From the Dental Research Station of the Royal Medical Board,
Vipeholm Hospital, Lund, Sweden.

THE VIPEHOLM DENTAL CARIES STUDY

Reliability of the Method in the Determination of Caries Activity

CARL-ERIK QUENSEL, PH.D., BENGT E. GUSTAFSSON, M.D.
& HANS GRAHNÉN, L.D.S.

Registration of the site, size and number of carious lesions constitutes a fundamental factor in the recording of caries activity in a given case.

All methods hitherto available for the clinical recording of dental caries are to a certain extent unreliable, this unreliability being apparent from differences found between two immediately successive examinations of the state of the teeth of one and the same series of patients, irrespective of the fact whether the examinations are carried out by one and the same examiner or by two.

LITERATURE

GYTHFELDT (1938) and others point out that most investigations of caries must be considered with caution, because they do not define what is to be understood by caries, nor do they describe the method and the means by which the recordings were made. GYTHFELDT had a school class of 23 girls examined by 7 dental surgeons and 7 dental hygienists and found that of altogether 4,479 cavities detected, only 742 of them were observed by all 14 examiners. The deviation from the mean was on the average 22.8 per cent. All of the examiners worked under identical conditions with the same type of mirrors, probe and syringe and with good illumination etc.

SOGNNAES (1940) studied the importance of variations in the method of registration in school-children. On examination with

the mirror and probe, he found only 74.2 per cent of the lesions that could be detected if the teeth were thoroughly cleaned and with the aid of X-ray films.

JACKSON (1950) showed that the variation between different examiners is so great that, if the data of the state of the teeth in a given series are to be comparable, the examiners must work according to standard methods and under identical conditions. This will not eliminate individual differences, but it will at any rate decrease them. DEATHERAGE, WILSON & LEDGERWOOD (1939) shared this point of view.

In a clinical, roentgenological and histological examination, BURKET (1941) found that 24 per cent of the carious lesions could only be detected microscopically.

It is generally agreed that roentgenography is an excellent aid; DAY & SEDWICK (1935), FIXOTT (1937), BODMER (1939), SOGNNAES (1940), CHEYNE & HORNE (1948) and others. As to the number of lesions missed unless roentgenography is used, opinions differ, some believing that only 5 per cent are missed, others claiming that up to 50 per cent can remain undetected. It is apparent, (BODMER 1939 and others) that the use of bite-wing films is superior to other methods for discovering proximal caries. By this means the picture obtained is excellent when the plane of the film is parallel to the longitudinal axis of the dental crowns (cf. LUNDQVIST, BONOW & GRAHNÉN 1948). It is still often difficult to decide what should be judged as roentgen caries, especially in the molars and premolars, because there the roentgen rays pass through a thick layer of enamel with the risk of projection anomalies. However, any funnel-shaped reduction in the density of the image of the enamel and eventually also of the dentin cervical to the point of contact can with great probability be regarded as caries.

DIRKS, VAN AMERONGEN & WINKLER (1951) found that, if the rubber dam were used at the clinical examination, and if the teeth were separated, the standard error of the registration method could be reduced to 2 per cent. However, every examination took more than 1 hour per patient.

In order to obtain roentgen films taken at identical projection these authors used a special film holder. With this method the authors examined 266 children and on the basis of roentgen films

determined the number of carious proximal surfaces on two occasions at an interval of 14 days. The standard error for every surface was 1—2 per cent. For all surfaces the standard error was 0.3 per cent.

The investigations of these authors demonstrated the lower limit of the magnitude of the error in the determination of the dental state under optimal conditions.

In the above-mentioned investigations, the material consisted of school-children. The deviations would probably have been greater if the persons studied had been adults possibly with periodontitis and dental calculus which make inspection difficult.

GENERAL CONSIDERATIONS ON THE ERROR OF THE METHOD IN THE RECORDING OF CARIES

Carious lesions which can be demonstrated by inspection and/or felt with a sharp probe are usually classed as clinical caries. However, it may sometimes be difficult to detect caries with certainty, even on surfaces that can be inspected. In a fissure system there might be an abnormally deep and narrow fissure or fossa in which the sharp probe is caught; then it is difficult to say whether the surface is decayed or not. In patients in whom the gingiva is retracted, the cementum is exposed and it might, especially proximally, be difficult to decide the presence or absence of caries. If the term caries is extended to include decalcified spots and discolorations of pre-carious type *i. e.* "caries without defect" where there is no macroscopic loss of substance, the degree of uncertainty will be even greater. These chalky spots can be confused with slight specific mineralisation disorders of the enamel. As the pre-carious changes belong to the earlier type of caries, they are of great importance in dietary experiments with successive examinations. In the investigations of the commonest type, *i. e.* analysis of the state of the teeth as judged by one examination, it is of less importance to include them in the calculations if these above-mentioned spots are distributed evenly among the entire material. In such cases they can be excluded if they are regarded as uncertain; they should, however, be analysed separately.

