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Effect of different diagnostic thresholds on dental caries calibration – a 12 month evaluation

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Abstract – *Objective:* To analyze the reproducibility of a calibration trial, at different diagnostic thresholds of dental caries, in a 12-month evaluation. *Methods:* A group of dental examiners ($n = 11$), who had previous experience in epidemiological surveys, participated in the study. An initial training phase (theoretical and clinical) and five calibration exercises (baseline, 3, 6, 9 and 12 months) were arranged. World Health Organization (WHO) criteria, including the active initial lesions (IL) were used. Six- to 7-year-old children took part in the study. They were selected according to past history and dental caries activity. The data were analyzed at WHO and WHO + IL diagnostic thresholds in accordance with tooth and dental surfaces. *Results:* Excellent mean intra- and inter-examiner Kappa values were obtained for both diagnostic thresholds, in accordance with tooth and surface, during the calibration phases. However, the most relevant errors were related to the decayed component and to IL diagnosis. *Conclusion:* It was possible to use the methodology proposed in this study in epidemiological surveys when examining the mixed dentition, although new strategies to improve training in IL diagnosis and calibration are necessary.

Key words: dental caries; epidemiology

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Recently there has been a great deal of discussion in the dental literature about the use of more sensitive diagnostic criteria for epidemiological dental caries studies (1). This may be justified because of changes observed in the epidemiological pattern over the last few decades, borne out by reduction in the prevalence of the disease and lesion progression (2, 3), subsequently resulting in a large number of initial lesions (IL; also called noncavitated or precavitated lesions) (1, 4, 5).

In surveys, caries has traditionally been recorded as unmistakable lesions, which means dentinal caries or 'D_3' lesions (6, 7). The decision to use these criteria [World Health Organization (WHO) D_3 diagnostic threshold] has been justified on the grounds that when large numbers of examiners have to be used, differences in clinical opinion and experience are inevitable and that these differences may be more marked when IL is included. Thus, the benefits derived from the extra information may be outweighed by an increased examiner and method error (8). Moreover, the use of less sensitive criteria is also justified by the fact that restorative intervention is usually carried out at the dentin cavitation stage (6).

However, the scientific literature has shown the real possibility of using more sensitive dental caries criteria. Clinical trials (9–11), cross sectional surveys and dental caries calibration studies (1, 7, 12–14) have demonstrated substantial to high levels of inter- and intra-examiner reliability at more sensitive diagnostic thresholds.

Therefore, in view of the changes in the dental caries pattern and the difficulties of diagnosing the disease appropriately, particularly under epidemiological conditions, as well as the problems with calibrating examiners, especially when the initial stages of disease are included in the examinations, the aim of this study, in a longitudinal 12-month period, was to analyze the intra- and inter-examiner reproducibility (reliability) of calibration trial, at different diagnostic thresholds of dental caries.

Material and methods

Ethical approval was obtained form the Ethical Committee in Research at the Piracicaba Dentistry School/UNICAMP (State University of Campinas), Protocol No. 068/2002, in agreement with Resolution 196/96 of the National Committee of Health/Health Department (BZ). The schools granted permission for the study and informed consent was obtained from the parents.

Study design

Sample and examiner selection

A heterogeneous group of 11 dentists (four salaried public health dentists and seven postgraduate students), all experienced examiners in dental caries epidemiological surveys according to the WHO (6) codes and criteria, participated in the study.

Six- to 7-year-old children from public schools in the city of Piracicaba-SP-Brazil were previously selected in an outdoor setting (school yard), by a professional, who did not participate in the experimental phase. The examiner used a dental mirror, a ball-ended CPITN probe (WHO-621 Trinity probe, Campomouráo, PA, Brazil) with a diameter of 0.5 mm, and previous dental brushing and drying for the examinations. Therefore, 10–13 different children with mixed dentition were selected for each training and calibration period. The individuals were selected and distributed in accordance with the dental caries pattern (Fig. 1) (15, 16). Children having local or general problems such as the use of a fixed orthodontic device, severe fluorosis and hypoplasia, or a serious systemic disease were excluded from the sample.

