CLINICAL INVESTIGATIONS

Validation of Visual Caries Activity Assessment: A 2-yr Cohort Study

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Abstract: *We evaluated the predictive and construct validity of a caries activity assessment system associated with the International Caries Detection and Assessment System (ICDAS) in primary teeth. A total of 469 children were reexamined: participants of a caries survey performed 2 yr before (follow-up rate of 73.4%). At baseline, children (12–59 mo old) were examined with the ICDAS and a caries activity assessment system. The predictive validity was assessed by evaluating the risk of active caries lesion progression to more severe conditions in the follow-up, compared with inactive lesions. We also assessed if children with a higher number of active caries lesions were more likely to develop new lesions (construct validity). Noncavitated active caries lesions at occlusal surfaces presented higher risk of progression than inactive ones. Children with a higher number of active lesions and with higher caries experience presented higher risk of developing new lesions. In conclusion, the caries activity system associated with the ICDAS presents predictive and construct validity in primary teeth in the assessment of occlusal caries lesions, but predictive validity was not observed in smooth surfaces.*

Key Words: ICDAS, dental caries, validity, preschool children, diagnosis, longitudinal studies.

Introduction

Because of the variability of criteria described for visual inspection (Ismail, 2004), efforts were made to create a standardized caries detection system based on visual inspection—denominated the International Caries Detection and Assessment System (ICDAS) (Ismail *et al.*, 2007). Additional criteria systems for activity assessment have been investigated to be used in association with the ICDAS (ICDAS Coordinating Committee, 2005; Ekstrand *et al.*, 2007; Braga *et al.*, 2009; Braga *et al.*, 2010; Ferreira-Zandona *et al.*, 2012; Gimenez *et al.*, 2013; Piovesan *et al.*, 2013).

Previous studies have tried to validate one of these activity assessment systems through pH indicator methods (Ekstrand *et al.*, 2007; Braga *et al.*, 2010). Nevertheless, some authors have asserted that this type of validation is not the best option for caries activity. The predictive ability of the activity assessment criteria would be more useful (Nyvad, 2004; Baelum, 2010); hence, dentists could know what type of caries lesions would be more

probable to progress, concentrating their efforts in arresting them.

Therefore, we aimed to evaluate the predictive and construct validity of the caries activity assessment system associated with the ICDAS (ICDAS Coordinating Committee, 2005) in preschool children. Other studies evaluated the risk of progression of active and inactive caries in permanent teeth (Nyvad *et al.*, 2003; Ferreira-Zandona *et al.*, 2012), but no previous research was conducted in primary teeth.

The premises used to evaluate the predictive validity were that caries lesions classified as active would be more prone to progress to higher ICDAS scores, whereas inactive lesions would be more likely to maintain or diminish their ICDAS scores after the follow-up. To evaluate the construct validity, we postulated that children with a higher number of active caries lesions at baseline would have more risk to develop new caries lesions.

Materials & Methods

Protocol Approval, Study Design, and Participants

This observational follow-up study was approved by the local Committee for

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A supplemental appendix to this article is published electronically only at <http://jdr.sagepub.com/supplemental>.

Table 1.

Description of International Caries Detection and Assessment System and Criteria Based on Features Used to Assess Caries Lesions Activity

Score	Description	Clinical Characteristics of Caries Lesion	
		Active	Inactive
0	No or slight change in enamel translucency after prolonged air-drying (5 s)		
1	First visual change in enamel (seen only after prolonged air-drying or restricted to within the confines of a pit or fissure)	Surface of enamel is whitish/yellowish opaque with loss of luster; feels rough when the tip of the probe is moved gently across the surface; lesion is in a plaque stagnation area	Surface of enamel is whitish, brownish, or black; enamel may be shiny and feels hard and smooth when the tip of the probe is moved gently across the surface
2	Distinct visual changes in enamel		
3	Localized enamel breakdown in opaque or discolored enamel (without visual signs of dentinal involvement)		
4	Underlying dark shadow from dentine	Probably active	
5	Distinct cavity with visible dentin	Cavity feels soft or leathery on gently probing the dentine	Cavity may be shiny and feels hard on gently probing the dentine
6	Extensive distinct cavity with visible dentine (involving more than half the surface)		

Based on International Caries Detection and Assessment System Coordinating Committee (2005) and Ismail *et al.* (2007).