One of the many advantages of the Moulage System for recording primary caries according to WESTIN and co-workers is that the diagnosis of caries is more uniform. WESTIN & WOLD (1943) also found good agreement between several investigators after a training period. In the present investigation, the examiners also underwent satisfactory preparatory training.

In order to standardise the conditions as far as possible for the recording of clinical caries in the Vipeholm investigation, the following rules were stipulated.

1. The material should be examined by one and the same examiner, who should follow the series already before the beginning of the study of an experimental variable and who should be well-acquainted with the standardised methods adopted.

2. It was agreed upon what should be understood by carious lesions. Chalky carious spots were distinguished from mineralisation disorders.

3. The recordings should be carried out under identical conditions and with the same type of instruments. A sharp probe of a certain mark should be used. The mirror should be of good quality and illumination should be satisfactory.

4. All dental surfaces should be carefully cleaned, especially the gingival third of the facial surface, immediately before the examination.

5. Generous use should be made of the air syringe in order to visualise chalky spots.

6. The bite-wing X-ray film should be used as a diagnostic adjunct.

7. The best possible co-operation between the patient and the examiner should be aimed at.

Despite careful observation of these rules, discrepancies were found between the number of carious surfaces noted at consecutive examinations (QUENSEL 1948, GUSTAFSSON et al. 1954), which might be referable to the error of the method. On repeated examination of the material it was observed that cavities diagnosed earlier were missed or not conceived as caries at subsequent examination, which resulted in great difficulties in the statistical calculations. As soon as these discrepancies were discovered, it was decided that the examiner should have access to data from the previous examinations. Furthermore, every patient was always examined by one and the same dentist.

Some of the deviations in the recording of caries might be ascribable to neglect of the examiner, or to poor co-operation with the patient. The most important cause was, however, probably the above-mentioned

doubt which is sometimes unavoidable as to what could be classed as a carious lesion. Divergences of opinion in this respect might give rise to systematic discrepancies which cause serious difficulties. If the deviation is in one and the same direction throughout, e. g. when an examiner constantly records too few carious lesions, the data can be analysed and provide a basis for valid conclusions, if the patients are examined by the same examiners throughout the entire period of the study. If the number of patients is large and therefore at least two examiners must be employed, every group of patients should be divided into two sub-groups, after which one sub-group should be assigned to each examiner. This was done in the Vipeholm investigation proper. Even under these circumstances it is important to know the order of the systematic error for each examiner and to know whether there is any appreciable difference between them regarding what they conceive as caries.

The systematic errors discussed above are due to the subjective opinion of the examiner, as to which changes should be classed as caries. It may therefore be supposed, that he might be influenced by knowledge of the fact that a certain change in caries activity is to be expected in a group of patients because of the experimental conditions. This might lead to imaginary differences in caries activity and therefore it is also of importance to know whether any systematic error is constant and independent of the experimental conditions.

Even if the deviations in the systematic registrations are small, there will always be a certain error of observation due to occasional unavoidable erroneous registration. The changes in the mean of caries activity figures are influenced not only by any difference due to the experimental conditions, but also, *inter alia*, by this error of the method and the individually varying caries disposition. In general, the distribution of the patients regarding the number of carious surfaces is also extremely skew in a certain group of patients, for which reason it is difficult to calculate the standard error of the mean with certainty.

In view of the above, the answers to the following questions are of great importance in a caries study.

1. Do the examiners differ with regard to the systematic deviations concerning their conception of caries?
2. If so, is it one or more types of carious lesions that give rise to such uncertainty?
3. Of what type are these systematic variations and of what order are they?
4. Are the deviations constant for one and the same examiner?
5. Do the deviations vary with the caries activity?
6. Is it possible numerically to determine the error of the method?

AUTHOR'S INVESTIGATIONS

In order to eludicate these problems a number of control studies were carried out in connection with the Vipeholm investigation.

The Error in the Determination of Caries Frequency

During the first year of Carbohydrate Study II of the Vipeholm investigation proper, 30 patients with high mean activity were selected and examined by four different examiners, first without knowledge of the notes or recordings made earlier in the record cards and then afterwards with the record cards of previous examinations at hand.

