©Operative Dentistry, 2015, **40-5,** E189-E196

Lesion Activity Assessment (LAA) in Conjunction With International Caries Detection and Assessment System (ICDAS) for Occlusal Caries Diagnosis in Permanent Teeth

FVMD Cotta • LS de Castilho • AN Moreira
SM Paiva • EF Ferreira • LCN Ferreira
CS Magalhães

Clinical Relevance

The ICDAS proved to be a reproducible method with good performance in detecting carious lesions in the dentin threshold. The ICDAS-LAA criteria were reproducible to assess caries activity, but with a low degree of accuracy.

SUMMARY

Objective: The aim of this study was to investigate the clinical performance and to validate the Lesion Activity Assessment (LAA) in conjunction with the International Caries Detection and Assessment System (ICDAS) for occlusal caries diagnosis in permanent teeth.

Methods: Patients with erupted or partially erupted third molars were recruited from the surgery clinic of the School of Dentistry of the Universidade Federal de Minas Gerais, Brazil. A calibrated examiner evaluated 49 teeth using the ICDAS-LAA criteria. The histologic criterion proposed by Ekstrand and others was used

Fernanda Vaz de Melo Diniz Cotta, MS, Department of Restorative Dentistry, School of Dentistry, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil

Lia Silva de Castilho, PhD, Department of Restorative Dentistry, School of Dentistry, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil

Allyson N. Moreira, PhD, Department of Restorative Dentistry, School of Dentistry, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil

Saul M. Paiva, PhD, Department of Pedodontics and Orthodontics, School of Dentistry, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil

Efigênia Ferreira e Ferreira, PhD, Department of Community and Preventive Dentistry, School of Dentistry, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil

Luiz Cláudio Noman Ferreira, PhD, Department of Oral Surgery and Pathology, School of Dentistry, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil

*Claudia S. Magalhães, PhD, Department of Restorative Dentistry, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil

*Corresponding author: Avenida Antonio Carlos, 6627, Campus Pampulha, Belo Horizonte, MG, 31270901, Brazil; e-mail: silamics@yahoo.com

DOI: 10.2341/13-332-C

to validate severity at the thresholds D1 (outer half of the enamel), D2 (inner half of the enamel and outer third of the dentin), and D3 (inner or middle third of the dentin). Lesion activity was validated using 0.1% methyl red solution.

Results: The method demonstrated good reliability (weighted kappa for severity=0.60; unweighted kappa for activity=0.61). The ICDAS presented a higher performance for lesion detection (area under the receiver operating characteristic curve [Az]=0.79) using the threshold D3. At the thresholds D1 and D2, the results for Az were 0.57 and 0.74, respectively. Regarding the ICDAS-LAA, Az = 0.59.

Conclusions: Clinical protocols can use ICDAS for the severity diagnosis of occlusal caries, but the LAA performance was poor.

INTRODUCTION

Epidemiologic studies have demonstrated that dental caries continues to be a public health problem worldwide. Changes in the preferential sites of occurrence and behavior of carious lesions have made diagnosis difficult. With its complex anatomy, the occlusal surface of molars favors the buildup of biofilm. Such sites are more vulnerable to the development of caries, so there is increased concern regarding the detection of these lesions[1-3] and their activity status.

The International Caries Detection and Assessment System (ICDAS) was developed to improve the accuracy of clinical decisions on caries assessment. The system was modified in 2005 by adding criteria for lesion activity assessment (LAA).[4] The LAA is based on the study of Nyvad and others[5] and was validated by Ekstrand and others.[6]

The LAA is one available system that may be used in conjunction with ICDAS to assess caries activity, although there are other options.[5,7] Assessing lesion activity is important because of the decreasing incidence of caries in contemporary populations and because the overall slow rate of caries progression requires a more sensitive diagnostic criterion. A diagnostic system that reflects the dynamic nature of caries is crucial to evaluate the effect of various nonoperative interventions for caries control.[5] Furthermore, more accurate treatment decisions can be made when one can distinguish active and non-active carious lesions in conjunction with their depths.[6]

One clinical study tested the accuracy of the scoring system for assessing caries activity (LAA) in permanent and primary teeth, using an impression material (Clinpro Cario Diagnosis, Full Arch Lactic Acid Locator, 3M ESPE, Maplewood, MN, USA) as a validation method.[6] Only one *in vivo* study has assessed the activity of carious lesions in the primary dentition, and it included the ICDAS-LAA with histologic validation (0.1% methyl red dye). The authors concluded that the ICDAS-LAA seems to overestimate the activity in the cavitated lesions.[8]

However, clinical studies have not yet been conducted to assess the reliability and accuracy of the ICDAS-LAA to evaluate occlusal caries activity in permanent teeth incorporating histologic validation. The aim of this study was to investigate the clinical performance and to validate with histologic exam the ICDAS-LAA for diagnosing occlusal caries in permanent teeth.