Ethics in Research, and the participants' parents signed an informed consent form. We followed the checklist of the STROBE guideline (*i.e.*, Strengthening the Reporting of Observational Studies in Epidemiology). On June 12, 2010, a sample of 639 children, 12 to 59 mo old (Piovesan *et al.*, 2013), was examined by 15 trained and calibrated examiners during a caries epidemiologic survey in Santa Maria, Brazil.

Visual inspection based on the ICDAS was performed on dental units with conventional illumination, aided by dental mirror and ball-ended probe. Plaque was previously removed, and the surfaces were first examined wet and then air-dried. The examiners also assessed the caries lesions activity based on the clinical characteristics of the lesions. Descriptions of the ICDAS and the clinical features used to assess caries lesions activity (ICDAS Coordinating Committee, 2005) are presented in Table 1.

Follow-up Assessment

To evaluate the predictive and construct validity of this activity assessment system, we designed a cohort study using these participants, trying to contact them in 2012. The children were reexamined by 4 calibrated examiners unaware of the

baseline data who had participated in the first survey. Intra- and interexaminer reliability was assessed by weighted kappa values. These new evaluations were performed with the ICDAS, but activity status was not reassessed.

As the reexaminations took several months, the time after the first examination was used to adjust all statistical analyses to avoid bias due to the different interval times.

Statistical Analysis

Concerning predictive validity, we considered only caries lesions classified as noncavitated (ICDAS scores 1 or 2) or lesions scored as 3 at baseline. To evaluate if lesions classified as active would have higher risk of progression to more severe conditions in the follow-up than inactive lesions or if inactive lesions would present higher probability to regress to sound or to remain arrested, we conducted stratified Poisson multilevel analysis. This analytical approach allowed estimating the relative risk and respective 95% confidence intervals.

In the analyses performed to evaluate the predictive validity, 3 outcomes were considered: (1) probability of a caries lesion to become sound or to remain arrested after the follow-up,

(2) probability of a lesion to progress to a more severe condition, and (3) probability of a lesion to become frankly cavitated (score 5 or 6), restored, or missed. We performed these analyses separately for occlusal, proximal, and smooth surfaces, first considering only noncavitated caries lesions and then using lesions classified as score 3. We also analyzed all surfaces together.

For an additional analysis related to predictive validity, we evaluated the influence of other variables in the progression of caries lesions scored as 1 to 3. The outcome was a dichotomous variable (progressed or not). The first-level variables were initial ICDAS score, initial activity status, and type of surface; the second-level variables were region of the mouth and type of the tooth; and the third-level variables were sex and age. We performed nonadjusted multilevel Poisson regression analysis, then multiple analysis, including in the final model only variables with a *p* value lower than .05.

Construct validity assessed if children with a higher number of active caries lesions at baseline were more likely to develop new caries lesions. For this analysis, we considered only sound surfaces or surfaces of nonerupted tooth

at the baseline that presented cavitation reaching the dentin or worse after the follow-up. To evaluate the construct validity, the outcome variable was the number of evident cavitated lesions and restored or missed surfaces, and explanatory variables were number of surfaces with active lesions, number of surfaces with inactive lesions, and caries experience. Then, we performed unadjusted and adjusted Poisson regression analysis with robust variance.

The multilevel analysis was performed with the software MLwin 2.10 (Centre for Multilevel Modeling, University of Bristol, Bristol, UK), and the Poisson analysis was performed with Stata 12.0 (Stata Corp, College Station, TX, USA). The level of significance was adjusted at 5%.

Results

Reproducibility and Characteristics of the Sample after the Follow-up

At baseline, weighted kappa values for interexaminer reproducibility considering 15 examiners varied from 0.86 to 0.92 for ICDAS scores and from 0.68 to 0.86 for the activity assessment. The intraexaminer values for ICDAS scores ranged from 0.77 to 0.94 and for caries activity assessment, from 0.58 to 0.78. After the follow-up, 4 examiners reached intra- and interexaminer reproducibilities varying from 0.85 to 0.96 and from 0.91 to 0.95, respectively. From 639 children examined in 2010, we reexamined 469 children (a 73.4% follow-up rate). From these participants, 234 (49.9%) were boys and 235 (50.1%) were girls. Regarding the age at the beginning of the study, 80 (17.1%) children were 12 to 23 mo old; 78 (16.6%) were 24 to 35 mo old; 120 (25.6%) children were 36 to 47 mo old; and 191 (40.7%) were 48 to 59 mo old. The nonparticipants refused to take part in this new examination ($n = 13$) or were not found ($n = 157$). There were no statistical differences (Poisson regression analysis) comparing the dropouts and the participants regarding sex ($p = .666$), caries experience ($p = .474$), and the number of active ($p = .269$) and inactive lesions ($p = .541$). However, the reexamined children were significantly older than the children that were not reached ($p < .001$).

