Design of a socio-ecologic caries model and testing on 50-year-old citizens of Oslo, Norway

Espen Bjertness and Harald M. Eriksen

Department of Epidemiology, National Institute of Public Health, and Department of Operative Dentistry, Dental Faculty, University of Oslo, Oslo, Norway

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The purpose of the present study was to design a socio-ecologic caries model based on a general health model and to test the fit of data collected from a random sample of 200 50-year-old Oslo citizens to this designed model. The intention was also to investigate the relative importance of the four items environmental, behavioral, human biology, and health care organization factors. The dependent variable, number of carious surfaces, was recorded clinically and radiologically. The mean number of carious surfaces was 3.0 (SD, 3.5), with a range from 0 to 17, and the four items explained 5%, 25%, 28%, and 13% of the variance in number of carious surfaces, respectively. The complete model explained 42%, whereas traditionally used variables on the basis of the Keyes triad explained only 22% of the variance. The findings from the present study indicate that dental caries is a multifactorial disease with both behavioral and biologic determinants, and the socio-ecologic caries model represents a relevant supplement to the Keyes triad. □ *Adults; behavior; dental caries; environment; epidemiology; health care organization*

Espen Bjertness, National Institute of Public Health, Department of Epidemiology, Geitmyrsvn. 75, 0462 Oslo, Norway

Although psychologic and sociologic indicators for dental caries have been acknowledged for a long time, research has been concerned mainly with caries as a biologic process (1). The prevailing concept of caries pathogenesis was developed 40 years ago, on the basis of experimental animal studies (2) and further confirmed through experimental (3) and epidemiologic (4) studies in man. There is no doubt that this concept has played, and still plays, an important role in providing a scientifically sound basis for preventive and curative intervention.

But in the light of the dramatic decrease in caries prevalence in many industrialized countries over the past 20 years, particularly well documented among children and adolescents (5), the concept of dental caries may be revised. Whereas the Keyes triad (2) still explains how caries is initiated, it does not attempt to explain what the driving forces triggering this pathogenesis are. These background variables may be increasingly relevant to explain why some people, despite widespread use of fluorides and abundant information about caries prevention, have many carious surfaces.

Within medicine a health-centered, rather than disease-centered, approach has been introduced (6), stating that pathogens are ubiquitous, that health and disease as experienced by man is a continuum, not a dichotomy, and that there are several factors that contribute to health, many with general, not specific, relevance to a particular disease. They include physical conditions, socioeconomic status, inherent biologic properties, attitudes, knowledge, and cultural coherence supportive of health-promoting activities (7). This concept of health and disease may also be increasingly relevant to dental health. A multidisciplinary health-centered approach implies a research strategy that has to be conceived from an appropriate theoretic basis in joint cooperation across traditional borders, particularly between natural sciences and social sciences (8). This represents a challenge for progress in this field.

Within dentistry, various conceptual

models of varied complexity have been proposed (1, 9–24). In principle, most of these models are based either on a biomedical (9–13) or a psycho-social/behavioral philosophy (14–17). However, these two aspects should be considered complementary, not mutually exclusive (6). A few multidisciplinary dental health models including both aspects of dental health have been proposed (18–24) and also to some extent tested (18, 19, 21, 24, 25).

One of the most elaborate multidisciplinary health models available has been presented by Blum and Lalonde (26) and described as the 'health field concept' (Fig. 1). The purpose of the present investigation was to design a dental health model based on the philosophy presented in this concept. One of the limitations connected with the multifactorial approach is that many of the models are not tested scientifically. They may therefore be intellectually stimulating but not very clarifying with regard to the relative importance of the various factors included about dental health. The aim of the present study was therefore also to use information obtained from a random sample of 50-year-old Norwegians to investigate the fit of the data to the designed model and to investigate the relative importance of the factors environmental, behavioral, human biology, and health care organization.