METHODS AND MATERIALS

Ethical Considerations

This study was approved by the ethics committee of the Universidade Federal de Minas Gerais, Brazil (ETIC: 0484.0.203.000-10). The participants received information on the objectives and procedures and signed a statement of informed consent agreeing to participate in the study.

Sample Selection

Initially, 42 volunteers (20 males and 22 females; age range 16 to 39 years) participated in the study. All subjects were scheduled for extractions at the surgery clinic of the School of Dentistry of the Universidade Federal de Minas Gerais, Brazil. Erupted or partially erupted third molars were selected based on the following inclusion criteria: an occlusal surface that was free for exam; lack of restorations or sealants on the occlusal surface; absence of extensive carious lesions on the buccal, lingual, and proximal surfaces; and absence of advanced degrees of hypoplastic and fluorotic defects. The teeth were examined visually using the ICDAS-LAA criteria by one researcher (FVMDC) before the surgical procedure. All surgical procedures were performed at the aforementioned surgical clinic.

Calibration Process

One examiner (FVMDC) underwent a calibration process according to the ICDAS Coordinating Committee *Criteria Manual*.[9] The benchmark examiner (SMP) presented the criteria in a 90-minute class. Then, the researcher and the benchmark examiner evaluated 36 tooth images and discussed the criteria

and codes used to assess the lesion severity and activity. One week after the theoretical calibration, clinical training was carried out on third molars (n=20). The teeth were cleaned with a pumice and water paste using a brush, followed by rinsing. First, 10 teeth were examined under a dental operating light with isolation by cotton rolls, using a 3-in-1 syringe, a plane dental mirror, and a World Health Organization (WHO) probe (Hu-Friedy, Rio de Janeiro, Brazil). During the visual exam, the benchmark examiner and the researcher discussed the ICDAS-LAA criteria and codes. After the clinical training, they independently examined the other 10 teeth and recorded the codes. One week later, they repeated the exam to determine intra- and inter-examiner agreement. The weighted kappa index for interexaminer agreement was 0.67 for severity, and the simple kappa index was 0.70 for activity. The weighted kappa index for intraexaminer agreement was 0.84 for severity, and the simple kappa index was 1.0 for activity.[10]

Visual Clinical Exam

The clinical exams were conducted at the dental offices following the ICDAS Coordinating Committee *Criteria Manual* recommendations.[9] The teeth were examined after cleaning with a brush and a pumice and water paste, followed by rinsing. The clinical exam was performed under a dental operating light with isolation by cotton rolls, using a 3-in-1 syringe, a plane dental mirror and a WHO probe. The examiner chose the site presenting the severest lesion and recorded on a schematic drawing of the tooth occlusal surface. Then, the code was assigned to the site as follows: 0 = no or slight change in enamel translucency after prolonged air drying for 5 seconds; 1 = first visual change in enamel (seen only after prolonged air drying or restricted to within the confines of a pit or fissure); 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 dentin; 5 = distinct cavity with visible dentin; and 6 = extensive distinct cavity with visible dentin (involving more than half of the surface).

Based on the ICDAS-LAA criteria, activity was defined using the combined knowledge obtained from the visual appearance, tactile feel, and potential for biofilm accumulation. All sites were considered natural biofilm stagnation area as the teeth were not in occlusion. The appearance and texture criteria were verified with a WHO probe without assigning scores. The ICDAS codes 1, 2, and 3 were considered active lesions when the enamel surface was whitish/yellowish opaque, showed loss of luster, and felt rough when the tip of the probe was moved gently across the surface, which would indicate that the enamel was rough because of caries and not because of staining or partly mineralized debris, calculus, or anatomy. Inactive enamel lesions were recorded when the surface was whitish, brownish, or black and the enamel was shiny and felt hard and smooth when the tip of the probe was moved gently across the surface. When the enamel was smooth to probing, superficial defects were accepted if they were open and the borders were smooth to probing. [9] An ICDAS code 4 was considered active. ICDAS codes 5 and 6 were considered active when the dentin surface felt soft or leathery on gently probing. An inactive lesion was recorded when the dentin was shiny and felt hard on gentle probing.[6]

After 7 days, the exam was repeated in 10 randomly selected teeth to calculate intraexaminer reproducibility.

