Comparison of Epidemiological Evaluations under Different Caries Diagnostic Thresholds

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Objective: To investigate the influence of different settings, epidemiological and clinical, and different diagnostic thresholds on caries detection in a group of 7–10-year-old children in Brazil.

Materials and Methods: In total, 983 children aged 7–10 years old and enrolled in four public schools were randomly selected. Three examiners performed epidemiological examinations followed by an examination of the same children in a clinical setting. The examinations of cleaned and dried teeth in both settings were carried out using a dental mirror and ball-ended probe, under natural light in the epidemiological setting examinations and under artificial light during the clinical setting examinations. For the analysis of results, comparisons were focused on WHO (World Health Organization) diagnostic thresholds versus WHO+IL (initial lesions) diagnostic thresholds, both under epidemiological conditions, in order to demonstrate the influence of the inclusion of IL in the study; and WHO+IL in the epidemiological setting versus WHO+IL in the clinical setting, aiming to demonstrate the importance of examination setting. Outcome measures were dmfs, DMFS, ds, Ds, sealants and number of children 'free' of caries. Paired *t*-test and McNemar's test were used to test the difference between means and proportions for each age group.

Results: Epidemiological examinations, under the WHO diagnostic threshold, showed significant differences for all outcome measures when compared with the WHO +IL threshold. Statistical differences were also detected when comparing the WHO+IL threshold under different settings.

Conclusion: The choice of a diagnostic threshold (WHO or WHO+IL) and the conditions of examination (epidemiological or clinical) were important for caries detection.

Key words: dental caries, diagnosis, epidemiology

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Surveys are used to monitor trends in oral health and disease, to develop policy, to evaluate dental health programmes, and to assess dental needs (Burt, 1997). However, when the epidemiological data are compared with those obtained in standard clinical settings, epidemiological surveys underestimate the prevalence of the disease, particularly in the case of untreated dental caries (Lindwood et al, 1979). Furthermore, the epidemiological evaluation of dental caries is a poor indicator for determining the number of surfaces that will subsequently be treated (Nuttall, 1983; Nuttall and Davies, 1988), and has no discriminatory power in the prediction of an individual's future restorative treatment (Nuttall and Deery, 2002).

Differences in the examination conditions of both settings (epidemiological and standard clinical setting) may be relevant factors in the underestimation of disease in surveys. For instance, artificial light, compressed air, radiographs and other diagnostic aids, as well as patient history, are frequently used by dentists

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in clinical settings, while epidemiologists usually use only clinical examinations under conditions very different from those found in a clinical setting (World Health Organization, 1997; Lundman et al, 1998; Meneghim et al, 2003).

In addition to these factors, the criteria employed in most cross-sectional surveys of prevalence consider dental caries only at the point of cavitation, excluding the initial lesions (IL), thus resulting in underestimation of disease (World Health Organization, 1997). Some reasons for these criteria are based on inherent difficulties in the epidemiological examination to diagnose earlier stages of the disease. Furthermore, the invasive treatment is only suitable once there is a lesion in the dentine (Pitts and Fyffe, 1988; World Health Organization, 1997).

Scientific evidence has shown the need for changes in the criteria used in surveys, including the use of epidemiological diagnosis of IL (Nyvad et al, 1999; Fyffe et al, 2000; Pitts, 2004). Recent epidemiological research has shown that the prevalence of IL is higher than the prevalence of cavitated lesions (Ismail, 1997; Amarante et al, 1998; Biscaro et al, 2000). The inclusion of IL within epidemiological surveys is likely to establish a clearer relationship between the epidemiological estimates of dental caries prevalence and the treatment needs, invasive as well as non-invasive, in individuals and/or groups (Pitts, 2004).

Despite the clear need for consideration to include IL in epidemiological surveys, previous studies have measured the differences of established caries between surveys and clinical settings using different combinations of diagnostic adjuncts with the same or with different diagnosis criteria from that used by the WHO (World Health Organization) (Lindwood et al, 1979; Lundman et al, 1998; Meneghim et al, 2003; Assaf et al, 2004). Lundman et al (1998) and Assaf et al (2004) showed that there were no differences between examinations carried out in a school outdoor setting and in a clinical setting, under the WHO diagnostic criteria. However, the exclusion of IL in epidemiological examinations resulted in underestimation of caries (Assaf et al, 2004).

Differences between the levels of dental caries under epidemiological surveys and the normative treatment need of the group/population have therefore been observed (Biscaro et al, 2000; Nuttall and Deery, 2002; Assaf et al, 2004). Surveys may therefore be limited as an instrument for the appropriate planning of preventive/curative strategies in the dental health services.