RESULTS

Table 1 shows the results calculated for the total number of carious lesions. The results demonstrated the well-known fact that caries frequency figures must be judged with caution when caries is recorded by different examiners. It is obvious that the deviations were much smaller when the records of previous examinations were available to the examiners, which is clear partly from the differences between the highest and lowest values of each registration decreasing and partly from the fact that the number of cavities observed by all 4 examiners increased. B-w and G-n carried out the main examinations in the Vipeholm examination proper and it is therefore interesting to note that the difference between them was slight concerning the total number of carious lesions observed.

The Error in the Determination of Caries Activity

The above-mentioned difference between the examiners does not permit any valid conclusion concerning the error of the method for examining caries activity in the way the method was used in the evaluation of the results in studies of the relationship between the diet and caries activity. As far as the registration of new carious defects is concerned, *i. e.* small deviations from the state of the

TABLE 1

Method controls of caries frequency
30 patients with high caries activity recorded by 4 different examiners

Examination		Total number of cavities				Cavities observed by all examiners
		B-w	G-n	K-e	Lqt	
I a	Without knowledge of recordings 1 year earlier	602	471	440	378	281
I b	With knowledge of recordings 1 year earlier (same patients as in I a)	569	551	472	434	377

teeth recorded at a previous examination, the error of the method might be expected to be great.

In an attempt to estimate this, two types of control examinations (A and B) were carried out by the examiners B-w and G-n on patients with high respectively low caries activity.

Control examination type A. In the same patient material with a high mean activity during Carbohydrate Study II, the number of new carious surfaces in relation to a corresponding examination made one year earlier was carried out as a control recording (I) by two examiners independently of one another. Here the examinations were also performed first with and then without access to earlier record sheets (Table 2). At a later control examination (II) on another series of patient the examiners also had pre-knowledge of the notes made in the record sheets of earlier examinations.

These investigations showed the order of the divergence in the recording of caries between the two examiners. Thanks to the Moulage System a good idea was obtained of the types of cavities that were responsible for the difference of opinion as to whether a surface was decayed or not (Table 3). Here, this applies most to "caries without defect" (chalky spots) and the initial stage of

TABLE 2

Method controls of caries activity

Examination	Number of pat.	New carious surfaces				
		All types of cavities			per person per year	
		B-w	G-n	observed by both	B-w	G-n
I a Without knowledge of recordings 1 year earlier	30	198	107	78	6.60	3.57
I b With knowledge of recordings 1 year earlier (same patients as in I a)	30	174	152	97	5.77	5.03
II With knowledge of recordings 1 year earlier	30	133	155	104	4.43	5.17

fissure caries (M 1)[1]. It is also apparent that the differences in the conception of what should be classed as caries are systematic in the following way. B-w has stricter criteria for "caries without defect" than G-n. In examination II all the differences of this type were due to G-n. On the other hand G-n requires larger changes in the fissures than B-w. As to the other types of cavities, no such distinct differences in diagnosis were noted.

Control examination type B. During the main registrations of the entire material at Vipeholm, some patients from all experimental groups that had already been examined once (in the following called first examination), were control-examined 3—4 weeks later among patients who were examined during a later stage of the recording work (in the following called second examination). In this control-series, patients were thus examined twice by one and the same dentist at short intervals and without the dentist being initially aware that the registration was being carried out for control purposes. On both occasions the dentist had pre-knowledge of the state of the teeth one year earlier. The bite-wing status was the same at the first and second exami-

[1] The different recordings according to the Moulage System are given with the prefix M and the figure.

TABLE 3

Types of cavities causing differences between two examiners. B-w+, G-n — denotes that the cavity was diagnosed by B-w but not recorded as such by G-n etc.

