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Student Versus Faculty Performance Using a New Visual Criteria for the Detection of Caries on Occlusal Surfaces: An *In Vitro* Examination with Histological Validation

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Clinical Relevance

One of the first actions that needs to be taken to disseminate the new visual caries detection criteria ICDAS is to assess how it is assimilated by different groups and levels of experience.

SUMMARY

The current study compared three groups of participants with different levels of clinical experience in using the International Caries and Detection System (ICDAS) on occlusal surfaces. Thirty participants (faculty, graduate and undergraduate students), after a lecture and hands-on training session on two occasions, examined 60 occlusal surfaces previously examined by two criteria expert examiners. There were no significant differences between the groups for intra- and inter-examiner agreement for ICDAS severity or activity on occlusal surfaces as measured by kappa. Previous clinical dental experience does not seem to play a significant role in learning ICDAS.

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INTRODUCTION

There is increasing agreement[1-2] that the traditional measurement of caries at the stage of cavitation, excluding the precavitation stages of caries,[3] is no longer sufficient to reflect changes in the incidence of caries in present-day populations exhibiting an overall slower rate of caries progression.[4] Furthermore, it has been shown that the diagnosis of caries at the cavitation level results in a significant underestimation of the actual caries experience in populations.[5-11] Several new visual criteria have been promoted,[1,12-13] and the new

visual criteria known as the International Caries Detection and Assessment System (ICDAS)[14-16] has received considerable attention. ICDAS was developed to provide an international system for caries detection that would allow for comparison of data collected in different locations as well as at different points in time, and to bring forward the current understanding of the process of initiation and progression of dental caries to the fields of epidemiological and clinical research. As such, ICDAS has raised the interest of several groups using this methodology for caries detection and has raised the question of how this criteria is assimilated.

The current study compared three groups of participants with limited or no training in ICDAS to experts, and the study assessed the influence of previous clinical dental experience in using ICDAS severity and an activity criteria on occlusal surfaces.

METHODS AND MATERIALS

Study Participants

A total of 30 participants (10 undergraduate, 10 graduate students and 10 full time faculty members) from the Indiana University School of Dentistry (IUSD), Indianapolis, IN, USA, were recruited.

Sample Selection

Ninety unrestored posterior teeth representing all ICDAS scores on occlusal surfaces were selected from a pool of recently extracted teeth (reasons for extraction unknown) stored in 0.1% thymol. The occlusal surfaces were cleaned with a rotating brush and water and photographed, and a site was selected and marked on a drawing. The teeth were then mounted in models using Phantom Heads to simulate the clinical situation by not allowing free manipulation of the models and maintenance of the teeth wet. For the hands-on training session, 30 of those teeth were distributed in 10 models with three teeth each (one premolar and two molars). For the study session, 60 teeth (40 molars and 20 premolars with an equal number from the upper and lower arch) were distributed in 10 models (five upper and five lower models) with each model containing six teeth (one premolar and two molars per quadrant). The selected teeth had complete root formation. No attempt was made to select teeth to match their location in the models; upper or lower, first or second premolars or first, second or third molars were used by distributing them as described.

Two expert examiners (members of the ICDAS Coordination Committee, calibrated and experienced in use of the criteria) scored each site independently using the ICDAS severity criteria and an activity criteria (Table 1). The activity scores were: a) active or b) non-active lesions. Active lesions in enamel were described as whitish (with no or minimal staining), with a dull and chalky surface that may appear or "feel" rough. Non-active lesions in enamel were described as having a white to brown discoloration, with a shiny, smooth surface (determined by running the side of an explorer) that appears dense or semi-transparent. The lesions in dentin were classified as active, if the dentin was soft and yellow, and inactive, if the dentin was hard and the discoloration was brown or scored dark brown. Sites with disagreements (five out of the 60 sites) were re-examined by both for consensus of a score, which was subsequently used as the expert's severity, and activity scores.

Training Session

The training consisted of a 90-minute lecture on the ICDAS severity criteria (Table 1) and activity criteria followed by hands-on training by visual examination of the occlusal surfaces of 30 teeth. Immediately after scoring each model, the participants reviewed their scores by comparing them with the scores of the experts and they had an opportunity for questions and answers.

Examination Method

For the study examinations, during a maximum of six minutes, the participants visually examined 60 occlusal surfaces. As the participants were examining only the occlusal surface, 30 seconds was more than adequate to decide on the surface score. Not all the examiners needed all the allotted time to complete the examinations. After a 30-minute break, the models were placed in a different order, and the participants repeated the visual examination of all the study teeth (60) to assess intra-examiner reproducibility.