The children were reexamined from May 2012 to February 2013. The mean (standard deviation) of time after the first examination was 849.8 days (95.1), but this variable was not significantly associated with activity status of the lesions ($p = .920$).

The classification of the surfaces at the baseline examination and the condition after the follow-up are presented in the Appendix Table. Some void transitions were found (e.g., transition from ICDAS score 5 at the baseline to a sound surface in the follow-up), but they were infrequent (93 occurrences totaling around 0.2% of the surfaces examined). We performed sensitivity analysis to observe if these void transitions could modify the results through investigating the best and worst scenarios, but no significant differences were observed.

Predictive Validity Analysis

The transitions of the lesions considering the activity status assessed at the baseline are presented in the Table 2. Considering all surfaces, around 10% of the active noncavitated lesions and 50% of surfaces with cavitation limited to the enamel became frankly cavitated, restored, or missed in the follow-up. These figures for inactive lesions were 6.2% and 34.3% for noncavitated and microcavitated lesions, respectively (Table 2).

Active noncavitated caries lesions on occlusal surfaces had around 60% higher risk to progress to a worse condition and around twofold higher risk to become frankly cavitated, restored, or missed when compared with inactive noncavitated caries lesions. Considering all surfaces, active noncavitated caries lesions presented higher risk to progress than inactive ones. For smooth surfaces or cavitations limited to the enamel, we did not observe significant higher risk when comparing active and inactive lesions (Table 3).

Lesions with higher initial ICDAS scores presented higher risk of progressing, as well as active lesions. Caries lesions on occlusal surfaces also presented higher risk to progress compared with smooth surfaces. Furthermore, lesions in first primary molars and canines presented

lower risk of progression than lesions in second primary molar teeth (Table 4).

Construct Validity Analysis

Considering the unadjusted Poisson regression analysis to evaluate the construct validity, all variables related to the dental caries presented significant association. The following coefficients (β) and standard errors were observed: number of active caries lesions ($\beta = 0.0453$, $SE = 0.0068$, $p < .001$), number of inactive lesions ($\beta = 0.0643$, $SE = 0.0264$, $p = .015$), and caries experience ($\beta = 0.0824$, $SE = 0.0126$, $p < .001$). However, only children with a higher number of active lesions and with higher caries experience presented a significant association in the adjusted model: number of active lesions ($\beta = 0.0204$, $SE = 0.0088$, $p = .020$), number of inactive lesions ($\beta = 0.0244$, $SE = 0.0253$, $p = .335$), caries experience ($\beta = 0.0569$, $SE = 0.0171$, $p = .001$).

Discussion

Previous cross-sectional studies evaluated the criterion validity of an additional activity assessment system associated with the ICDAS (Ekstrand *et al.*, 2007; Braga *et al.*, 2010). Nevertheless, no longitudinal study has addressed this issue. Longitudinal studies are not able to determine the criterion validity; however, the capability of estimating the risk of a lesion progression would be more useful for patients and clinicians. We evaluated this ability assessing the predictive and construct validity through a cohort study and observed that occlusal noncavitated active caries lesions were more likely to progress than inactive ones. When all surfaces were analyzed together, we found that active noncavitated lesions were also more probable to progress; however, the analysis performed separately for smooth or proximal surfaces was not statistically significant. Therefore, at least at occlusal surfaces, we could observe that the activity assessment criteria associated with the ICDAS (ICDAS Coordinating Committee, 2005) in primary teeth have predictive

Table 2.Transition of Noncavitated Active and Inactive Caries Lesions^a and Caries Lesions with Cavitation Limited to the Enamel^b after the Follow-up