Type of cavity	I a. Without knowledge of earlier recordings				1 b. II. With knowledge of earlier recordings			
	Bw + Gn −	Bw − Gn +	Relative frequency of differences %	Relative frequensy of cavities %	Bw + Gn −	Bw − Gn +	Relative frequency of differences %	Relative frequency of cavities %
Cwd	13	5	12.0	14.1	2	35	17.5	14.7
Rtg	13		8.7	4.3	3	2	2.4	3.1
M 1	31	3	22.8	19.3	30	6	17.0	12.5
11	2	2	2.7	2.0	4	3	3.3	1.3
12	1		0.7	0.3	1	1	0.9	0.5
14	1		0.7	0.3				
15								0.3
31	4	4	5.4	4.3	6	1	3.3	3.6
32	2	1	2.0	2.3		2	0.9	1.8
33								0.5
41	9		6.0	7.2	1	3	1.9	4.6
42	1		0.7	1.6		1	0.5	0.5
43	1	1	1.3	1.3		2	0.9	1.3
44				0.7				0.8
45				0.3				0.3
51	15	3	12.0	14.1	26	15	19.3	16.4
51/63	1		0.7	0.3				
52	2		1.3	2.0		1	0.5	1.6
55	13	8	14.1	14.1	21	25	21.7	23.3
56		1	0.7	5.2	1	3	1.9	7.2
58					2		0.9	1.0
59					4		1.9	1.3
61	3		2.0	2.3	2	1	1.4	1.1
63	2	1	2.0	1.3	2	3	2.4	0.8
66	1		0.7	0.3				
71	1		0.7	0.3	1		0.5	0.2
72	1		0.7	0.3				0.7
78/01	1		0.2	0.3				
74						1	0.5	0.3
77				0.3				
82	2		1.3	0.7				0.2
83				0.3				
91						1	0.5	0.2

TABLE 4

Method controls by recordings at short intervals by one and the same examiner. (With knowledge of earlier recordings)

Examination	Examiner	Number of patients	New carious surfaces					
			All types of cavities			per cent of 1st exam	per person and year	
			1st exam.	2nd exam.	at both exam.		1st exam.	2nd exam.
III a	G-n	44	104	139	81	77.9	2.36	3.16
b	G-n	30	97	110	88	90.7	3.23	3.67
IV a	B-w	42	82	111	53	64.6	1.95	2.64
b	B-w	29	112	137	101	80.4	3.86	4.72

nations. These control examinations (Table 4) are, with the exception of the time factor, a reproduction of how caries activity is usually determined in the Vipeholm investigation.

Of those cavities that were recorded on the first examination, G-n recorded 78 and 91 per cent on the second, the corresponding figures for B-w being 65 and 80 per cent. If the caries activity is calculated (Tables 2 and 4) variations in the mean value of new carious surfaces per person per year of 0.5 to 1 unit occur.

In the controls, III and IV, some of the difference, (about 0.25) can, however, be due to the time that had elapsed between the first and second examinations. Here the same types of caries dominate as before among those for whom variations were registered, although the tendency here is different. Thus both in examinations IV a and IV b, B-w recorded the greatest number of deviations for "caries without defect", whereas before it was for M 1 (Table 5).

DISCUSSION

Close analysis of the figures given inform us but little of the error of the method, because it is not possible on a given occasion to determine the *true value of the number of new cavities* with which the observed values are to be compared. Further, the recording made 1 year earlier and with which the subsequent examination data are to be compared has its own error. Therefore the

TABLE 5

Types of cavities causing differences between two recordings by one and the same examiner

Type of cavity	III a and b. With knowledge of recordings 1 year earlier				IV a and b. With knowledge of recordings 1 year earlier			
	Gn 1st exam.	Gn 2nd exam.	Relative frequency of differences %	Relative frequency of cavities %	Bw 1st exam.	Bw 2nd exam.	Relative frequency of differences %	Relative frequency of cavities %
Cwd	5	25	26.8	26.7	9	32	30.6	24.4
Rtg	5	4	8.0	4.4	5		3.7	3.8
M 1	5	6	9.8	7.6	6	17	17.2	16.3
02				0.7				0.7
11	1	3	3.6	4.4	3	5	6.0	5.2
12	1	2	2.7	2.9	2		1.5	2.5
13				2.4	1		0.7	0.2
14				0.9				
15								0.7
16								0.2
24				0.2				
31		9	8.0	4.7	2	7	6.7	3.4
32	2	3	4.5	3.3	1		0.7	3.6
33		1	0.9	0.7				0.9
34								0.5
35								0.7
41	3	5	7.1	15.3	3	7	7.5	8.4
42				0.2	1		0.7	2.0
43		2	1.8	4.7	1		0.7	0.5
43/64								0.5
44	1	1	1.8	1.1				
45				0.2				2.3
46								0.2
47	1		0.9	0.9				
51	2	4	5.4	6.2		16	11.9	11.1
52		1	0.9	1.3				0.5
53		1	0.9	0.2				
55	2	7	8.0	5.1	5	6	8.2	7.0
56	2	3	4.5	3.3		1	0.7	2.9
58		2	1.8	1.1				
61				0.4		1	0.7	0.2
63					1		0.7	0.2
66				0.2				
71						1	0.7	0.2
73								0.2
82		1	0.9	0.2				
83	2		1.8	0.4		1	0.7	0.7

calculation of the error of the method in determining caries activity cannot be made according to standard procedures and the analysis is in fact rather complicated. A difference between two successive observations may be due to various factors. For instance, an intact dental surface may have been erroneously recorded by the examiner as decayed, *plus-registration or over-registration*, or a carious surface may have been missed and therefore not registered by the examiner, *minus-registration or under-registration*. The number of new carious dental surfaces recorded by an examiner for a given patient can thus include errors of both types.