The teeth were kept hydrated between exams. All the examinations were conducted using a clinical light and air/water-syringe, and a blunt explorer was available to feel for roughness.

Histological Preparation and Examination

The roots of the individual teeth (60 teeth) were removed using Lapcraft's Lil Trimmer saw (standard model–part #8000) by a #19300 metal bonded style cutting blade, 0.5" arbor, 4" diameter, 0.014" thick (Lapcraft Inc, Powell, OH, USA), and the teeth were hemi-sectioned through the selected investigation site using hard tissue Microtome (Gillings-Hamco, Hamco Machine, Inc, Rochester, NY, USA) with a blade size of 4x0.12x½". Both sectioned surfaces were examined under a stereomicroscope (Nikon Measurescope UM-2, Melville, NY, USA) (10x), and the part with more extensive carious changes was photographed and chosen for histological evaluation of the enamel and dentin lesions using a ranked scale[13] independently by two examiners. A consensus of the score was used for calculations. The depth of enamel demineralization was assessed on wet sections at the area showing the greatest extension of opacity along the direction of the rods. The depth of dentin demineralization was assessed at the area

Table 1: *ICDAS Criteria Used in the Visual Examination and Corresponding Histological Criteria of the Lesion Severity*

Score	Visual Criteria	Score	Histology Criteria
0	No or questionable change in enamel translucency after prolonged air drying (>5 seconds). Artifacts, such as hypoplasias, fluorosis, wear and stains, must be avoided.	0	No demineralization or a narrow surface zone of opacity (edge phenomenon).
1	Opacity or discoloration not visible on the wet surface, but distinctly visible after air drying, or changes seen on a wet surface. but limited to the confines of the pit and fissure area.	1	Enamel demineralization limited to the outer 50% of the enamel layer.
2	Opacity or discoloration distinctly visible on a wet surface and/or wider than the fissure/fossa area.	2	Demineralization involving between 50% of the enamel and half of the dentin.
3*	Localized enamel breakdown due to caries, with no visible dentin or underlying shadow.	3	Demineralization involving the middle half of the dentin.
4**	Underlying dark shadow from dentin or without localized enamel breakdown (most easily seen when wet).	4	Demineralization involving the inner half of the dentin.
5	Cavitation in opaque or discolored enamel exposing the dentin beneath "frank cavitation." Visual evidence of demineralization at the entrance to the pit and fissure, and, in the examiner's judgment, dentin is exposed.		
6	Obvious loss of tooth structure, the cavity is both deep and wide and the dentin is clearly visible on the walls and at the base, revealing an extensive cavitation.		

where the color changed from a brownish yellow to a grey discoloration along a line at right angles to the enamel-dentin junction (EDJ) towards the pulp.[17]

Statistical Analysis

Intra-examiner agreement using the ICDAS severity criteria was evaluated for each participant using weighted kappa statistics. SAS version 9 was used for all of the analyses, which, by default, bases the weights for weighted kappa on the absolute value of the linear difference between the scores. Similar analyses were performed comparing each participant to the expert examiners. The ICDAS severity scores were then compared against the histology scores. Sensitivity and specificity were computed for each participant, defining the presence of caries as any ICDAS severity scores >0 and using the histology results of caries in enamel and dentin separately as well as combined to calculate sensitivity for all lesions, enamel lesions and dentin lesions. Kendall's tau-b was computed to assess the correlation between the expert ICDAS severity scores and the histology scores. Intra-examiner and inter-examiner agreement in using the activity score were evaluated for each participant using kappa statistics. In addition, kappas were computed for the activity score for each participant against the consensus activity score of the expert examiners. Comparisons of the agreement statistics and sensitivity and specificity among the groups were performed using the Kruskal-Wallis non-parametric tests.

With a sample size of 10 examiners per group, the current study was initially powered at 80% to detect a 30% difference in sensitivity (55% vs 25%) and a 10% difference in specificity (90% vs 80%) based on data from a previous study (unpublished).

RESULTS

Although all undergraduate dental students (DS) were invited to participate, only seniors (fourth year DS) (N=6) and freshmen (first year DS) (N=4) elected to participate. The graduate student group had a mean experience of seven years and were distributed as follows: Seven students from Operative, two students from Prosthodontics and one student from Periodontics. The faculty group had a mean experience of 23.4 years. Their distribution, according to departments, was five from Preventive and Community Dentistry, four from Restorative Dentistry and one each from Oral Pathology, Medicine and Radiology.