The present study aims to investigate the influence of different settings (epidemiological and clinical) and different diagnostic thresholds on caries detection in the primary and permanent teeth of a group of children aged 7 – 10 years old in Brazil.

MATERIALS AND METHODS

The project was first approved by the Ethical Committee in Research at Piracicaba Dentistry School/UNICAMP (State University of Campinas) in agreement with Resolution 196/96 of the National Committee of Health Department (Brazil). The schools granted permission for the study and informed positive consent was obtained from the parents.

Sample and examiners

The sample was calculated by age group, based on caries experience of previous surveys carried out in Piracicaba SP-Brazil with a design error of 2% and a sampling loss of 20%. The highest sampling error was in a confidence level of 95%. The final sample was 983 7 – 10-year-old children who were randomly selected from public schools.

Children with local or general problems, such as the use of a fixed orthodontic device, severe fluorosis, hypoplasia or a serious systemic disease were excluded from the sample (n = 54). Three examiners with clinical experience and epidemiological experience in surveys using WHO criteria (WHO, 1997) participated in the study.

Diagnostic thresholds used for the evaluation

Two diagnostic thresholds were used in the study: WHO diagnostic thresholds (WHO, 1997), where caries was defined as cavitated lesions only; and WHO+IL diagnostic threshold, where active IL were also defined as caries. The unit of evaluation used in examination was the DMFS and dmfs (decayed, missing, and filled surfaces for permanent and primary dentition respectively).

Diagnostic criteria and codes

The criteria and codes were those based on the WHO recommendations (WHO, 1997). Active caries with intact surfaces were recorded as IL: an adaptation of the criteria according to Nyvad et al (1999) and Fyffe et al (2000). Thus, IL are defined as active caries which,

Table 1 Summary of the criteria and codes, according to WHO and WHO+IL diagnostic threshold for caries, restorations, sealants and other dental conditions

WHO Codes Primary	Permanent	Criteria	WHO+IL Codes Primary	Permanent	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

Criteria 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

through visual assessment by a calibrated examiner, indicates an intact surface, no clinically detectable loss of dental tissue, with a whitish-/yellowish-coloured area of increased opacity, rough, with loss of lustre and presumed to be carious; when the probe is used, its tip should move gently across the surface. For the smooth surface, the caries lesion is typically located close to gingival margin. For the occlusal surface, the lesion extends along the walls of the fissure. In this study, localised surface defects (active micro-cavities) restricted to enamel only were also included in the IL group. Active white spot lesions and micro-cavities contiguous to sealants, restorations and cavitations were also recorded (Table 1).

Calibration of examiners

The three examiners were calibrated prior to the study. A benchmark 'gold standard' dental examiner, who routinely uses the WHO criteria, conducted training and calibration of examiners. The benchmark examiner had been trained and calibrated previously in the diagnosis of IL using similar criteria in other studies (Biscaro et al, 2000; Assaf et al, 2004).

The training and calibration exercise, carried out in both settings, began with theoretical discussions using clinical photographic slides to provide visual examples of each criterion, in order to instruct the examiners on the use of different sets of criteria and examination methods. Clinical training sessions were then held in an outdoor setting, under natural light, in four periods of 4 hours, followed by a calibration exercise to ensure all examiners were performing to the same standard. During a separate period (4 hours), clinical training and calibration were carried out in a traditional clinical setting under artificial light. Mean inter-examiner agreement, measured using a Kappa calculation (Landis and Koch, 1977) were Kappa = 0.88 for the WHO+IL and Kappa = 0.95 for the WHO diagnostic threshold under epidemiological conditions, and Kappa = 0.90 for the WHO+IL diagnostic threshold under a traditional clinical setting.

Examination procedures for the epidemiological and clinical settings

All subjects were examined using dental mirror and ball-ended probes with a diameter of 0.5 mm for removing debris and assessing presence of fissure

Table 2 Mean ds, dmfs, Ds and DMFS of the epidemiological examinations under WHO diagnostic threshold compared to each respective mean of ds, dmfs, Ds and DMFS of the epidemiological examinations under WHO+IL diagnostic threshold, according to 7–10-year-old groups