Materials and methods

Materials

During 1988 a simple random sample of 200 50-year-old citizens of Oslo, Norway, was drawn by the National Bureau of Statistics. Fifteen persons had moved out of Oslo and one was reported deceased. Of the remaining 184, 119 (64%) attended a combined oral and radiographic examination

SOCIO - ECOLOGIC CARIES MODEL

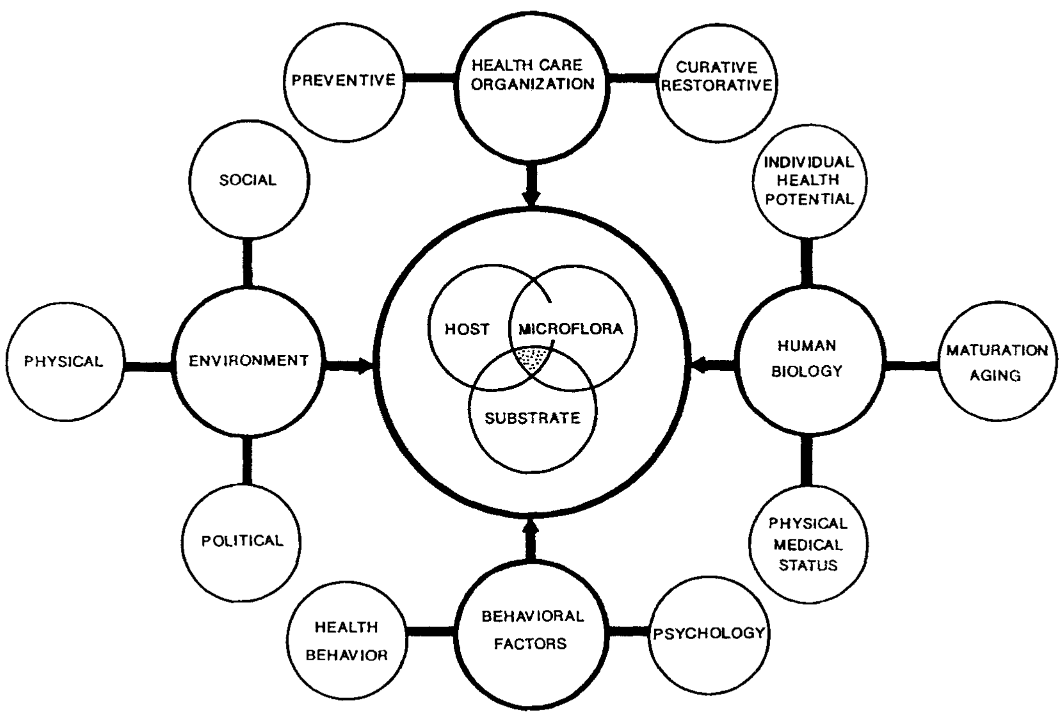

Fig. 1. A socio-ecologic caries model based on the health field concept with the caries triad centrally located.

and answered a questionnaire about their general health, psycho-social status, and oral health habits. The answers given in the questionnaires were subsequently checked at an interview session. Of the 65 non-respondents, 25 (38%) answered a questionnaire by mail (Table 1). The most frequent reasons for not participating were 'little time' (nine persons), 'not-interested' (five persons), and 'ill' (four persons). A further comparison of attenders and non-attenders is given in Table 1.

Methods

Dependent variable. The number of coronal carious surfaces was used as the dependent variable and recorded by one examiner (E. Bjertness) on the basis of a combined clinical and radiographic examination. A carious surface was recorded when a softened floor or wall of a cavity could be registered by probing (27, 28), and radiographically a carious lesion was registered in accordance with Hollender & Koch (29). Third molars were included.

Independent variables. Saliva tests were included, and stimulated secretion rate, buffer capacity (30), and number of *Streptococcus mutans* colony-forming units (31) were determined. The clinical examination included, in addition to registration of decayed surfaces, recording of missing and filled surfaces (DMFS) (27, 32), registration of periodontal disease (CPITN, PTNS) (28), and oral hygiene status (OHI-S) (33). The clinical procedures and the indices used have been described in detail in previous publications (27, 28, 34). The radiographic examination included two bitewing radiographs, an orthopantomogram, and intraoral radiographs of endodontically treated teeth.

