirty families, two or more susceptibles in sixteen families, and in only two families were both an immune and a susceptible observed. No detailed test will be presented here of the statistical significance of this distribution of occurrence of more than one immune, or susceptible, child in the same family; but it is apparent that certain families are marked by caries immunity while other families are characterized

Sex	Caries Group	Age (Years Last Birthday)										
		6	7	8	9	10	11	12	13	14	15	All Ages
		INDEX CASES										
Boys	S	—	—	—	—	3	8	13	8	8	7	47
	I	—	—	—	—	26	22	16	26	7	1	98
Girls	S	—	—	—	—	14	7	14	17	12	6	70
	I	—	—	—	—	30	26	19	6	3	2	86
Both Sexes	S	—	—	—	—	17	15	27	25	20	13	117
	I	—	—	—	—	56	48	35	32	10	3	184
		BROTHERS AND SISTERS										
Boys	S	3	11	15	10	17	15	14	8	2	2	97
	I	16	17	25	19	21	16	20	15	11	1	161
Girls	S	8	5	8	14	15	6	9	13	4	3	85
	I	7	13	28	24	17	8	18	14	15	1	145
Both Sexes	S	11	16	23	24	32	21	23	21	6	5	182
	I	23	30	53	43	38	24	38	29	26	2	306

Table 1. Age and sex distributions of 301 caries immune (I) and caries susceptible (S) index cases and those of their 488 brothers and sisters. (Data derived from dental examinations of 4,416 grade school children, Hagerstown, Md.)

by caries susceptibility. Such an impression may be derived from the simple fact that forty-six out of forty-eight families each contain two or more children who show similarity in respect to caries immunity or susceptibility while in only two families does this direct similarity fail to hold. This preliminary finding strongly suggests the existence of familial resemblances in caries immunity and susceptibility.

Methodological Considerations in the Comparison of Caries Experience in the Permanent Teeth of the Brother-Sister Classes. On the basis of the data just presented, brothers and sisters of immune children might be expected to show significantly lower levels of caries experience than those of caries susceptible children. Before proceeding with the presentation of detailed data in this connec-

tion, however, it becomes necessary to discuss the fact that the brothers and sisters of the susceptible index cases have a larger average number of erupted permanent teeth, and a smaller average number of deciduous teeth than the brothers and sisters of immune children. This difference between the two groups parallels the previously mentioned difference between the susceptible and immune children themselves. Data revealing this finding are shown in Table 2, which gives tabulations of the average numbers of permanent and deciduous teeth in the brother-sister classes and their index cases. The differences between the two groups of index

Table 2. Average numbers of erupted permanent teeth and of deciduous teeth present in the mouths of (a) 306 immune (I) and susceptible (S) index cases, and (b) of their 488 brothers and sisters. (Data derived from dental examinations of 4,416 grade school children, Hagerstown, Md.)

Item Tabulated	Sex and Caries Designation	Age (Years Last Birthday)									
		6	7	8	9	10	11	12	13	14	15
		(a) index cases									
Average Number Erupted Permanent Teeth per Child	Boys (S)	—	—	—	—	*	22.4	26.2	26.9	27.5	27.4
	(I)	—	—	—	—	15.4	19.3	20.7	26.6	26.1	*
	Girls (S)	—	—	—	—	19.5	24.4	25.6	27.2	27.2	27.5
	(I)	—	—	—	—	16.6	21.4	24.2	26.7	*	*
Average Number of Deciduous Teeth Present per Child	Boys (S)	—	—	—	—	*	1.9	.1	.3	.1	.3
	(I)	—	—	—	—	7.7	4.3	3.4	.3	.3	*
	Girls (S)	—	—	—	—	3.4	.3	.5	0	.1	0
	(I)	—	—	—	—	6.0	3.1	1.4	.2	*	*
		(b) brothers and sisters									
Average Number Erupted Permanent Teeth per Child	Boys (S)	*	7.3	10.7	13.7	15.6	21.1	22.8	26.3	*	*
	(I)	4.7	6.7	10.2	12.3	14.4	19.2	23.3	25.2	27.6	*
	Girls (S)	6.6	10.6	11.8	16.5	18.0	21.8	25.9	26.5	*	*
	(I)	4.9	8.7	11.3	13.1	16.5	22.6	23.8	25.1	27.5	*
Average Number of Deciduous Teeth Present per Child	Boys (S)	*	15.5	11.3	8.4	6.7	2.6	1.3	.1	*	*
	(I)	17.4	14.8	12.4	9.7	7.9	3.9	1.6	1.2	.1	*
	Girls (S)	16.0	10.0	11.1	4.3	3.9	1.8	.6	.2	*	*
	(I)	15.6	13.0	11.3	9.5	6.2	2.3	1.7	1.1	0	*