Diagnostic criteria and codes

The criteria and codes were those based on the WHO recommendations (6). For the IL, active caries with intact surfaces were recorded (an adaptation of the criteria according to Nyvad

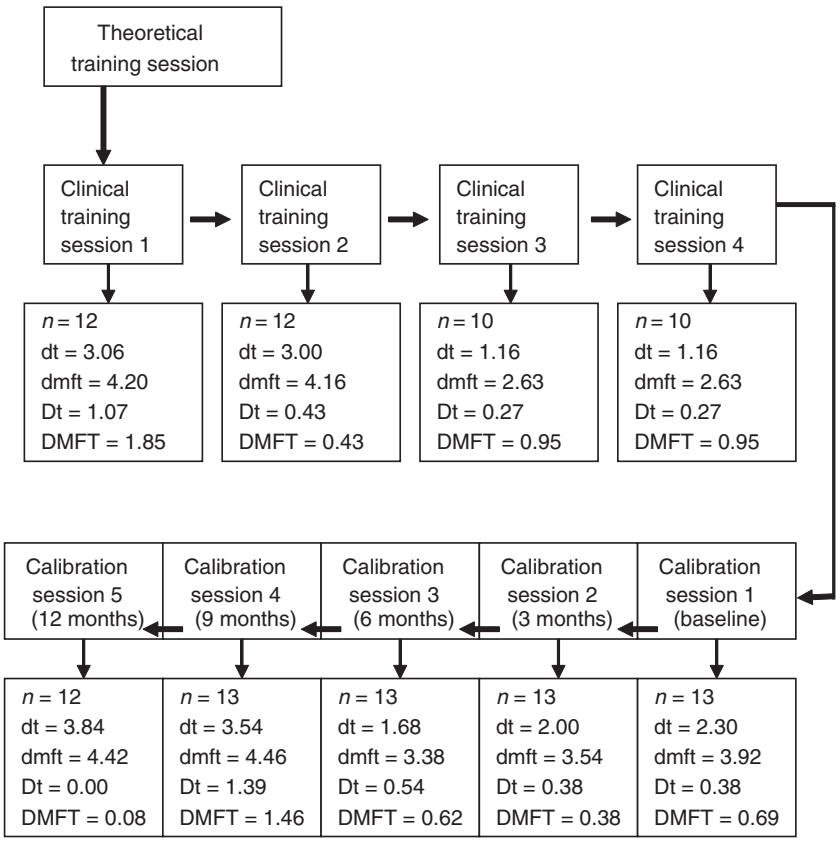

Fig. 1. Training and calibration model for examiners of 6–7-year -old children. Piracicaba, SP, Brazil, 2004.

et al. (13) and Fyffe et al. (14). Thus, an IL (initial lesion) was defined as active caries which, through visual assessment by a calibrated examiner, indicates intact surface, no clinically detectable loss of dental tissue, with a rough, whitish/yellowish colored area of increased opacity, with loss of luster and presumed to be carious (when the CPI probe is used, its tip should be moved gently across the surface). Smooth surface: caries lesion typically located close to gingival margin. Fissure/pit: intact fissure morphology: lesion extending along the walls of the fissure. In this study, localized surface defects (active microcavities) restricted to enamel only were included (use of the same code – W) in the IL group. Active white spot lesions and microcavities contiguous to sealants, restorations and cavitations were also recorded (Table 1).

Examiner training and calibration

A benchmark dental examiner ('Gold Standard') conducted the complete examiner training and calibrating process. The benchmark examiner (dentist who routinely uses the WHO criteria for exams) had been previously trained and calibrated in the diagnosis of IL and had routinely used these criteria in examinations in another study (17).

The training and calibration sequences were as follows: training sessions performed in a total of five periods (one theoretical, four clinical training) and calibration sessions initially conducted after the clinical training (time 0) and after intervals of 3 months (interval variation: 83–98 days; Fig. 1).

Theoretical discussions, using clinical photographic slides to provide visual examples of each criterion, were first held to verify examiners' knowledge about epidemiological diagnosis, according to WHO (6), to instruct the examiner on the use of the criteria and the examination method, and finally, to achieve an initial standardization of the 11 examiners for the criteria used in this study (e.g. to measure the ability of diagnosing IL, mainly focusing on the clinical characteristics, according to the location). Tests were applied to the examiners before and after the benchmark examiner explanation, using different clinical photographic slides. The mean Kappa for all the examiners in the final exercise was 0.86.