As the recording at the control examinations were carried out independently of one another, a given tooth surface may be classed in 4 different ways:

both examiners class it as carious;
B-w records it as carious, while G-n regards it as intact;
B-w regards it as intact, while G-n regards it as carious;
both examiners class the surface as intact.

If the number of plus-registrations or minus-registrations are relatively small, it will hardly occur that a given dental surface is classed erroneously by both examiners. Therefore, a surface that is classed as carious by two examiners must thus be regarded as really being carious and a dental surface classed as intact by both must also be regarded as really being intact.

The dental surfaces classed as decayed by both examiners can therefore be regarded as a minimum value of the true number of carious surfaces. The surfaces that are judged as carious by both of the examiners in common or separately, *i. e.*, the total number of surfaces that have been diagnosed as decayed, may be regarded as the maximum number of really carious dental surfaces.

The dental surfaces of a number of patients examined at the control examinations type A could thus be grouped as follows:

the number of surfaces which were recorded as carious by both examiners (minimum number);
the number of surfaces classed as carious by G-n;
the number of surfaces classed as carious by B-w;

TABLE 6

Maximum and minimum number of new carious surfaces. Same patients examined by different examiners

Examination			Distribution according to caries activity.			
			0	1—3	4—6	7—
1 a. Without knowledge of recordings 1 year earlier	Number of patients	30	1	9	5	15
	Maximum number of carious surfaces	227	0	18	24	185
	Rec. by B-w only	198	0	18	22	158
	Rec. by G-n only	107	0	3	6	98
	Minimum number of carious surfaces	78	0	3	4	71
1b. With knowledge of recordings 1 year earlier	Number of patients	30	3	9	4	14
	Maximum number of carious surfaces	229	0	16	20	193
	Rec. by B-w only	174	0	15	13	146
	Rec. by G-n only	152	0	7	12	133
	Minimum number of carious surfaces	97	0	6	5	86
1b. With knowledge of recordings 1 year earlier	Number of patients	30	3	10	5	12
	Maximum number of carious surfaces	184	1	16	26	141
	Rec. by B-w only	133	0	12	19	102
	Rec. by G-n only	155	0	15	22	118
	Minimum number of carious surfaces	104	0	10	15	79

the total number of surfaces judged as carious (maximum number).

Similar considerations and possibilites may also hold good for the results of the control examinations type B where the patients were re-examined after a short interval by the same examiners.

Tables 6 and 7 give these numbers for every control examination in relation to the caries activity classes of the patients calculated from the maximum numbers of carious surfaces.

As each patient was examined by only one dentist in the ordinary main investigation only *one* value of his caries activity is available.

After having decided upon the predominance of plus- respectively minus-registration, the unreliability of an individual observation can be assumed in these control studies by comparison with the above defined minimum- and maximum-values and with the observation of the other examiner.

If no plus-registrations are made but only minus-registrations, there must be a systematic error which may vary somewhat for the two examiners, B-w and G-n, and the order of the standard deviation and standard error can be determined by analysing the differences between the maximum numbers of carious surfaces and the values of the individual examiner.

If only plus-registrations are made, the difference between the value for the individual examiner and the minimum number is an expression of the average order and variation of the plus-registration.

If, on the other hand, the observations are compared pairwise with one another, the difference between them will be an expression of the error in both examinations. From this difference, the reliability of the individual examination can be determined, whereby it cannot, however, be decided whether the type of systematic error is plus- or minus-registration.

For the continued analysis it is of importance to determine whether the difference between the two examiners is referable mainly to the occurrence of minus-registration or the occurrence of plus-registration. In the evaluation of the error of the single observation, however, this analysis must still be done against the background of both possibilities.

The occurrence of minus-registration should be greater for persons with high caries activity, while plus-registrations should be independent of the caries activity of the patient.