Histologic Validation

Immediately after extraction, the teeth were scraped to remove debris, and stored at −20°C for up to 30 days.[7] Then they were thawed and sectioned perpendicularly to the carious site using a diamond blade (series 15 LC NO. 11-4276, Buhler Ltd, Lake Bluff, IL, USA) mounted on a precision saw (Isomet, Buhler Ltd). One trained examiner (k=0.77) blinded to the visual examination assessed the sections under a stereomicroscope (Carl Zeiss, Oberkochen, Germany) at 32× magnification. Carious lesions were defined based on the extent of a whitish or brownish demineralization zone in the occlusal-pulp direction and classified based on the following criteria: 0 = no demineralization, 1 = demineralization limited to the outer half of the enamel thickness, 2 = demineralization between the inner half of the enamel and the outer third of the dentin, 3 = demineralization in the middle third of the dentin, and 4 = demineralization in the inner third of the dentin.[11]

Validation of Caries Activity

One drop of 0.1% methyl red aqueous solution (Merck, Rio de Janeiro, Brazil) buffered with sodium hydroxide (pH=7) was applied to the histologic slices. After 1 minute, the excess solution was removed with absorbent paper, and the slices were examined under a stereomicroscope at 32× magnification. The staining on the enamel and dentin was recorded as yellow (indicative of inactive lesion: pH>5.5) or red (indicative of active lesion: pH<5.5).[11]

Table 1: *Comparison of ICDAS-LAA Activity Criteria and Methyl Red Stain (Gold Standard)*

ICDAS-LAA All Surfaces*	Methyl Red Stain		
	Active	Inactive	Total
Active	11	21	32
Inactive	3	14	17
Total	14	35	49
Enamel**			
Active	7	14	21
Inactive	2	10	12
Total	9	24	33
Dentin***			
Active	4	2	6
Inactive	1	0	1
Total	5	2	7

[a] *Scores 0–4 according to the histologic criteria.*
[b] *Scores 1–2 according to the histologic criteria.*
[c] *Scores 3–4 according to the histologic criteria.*

Table 2: *Comparison of the Histologic Gold Standard With ICDAS Severity Criteria Cut-off Points*

ICDAS	Gold Standard					
	0	1	2	3	4	Total
0	4	7	5	0	0	16
1	1	2	3	2	0	8
2	3	1	10	0	0	14
3	1	0	3	1	0	5
4	0	0	1	0	1	2
5	0	0	1	1	1	3
6	0	0	0	0	1	1
Total	9	10	23	4	3	49

Abbreviation: ICDAS, International Caries Detection and Assessment System Lesion Activity Assessment.

Statistical Analysis

Intraexaminer agreement for the ICDAS severity and activity criteria was determined using the weighted and simple Kappa statistic, respectively. The validity of the diagnostic tests was expressed as sensitivity, specificity, accuracy, and 95% confidence intervals (CIs) at the different thresholds (D1, D2, and D3). The cutoff points for ICDAS were defined as D1 (0 healthy and 1 to 6 carious), D2 (0 and 1 healthy and 2 to 6 carious), and D3 (0, 1, and 2 healthy and 3 to 6 carious). The histologic exam results were classified as D1 (0 healthy and 1 to 4 carious), D2 (0 and 1 healthy and 2 to 4 carious), and D3 (0, 1, and 2 healthy and 3 to 4 carious). Analysis of the area under the receiver operating characteristic curve (Az) and 95% CI was used to evaluate the performance of the diagnostic systems. Spearman correlation coefficients were calculated to determine correlations between the histologic exam and the ICDAS. Caries activity was analyzed after the data were dichotomized into healthy sites and inactive lesions or active lesions. Statistical analysis was also performed using only one tooth per patient, which was selected by computer randomization. The SPSS 14 program for Windows (Chicago, IL, USA) was used for statistical analysis.