		Classification after the Reexamination in the Follow-up, %				
Dental Surface: Activity Status at Baseline	No. of Surfaces	Sound	NC	Score 3	Score 4	C/R/M
Noncavitated caries lesions at the baseline						
Occlusal						
Inactive	171	50.9	30.4	8.8	1.8	8.2
Active	594	59.4	11.8	10.3	3.2	15.3
Proximal						
Inactive	13	100.0	0.0	0.0	0.0	0.0
Active	360	83.9	5.3	0.8	1.1	8.9
Smooth						
Inactive	103	67.0	26.2	3.9	1.0	1.9
Active	728	63.5	24.5	1.4	4.4	6.3
All						
Inactive	289	58.1	27.3	6.9	1.4	6.2
Active	1680	66.5	15.9	4.3	3.3	9.9
Cavitations clinically limited to the enamel at the baseline						
Occlusal						
Inactive	24	16.7	8.3	20.8	16.7	37.5
Active	94	17.0	4.3	18.1	6.4	54.3
Proximal						
Inactive	1	0.0	0.0	100.0	0.0	0.0
Active	22	18.2	9.1	22.7	50.0	22.7
Smooth						
Inactive	10	20.0	30.0	20.0	0.0	30.0
Active	40	10.0	15.0	37.5	7.5	30.0
All						
Inactive	35	17.1	14.3	22.9	11.4	34.3
Active	156	15.4	7.7	23.7	5.8	47.4

C/R/M = cavitated caries lesions (scores 5 and 6) / restored surface / missed surface; ICDAS, International Caries Detection and Assessment System; NC = noncavitated (scores 1 and 2 of the ICDAS).

^aScores 1 and 2 of the ICDAS.

^bScore 3 of the ICDAS.

validity. Moreover, since children with a higher number of active caries lesions developed a higher number of new caries lesions and since the number of inactive caries lesions was not significantly associated with caries incidence, we observed that the activity criteria system presented construct validity.

Children examined in the follow-up were significantly older than children not reached. This probably occurred because it is more usual for older children to

attend school than younger children. However, as the child's age was not significantly associated with the caries progression, this imbalance did not affect our findings. Moreover, sensitivity analysis according to Monte Carlo simulation also showed no influence of this difference.

No association between caries activity status and caries progression on smooth and proximal surfaces is comprehensible. The majority of proximal surfaces

were classified as active at baseline. Furthermore, smooth-surface caries lesions are easier to be arrested, even being active (Nyvad *et al.*, 2003). In addition, a few number of smooth-surface caries were observed, and the absence of significance could be related to lack of statistical power.

Moreover, smooth surfaces are easier to be cleaned, and occlusal surfaces are more subject to attrition. Therefore, lesions in these surfaces would be more

Table 3.

Relative Risk That an Active Caries Lesion Examined at Baseline Changed Its Condition after the Follow-up Compared with an Inactive Caries Lesion

Dental Surface: Activity Status	Relative Risk ^a (95% Confidence Intervals)		
	Regression or Arrestment	Progression to Worse Condition	Progression to C/R/M
Noncavitated caries lesions at the baseline			
Occlusal			
Inactive	1.00	1.00	1.00
Active	0.87 (0.72, 1.06)	1.64 ^b (1.10, 2.47)	2.04 ^b (1.11, 3.74)
Smooth			
Inactive	1.00	1.00	1.00
Active	0.95 (0.76, 1.17)	1.60 (0.70, 3.64)	3.03 (0.69, 13.33)
All^c			
Inactive	1.00	1.00	1.00
Active	0.96 (0.83, 1.09)	1.41 (0.98, 2.03)	1.95 ^b (1.12, 3.40)
Cavitations clinically limited to the enamel at the baseline			
Occlusal			
Inactive	1.00	1.00	1.00
Active	0.82 (0.42, 1.60)	1.19 (0.65, 2.19)	1.54 (0.76, 3.16)
Smooth			
Inactive	1.00	1.00	1.00
Active	0.89 (0.39, 2.06)	0.86 (0.22, 3.36)	0.89 (0.24, 3.31)
All^c			
Inactive	1.00	1.00	1.00
Active	0.89 (0.54, 1.47)	1.09 (0.64, 1.86)	1.44 (0.78, 2.65)

The outcomes variables were (1) regression from decayed to sound or no progression, (2) progression to a worse condition, and (3) progression to frankly cavitated caries lesions, restored surfaces, or missed surfaces (*i.e.*, progression to C/R/M).

^aValues adjusted for the number of days after the baseline examination.

^bStatistically significant association through multilevel Poisson regression analysis.

^cIt was not possible to calculate the relative risks of the proximal surfaces separately, but these surfaces were included in the calculation considering all surfaces together.

likely to remain arrested or to become sound. However, the large remission rate of lesions in proximal surfaces was unexpected. A possible explanation is that young children usually present wider proximal spaces (Novaes *et al.*, 2012), facilitating the visualization of these lesions at the baseline. Yet, after the follow-up, many lesions might have been overlooked, and the surfaces would have been classified as sound. Therefore, data obtained in proximal surfaces should be interpreted with caution.