Table 2 shows the distribution of the teeth based on histological examination. Seven teeth were sound, seven had a demineralization limited to the outer-half of enamel, 22 teeth had demineralization involving the inner-half of enamel or the outer-third of dentin, 10 teeth had lesions extending into the middle-third of dentin and 14 teeth had demineralization involving the inner-third of dentin.

The three groups did not have significantly different intra-examiner agreement for ICDAS severity as measured by weighted kappa. The three groups also did not have a significantly different agreement with

Table 2: *Sample Demographic and Agreement Between Experts' Severity Scores, Histology and Activity Scores*

	Histology Score/Activity Score					
Expert Severity Score	**0**	**1**	**2**	**3**	**4**	**Total**
0*	7	3	1	0	0	11
1		2 2 non-active 0 active	3 3 non-active 0 active			5 5 non-active 0 active
2	0	1 0 non-active 1 active	10 5 non-active 5 active	1 0 non-active 1 active	0	12 5 non-active 7 active
3	0	1 0 non-active 1 active	4 2 non-active 2 active	6 0 non-active 6 active	4 0 non-active 4 active	15 2 non-active 13 active
4	0	0	2 1 non-active 1 active	2 0 non-active 2 active	0	4 1 non-active 3 active
5	0	0	2 0 non-active 2 active	1 0 non-active 1 active	3 0 non-active 3 active	6 0 non-active 6 active
6	0	0	0	0	7 0 non-active 7 active	7 0 non-active 7 active
TOTAL	7	7	22	10	14	60

the expert examiners for ICDAS severity as measured by weighted kappa comparing each participant to the expert examiners (Table 3).

When the experts' ICDAS severity scores were compared against histology, specificity and sensitivity were high (1.00 and 0.93, respectively). Sensitivity for the detection of lesions in the middle- and inner-third of dentin was perfect (1.00), and for enamel lesions or lesions in the outer dentin, it was 0.71. The correlation between the experts' ICDAS severity scores and the histology scores was 0.73. For the study participants, the average specificity ranged from 0.83 (grad-

Table 3: *ICDAS Severity Activity Score Outcomes by Group*

Measure	**Faculty**	**Graduates**	**Undergraduates**
ICDAS Severity			
Intra-examiner Agreement: Wt Kappa	0.81, 0.69-0.92	0.84, 0.70-0.93	0.79, 0.60-0.88
Agreement with Expert: Wt Kappa	0.75, 0.62-0.83	0.74, 0.33-0.78	0.74, 0.59-0.84
Specificity	0.86, 0.57-1.00	0.86, 0.4301.00	0.86, 0.14-1.00
Sensitivity—All lesions	0.91, 0.79-0.94	0.90, 0.81-0.96	0.92, 0.81-1.00
Sensitivity—Enamel lesions	0.75, 0.43-0.79	0.71, 0.50-0.86	0.75, 0.50-1.00
Sensitivity—Dentin lesions	0.97, 0.92-1.00	0.97, 0.85-1.00	1.00, 0.92-1.00
ICDAS Activity			
Intra-examiner Agreement Kappa	0.64, 0.39-0.86	0.60, 0.43-0.93	0.71, 0.32-0.89
Agreement with Expert: Kappa	0.52, 0.15-0.65	0.54, 0.10-0.65	0.59, 0.41-0.68
Median Range			

uate and undergraduate students) to 0.87 (faculty), with no significant difference between the groups. The average sensitivity ranged from 0.88 (graduate students) to 0.91 (undergraduate students), with no significant difference between the groups. The average sensitivity for early lesions (1-2) was between 0.68 (faculty) and 0.73 (undergraduates), and for non-early lesions (3-6), it was between 0.95 (graduates) and 0.98 (undergraduates).

The three groups did not have significantly different intra-examiner agreement for activity as evaluated for each participant. The mean kappa for the three groups ranged from 0.62 (faculty) to 0.65 (undergraduates). The three groups did not have significantly different agreement with the experts' activity scores, as measured by kappa, which varied from 0.45 (faculty) to 0.56 (undergraduates).

DISCUSSION

Several studies have shown that the occlusal surfaces of permanent molars are more often attacked by caries than other surfaces.[18-19] Although teeth were selected to represent all possible scores equally on the ICDAS criteria, histologically, their distribution was: 11.7% of histological score 0, 11.7% of histological score 1, 36.7% of histological score 2, 16.7% of histological score 3 and 23.3% of histological score 4. Therefore, score 2 on the ICDAS I criteria represented more than one-third of the sample. This score can be considered one of the most difficult scores to be diagnosed, as it could easily be misdiagnosed with scores 1 or 4 on the ICDAS I criteria.