RESULTS

Sample Characteristics

Initially, 42 people agreed to participate in the study. After the teeth were extracted, 33 subjects remained (19 females, 14 males; age range, 16 to 39 years old). All participants reported the use of a 0.7 mg/l F water supply and fluoride toothpaste.

The sample consisted of 49 sites obtained from 49 extracted teeth: 11 right maxillary third molars, 10 left maxillary third molars, 15 right lower third molars, and 13 left lower third molars. The losses were due to teeth sectioned during surgery. There was no loss in teeth sectioned for microscopic examination.

Diagnosis of caries activity using methyl red showed 14 (28.5%) active and 35 (71.4%) inactive lesions. Methyl red identified 9 active enamel lesions and 5 active lesions in dentin. The LAA correctly classified 11 lesions (7 enamel and 4 dentin) (Table 1).

Histologic examination showed nine healthy sites (16.32%), 10 (20.4%) lesions extending to the outer half of the enamel (D1), 23 (46.9%) lesions extending to the inner half of the enamel and outer third of the dentin (D2), and 7 (14.28%) lesions to the inner or middle third of the dentin (D3) (Table 2). No significant differences were found between the analysis performed with one tooth per patient and that performed with more than one tooth per patient.

ICDAS-LAA Activity Criteria

The intraexaminer agreement for the ICDAS-LAA activity criteria was $k = 0.61$, which was considered good.[12] The ICDAS-LAA diagnosed 32 active lesions (65.1%), 16 (32.6%) sound sites, and one (2.0%) inactive lesion. Sound sites and inactive lesions were grouped for analysis in histologic and clinical outcomes. Compared with the methyl red gold standard, 25 sites (51.0%) were correctly classified (Table 1). Of the seven dentin lesions, LAA classified six as active and one as inactive lesions.

Table 3: *Specificity, Sensitivity, Accuracy, and Az (95% CI) for ICDAS-LAA in Relation to Methyl Red Stain*

ICDAS-LAA	Specificity	Sensitivity	Accuracy	Az
All surfaces[a]	0.40 (0.24–0.58)	0.78 (0.49–0.95)	0.51 (0.37–0.63)	0.59 (0.42–0.77)
Enamel[b]	0.42 (0.22–0.63)	0.78 (0.40–0.97)	0.51 (0.34–0.68)	0.59 (0.38–0.81)
Dentin[c]	0	0.80 (0.28–0.99)	0 (0–0.84)	0.40 (−0.064–0.86)

Abbreviations: Az, area under the receiver operating characteristic curve; CI, confidence interval; ICDAS-LAA Lesion Activity Assessment used in conjunction with the International Caries Detection and Assessment System.
[a] Scores 0–4 according to the histologic criteria.
[b] Scores 1–2 according to the histologic criteria.
[c] Scores 3–4 according to the histologic criteria.

The sensitivity, specificity, accuracy and Az for the ICDAS-LAA activity criteria were 0.78, 0.40, 0.51 and 0.59, respectively (Table 3).

ICDAS-LAA Severity Criteria

The intraexaminer agreement for the ICDAS-LAA severity criteria was kw = 0.60, which was considered good. [12] The disagreements were related to noncavitated lesions scored 0 to 2 (Table 2).

The ICDAS determined 67.3% of cavitated and noncavitated lesions (44.8% enamel and 22.4% dentin lesions). In relation to the gold standard, correct diagnoses were obtained for four healthy sites (8.16%), two D1 (4.0%), ten D2 (20.4%), and five D3 (10.2%) lesions (Table 2). The Spearman correlation coefficient (0.515) demonstrated a moderate correlation with the gold standard (p=0.01). Table 4 displays the specificity, sensitivity, accuracy, and Az for the ICDAS severity criteria. The highest sensitivity (0.71), specificity (0.86), accuracy (0.83), and Az (0.79) values were observed at the D3 threshold.

DISCUSSION

This study investigated the clinical performance and validated the LAA used in conjunction with the ICDAS for the diagnosis of occlusal caries in permanent teeth. Assessment of caries activity using the ICDAS-LAA criteria was reproducible but had low accuracy.