* Values based on less than five cases are omitted.

cases are readily apparent. For the brother-sister groups, if comparisons between the separate age-sex groups are restricted to those in which the averages are based on more than five children, it becomes evident that brothers and sisters of immunes definitely have fewer permanent teeth at comparable ages than do brothers and sisters of the susceptibles.

Further analysis of these data, although not reproduced here, leads to the significant conclusion that the brothers and sisters of immunes have, during the period of eruption of the permanent dentition, an average of approximately one erupted permanent tooth less than is found in the brothers and sisters of the susceptibles of comparable chronological age. The finding of lesser numbers of deciduous teeth in the brothers and sisters of susceptibles and greater numbers in those of immunes may be explained in part by these differences in eruption of the permanent teeth.[6]

In the light of these findings, the question may well be raised as to what analytical procedures are required for making a precise comparison of the caries experience of the two brother-sister groups. Since larger numbers of permanent teeth are present in the brothers and sisters of susceptibles, more teeth would be available for attack by caries and, because of this fact, more teeth might be found carious. Moreover, a larger number of erupted permanent teeth implies earlier eruption and, therefore, a longer period of mouth exposure during which attack by caries might take place.

This discussion leads directly to an attempt to express the caries experience in terms of the length of time the teeth are exposed to the risk of attack by caries. In a recent paper (9), a method for estimating the time of exposure of teeth in the mouth, *accumulated posteruptive tooth age,* is described. The following simple example will serve, for present purposes, to define the term *"accumulated posteruptive tooth age":* A child of exactly seven years of age has

[6] The finding of these differences in numbers of permanent and deciduous teeth in the sibling groups, which parallel similar differences between the two groups of index cases, strongly suggests the existence of familial resemblances in eruption patterns.

five permanent teeth erupted. The two lower first molars erupted at six years of age, the two upper first molars at six and one-half years, and the lower right central incisor erupted at six years, nine months of age. The accumulated posteruptive tooth age for this child is, therefore, three and one-fourth years; two years for the lower molars, one year for the upper molars, and one-fourth year for the incisor. This determination of length of time the teeth are exposed in the mouth is the sum of actually observed durations of exposure of the separate teeth. Where direct observations of this character are not available, it is possible to estimate the average value of accumulated posteruptive tooth age from quantitative data on the eruption of the teeth. Details of the mathematical derivation of these values are given in reference (9), in which is included a

Table 3. Number of decayed, missing, or filled (DMF) permanent teeth and tooth surfaces per child, and accumulated posteruptive tooth age per child, of brothers and sisters of immunes (I) and brothers and sisters of susceptibles (S). (Data derived from dental examinations of 4,416 grade school children, Hagerstown, Md.)