The independent variables represent a combination of clinical registrations and questions answered during the questionnaire/interview session. They were grouped under the four main items: environment, behavior, human biology, and health care organization. This approach represents a combined psycho-social/behavioral and biomedical approach hereafter called the socio-ecologic approach. In addition to assessing the fit of data to the model, the relative importance of the two main areas of relevance to dental caries was calculated by including both aspects of oral health and also exclusively indicate the relative importance of dental caries determinants included in the Keyes triad (Fig. 1). The criteria used and the generalizations with relevant references are given in Table 3. Further details about description and operationalization of independent variables are given by Bjertness (34). Reliability tests were performed before and during the examination period. Results from intraexaminer reliability testing of caries registrations performed during the examination period are shown in Table 2.

Statistical methods. Analysis of variance (F-test) were used for statistical evaluation of the bivariate relationships with the dependent variable. The level of significance was

Table 1. A comparison of 25 non-attenders and 119 attenders (percentage distribution)

	Non-attenders, $n = 25$	Attenders, $n = 119$
Sex		
Women	56	53
Men	44	47
Years at school*		
≤10	67	40
>10	33	60
Regular dental visit		
Yes	84	81
Last dental visit*		
<1 year	88	77
1–3 year	4	18
>3 year	8	5
Use of fluoride dentifrice*		
Yes	96	96
Smoking*		
Yes	63	42
Remaining teeth†	22.1 (SD, 8.5)	25.0 (SD, 5.1)
Full dentures (1 or 2)		
Yes	16	4
Partial dentures (1 or 2)		
Yes	16	7

* $n = 24$ (non-attenders) due to inadequate recording.

† $n = 23$ (non-attenders) due to inadequate recording.

chosen to be $p \leq 0.01$ owing to the large number of correlations included.

Multiple classification analysis (MCA) (35) was the multivariate method chosen for the present evaluation because of the ability to handle grouped independent variables. The relations between one dependent variable and a set of selected independent variables in this analysis were based on an additive model; that is, the method supposes that every score for the dependent variable is created by many additive effects (independent variables). The degree of relationship between independent and the dependent variable in the MCA is expressed by eta and beta coefficients. Eta indicates the relationship between the independent and the dependent variable, with no adjustment for possible relationship between the other independent variables. Beta indicates the relationship between the independent and the dependent variable, and contains adjustment for the relationship between the other independent variables. Beta gives a measure of the relative ability (power) of the independent variable to explain the variation of the dependent variable. R^2 indicates the part of the variation of the dependent variable which can be explained by all the independent variables together—that is, the fit of the data to the model. A program package, the DDPP (Discrete Data Program Package), developed at the University of Oslo, was used for statistical analyses (36).

All the independent variables were bivariately related to the number of carious surfaces (the dependent variable) (Table 3). The independent variables in each of the four items that had lowest p value when related to the number of carious surfaces were chosen for further analysis. Possible correlations between independent variables were checked, and one of the two variables in each pair which correlated stronger than ± 0.35 was excluded before applying the MCA (35). For this purpose the Pearson correlation coefficient was used. MCA were then used for each of the four main items, with number of carious surfaces as the dependent variable (Tables 4–7), to compare the explained variance for each of the items and to select variables for further analysis.

The variables with strongest beta values within the four items were chosen for a final testing of the complete socio-ecologic caries model (Table 8). The traditional inde-

Table 2. Intraexaminar testing of caries registration.