With regard to the other variables, lesions on occlusal surfaces were more likely to progress than those in proximal and smooth surfaces. Furthermore, lesions in

posterior teeth, mainly second primary molar teeth, progressed more frequently, corroborating previous results in permanent teeth (Ferreira-Zandona *et al.*, 2012).

Our results also showed that the activity assessment presented construct validity. In theory, children presenting a higher number of active caries lesions would have higher risk to develop new caries lesions. This hypothesis was confirmed since in the multiple regression model, number of active caries lesions remained significantly associated with development of new caries lesions, while number of inactive caries lesions did not.

Although baseline examinations were performed in dental chairs with all their

accessories, the evaluations occurred in a single day in the context of an epidemiologic survey (Piovesan *et al.*, 2013). Examinations made in the routine of a dental office would probably be more accurate. Moreover, the huge number of examiners might be another limitation of our study, although they have reached acceptable reliability values. The activity assessment based on clinical features of the lesions (ICDAS Coordinating Committee, 2005) is less time-consuming and presented similar performance (Gimenez *et al.*, 2013) as the system based on numerical values (Ekstrand *et al.*, 2007); hence, it was more appropriate to be used during the survey.

Table 4.

Explanatory Variables Related to the First, Second, and Third Levels with Progression of Caries Lesions Classified as Scores 1, 2, and 3 of the ICDAS (Any Type of Progression)

Explanatory Variables	Crude RR (95% CI)	<i>p</i>	Adjusted RR (95% CI)	<i>p</i>
First level: Dental surface				
Initial ICDAS score (ref. score 1)		< .001		< .001
Score 2	2.07 (1.32, 3.25)		1.98 (1.25, 3.14)	
Score 3	7.55 (4.59, 12.43)		6.28 (3.79, 10.39)	
Activity status (ref. inactive)		.026		.020
Active	1.64 (1.06, 2.54)		1.72 (1.09, 2.71)	
Type of surface (ref. smooth)		< .001		< .001
Occlusal	2.85 (2.07, 3.91)		2.20 (1.55, 3.13)	
Proximal	1.56 (1.02, 2.38)		1.49 (0.98, 2.27)	
Second level: Tooth				
Region (ref. anterior)		< .001		—
Posterior	1.89 (1.31, 2.73)			
Type of tooth (ref. second molars)		< .001		.028
First molars	0.75 (0.57, 1.00)		0.69 (0.52, 0.93)	
Incisors	0.56 (0.36, 0.89)		0.79 (0.49, 1.29)	
Canines	0.32 (0.16, 0.63)		0.45 (0.21, 0.96)	
Third level: Child				
Sex (ref. male)		.452		—
Female	0.87 (0.60, 1.26)			
Age (ref. 12-23 mo), mo		.609		—
24-35	1.73 (0.50, 6.03)			
36-47	1.70 (0.50, 6.03)			
48-59	2.02 (0.61, 6.70)			

Dash (—) indicates that variable was not included in the adjusted model. CI, confidence interval; ICDAS, International Caries Detection and Assessment System; RR, relative risk.

Even though the evaluation of the caries lesions activity status has predictive and construct validity, the actual utility of assessing caries activity is not obvious. Although children with a higher number of active lesions had higher caries risk, caries experience—*independent of the activity status*—was also a significant predictor, and this variable would be easier to be collected.

Additionally, active noncavitated lesions were more probable to progress than inactive ones; thus, the dentists could put efforts toward arresting these lesions. However, the evidence is limited about the efficiency of noninvasive methods applied individually on the

lesions. Most methods that have shown benefits in decreasing the progression of noncavitated lesions are usually applied on all teeth, such as fluoride products (Tellez *et al.*, 2013). The technique with some evidence of efficacy for the management of individual lesions is use of sealants (Tellez *et al.*, 2013), but an earlier study showed that treating all teeth with noncavitated caries lesions independent of activity assessment could be more cost-effective (Piovesan *et al.*, 2013). Therefore, the real benefit of the caries activity assessment is still unclear.

In conclusion, as we observed that active occlusal caries lesions were more likely to progress to worse conditions

than inactive lesions, the additional criteria for lesion activity assessment associated with the ICDAS performed in primary teeth have predictive validity on occlusal surfaces. However, predictive validity was not observed in smooth surfaces. Moreover, since children with a higher number of active caries lesions were more prone to develop new caries lesions after the follow-up, the system also presents construct validity.

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