Item Tabulated	Sex and Caries Designation	Age (Years Last Birthday)									
		6	7	8	9	10	11	12	13	14	15
Number of DMF Permanent Teeth per Child	Boys (S)	*	1.0	1.9	3.0	3.0	3.9	6.0	5.0	*	*
	(I)	0	.6	.6	1.0	1.4	1.6	2.7	3.0	2.6	*
	Girls (S)	.9	1.6	1.0	2.9	3.1	4.2	4.3	8.2	*	*
	(I)	.3	.4	.9	1.0	1.5	1.6	2.3	2.9	4.5	*
Number of DMF Permanent Tooth Surfaces per Child	Boys (S)	*	2.1	2.5	5.5	6.7	7.0	13.3	13.6	*	*
	(I)	0	.7	.8	1.4	2.9	3.4	4.5	7.6	4.0	*
	Girls (S)	1.6	1.6	1.3	7.4	5.7	8.0	8.8	15.6	*	*
	(I)	.6	.4	1.2	1.8	2.7	1.9	4.7	5.5	9.7	*
Accumulated Posteruptive Tooth Age in Years per Child[1]	Boys (S)	*	6.5	15.7	30.0	39.5	66.7	77.0	107.0	*	*
	(I)	3.3	5.5	14.0	23.0	33.5	57.0	80.0	94.0	—	*
	Girls (S)	6.0	15.0	19.5	40.7	47.5	67.0	104.0	113.5	*	*
	(I)	3.7	9.5	17.3	25.5	40.5	72.5	82.0	95.5	—	*

* Values based on less than five cases are omitted.

[1] The values of accumulated posteruptive tooth age given here were derived from a nomogram (Fig. 3 in reference 9) relating average number of erupted permanent teeth to tooth age. The average numbers of erupted permanent teeth for the different age-sex groups of brothers and sisters are given in Table 2 of this paper. Since the relationship between the number of erupted teeth and posteruptive tooth age cannot be considered as accurately determined when the number of erupted teeth approaches twenty-eight, the table does not give tooth age values for average numbers of erupted teeth above twenty-seven.

nomogram from which it is possible to obtain estimated average values of posteruptive tooth ages for given average numbers of erupted permanent teeth.

Caries Experience in the Permanent Teeth of the Brother-Sister Classes. Table 3 gives data from which it is considered possible to make an accurate and precise comparison of dental caries experience in the permanent teeth of brothers and sisters of the immune and those of the susceptible index cases. The first section of the table shows the number of decayed, missing, and filled (DMF) permanent teeth per child; the second section shows the number of DMF tooth surfaces per child, and the third section gives the average accumulated posteruptive tooth age per child for each age-sex group of the brother-sister classes. Inspection of the upper two divisions of the table indicates that the brothers and sisters of the susceptibles generally have of the order of twice as many teeth and tooth surfaces attacked by caries as the brothers and sisters of the immunes.

Although several different methods may be adopted for showing, in the two groups, the relation of posteruptive tooth age to attack by caries, the purposes of the present discussion are perhaps best served by the graphic presentation of data as given in Figure 1. Despite some irregular variation of the individual curves, the heavy solid lines, representing moving averages,[7] for the combined sexes, show very clearly a striking difference between the two groups. When posteruptive tooth age reaches an average of ten years per child, the brothers and sisters of the immunes have slightly less than one carious surface per child, while the brothers and sisters of the susceptibles have nearly two carious surfaces per child; when tooth age reaches fifty years, the brothers and sisters of immunes show less than three DMF surfaces, while those of the susceptibles show more than seven DMF surfaces. Ratios, for the two groups, of

[7] Each point of the moving average represents the mean of six values, three for boys and three for girls. These six values were obtained by reading the ordinates from the irregular line curves for successive ten-year units of accumulated posteruptive tooth age.