		First examination		
		Filled/ intact	Caries primary	Caries recurrent
A)*				
Second examination	Filled/intact	669	9	1
	Caries primary	1	7	0
	Caries recurrent	1	0	18

		First examination			
		Filled/ intact	Caries enamel	Caries dentin	Caries recurrent
B)†					
Second examination	Filled/intact	583	1	1	0
	Caries enamel	1	5	0	0
	Caries dentin	1	0	5	0
	Caries recurrent	2	0	0	10

* A) Clinical: kappa = 0.80 ± 0.04.
† B) Radiologic: kappa = 0.86 ± 0.04.

Table 3. A bivariate analysis of the independent variables used with operationalization, distribution of individuals, mean and standard deviation of carious surfaces, and statistical significance indicated

	n	Mean score	SD	Probability (*p*)
Environment				
Years at school[ex]				
≤10	47	3.9	4.13	0.032[ns]
>10	72	2.5	2.88	
Social class (35)				
Class 1	27	1.9	2.38	
Class 2	66	2.9	3.14	0.014[ns]
Class 3	26	4.6	4.64	
Economy				
Unsatisfied	19	4.0	4.98	0.176[ns]
Satisfied	100	2.8	3.12	
Behavioral factors				
Nutritional status				
Unsatisfactory	47	3.6	4.01	0.106[ns]
Satisfactory	72	2.6	3.06	
Alcohol				
No alcohol problems	108	2.5	2.86	0.000*
Alcohol problems	11	8.3	4.69	
Exercise				
No	72	3.4	3.66	0.156[ns]
Yes	47	2.4	3.14	
Smoking[ex]				
No	69	2.1	2.64	0.001*
Yes	50	4.3	4.09	
Psychologic status (38)				
Satisfied	106	2.7	3.29	0.007*
Unsatisfied	13	5.5	4.16	
Sugar between meals				
Seldom	104	2.8	2.94	0.039[ns]
Often	15	4.7	5.90	
Tooth cleaning[ex] (33)				
Good	46	1.4	1.75	
Medium	40	3.0	3.38	0.000*
Bad	33	5.2	4.19	
Brushing				
Once/day	24	4.2	4.29	0.058[ns]
> Once/day	95	2.7	2.71	
Interdental cleaning				
No	33	4.1	4.85	0.041[ns]
Yes	86	2.6	2.71	
Use of fluoride[ex]*				
No	5	7.0	6.63	0.008*
Yes	114	2.8	3.22	
Human biology				
Sex				
Woman	63	2.0	2.67	0.000*
Man	56	4.2	3.90	
Physical fitness				
Unsatisfied	13	3.9	5.11	0.317[ns]
Satisfied	87	3.2	3.70	
Allergy				
No	87	3.1	3.63	0.711[ns]
Yes	32	2.8	3.10	
Weight status				
Unsatisfied	32	2.6	2.80	0.433[ns]
Satisfied	87	3.2	3.70	

(Continued next page)

Table 3. (*continued*)

	n	Mean score	SD	Probability (*p*)
Streptococcus mutans (31)				
≤ 20 colonies	58	2.9	3.29	0.814^{ns}
> 20 colonies	61	3.1	0.68	
Buffer capacity (pH) (32)				
> 4.0	78	2.3	3.02	0.002*
≤ 4.0	39	4.5	3.96	
Missing teeth				
≤ 5	59	2.1	2.29	0.004*
> 5	60	3.9	4.17	
Saliva secretion (ml/min) (30)				
≥ 1.0	68	2.6	2.87	0.158^{ns}
< 1.0	51	3.5	4.13	
Chronic disease				
No	87	2.9	3.22	0.606^{ns}
Yes	32	3.3	4.15	
Medication				
No	85	2.9	3.47	0.740^{ns}
Yes	34	3.2	3.56	
Health care organization				
Regular dental visits (today)				
No	22	5.7	5.49	0.000*
Yes	79	2.3	2.43	
Regular dental visits (15–25 years old)[ex]				
No	40	4.4	4.69	0.002*
Yes	79	2.3	2.43	
School dental care				
No	21	3.1	4.85	0.900^{ns}
Yes	98	3.0	3.14	
Recall system[ex]				
No	31	4.5	5.17	0.006*
Yes	88	2.5	2.48	

* $p < 0.01$; ns = not statistically significant.
[ex] Excluded from the MCA analysis owing to high correlation with other independent variables.
[ex*] Excluded from the MCA analysis owing to a low number of individuals in one of the categories.

pendent variables included in the Keyes triad were also analyzed separately with MCA, to compare the explained variance with the variance explained by the complete model (Table 9).