Therefore, if the patients in the control studies are divided according to activity, as in Table 8, on the basis of the above-de-

TABLE 7

Maximum and minimum number of new carious surfaces. Patients examined at short intervals by one and the same examiner. (With knowledge of recordings 1 year earlier)

Examination			Distribution according to caries activity.			
			0	1–3	4–6	7–
III a. G-n	Number of patients	44	13	16	10	5
	Maximum number of carious surfaces	162	0	33	50	79
	Rec. at 1st exam.	104	0	21	33	50
	Rec. at 2nd exam.	139	0	25	41	73
	Minimum number of carious surfaces	81	0	13	24	44
III b. G-n	Number of patients	30	10	6	9	5
	Maximum number of carious surfaces	119	0	11	41	67
	Rec. at 1st exam.	97	0	8	30	59
	Rec. at 2nd exam.	110	0	10	37	63
	Minimum number of carious surfaces	88	0	7	26	55
IV a. B-w	Number of patients	42	8	18	9	7
	Maximum number of carious surfaces	140	0	25	40	75
	Rec. at 1st exam.	82	0	14	22	46
	Rec. at 2nd exam.	111	0	21	33	57
	Minimum number of carious surfaces	53	0	10	15	28
IV b. B-w	Number of patients	29	4	11	6	8
	Maximum number of carious surfaces	148	0	16	27	105
	Rec. at 1st exam.	112	0	4	18	90
	Rec. at 2nd exam.	137	0	15	25	97
	Minimum number of carious surfaces	101	0	3	16	82

TABLE 8

Distribution of minus-registrations according to caries activity

Examiner		Activity class (according to max. number of new surfaces)		
		1–3	4–6	7–
G-n	Number of patients	41	28	36
	Maximum number of new carious surfaces	76	137	480
	Recorded by G-n only	54	104	373
	Minus-registrations in per cent of the maximum numbers	29	24	22
B-w	Number of patients	28	24	41
	Maximum number of new carious surfaces	73	113	511
	Recorded by B-w only	54	81	393
	Minus-registrations in per cent of the maximum numbers	26	28	23

fined maximum number of carious surfaces, it will be seen that the number of cavities detected by the examiner in relation to the maximum number varies only slightly with the caries activity of the patient. In the group with highest activity, the discovery per cent of the single examiner was 77 against 73 per cent for the groups with lowest activity. The difference is only slightly less than the standard error of the mean. The slightly lower figures for the percentage of discoveries in the groups with lower activity suggests that the number of any plus-registrations should be smaller in relation to the number of minus-registrations. It should, however, be observed that the material used for control examination consisted mainly of patients with high caries activity. It was not possible with this material to draw any precise conclusions regarding the relationship between the number of plus-registrations and minus-registrations.

Table 8 shows that there was no difference between B-w and G-n regarding the percentage of cavities discovered. This is also apparent from Table 9. The percentages of the discoveries there also fluctuated, though without any added difference between the

TABLE 9

Discovery per cent in all control examinations

Examination	Examiner	
	G-n	B-w
I a	47	87
I b	66	76
II	84	74
III a	75	—
III b	87	—
IV a	—	69
IV b	—	84

recordings made by the examiners in examination 1 a, which was performed in a manner deviating from the ordinary examinations in that it was done without the examiners having access to the dental cards from the preceding examination.

The Error of the Single Observation

The value observed at a given examination for a patient must, according to what was said above, be regarded as including an error of varying order. In addition to fluctuation from one examination to the other, the error of the method can be systematic in that either plus-registration or minus-registration might be predominant. In accordance with what was said above it might be assumed that the minus-registrations were predominant and then one might imagine two imaginary extreme cases, one in which no plus-registrations are possible and another in which the minus-registrations and plus-registrations occur at one and the same average frequency.

If only minus-registrations occur, the observed values will be below or identical with the true value. If the error in this case is measured by the difference between the calculated maximum number and that observed by the individual examiner, the result will be that given in Table 10.

The average number of minus-registrations per patient is judged in this way to be 1.12 per patient in these active groups and the standard deviation as 1.7. As it cannot be avoided that some

TABLE 10

The frequency of minus-registrations

Number of minus-registrations	Number of patients with number of minus-registrations in the first column	
	Examiner G-n	Examiner B-w
0	115	101
1	47	43
2	18	27
3	13	13
4	4	5
5	4	3
6	3	5
7	2	—
8	1	1
9	—	—
10 o. fl.	1	4
Number	208	202
Mean	1.00	1.23

cavities remain undetected by any of the examiners, the number of minus-registrations was probably slightly higher.

For patients with a low observed number of new carious surfaces, on the other hand, the figures are lower. For patients with an observed number=0, the minus-registrations are assessed at about 0.46 per person with a standard deviation of 1.0 units (Table 11). If the observed value 1—3 cavities is judged in this

TABLE 11

Minus-registrations and caries activity

Activity class	Minus-recording		
	Number	Mean	Standard deviation
0	113	0.47	1.0
1—3	155	0.92	1.5
4—6	62	1.29	2.0
7—	80	2.25	2.5
Total	410	1.12	1.7

manner, the number of minus-registrations will be 0.93 with a standard deviation of 1.5 units, *i. e.* the true value should be assessed at 0.93 units higher than that observed.