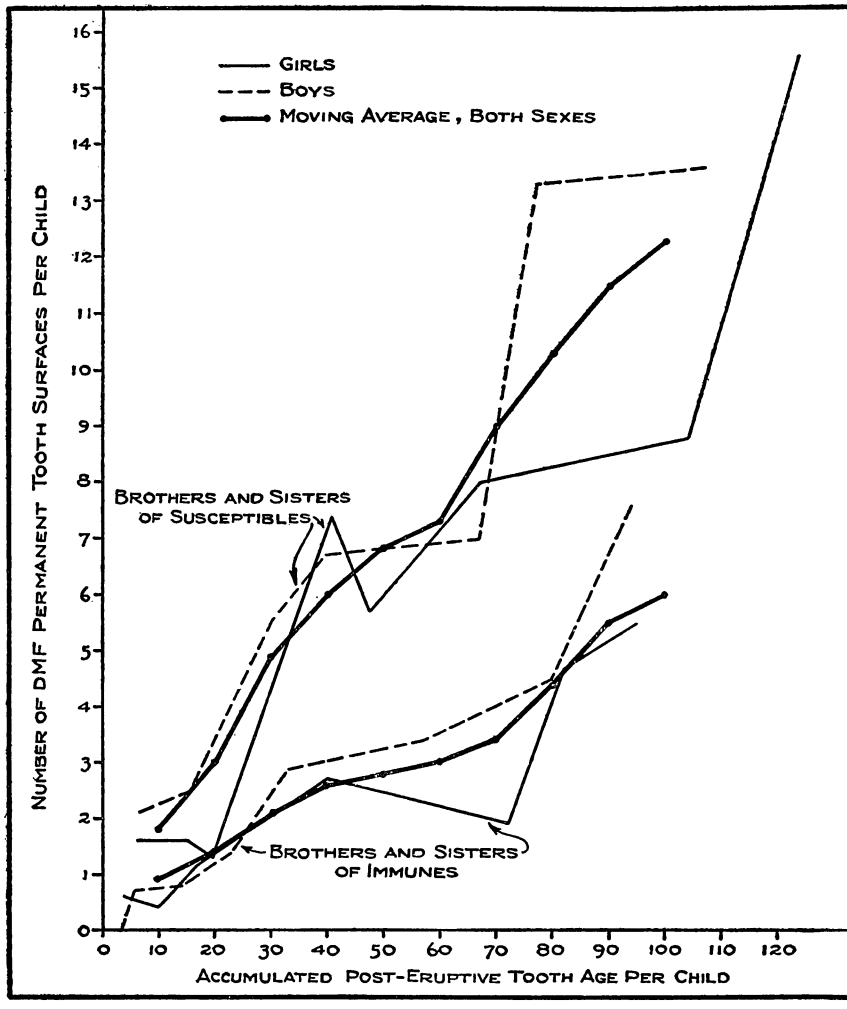

Fig. 1. The relation between accumulated posteruptive tooth age and the number of decayed, missing, or filled (DMF) permanent tooth surfaces.

the number of tooth surfaces attacked by caries for different comparable levels of tooth age indicate that from two and one-fourth to two and one-half times as much caries is present in the permanent teeth of the brothers and sisters of the susceptibles as is found in brothers and sisters of the immunes.

Caries in the Deciduous Teeth of the Brother-Sister Classes. For reasons fully discussed in a previous publication (7) and mentioned

Item Tabulated	Sex and Caries Designation	Age (Years Last Birthday)									
		6	7	8	9	10	11	12	13	14	15
Number of Deciduous Teeth Present	Boys (S)	*	170	170	84	114	39	18	1	*	*
	(I)	278	251	311	185	166	62	32	18	1	*
	Girls (S)	128	50	89	60	58	11	5	3	*	*
	(I)	109	169	317	229	105	18	31	16	0	*
Number of Carious[1] Teeth per 100 Teeth Present	Boys (S)	*	43.5	61.2	57.1	51.8	64.1	55.6	100.0	—	—
	(I)	11.2	29.1	36.0	37.8	34.3	41.9	43.8	33.3	100.0	—
	Girls (S)	55.5	76.0	48.3	63.3	55.2	90.9	60.0	100.0	—	—
	(I)	30.3	18.9	34.7	32.8	35.2	16.7	48.4	37.5	—	—
Number of Carious[1] Tooth Surfaces per 100 Teeth Present	Boys (S)	*	89.4	154.1	122.6	128.1	182.1	144.4	500.0	—	—
	(I)	20.1	57.8	69.5	91.4	66.9	72.6	84.4	61.1	200.0	—
	Girls (S)	126.6	238.0	100.0	133.3	124.1	154.6	100.0	200.0	—	—
	(I)	45.0	36.7	70.7	65.9	69.5	22.2	119.4	100.0	—	—

* Values based on less than five cases are omitted.
[1] Decayed or filled.