Results

The mean number of carious surfaces was 3.0 (SD, 3.5) with a range from 0 to 17. The bivariate relations between the independent variables and the dependent variable, the number of carious surfaces, is presented in Table 3. Social class shows the lowest *p* value among the variables classified under 'environment'. Among the behavioral variables there was a statistically significant dif-

Table 4. Analysis (MCA) of the independent variables related to environment. Five per cent of the total variation in the dependent variable carious surfaces could be explained by these variables

	Eta	Beta
Social class	0.266*	0.253*
Economy	0.125^{ns}	0.086^{ns}

$R^2 = 0.05$.
* $0.05 > p > 0.01$; ns = not statistically significant.

Table 5. Analysis (MCA) of the independent variables related to behavioral factors. Twenty-five per cent of the total variation in the dependent variable carious surfaces could be explained by behavioral factors

	Eta	Beta
Alcohol	0.485***	0.419***
Psychologic status	0.248**	0.165*
Interdental cleaning	0.188*	0.078^{ns}
Nutritional status	0.147^{ns}	0.075^{ns}
Exercise	0.131^{ns}	0.046^{ns}
Sugar between meals	0.189*	0.043^{ns}

$R^2 = 0.245$.
* $0.05 > p > 0.01$; ** $0.01 > p > 0.001$; *** $p < 0.001$; ns = not significant.

Table 7. Analysis (MCA) of the independent variables related to health care organization. Thirteen per cent of the total variation in the dependent variable carious surfaces could be explained by utilization of the dental health services

	Eta	Beta
Regular dental visits	0.374***	0.392***
School dental care	0.012^{ns}	0.080^{ns}

$R^2 = 0.131$.
*** $p < 0.001$; ns = not significant.

ference in the number of carious surfaces related to alcohol problems, smoking, tooth-cleaning (OHI-S), psychologic status, and use of fluorides. Among human biology variables there was a statistically significant difference in the number of carious surfaces related to remaining teeth and saliva buffer capacity. Of the biomedical variables, saliva secretion rate and number of *Strep. mutans* colonies, there was no difference. In the group of health care organization variables a statistically significant difference was found in relation to regular dental visits and the use of recall systems.

After independent variables showing a correlation stronger than ± 0.35 with other independent variables within each of the four items had been excluded, MCA were performed (Table 4–7). The independent variables excluded are indicated by 'ex' in Table 3. The explained variances (R^2) when using MCA were 5% for the item environment ($R^2 = 0.050$) (Table 4), 25% for the item behavior ($R^2 = 0.245$) (Table 5), 28% for human biology variables ($R^2 = 0.281$) (Table 6), 13% for the health care organization variables ($R^2 = 0.131$) (Table 7), and 22% for the biomedical variables included in the Keyes triad ($R^2 = 0.222$) (Table 9).

Among the behavioral variables (Table 5) the uncontrolled effects of sugar between meals and interdental cleaning are significantly reduced when controlling for the other independent variables (beta < eta). With regard to the human biology variables (Table 6) the effect of sex on the number of carious surfaces is slightly increased when controlled for the other independent variables expressed by a higher beta (0.435) than eta value (0.341).

Table 6. Analysis (MCA) of the independent variables related to human biology. Twenty-eight per cent of the total variation in the dependent variable carious surfaces could be explained by variables related to human biology

	Eta	Beta
Sex	0.341***	0.435***
Buffer capacity	0.287***	0.287***
Missing teeth	0.280***	0.181*
Weight status	0.054^{ns}	0.148^{ns}
Saliva secretion	0.136^{ns}	0.146^{ns}
Physical fitness	0.089^{ns}	0.104^{ns}

$R^2 = 0.281$.
* $0.05 > p > 0.01$; *** $p < 0.001$; ns = not statistically significant.

