

Explanatory model for the interaction of factors in the caries process

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The interaction of factors in the caries process has recently been discussed in a number of articles. Based on this, a new explanatory model has been constructed, consisting of an equilateral triangle with one of the apices on a horizontal line, along which dietary and oral hygiene habits are scaled. The triangle represents the total area of interaction. A horizontal line of resistance cuts off a lower part corresponding to the area within which caries does not occur. Through planogeometric calculations the remaining part of the triangle can be divided into areas, approximately corresponding to the relative caries values of various combinations of dietary and oral hygiene habits. The model has proved to be a useful instrument for demonstrating and creating an understanding of interactive processes among various groups of dental health personnel. The example presented is based on a pilot study of 55 4-year-old children in Malmö.

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The interaction of factors in the caries process has been elucidated recently in a number of studies (1, 2, 3, 4, 5). One of the main conclusions was that the effect of one caries-preventive measure is most marked when other background factors are most unfavorable.

The model of interaction generally referred to was proposed by Keyes (6) and consists of three circles, representing substrate, bacteria, and tooth surface. It demonstrates that when the circles are superimposed, caries may develop, *i.e.* a

planogeometric representation of Miller-Black's fundamental theory of caries. If one of the factors is excluded, no caries will occur. The model, however, tells us nothing about the interaction of diet and oral hygiene at different levels of cariogenicity. Neither does it allow for variations in caries susceptibility.

The aim of the present paper is to present the principles of a new model to explain the interaction of diet and oral hygiene, based on values from a pilot study in 4-year-old children.

MATERIAL AND METHODS

The subjects were 55 randomly selected children from the city of Malmö, aged 4 years and 2 to 3 months. One of us obtained a dietary history of the child by interviewing the mother or father. Questions were also asked about the use of fluoride tablets and of toothpaste containing fluoride. During the interview the other investigator recorded smooth-surface caries and the state of the gingiva. X-ray films were not available.

Dietary and oral hygiene variables were chosen so that they could be presumed to cause the same interaction effect at the respective levels. Preliminary guidelines were established from the study by Granath et al. (5). The variations were as follows. Diet: 3) > 2, 2) 1-2, and 3) no regular high-sucrose between-meal eating or snacks per day. Oral hygiene: 3) General gingival bleeding on probing, 2) general gingivitis without bleeding on probing or with only a few bleeding points, and 3) a gingiva practically free from clinical signs of inflammation.

Topical application of fluoride by means of tablets or toothpaste was classified according to the time during which it had been practiced: regularly for a continuous period of at least 1 1/2 years, irregularly for a shorter period, or not at all.

Surface demineralization or more advanced stages were registered. Thus, sub-surface lesions were not scored as caries.

All combinations were given an estimated mean value of caries, relative to the original value of neighboring combinations and based on the previous finding that the effect of one preventive measure is greatest when other background factors are most unfavorable and that the increase of caries as a result of a continuously impaired variable follows a gradient (4, 5). From these figures, a new model of interaction was constructed. It consists of an equilateral triangle with one of the apices on a horizontal line, along which the dietary and oral hygiene variables are scaled. The triangle

represents the total area of interaction. A horizontal line, the line of resistance, cuts off a lower part corresponding to the area within which caries does not occur. Through simple planogeometric calculations the remaining part of the triangle was divided into areas, approximately corresponding to the estimated values of the various combinations of dietary and oral hygiene variables. The model describes how the amount of caries increases continuously with impaired diet and oral hygiene, either as a consequence of a change in one variable in the interaction while the other remains constant or through increases in both variables. The former situation presupposes that neither of the variables is considered to be strictly non-cariogenic.

Differences in caries between combinations represented by 5 or more subjects were tested statistically, using the *t* test. The caries scores of each of these combinations were found to have an approximately normal distribution. This was checked by comparing the calculated standard deviation with the estimated standard deviation according to Tippett (7). All tests were performed one-sidedly, since the alternative hypothesis was that a combination with one variable at a higher level than the corresponding variable of the compared group and with the other variable at the same level should result in a higher mean value. Differences at the 5% level of probability were said to be statistically significant. The number of degrees of freedom was chosen as $[\text{minimum}(n_{D_i O_i}, n_{D_i \bar{O}_i}) - 1]$, which means that the test was conservative.

RESULTS

Table 1 reports the data of 54 of the 55 children. One child was excluded from the test because a complete change of habits had occurred at the age of 3 years as a result of information about dental health care in connection with treatment of advanced caries

Table 1. *Distribution of 54 4-year-old children among combinations of dietary and oral hygiene habits, and mean value of smooth-surface caries in the combinations*

D 3/0 3 n = 1 \bar{x} = 25 \bar{x}_e = 30	D 3/0 2 n = 9 \bar{x} = 14.2 \bar{x}_e = 15	D 3/0 1 n = 2 \bar{x} = 0 \bar{x}_e = 7
D 2/0 3 n = 3 \bar{x} = 22.3 \bar{x}_e = 15	D 2/0 2 n = 12 \bar{x} = 5.1 \bar{x}_e = 5	D 2/0 1 n = 10 \bar{x} = 2.2 \bar{x}_e = 2.5
D 1/0 3 n = 0 \bar{x}_e = 7	D 1/0 2 n = 12 \bar{x} = 2.3 \bar{x}_e = 2.5	D 1/0 1 n = 5 \bar{x} = 1.0 \bar{x}_e = 1