If it be assumed that both minus-registrations and plus-registrations were just as common, the following procedure might be adopted. Every measurement of caries activity includes an error that might be positive or negative. The difference between two measurements is therefore composed of two errors which are independent of each other.

According to the ordinary statistical rules, then, the average error of the method ε is calculated from the average value of the squares of the differences in accordance with the formula

$$\varepsilon = \sqrt{\frac{\Sigma d^2}{2n}}$$

where d indicates the observed difference and n the number of observations.

The formula of course requires that both examiners use the same measuring technique. Figures given earlier suggest that there was no appreciable difference between the examiners in this respect.

Even if plus-registrations and minus-registrations be supposed to be just as common this does not hold true if the data are grouped according to activity classes. It is thus evident that the observed value 0 can never be influenced by plus-registrations but only by minus-registrations. A high observed value should thus, in the same way, likewise be regarded as influenced more by plus-registrations than by minus-registrations. But the value of the co-examiner does give a non-systematically influenced expression for the correct number of new carious dental surfaces.

This is illustrated in Table 12, where the differences between the observed values and the values recorded by the co-examiner are recorded against different activity classes.

In the previous analysis, all dental surfaces in which carious changes were observed were classed as new carious surfaces. In order to investigate whether the observations could be classed as more certain or less certain when cavities of the type roentgen caries, "caries without defect" and M 1 were not included, these

TABLE 12

Order of systematic difference in relation to caries activity

Activity class	Mean	Standard deviation
0	— 0.46	0.7
1—3	— 0.26	1.2
4—6	+ 0.32	1.7
7—	+ 0.88	2.8

types of lesions were excluded. Here the same calculation was performed in this respect as in the corresponding calculations in the Vipeholm investigation proper. Thus, only surfaces with cavities other than roentgen caries, "caries without defect" and M 1 were regarded as new carious surfaces. Therefore, a cavity of larger type which at an earlier examination had been of the type for example "caries without defect", will be classed as a new carious lesion. Then, in an analogous manner as for the total number of cavities, the maximum number and the minimum number of new carious surfaces were calculated (Table 13) and the relative frequency of minus-registrations (Table 14). These figures suggested a slight tendency to more accurate results if the smaller changes were excluded from the observations. If the unreliability of the single observation was calculated in the same manner as when all types of lesions were included the values obtained are given in Table 15.

As long as the relative frequency of plus- and minus-registrations is constant, the comparison between different groups of patients is not influenced.

If the percentage of minus-registrations is just as large independently of the caries activity of the patients, the absolute but not the relative differences between different groups will be influenced.

For estimating the differences between different patient groups it is therefore more or less immaterial whether the plus- or minus-registrations are predominant as long as they are only constant throughout. The most important factor is the reliability with which the caries activity of a given person can be determined.

TABLE 13

Maximum and minimum number of new carious surfaces if initial lesions (Cwd, Rtg and M 1) are not recorded

	Examination			
	I a	I b	II	
Number of patients	30	30	30	
Maximum number of carious surfaces	187	195	172	
Rec. by G-n only	99	133	147	
Rec. by B-w only	162	156	129	
Minimum number of carious surfaces	74	94	104	
	III a	III b	IV a	IV b
Number of patients	44	30	42	29
Maximum number of carious surfaces	124	116	115	144
Rec. by G-n only	81	91	69	109
Rec. by B-w only	107	109	92	127
Minimum number of carious surfaces	64	84	46	92

TABLE 14

Relative number of minus-registrations if initial lesions (Cwd, Rtg and M 1) are not recorded

Examination	Examiner	
	G-n	B-w
	%	%
I a	53	87
I b	68	80
II	85	75
III a	76	—
III b	86	—
IV a	—	70
IV b	—	82

TABLE 15

Order of systematic difference in relation to caries activity if initial lesions (Cwd, Rtg and M 1) are not recorded

Activity class	Mean	Standard deviation
0	— 0.29	0.4
1—3	— 0.22	1.1
4—6	+ 0.13	2.1
7—	+ 1.05	2.4

On the basis of the standard deviation calculated here (Tables 11, 13 and 15), it may be concluded that the error of the single observations in a group of patients with low mean activity can be of the order of 1 new carious surface per person or somewhat lower. A mean based on 40—50 individuals will therefore have an uncertainty of 0.15 because of the error of the observation. With observations of the same group at different occasions, this error might mean a deviation of, on the average, 0.2 new carious surfaces per person, or, sometimes, still more. It is highly probable that a difference in two successive means of 0.5 units is not due to an error in the determination of caries activity. In the evaluation of differences in means of caries activity between two different groups, it should, however, be borne in mind that the differences found are not due entirely to the error of determinations but also to the individual differences in caries susceptibility, for which reason the difference between two means for caries activity must be greater than 0.5 units to be significant.