There were three groups of participants in this study, 10 per group. The freshmen did as well as the seniors, even though in the IUSD curriculum, the first exposure to caries detection is in the second semester of the freshmen year and the current study was completed prior to their first exposure to the cariology curriculum. The authors of the current study could not detect any effect caused by a difference in the number of years of experience or differences in graduate programs between the graduate students in all parameters. The same lack of effect was observed with the faculty group. The possible reasons for not detecting any significant difference among the three groups is that, as a scoring system, ICDAS could be considered a new subject for most participants, even though the topic (caries detection) was familiar to all, except the freshman students, and the lack of familiarity of the observers with the ICDAS criteria was equal among the three groups, or the clarity of the criteria made visual detection of occlusal caries for the undergraduate students such a simple task that the minimal instruction provided allowed them to accomplish the task to the level that they did.

When the authors of the current study reviewed the previous studies, which detected the influence of experience on the diagnosis of caries using visual criteria, the authors found that their results were not in agreement with the results found by Fyffe and others,[20] who found some significant differences between the two groups of examiners, with the novice examiners tending to perform better than the experienced examiners. On the other hand, El-Housseiny and others[21] found no significant difference between the two groups of dentists with different levels of experience using the visual method alone, but the less experienced dentists performed better with both visual and explorer detection. Fung and others[22] found students to have the highest sensitivity compared to the more experienced groups (General Dental Practitioners and Academic Clinicians), which had the highest specificity. The same results were found by Bengtson and others[23] and Souza-Zaroni and others,[24] where dental students had higher sensitivity and lower specificity than the other examiner groups in detecting occlusal caries lesions. Although there was a trend toward undergraduate students having higher sensitivities in the current study, there were no significant differences with the other groups. Likewise, in the current study, there was a trend toward increasing specificity with the faculty group, although it was not significantly different from the other groups. Experienced dentists who have seen the long-term results of restoration placement (the commitment of a tooth to a lifetime of restorative treatment) may be more willing to avoid placement of a restoration in a questionably diseased tooth, rather than place a restoration in a caries-free tooth.[25] The high disease prevalence rate in the sample (88% caries) of the current study may also have influenced the results. At a lower prevalence rate, it is possible that the higher specificity of the faculty (even though it was not significantly higher) would have allowed the faculty to demonstrate a significantly higher agreement.

The assessment of the caries activity status of early lesions is currently very challenging, as it relies on the clinician's ability to identify subtle changes in enamel by visual and tactile inspection. This is very clear in the results of the current study, where the kappa values of the three groups of participants, in the agreement with the experts' activity scores, ranged from slight to substantial (0.10-0.68). Ekstrand and others,[26] in a recent study, pointed out the difficulty of trying to differentiate active lesions from inactive ones in one single appointment without specific training or calibration. A more recent publication[15] indicates that activity can be assessed clinically by using a combined knowledge obtained from the visual appearance, the location of the lesion and the tactile sensation during probing. The *in vitro* design on the current study limits the applicability of some of these parameters.

In the present study design, no long-term effects of theoretical or practical training can be assessed, as the study was concluded in a very short interval with lecture, practical training and study exams done within a period of seven days or less. Likewise, the results of the intra-examiner agreement must be evaluated within the context of the current study; that is, with repeat exams done after a short interval (30 minutes) after the first exam. The allotted time for the exams was 30 seconds per surface, which was agreed upon after the training was conducted. Most participants did not need the full six minutes to complete the exam, as the number of surfaces examined in the study (60) were less than half of what would be examined during a full mouth exam on a fully dentate patient.

A limitation of the current study that should be addressed is whether the number of participants in each group (10 per group) was adequate to separate or detect differences among the groups. Post-study power calculations were performed to determine whether the study had sufficient power to detect differences among the groups. Using the variability observed in the current study, it had 80% power to detect an 8.5% difference in the average sensitivity levels among groups and a 31% difference in average specificity levels among groups. The power of detecting differences in sensitivity was increased, while the power for detecting differences in specificity was decreased, compared to what was expected from the calculations used to size the study. The differences actually observed among the groups were less than 5% for both sensitivity and specificity; therefore, concluding no significant differences among groups is still valid.

CONCLUSIONS

The current study found that, for the use of ICDAS criteria on occlusal surfaces, the previous clinical dental experience does not play a significant role in learning those criteria and the examiners can reproduce the scores. The limited training to which participants were exposed in this study demonstrated that it is feasible to teach this methodology in an academic setting, although this training design certainly would not be adequate for a research setting.

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