Age	Threshold	ds	dmfs	Ds	DMFS
7 (n=194)	WHO	2.541 (5.123)* [89.47]	4.979 (7.061)* [95.64]	0.113 (0.417)* [23.59]	0.309 (0.985)* [45.77]
	WHO+IL	2.840 (5.560) [100.00]	5.206 (7.435) [100.00]	0.479 (0.961) [100.00]	0.675 (1.264) [100.00]
8 (n=270)	WHO	1.615 (4.042)* [82.10]	4.874 (6.899)* [93.66]	0.111 (0.599)* [33.64]	0.433 (1.256)* [66.41]
	WHO+IL	1.967 (4.573) [100.00]	5.204 (7.233) [100.00]	0.330 (0.874) [100.00]	0.652 (1.421) [100.00]
9 (n=284)	WHO	1.194 (2.518)* [77.79]	3.971 (5.289)* [92.52]	0.264 (1.004)* [41.19]	0.771 (1.534)* [67.40]
	WHO+IL	1.535 (2.965) [100.00]	4.292 (5.591) [100.00]	0.641 (1.787) [100.00]	1.144 (2.175) [100.00]
10 (n=235)	WHO	1.247 (3.434)* [78.38]	3.272 (5.256)* [90.46]	0.230 (0.973)* [40.93]	0.902 (1.698)* [72.57]
	WHO+IL	1.591 (3.965) [100.00]	3.617 (5.649) [100.00]	0.562 (1.377) [100.00]	1.243 (1.971) [100.00]

*p<0.001
( ) standard deviations in parentheses
[ ] percentage of observed WHO epidemiological examination results with WHO+IL epidemiological examinations as a reference

sealants, and to check the surface texture of IL, associated with previous dental drying and brushing, in both the epidemiological and clinical settings by the three examiners. During the examinations, all the examiners were given note-taking assistance.

Teeth were cleaned by the subject under supervision prior to examination using the modified Bass technique with fluoridated dentifrice for a standardised time of 2 minutes. Prior to examination, dental drying was carried out for approximately 5 seconds per tooth with the use of compressed air through a dental compressor (Proquest Delivery System, model 4010, Compressor Technologies LTD, Englewood, USA).

All clinical examinations followed the epidemiological examinations due to practical reasons. A minimum interval of 15 days between the epidemiological and clinical examinations was established to avoid examiners' familiarity to the clinical conditions of the volunteers.

Epidemiological examinations

The examinations of cleaned and dried teeth were carried out in an outdoor setting under standardised conditions using natural light. Examinations were only performed on days with an appropriate natural luminosity.

Examinations in clinical settings

The examinations were carried out using the same method of exam and diagnostic adjuncts as the epidemiological examinations, except for the additional use of artificial light. Children were positioned in the dental chair as closely as possible to that used in the epidemiological setting, so that the dental chairs were not fully reclined.

Re-examinations were performed in 10% of the sample for each epidemiological and clinical examination. Kappa statistics (Landis and Koch, 1977) were employed to determine intra-examiner error. Mean Kappa values of intra-examiner agreement were Kappa = 0.96 (WHO) / Kappa = 0.89 (WHO+IL) for the

Table 3 Mean ds, dmfs, Ds and DMFS of the epidemiological examinations compared to examinations performed in clinical setting, both under WHO+IL diagnostic threshold, according to 7 to 10-year old groups

Age	Setting	Ds	dmfs	Ds	DMFs
7 (n=194)	Epidemiological	2.840 (5.560)** [91.67]	5.206 (7.435)* [92.75]	0.479(0.961)* [76.15]	0.675(1.264)* [79.88]
	Clinical	3.098 (5.884) [100.00]	5.613 (7.749) [100.00]	0.629 (1.026) [100.00]	0.845 (1.334) [100.00]
8 (n=270)	Epidemiological	1.967 (4.573)*** [88.68]	5.204 (7.233)* [99.09]	0.330 (0.874)** [77.46]	0.652 (1.421)** [87.16]
	Clinical	2.218 (4.838) [100.00]	5.252 (7.392) [100.00]	0.426 (0.983) [100.00]	0.748 (1.489) [100.00]
9 (n=284)	Epidemiological	1.535 (2.965) * [88.78]	4.292 (5.591)** [96.58]	0.641 (1.787)** [79.53]	1.144 (2.175)** [84.37]
	Clinical	1.729 (3.126) [100.00]	4.444 (5.549) [100.00]	0.806 (1.957) [100.00]	1.356 (2.323) [100.00]
10 (n=235)	Epidemiological	1.591 (3.965)* [91.65]	3.617 (5.649)** [95.51]	0.562 (1.377)** [80.52]	1.243 (1.971)*** [85.90]
	Clinical	1.736 (4.048) [100.00]	3.787 (5.661) [100.00]	0.698 (1.645) [100.00]	1.447 (2.272) [100.00]

* p<0.05, ** p<0.01, *** p<0.001
( ) standard deviations in parentheses
[ ] percentage of observed WHO+IL epidemiological examination results with WHO+IL examination results performed in clinical setting as a reference

epidemiological examinations and Kappa = 0.87 (WHO+IL) for the examinations performed in a traditional clinical setting, respectively. Children who needed treatment were then treated in a preventive-restorative programme at the Dental School of Piracicaba-UNICAMP, SP, Brazil.