In the evaluation of the examinations performed here of the error involved in the determination of caries activity, it must be recollected that the material consists of mentally deficient patients who sometimes co-operate only poorly at the examination. The results thus show nothing of the accuracy of the clinical examinations or recording of caries in general. As the error of the method was studied only concerning the question whether a surface was decayed or not, the investigation was not a measure of the value of the Moulage System for registering pri-

mary caries according to WESTIN and co-workers. This is also accentuated by the fact that the examinations included carious changes of the type roentgen caries, "caries without defect", which lesions are not included as caries in the Moulage System.

Summary

The questions posed in the introduction could thus be answered as follows by the control examinations and the successive analysis regarding the examiners and the methods used in the Vipeholm Dental Caries Study:

1. The method for determining caries activity had inherent systematic errors. There was a slight difference between the criteria of the two examiners concerning what should be regarded as caries in initial stages in fissure systems and on facial surfaces.

2. The deviations seemed to consist mainly of a tendency to under-registration.

3. The differences were of the same order for both examiners and appeared to be independent of the caries activity of the material.

4. In a series with low mean activity (1—3 new carious surfaces per person per year) the error of a single observation was of the order of 1 new carious surface. A mean of caries activity based on 40—50 individuals thus had an unreliability of on the average 0.2 new carious surfaces per person per year.

LITERATURE

BODMER, E.: Diagnosis of dental caries by means of oral (or clinical) and radiographic examination. Northwest. Univ. Bull. 39: 2, 1939.

BURKET, L. W.: The accuracy of clinical and roentgenologic diagnosis of dental caries as determined by microscopic studies. J. Dent. Res. 20: 71, 1941.

CHEYNE, V. D. & HORNE, E. V.: The value of the roentgenograph in the detection of carious lesions. J. Dent. Res. 27: 58, 1948.

DAY, C. D. M. & SEDWICK, H. J.: Studies on the incidence of dental caries. Dental Cosmos 77: 442, 1935.

DEATHERAGE, C. F., WILSON, L. A. & LEDGERWOOD, R.: Variability of routine diagnoses of dental defect in children of schoolage. J. A. D. A. 26: 1739, 1939.

DIRKS, O. B., VAN AMERONGEN, J. & WINKLER, K. C.: A reproducible method for caries evaluation. J. Dent. Res. 30: 346, 1951.

FIXOTT, H. C.: Use of roentgen rays in the practice of childrens' dentistry. J. A. D. A. 24: 91, 1937.

GUSTAFSSON, B. E., QUENSEL, C.-E., SWENANDER LANKE, L., LUNDQVIST, C., GRAHNÉN, H., BONOW, B. & KRASSE, B.: The Vipeholm Dental Caries Study. The effect of different levels of carbohydrate intake on caries activity in 436 individuals observed for five years. Acta Odont. Scand. 11: 232, 1954.

GYTHFEELDT, T.: Die Grundlage Cariesstatistischer Untersuchungen. Norsk Tannlægeforen. Tid. 48: 243, 1938.

JACKSON, D.: The clinical diagnosis of dental caries. Brit. Dent. J., 21: 207, 1950.

LUNDQVIST, C., BONOW, B.-E. & GRAHNÉN, H.: Tandsjukdomarnas diagnostik. Sv. Tandl.-Tidskr. 41: 16, 1948.

QUENSEL, C.-E.: Tandkaries förekomst och utveckling. Medicinalstyrelsens odontologiska försöksverksamhet vid Vipeholms sjukhus i Lund. Sv. Tandl.-Tidskr. 41: 34, 1948.

RÖNNHOLM, E., MARKÉN, K. E. & ARWILL, T.: Record systems for dental caries and other conditions of the teeth and surrounding tissues. Odont. Tidskr. 59: 34, 1951.

SOGNNAES, R. F.: The importance of a detailed clinical examination of carious lesions. J. Dent. Res. 19: 11, 1940.

WESTIN G. & WOLD, H.: 1942 års tandmönstring av inskrivningsskyldiga. Odont. Tidskr. 51: 487, 1943.