Table 8. Analysis (MCA) of the independent variable selected to represent the main factors included in the socio-ecologic caries model. Forty-two per cent of the variation in the dependent variable carious surfaces could be explained by these independent variables

	Eta	Beta
Alcohol	0.484***	0.309***
Buffer capacity	0.287***	0.293***
Sex	0.341***	0.288***
Regular dental visits	0.418***	0.250***
Social class	0.272*	0.126^{ns}
Psychologic status	0.245***	0.098^{ns}

$R^2 = 0.422$.
* $0.05 > p > 0.01$; *** $p < 0.001$; ns = not significant.

Table 9. Analysis (MCA) of the independent variables traditionally used as biomedical variables with carious surfaces as the dependent variable. Twenty-two per cent could be explained by these commonly used biomedical variables

	Eta	Beta
Tooth cleaning	0.447***	0.414***
Sugar between meals	0.189*	0.175*
Use of fluorides	0.241**	0.153^{ns}
Streptococcus mutans	0.022^{ns}	0.001^{ns}

$R^2 = 0.222$.
* $0.05 > p > 0.01$; ** $0.01 > p > 0.001$; *** $p < 0.001$; ns = not significant.

The most important independent variables (highest beta values) in each of the four main groups were then selected for final MCA. In the group of environmental variables, social class was chosen as predictor, and among the behavioral variables, alcohol and psychologic status. With regard to biologic and health care organization variables, sex, buffer capacity, and regular dental visits were chosen as caries indicators for the final multiple classification analysis. The selected independent variables explained a total of 42% of the variation in the number of carious surfaces among 50-year-old Oslo citizens ($R^2 = 0.422$) (Table 8). The observed effect of psychologic status and social class was, however, eliminated when controlled for the other independent variables, and the effect of regular dental visits was reduced markedly (Table 8). The two human biology variables, however, were quite stable.

Discussion

The material

The response rate (64%) is comparable to those of similar investigations (39) but lower than in a study of 35-year-old Oslo citizens in 1984 (27). This may confirm a trend of decreasing interest in participating in this kind of health investigation (40) but may also indicate that middle-aged people are less interested in taking part in dental health studies than young adults in the Oslo community. On the basis of the 25 questionnaires from the non-respondents, there were small differences in the number of remaining teeth, years at school, and smoking habits between attenders and non-attenders (Table 1), which may indicate a slightly inferior dental health in the present population. Thus, generalization should be restricted. This may not be of crucial importance when considering the socio-ecologic caries model as a process that may be evident independent of the representativity of the sample (41).

The dependent variable

The reliability of the registration of the number of carious surfaces may be considered acceptable (Table 2). The mean number of carious surfaces in the present investigation (3.0) was higher than in a study from the northern (42) and middle (15) parts of Norway and from Denmark (43), but the number of remaining teeth (24.5) was also higher, in part due to the inclusion of third molars.

The independent variables

Operationalization. We have supposed a relationship between the various indicators

DYNAMIC SOCIO-ECOLOGIC CARIES MODEL

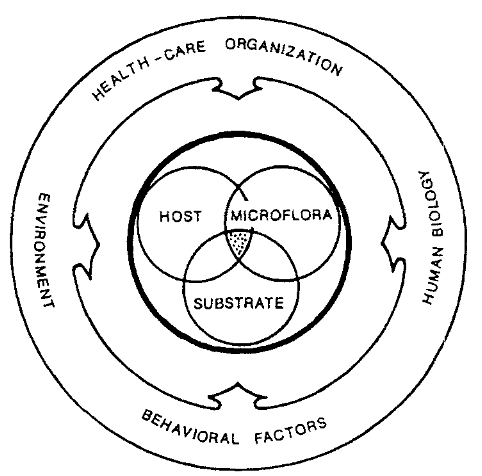

Fig. 2. The socio-ecologic caries model in a dynamic perspective. The outer ring represents possible 'pressure' from background factors on the centrally located caries triad, illustrating the mechanism of disease.