Diet: D 3 > 2, D 2 = 1-2, and D 1 = no regular high-sucrose between-meal eating or snacks per day; oral hygiene: 0 3 = general gingival bleeding on probing, 0 2 = general gingivitis without bleeding on probing, and 0 1 = a gingiva practically free from clinical signs of inflammation; n = number of subjects; \bar{x} = mean value and \bar{x}_e = estimated mean value of decayed, extracted, and filled surfaces.

lesions. The estimated values of the combinations D 3/0 1 and D 1/0 3 were based upon previous findings, which indicated that they should be higher than those of D 2/0 1 and D 1/0 2, respectively, and also higher than the value of D 2/0 2. Further, the difference between the values of D 3/0 3 and D 3/0 2 should be greater than that between D 3/0 2 and D 3/0 1. It was not possible

to establish any consistent effect of topical application of fluoride.

The results of the statistical tests are given in Table 2. All tested differences were statistically significant except those of D 2/0 1 versus D 1/0 1 and D 1/0 2 versus D 1/0 1. With the low number of observations, the systematic numerical difference in these cases was too small to be of statistical significance.

The model of interaction is presented in Fig. 1, which highlights the area relating to combination D1/0 3. With the area within which caries does not occur occupying 1/32 of the triangle, it was easy to scale the variables so that the different areas of interaction approximately corresponded to the estimated values of the respective combinations.

Table 2. *Results of significance tests of differences in smooth-surface caries between combinations represented by 5 or more subjects (t test of approximately normally distributed independent observations)*

	m	t	p
D 3/0 2 vs D 2/0 2	9.1	2.82	< 0.05
» » D 2/0 1	12.0	3.55	< 0.01
» » D 1/0 2	11.9	3.75	< 0.01
» » D 1/0 1	13.2	2.78	< 0.05
D 2/0 2 » D 2/0 1	2.9	2.10	< 0.05
» » D 1/0 2	4.1	1.99	< 0.05
» » D 1/0 1	2.8	2.40	< 0.05
(D 2/0 1 » D 1/0 2	-0.1)		
» » D 1/0 1	1.2	1.04	N.S.
D 1/0 2 » D 1/0 1	1.3	0.89	N.S.

m = mean difference of decayed, extracted, and filled surfaces

p = level of significance

DISCUSSION

The authors have tried out the model in professional educational situations and found it to be a useful instrument for creating a visual understanding of the interaction of factors in the caries process.

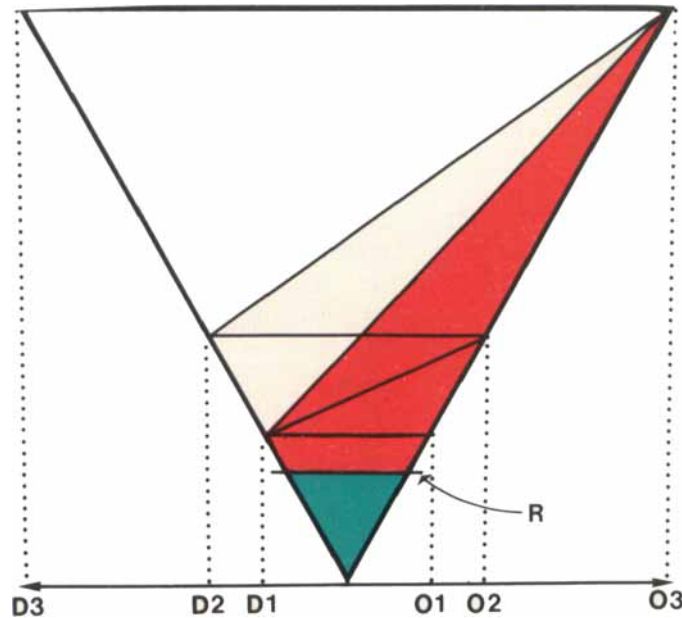


Fig. 1. Model of interaction; the green area, bounded by the line of resistance (R), represents the part of the equilateral triangle (total area of interaction) within which caries does not occur; red represents the relative amount of caries that will result from combination D 1/0 3 in 4-year-

old children; the symbols are explained in Table 1; the geometric calculations are based on the estimated values in the same table; $D\ 1/0\ 1 = 1/30$, $D\ 1/0\ 2$, $(D\ 2/0\ 1) = 1/12$, $D\ 2/0\ 2 = 1/6$, $D\ 1/0\ 3$, $(D\ 3/0\ 1) = 1/4.3$, $D\ 2/0\ 3$, $(D\ 3/0\ 2) = 1/2$, and $D\ 3/0\ 3 = 1/1$ of the area above R.

The present application is based on the caries values of a pilot study. Although the number of observations is limited, the definition of the variables is sufficiently accurate to result in statistical separation of most of the combinations.

The results prompt the collection of more extensive subject materials so that interaction models can be developed and refined for different age groups, tentatively at 4, 6, 12 and 15 years. It is surely important, on various occasions, to be able to predict the occurrence of caries as a result of different combinations of dietary and oral hygiene habits and preventive measures. The model also seems to be helpful when it comes to explaining these interactive effects.

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