Statistical analysis

For the analysis of results, comparisons were: a) WHO versus WHO+IL, to demonstrate the influence of inclusion of IL under epidemiological conditions; and b) WHO+IL in the epidemiological setting versus WHO+IL in the clinical setting, aiming to demonstrate the importance of the examination setting. Main outcome measures were the dmfs, DMFS, ds, Ds, sealants in primary and permanent teeth and number of children ‘free’ of caries, by age group (7–10-year-old children) (Tables 2 to 5). Paired *t*-tests were used to compare dmfs, DMFS, ds, Ds and sealant means according to different thresholds (item a) and settings (item b); McNemar’s test was used to compare the proportion of children 'free' of caries experience, according to different thresholds (item a) and settings (item b).

RESULTS

Epidemiological examinations under the WHO diagnostic threshold presented significant differences when compared with epidemiological examinations under WHO+IL diagnostic threshold, for all age groups. The percentages of observed epidemiological examination outcomes under the WHO diagnostic threshold with WHO+IL threshold as a reference varied from 23.59% for the Ds, to 95.64% for the dmfs (7-year-olds) (Tab 2).

Epidemiological examinations under the WHO+IL diagnostic threshold were significantly different from those examinations under the same threshold performed in clinical setting, for all age groups. The percentages of observed epidemiological examination outcomes with the clinical setting examination as a reference varied from 76.15% for the Ds (7-year-olds) to 99.09% for the dmfs (8-year-olds) (Table 3).

Table 4 Mean number of sealants in deciduous and permanent molars under the epidemiological and clinical setting examinations, according to each age group

Age	Deciduous		Permanent	
	Epidemiological	Clinical	Epidemiological	Clinical
7	0.010 (0.101) [100.00]	0.010 (0.101) [100.00]	0.660 (1.194) [95.65]	0.690 (1.220) [100.00]
8	0.018 (0.182) [60.00]	0.030 (0.226) [100.00]	1.430 (1.611) [91.90]	1.511 (1.644) [100.00]
9	0.042 (0.344) [60.00]	0.070 (0.444) [100.00]	1.299 (1.513) [83.64]	1.553 (1.580)*** [100.00]
10	0.299 (0.194) [100.00]	0.299 (0.170) [100.00]	1.464 (1.824) [84.99]	1.723 (1.958)** [100.00]

**p<0.01, ***p<0.001
( ) standard deviations in parentheses
[ ] percentage of observed epidemiological examination results with clinical setting as a reference

Table 5 Comparison of the number and percentage (in parentheses) 'free' of caries, in both dentitions, between epidemiological examinations under WHO and WHO+IL diagnostic thresholds, and comparison of the number and percentage (in parentheses) 'free' of caries of the examinations performed in epidemiological and clinical settings under WHO+IL diagnostic threshold, according to each age group

Age	Epidemiological examinations		Examinations in clinical setting
	WHO	WHO+IL	WHO+IL
7	71 (36.60)^{A}	61 (31.44)^{Ba}	57 (29.38)^{b}
8	100 (37.04)^{A}	92 (34.07)^{Ba}	82 (30.37)^{b}
9	99 (34.86)^{A}	88 (30.99)^{Ba}	77 (27.11)^{b}
10	82 (34.89)^{A}	68 (28.94)^{Ba}	66 (28.08)^{a}

^{A,B} indicates comparison between different thresholds (WHO and WHO+IL) are statistically different (p<0.05)
^{a,b} indicates comparison between different settings (epidemiological and clinical) are statistically different (p<0.05)

Regarding the sealants, significant differences were not found between the epidemiological and clinical setting examinations, except for the permanent teeth of 9–10-year-old individuals. Epidemiological settings resulted in the estimation of 60% to 100% of sealants observed under clinical setting conditions (Table 4).

There were statistical differences between the epidemiological examinations and the clinical setting examinations, both under the WHO+IL diagnostic threshold and for the number of children ‘free’ of caries, except for the 10-year-old group. Statistical differences were also found between different thresholds under epidemiological conditions for all age groups. These differences in observed ‘caries free’ numbers between settings and thresholds were lower than 10% for all age groups (Table 5).