The clinical training sessions were held, followed by the calibration exercises. Both clinical training and calibration were carried out in an outdoor setting under conditions such as natural light, with dental mirror and ball-ended CPITN probes with a diameter of 0.5 mm (for removing debris, assessing presence of fissure sealants and, in case of doubt, to check the surface texture of IL), dental drying and previous tooth brushing. Tooth brushing was

Table 1. Summary of the criteria and codes, according to WHO and WHO + IL diagnostic threshold for caries, restorations, sealants and other dental conditions for the primary (Prim) and permanent (Perm) dentition

WHO			WHO + IL		
Codes			Codes		
Prim	Perm	Criteria	Prim	Perm	Criteria
A	0	Sound	A	0	Sound, excluding the W (white spot)
			W	WP	W (active white spot/surface discontinuity in enamel only)
B	1	Decayed	B	1	Decayed without W (chronic lesion)
			BW	1W	Decayed with W (active lesion)
C	2	Filled, with decay	C	2	Filled, with decay (chronic lesion)
			CW	2W	Filled, with W + decay (active lesion)
D	3	Filled, no decay	D	3	Filled, no decay
			DW	3W	Filled with W
E	4	Missing, as a result of caries	4	4	Missing, as a result of caries
–	5	Missing, any other reason	5	5	Missing, any other reason
F	6	Fissure sealant	F	6	Fissure sealant
			FW	6W	Fissure sealant with W
G	7	Bridge abutment, special crown or veneer/implant	7	7	Bridge abutment, special crown or veneer/implant
–	8	Unerupted tooth		8	Unerupted tooth
T	T	Trauma (fracture)	T	T	Trauma (fracture)
–	9	Not recorded	–	9	Not recorded

Code W – presence of white spot or surface discontinuity in enamel in dental surfaces (W, WP), as well as in sealants (FW, 6W), filled (DW, 3W) and other conditions. 'Decayed' criteria indicate cavitated lesions into dentine.

carried out before the individuals were examined, according to the modified Bass technique with fluoridated dentifrice for a standardized time of 2 min. Prior dental drying was carried out during the examinations for about 5 s per tooth with the use of compressed air through a dental compressor (Proquest Delivery System, model 4010, Compressor Technologies LTD, Englewood, USA). During the examinations, all the examiners were helped by note takers.

For each period of clinical training, 10–12 children, with different dental caries prevalence were evaluated by all 11 examiners (Fig. 1). Discussions among the examiners and the benchmark examiner, regarding clinical diagnosis, codes and criteria used, and recording and other errors, were held during the training, with the aim of achieving an acceptable level of agreement (Kappa >0.85). It is important to emphasize that the training sessions were not held during the longitudinal evaluations.

Following the clinical training exercises, the examiners undertook two calibration exercises with an interval of 1 week between them. These were also undertaken after 3, 6 9, and 12 months after the first calibration phase (time 0). Each calibration phase (0, 3, 6, 9, 12 months) used different groups of children (12–13 children) and for each session the same children were evaluated by all 11 examiners in order to evaluate the inter- and intra-examiner reproducibility. As mentioned above, the children presented different clinical situations, especially cavitations in dentine and IL (Fig. 1). No discussion was permitted among the examiners and the benchmark examiner with regard to interpreting the criteria during these calibration phases.

Diagnostic thresholds used for assessment and statistical analysis

Two diagnostic thresholds were used to calculate the reproducibility of examiners: WHO diagnostic threshold (6), in which caries is considered a cavitated lesion, and WHO + IL diagnostic threshold, including those active ILs. For the WHO + IL, an adaptation of the WHO codes with the inclusion of IL was developed (Table 1). For the analysis of the results, both units of measurement, tooth and dental surface, were used for primary and permanent teeth.

The results of the first calibration exercise, according to each calibration phase (0, 3, 6, 9, 12 months), were used to calculate the inter-examiner reproducibility, while the first and the second calibration exercises (after an interval of 1 week) were used to calculate the intra-examiner reproducibility, according to different diagnostic thresholds (WHO and WHO + IL), for both units of measurement. For inter- and intra-examiner reproducibility tests Kappa values >0.85 were classified as high (6).

It is important to mention that some dentists did not participate in all phases of calibration. There were absences in at least one exercise of the respective calibration phases, as follows: one examiner in the second exercise of the first (time 0) calibration phase, three dentists in the second exercise of the second phase (after 3 months), one dentist in the first exercise and two in the second exercise of the third phase (after 6 months) and three dentists in the first and second exercises of the fourth and fifth phases (after 9 and 12 months) of calibration. For this reason, statistical tests, such as paired *t*-test, could not be applied to analyze the results.

Results

Mean results of high intra- and inter-examiner reproducibility (Kappa >0.90) with small variations of both measurements, were detected, for both diagnostic thresholds and units of evaluation (tooth and surface), during the 12 months of the study. In general, higher mean intra- and inter-examiner reproducibility values were found for the WHO threshold when compared with the mean of the WHO + IL threshold values.