Table 4. Data showing caries present in the deciduous teeth of 488 brothers and sisters of immune (I) and susceptible (S) index cases. (Data derived from dental examinations of 4,416 grade school children, Hagerstown, Md.)

earlier in this paper, caries experience cannot be completely reconstructed for the deciduous teeth from survey data such as are available for the present study. An *approximation* of the level of caries in deciduous teeth may be obtained, however, by expressing the number of teeth or tooth surfaces observed to be carious, and (or) filled, as a ratio (times 100) of the total number of deciduous teeth present in the mouth.[8] Data arranged in this form are given in Table 4 for the two brother-sister groups, and Figure 2 illustrates graphically the relation between chronological age and the number of carious deciduous tooth surfaces per 100 deciduous teeth present in the mouth. In general, this material shows that caries in the deciduous teeth of brothers and sisters of susceptibles is approximately twice as extensive as in the brothers and sisters of immunes.

Obviously this finding, and its interpretation, is not entirely con-

[8] Such an arrangement of the data tends also to equalize differences, such as are present in the two groups under investigation here, in the number of deciduous teeth present in the mouth.

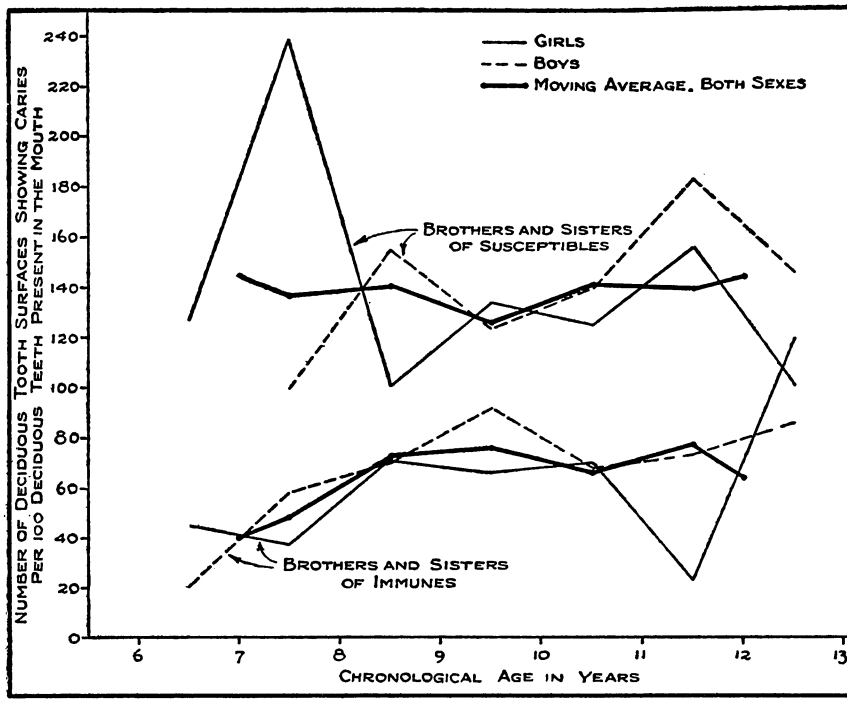

Fig. 2. The relation between chronological age and number of carious or filled deciduous tooth surfaces per 100 deciduous teeth present in the mouth. (The heavy solid lines represent three-point moving averages, except that the points at the two ends of the age range represent two-point averages.)

clusive, since the two brother-sister groups are markedly different in numbers of deciduous teeth present in the mouth, and, very probably, the length of time the deciduous teeth have been present in the mouth may be different for the two contrasted groups of children. From one point of view, it is possible that the finding in the brothers and sisters of susceptibles of approximately double the amount of caries found in those of the immunes may constitute an *understatement* of the actual differences between the two groups. Thus it may be recognized that the finding of fewer deciduous teeth present in the mouths of the brothers and sisters of the susceptibles may represent, in part, the premature loss of these teeth because of severe caries. On the whole, therefore, it seems reasonable to conclude that the analysis of the data indicates a definite

difference between the two groups in attack of the deciduous teeth by caries, and that this difference is of the order of two to one, in brothers and sisters of susceptibles as compared with brothers and sisters of immunes.