DISCUSSION

This study aimed to examine the influence of two distinct conditions of examinations (epidemiological and clinical), as well as to assess the use of different diagnostic thresholds on the detection of caries. Comparisons were made in such a way as to minimise methodological bias by using the same visual-tactile method of examination, the same diagnostic adjuncts (previous dental brushing and drying), as well as standardisation of the positioning of children in chairs in both clinical and epidemiological settings. The only source of variation was the light, which was natural in the epidemiological examinations and artificial in the clinical setting examinations. Moreover, intervals of a minimum of 15 days between epidemiological and clinical examinations were performed to reduce the possibility of memorisation by the examiners of the children's dental conditions, although this was unlikely due to the large number of examined individuals.

Diagnosis of sealants in primary and permanent teeth was considered satisfactory during the epidemiological examinations. Although statistical differences between conditions of examinations were found for the permanent teeth in the 9–10-year-old groups, the analysis of percentages showed underestimated values of 16.36% and 15.01%, respectively (Table 4).

The present study shows that both settings (clinical and epidemiological) and diagnostic thresholds (WHO and WHO+IL), could influence on the detection of lesions for the 7–10-year-old children. The inclusion of IL in the examinations could be a relevant factor in the degree of underestimation in dental surveys. Furthermore, the use of artificial light, which was only used in the clinical setting examinations, could be considered an essential factor to improve the IL diagnosis during the epidemiological examinations (Mitropoulos and Worthington, 1984; Meneghim et al, 2003; Assaf et al, 2004). Therefore the differences in IL detection under different conditions of examinations, epidemiological and clinical settings, could be due to the absence of this diagnostic adjunct.

In accordance with previous studies (Pitts and Fyffe, 1988; Amarante et al, 1998; Biscaro et al, 2000), the present study showed an increase in the prevalence of dental caries in both dentitions and in all age groups when using a criterion that included the IL under epidemiological conditions. This increase was more evident for the decayed component in deciduous and permanent teeth. However, in contrast to the findings of Pitts and Fyffe (1988) and Biscaro et al (2000), differences in relation to the number and percentage of children considered 'free' of caries were small between the diagnostic thresholds, indicating, therefore, that most of the IL were present in children with past history of caries (Tables 2, 3 and 5). Divergence in results could be explained by the differences found in the methodologies of each study, particularly the variation of caries criteria used, even when including the initial stages of caries.

It should be noted that clinical setting examinations were used for comparison with the epidemiological examinations under the WHO+IL diagnostic threshold without the association of any additional method of detection of lesions, such as X-ray, or even by opening suspected cavities. The literature has shown that clinical caries detection, performed generally in clinical practice, results in both under- and over-estimation of diagnosis (Bader et al, 2002; Nyvad, 2004). Although considered a relevant diagnostic method, X-rays were not used in the present study to confirm the presence of suspected lesions, such as the clinical diagnosis of microcavities, due to practical and financial reasons. Furthermore, one aim of the present study was to show the success of detecting cavitated and non-cavitated lesions by using artificial or natural light.

Studies that have evaluated the conventional clinical examination by using a method of validation have shown that, in general, validation methods such as the determination of the depth of lesion penetration determined after minimal operative intervention are currently used in clinical research, although they may not represent the 'gold standard' for detecting caries. In the present study, this was not possible due to practical and ethical issues, such as ethical problems of opening lesions.

It is important to note that these results cannot be extrapolated to all populations and regions or countries. Different results may be found when comparing different regions. In tropical countries natural light is usually recommended because variations of luminosity are slight during the year, while in temperate countries the examinations are only possible under artificial light, in closed spaces (Pitts and Evans, 1997; Biscaro et al, 2000).

Studies have been conducted in the epidemiology of dental caries in order to develop new strategies, such as the use of criteria that include the IL in epidemiological examinations, as well as the use of other methods of diagnosis. Studies have shown better performances in the detection of carious lesions when the epidemiological examinations have employed FOTI (fiber-optic transillumination) and bitewing radiography (Deery et al, 2000; Poorterman et al, 2000). Such improvements may contribute to a reduction in the levels of underestimation of disease, and, consequently, to a better classification of the dental caries levels in groups or populations (Ismail, 1997; Nyvad et al, 1999; Fyffe et al, 2000; Pitts, 2004). This would, consequently, lead to more accurate reflection of epidemiological disease data, depicting trends for a future redirection in epidemiology, not only with regard to correct epidemiological diagnosis but also to the implementation of preventive-therapeutic measures for the population.

CONCLUSIONS

The choice of a diagnostic threshold (WHO or WHO+IL) and the conditions of examination (epidemiological or clinical) are important for the detection of caries. The inclusion of IL in the epidemiological examinations contributed to the reduction of caries underestimation among children aged 7–10 years old.

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