For the inter-examiner reproducibility, at the WHO + IL threshold, values for Kappa were between 0.90 (examiners' range: 0.85–0.93), at the baseline, and 0.93 (examiners' range: 0.89–0.96), after 12 months, for tooth; between 0.95 (examiners' range: 0.92–0.97), after 3 months, and 0.97 (examiners' range 0.96–0.98), after 9 months, for surface. Values for Kappa, at the WHO threshold, were between 0.95 (examiners' range: 0.93–0.99), at the baseline, and 0.96 (examiners' range: 0.94–0.98), after 12 months, for tooth; between 0.96 (examiners' range: 0.94–0.98), after 6 months, and 0.98 (examiners' range: 0.97–0.99), after 9 months, for surface.

As regards intra-examiner reproducibility, at the WHO + IL threshold, values for Kappa were between 0.92 (examiners' range: 0.90–0.94), after 9 months, and 0.97 (examiners' range: 0.93–1.00), at the baseline, for tooth; between 0.97 (examiners' range: 0.95–0.98), after 3 months, and 0.99 (examiners' range 0.98–1.00), at the baseline, for surface. Values for Kappa, at the WHO threshold, were between 0.95 (examiners' range: 0.93–0.98), after 9 months, and 0.99 (examiners' range: 0.96–1.00), at

Table 2. Kappa ranges for each code, among all the examiners, during the calibration phases (1–5), at the WHO and WHO + IL diagnostic thresholds and according to the tooth

	Kappa range	
Code	WHO	WHO + IL
A	0.90–0.95	0.87–0.94
0	0.94–0.97	0.89–0.95
W	–	0.09–0.33
WP	–	0.09–0.29
B	0.71–0.87	0.36–0.63
1	0.16–0.95	0.20–0.52
BW	–	0.37–0.65
1W	–	0.11–0.65
C	0.37–0.58	0.37–0.58
2	0.06	0.06
CW	–	–
2W	–	–
D	0.70–0.88	0.70–0.88
3	0.53–0.80	0.46–0.80
DW	–	–
3W	–	–
F	–	–
6	0.22–0.71	0.11–0.73
FW	–	–
6W	–	0.04–0.07

the baseline, for tooth; between 0.98 (examiners' range: 0.97–1.00), after 12 months, and 1.00 (examiners' range: 0.98–1.00), at the baseline, for surface.

In general, the analysis of mean Kappa among all examiners, according to each code and tooth as unit of evaluation, for all calibration phases, showed the highest values for the sound teeth (codes A and 0 – mean Kappa values higher than 0.87), followed by restored primary teeth (code D – Kappa range: 0.70–0.88) for both diagnostic thresholds. However, lower values were observed for the sealants, mainly for those with the presence of IL (code W – Kappa range: 0.04–0.07), decayed component, mainly at the WHO + IL diagnostic threshold and IL lesions alone (codes W and WP). Spaces left blank indicate that there were no registered cases according to each condition (Table 2).

Discussion

Surveys may be carried out under various circumstances, such as monitoring trends in oral health and disease, policy development, evaluation of dental health programs and assessment of dental needs (18). Training and calibration exercises are an important part of dental caries prevalence surveys, as they establish the standard to which the examiners are expected to work and provide information to establish whether the survey results are reliable. Lack of examiner agreement could indicate inaccuracy and lead to problems of data interpretation and lack of comparability with other datasets (14).

This study aimed to verify the reproducibility of the calibration at two different thresholds: WHO diagnostic threshold, which is usually used in surveys and the WHO + IL diagnostic threshold, which could generate more diagnostic errors among the examiners because of the inclusion of IL.

In general, results of intra- and inter-examiner reproducibility were maintained at a high level for the WHO diagnostic threshold during 12 months of the study, showing that additional periods of examiner training and calibration are not necessary within this period of time, with the proposed methodology for dental caries calibration in the 6- to 7-year-old group.