SUMMARY AND CONCLUSIONS

This paper contains the preliminary results of a study on familial characteristics of dental caries. The basic data were derived from records of dental examinations of essentially all of the elementary school children in an urban community (Hagerstown, Md.), which has a population of approximately 30,000 persons. The major steps in the analysis are as follows: from the dental records of 4,416 white children, two defined groups were selected—one, those being relatively immune to caries, the other, those showing relatively high susceptibility to caries. Records for the brothers and sisters, of grade school age, of the "immunes" and "susceptibles" were then assembled and analyzed to show the level of caries in the two contrasted groups of brothers and sisters. The results of the analysis indicate that brothers and sisters of susceptibles have somewhat over twice as much caries in both the permanent and deciduous teeth as do brothers and sisters of the immunes. Since the material available for study constitutes a relatively large sample of children, it is possible to conclude that the existence of familial resemblances in caries experience of children is definitely established. In this paper, and at the present time, no specific explanation is offered for the observed familial differences.

REFERENCES

1. Day, C. D. M. and Sedwick, H. J.: Studies on the Incidence of Dental Caries. *Dental Cosmos,* 1935, 77, p. 442.

2. Bunting, R. W.: Bacteriological, Chemical, and Nutritional Studies of Dental Caries by Michigan Research Group—A Summary. *Journal of Dental Research,* 1934, 14, p. 97.

3. Kappes, L. O.: Factors in the Decay of Teeth. *American Journal of Diseases of Children,* 1928, 36, p. 268.

4. Detlefsen, J. A.: Malocclusion and Extraction of Teeth. *Journal of Dental Research,* 1934, 14, p. 217. (Abstract.)

5. Kugelmass, I. N.: Dental Caries in Children. *New York State Journal of Medicine,* 1937, 37, p. 1733.

6. Miller, H. C. and Crombie, D. M. R.: Complete Freedom from Caries, A Comparative Study of Twenty-Five Children. *Lancet,* July 15, 1939, 137, p. 131.

7. Klein, Henry; Palmer, C. E.; and Knutson, J. W.: Studies on Dental Caries. I. Dental Status and Dental Needs of Elementary School Children. *Public Health Reports,* 1938, 53, p. 571.

8. Klein, Henry; Palmer, C. E.; and Kramer, M.: Studies on Dental Caries. II. The Use of the Normal Probability Curve for Expressing the Age Distribution of Eruption of the Permanent Teeth. *Growth,* 1937, 1, p. 385.

9. Palmer, C. E.; Klein, Henry; and Kramer, M.: Studies on Dental Caries. III. A Method of Determining Posteruptive Tooth Age. *Growth,* 1938, 2, pp. 149-158.

10. Knutson, J. W. and Klein, Henry: Studies on Dental Caries. IV. Tooth Mortality of Elementary School Children. *Public Health Reports,* 1938, 53, p. 1021.

11. Klein, Henry and Palmer, C. E.: Studies on Dental Caries. V. Familial Resemblance in the Caries Experience of Siblings. *Public Health Reports,* 1938, 53, p. 1353.

12. Klein, Henry and Palmer, C. E.: Studies on Dental Caries. VI. Caries Experience and Variation in the Time of Eruption of the Permanent Teeth. *Child Development,* June, 1938, 9, p. 203.

13. Klein, Henry and Palmer, C. E.: Studies on Dental Caries. VII. Sex Differences in Dental Caries Experience of Elementary School Children. *Public Health Reports,* 1938, 53, p. 1685.

14. Knutson, J. W.; Klein, Henry; and Palmer, C. E.: Studies on Dental Caries. VIII. Relative Incidence of Caries in the Different Permanent Teeth. *Journal of the American Dental Association,* 1938, 25, p. 1923.

15. Klein, Henry and Palmer, C. E.: Studies on Dental Caries. IX. The Prevalence and Incidence of Dental Caries Experience, Dental Care, and Carious Defects Requiring Treatment in High School Children. *Public Health Reports,* (In press).

16. Klein, Henry and Palmer C. E.: Dental Caries in American Indian Children. *Public Health Bulletin* No. 239, December, 1937. United States Government Printing Office.