within the four items as illustrated in Fig. 2. The operationalization of the values for the independent variables to ordinal scales was done to obtain rough estimates of the factors and to minimize the problems with outliers. Besides, the independent variables must be grouped before using MCA (35). The choice of the values for allocation to various groups was in part based on commonly used division (see buffer capacity, Table 3) and considering equal distribution of individuals (see missing teeth, Table 3). Some of the indicators (Table 3) are based on assessment of own satisfaction. Thus, this may not give 'true' estimates, but rather indications. This was done for practical reasons and must be considered when interpreting the results. A more detailed discussion of the independent variables is given by Bjertness (34).

The main intention of the present study was to present and test a multivariate caries model. However, some of the bivariate relationships with caries ought to be established to justify the socio-ecologic approach.

Of the environmental factors, years at school and social class had the lowest p value when related to caries. There was, however, no statistically significant difference in the number of carious surfaces when related to these variables. This was unexpected on the basis of earlier investigations (15, 27). Years at school was not included in the multivariate analysis owing to a high correlation with social class. Because of the homogeneity of this population of 50-year-olds many environmental factors were considered irrelevant for testing.

Of the behavioral factors, alcohol, oral hygiene, and smoking all showed low p values when bivariately related to the variation in caries. Oral hygiene and smoking were not included in the MCA owing to the high correlation with alcohol problems and other behavioral factors. The relation between oral hygiene and caries confirms the results from a study of 35-year-old Oslo citizens (27, 34).

Of the human biology factors sex, buffer capacity, and missing teeth were most strongly related to caries. Women had statistically significantly fewer carious surfaces than men, which is in accordance with a study from northern Norway (42), in which 55-year-old men had more than three times as many decayed surfaces as women. This is also a tendency detected in other studies (15, 27). However, no studies conclude that the difference in caries status between women and men is due to biologic differences. It is, however, of importance to note that in the MCA of biologic factors the explanation factor of 28% ($R^2 = 0.281$) (Table 5) was mainly a result of sex together with some factors directly related to the conditions in the oral cavity (missing teeth and buffer capacity). Sex appears as a variable correlated with independent behavioral variables that were not used in the final MCA of the model. Further analyses must therefore be performed to elucidate the effect of sex. The biologic factors saliva secretion rate and the number of *Strep. mutans* colonies, variables commonly used in caries prediction (9), did not show any statistical relation with carious surfaces. This is in contrast to a recent study in which *Strep. mutans*, together with dietary scores, DMFS, and plaque index, was found to be the most relevant factor for distinguishing caries-active and caries-inactive individuals (9, 44).

Of the health care organization factors, regular dental visits were statistically strongly correlated with variation in caries. This supports the importance of regular dental visits and is in agreement with other studies (15). This relation may, however, in part be due to a high repair rate and not necessarily lower caries activity. Regular dental visits and school dental care were the only variables included in the MCA because of high correlation with other independent variables.

On the basis of previous research there has been a schism between biomedical and psycho-social/behavioral approaches to general and dental health (6). The most important biomedical determinant for variation or changes in dental caries is the use of fluorides. This is, however, in such common use among Norwegian adults (Table 3) that it can no longer be considered a variable. *Strep. mutans* and lactobacillus counts are strongly associated with dental caries (11, 45), but the differentiation between these microorganisms as caries indicators is difficult. Saliva secretion rate and buffering capacity are correlated, and both play a role as caries determinants (30, 46). In addition, previous caries experience is known to correlate with caries activity (9, 10, 47).

Type and frequency of sugar intake (48) have repeatedly been demonstrated to influence caries activity and prevalence, whereas the effect of oral hygiene status is more controversial (49).