When considering kappa statistics according to each code, at the WHO diagnostic threshold and the tooth as the unit of evaluation, it is interesting to find that the conditions that allowed the lowest Kappa results among the examiners were mainly related to the decayed teeth, filled teeth with decay and sealed permanent teeth (Table 2). In general, these results can be explained by the fact that the visual and visual-tactile methods have shown low sensitivity and moderate to high specificity (19). Moreover, Deery et al. (20), in an '*in vitro*' study, evaluating the validity and the reproducibility of dental caries diagnosis in fissures before and after the application of sealants in 112 molars, concluded that sealants could have an adverse influence on the reproducibility of caries diagnosis. In this study, the low agreement obtained for sealed teeth (code 6) could be justified by because most of the sealants were tooth colored materials, like resin sealants, generally generating wrong diagnosis among examiners.

The visual tactile method associated with diagnostic adjuncts such as prior dental brushing and drying under natural light was used in the examinations. Some criticism could be leveled about the use of such diagnostic adjuncts, because they are not usually used in surveys according to WHO criteria and they could facilitate the diagnosis of not only the IL but also of cavitated lesions. However, Assaf et al. (17) showed that there were no statistical differences between the visual tactile method (WHO standard method), with or without the association of these diagnostic adjuncts, and the examinations in dental setting for groups of low

and moderate caries prevalence, at the WHO diagnostic threshold.

It is interesting to observe that the present study showed high mean intra- and inter-examiner agreement results (K > 0.90) at the WHO + IL diagnostic threshold. However, the most relevant errors were related to IL diagnosis, mainly those isolated and contiguous to sealants. One of the reasons for the low results for IL is that they are the results of crossroads among all the examiners in relation to each specific dental condition. Higher Kappa results could probably be obtained if a smaller group of examiners participated in the study (Table 2). Moreover, these poor IL diagnosis results could be justified because no artificial light was used during the examinations, and because of the inherent difficulties in diagnosing IL, mainly under epidemiological conditions. For these reasons, new training sessions that include the use of extracted teeth with IL lesions, for example, as well as the use of artificial light during the examinations, should be recommended in order to improve the examiners' diagnosis under these specific conditions (17, 21, 22).

When compared with the threshold based in the diagnosis of cavities (WHO), the inclusion of IL in surveys clearly has a major effect on the assessment of dental health needs, as it allows the proportion of the studied population requiring preventive and restorative care to be identified and estimated. Its use, however, should be appropriately indicated, as there are some situations in which the inclusion of IL would enhance the value of survey data, and others in which the additional cost would not be offset by additional benefits. It may be beneficial, for instance, to include IL in studies that involve the natural history of caries and its treatment, in order to demonstrate differential effects between different formulations of caries preventive agents, like fluoridated toothpastes; and in clinical trials or in surveys being conducted to plan oral health programs (7, 11, 18, 25). On the other hand, including IL in national surveys only to obtain descriptive information on the population's dental health would not only be very expensive, but it would also be of less apparent value (18).

When compared with the literature, this study showed higher mean intra- and inter-examiner Kappa values than some previous studies, such as Nyvad et al. (13) (mean kappa values: 0.74–0.85) and Fyffe et al. (14) (mean kappa values: 0.47–0.61), while other studies showed similar reliability results with the use of more sensitive criteria (12, 23). These divergences could be explained because of differences in the calibration process methodologies, as well as the dental caries criteria used in these studies. For instance, in the Fyffe et al. (14), the use of more detailed criteria and a shorter clinical training time (duration = 1 h and 40 min) than those used in the present study may justify the considerable differences in the reliability values.

In general, there is an evident lack of standardization of criteria, clinical examination and examiner calibration methodologies (1, 7, 10, 12–14, 23). Some studies, for instance, do not even report on the calibration process and the results of intra- and/or inter-examiner agreement among the examiners (24, 25). This variability has made it difficult to compare the results of these different studies; for instance, when the results of a study that uses a sensitive diagnostic threshold in an area of low dental caries prevalence, are critically compared with the results of another study, using less sensitive diagnostic criteria in an area of high caries prevalence, consequently leading to wrong conclusions.

Therefore, new strategies have been discussed among the cariology experts to develop, in the near future, one scientifically based protocol for calibrating examiners, which would define the methods and examination conditions, period of examiner training time, as well as a standardized system for detecting dental caries, which could be used 'universally' by all researchers (26).

Conclusion

The methodology proposed in this study showed that it is possible to make direct use of a new diagnostic threshold during surveys, with the inclusion of IL. However, new strategies to improve training in IL diagnosis and calibration, as well as the introduction of additional diagnostic adjuncts, such as artificial light, are necessary. This modification, although complex, would mainly benefit the planning and evaluation of public dental health services, especially with regard to adequate assessment of dental needs, such as correct indication of preventive-therapeutic measures in the group/population.

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