The present conclusions are almost entirely derived from bivariate correlation studies. There are, however, some studies focusing on the combined effect of many biomedical variables using a multivariate approach with dental health as the dependent variable (10, 12, 19). From these studies previous caries experience (10, 12), salivary *Strep. mutans* counts (10, 12), and oral hygiene scores (10) seem to be the most important variables (44).

Among many psycho-social factors of importance for dental caries, socio-economic status has repeatedly been shown to correlate with caries prevalence (36). However, whereas the lower socio-economic groups show the highest prevalence in industrialized countries, the opposite pattern is found in many developing countries (50, 51). Although oral hygiene (52) and frequency of intake of sweets (48, 53) are repeatedly shown to be caries determinants of major importance in experimental studies in animals and man, investigations emphasizing behavioral variables related to these factors frequently conclude with no or only weak correlations (16, 17, 54). This may be due to the validity and reliability of methods used for registration of behavioral variables and is one of the main reasons why a behavioral approach to dental health problems is frequently denounced as irrelevant (16, 54). However, our present results based both on bi- and multi-factorial analyses in adults indicate high correlations between dental caries and various behavioral variables such as alcohol consumption, smoking habits, tooth cleaning, and psychologic status (Tables 3 and 5).

Most of the studies analyzing both biomedical and psycho-social factors in a multivariate approach conclude with a higher percentage of the total variance in dental caries explained by the biomedical than the social, behavioral, and psychologic variables (18, 19, 24). In the present study the two main items seem to play an equally important role as caries indicators (Tables 5, 6, and 9).

So far, biomedical factors still have more extensive scientific support than the psycho-social factors studied. Furthermore, most of the studies available show a better correlation between biomedical variables and dental caries than the psycho-social variables do. However, most of the studies dealing with caries indicators both bivariately and multivariately have investigated dental health in children and adolescents (9, 12, 16–18, 21, 24, 54), whereas relatively few have been concerned with adult dental health (10, 19, 25).

In children and adolescents, psycho-social indicators will reflect a combination of individual and parental factors masked by the impact of regular public dental health care delivery systems. It is therefore not surprising that a clear pattern of psycho-social variables related to dental caries does not emerge, with the exception of socio-economic status (53). From the multifactorial investigations on adults, psycho-social variables seem to play a more distinct role (10, 19). Supported by the well-designed study of Beck et al. (19), the psycho-social factors seem in part to measure another dimension of oral health than the biomedical factors, thereby complementing the predictive value and appreciation of dental caries as a multifactorial disease. Our own results strongly support this statement (Table 8, Fig. 2). We found that the socio-ecologic caries model, based on the general health concept (26), explained 42% of the variation in the number of carious surfaces among 50-year-old Oslo citizens. The behavioral variable alcohol problems was the most important variable in the model (highest beta value), followed by the human biology variables buffer capacity and sex. The bivariate correlations between buffer capacity and sex versus number of carious surfaces were not significantly influenced by the other independent variables (eta = beta) (Table 8). This may indicate that human biology factors and the other items represent at least two different mechanisms leading to variation in number of carious surfaces.

Of the four items (Tables 4–7) human biology and the behavioral factors explained more of the variation than did the two others. This may indicate that these items are more important than environmental and health care organization factors with regard to the population investigated.

Conclusion

The present analysis of the socio-ecologic caries model shows that dental caries is a multifactorial disease with both behavioral and biologic determinants. The fact that the traditionally used biomedical variables alone (Table 9) explained only 22% of the variation in number of carious surfaces indicates that the present socio-ecologic caries model represents a relevant supplement to the Keyes triad.

A caries model should probably include both factors that directly influence the mechanism of the caries process and modifying factors or determinants that might have an indirect effect on the process. Furthermore, the model should be flexible to be adaptable to cultural and demographic variations. It is also of importance that the model appears logical and easy to comprehend. The present socio-ecologic caries model (Fig. 2) is believed to fulfill these criteria.

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