Sensitivity and specificity are test properties used to quantify diagnostic ability. Sensitivity is the proportion of true positives that are correctly identified by the test. Specificity is the proportion of true negatives that are correctly identified by the test. Sensitivity and specificity are proportions; thus, CIs were calculated to express their variabilities.[13]

The presence of dental biofilm is a predictor of lesion activity, but the ICDAS system requires that it be removed before the initial examination to accurately access the lesion. Thus, biofilm could not be used. Therefore, the criteria of whether or not the lesion was located in a stagnation area was used as a substitute for biofilm accumulation as, under normal conditions, lesion progression will occur only in biofilm stagnation areas.[6] In the present study, the teeth were not in occlusion and all the occlusal surfaces were considered stagnation areas. This was a shortcoming of the study as all the sites were considered a stagnation area without actually assessing the presence of biofilm.

The low accuracy found for LAA in the present study may be because of the difficulty of examining the occlusal surface of third molars. Their distal position limits the light access, and gingival flaps hamper the maintenance of dry surfaces for the visual examination. Furthermore, the use of methyl red for the activity validation can be considered a subjective method that has limitations.[8] Nowadays, no accepted gold standard is available to differentiate between an active and an arrested lesion upon single examination. To overcome this lack of an accepted gold standard, a known theoretical condition, which is associated with caries activity, can be

Table 4: *Specificity, Sensitivity, Accuracy, and Az (95% CI) for ICDAS at the D1, D2, and D3 Thresholds*

ICDAS	D1	D2	D3
Specificity	0.44 (0.30–0.57)	0.68 (0.55–0.81)	0.86 (0.76–0.94)
Sensitivity	0.71 (0.59–0.83)	0.66 (0.53–0.79)	0.71 (0.59–0.83)
Accuracy	0.65 (0.52–0.78)	0.67 (0.54–0.80)	0.83 (0.73–0.93)
Az	0.57 (0.44–0.70)	0.74 (0.61–0.86)	0.79 (0.67–0.90)

Abbreviations: Az, area under the receiver operating characteristic curve; CI, confidence interval; ICDAS International Caries Detection and Assessment System; D1, outer half of the enamel; D2, the inner half of the enamel and outer third of the dentin; D3, the inner or middle third of the dentin.

used as "construct validity."[6] The critical pH for the demineralization of enamel is 5.5,[7,11] and methyl red changes from yellow to red in the pH range of 4.4 to 6.0.[11] Based on this pH range, methyl red may not be capable of adequately classifying some lesions. Certain active lesions with only a slight degree of demineralization may exhibit yellowish staining.[8,11]

A previous study compared methyl red dye to polarized light microscopy examination of teeth sections imbibed in quinolone to assess caries activity based on acid production. Comparison of these techniques showed 85% agreement. Considering the tooth loss after sectioning for polarized light microscopy, the use of the simple dye method was justified to histologically distinguish active and inactive lesions.[11] Therefore, this method was chosen because of practicality and comparability with other *in vivo* studies. [8,11]

Intraexaminer agreement for the activity criterion was lower than that reported in clinical studies on primary[8] and permanent teeth.[6] This could be due to the subjectivity of the criterion as well as the different experiences of the examiners using ICDAS-LAA system.

The gold standard showed 81.6% of carious lesions involving enamel or dentin. Similar results were found for third molars examined in 19- to 30-year-old Brazilians (81.8%).[14] A frequency of 95% was reported in premolars and molars in 18- to 35-year-old Brazilians after histologic validation.[15] These high caries frequencies may be attributed to the patients' risk of lesion development during the eruption of permanent molars. The complex occlusal anatomy, the difficulty in performing hygiene, and the lack of occlusal contact can contribute to the stagnation of biofilm.[11,16,17] The use of third molars is a possible shortcoming of validation studies in permanent teeth. The present study could not be carried out on first and second molars because they are rarely extracted. First and second permanent molars have a more pronounced groove-fossa system than third molars.[11] However, third molars may be difficult to clean, simulating the condition in which patients are not removing biofilm and occlusal caries can develop within a year after tooth eruption.[17]

A risk assessment for dental caries was not performed and that could have affected the outcome. If we had selected only high- or low-risk patients the caries spectrum could have been different, thereby influencing test performance. However, we focused on selecting patients with teeth available for histologic validation. Risk assessment would be crucial if we aimed to associate the dental caries with the patient's related variables, but it was not the purpose of this study.

This *in vivo* study demonstrates that the ICDAS performance was higher on detecting dentin lesions than enamel lesions. The accuracy for detecting early demineralization on enamel was moderate. The Az showed that ICDAS was poor regarding the diagnosis of dental caries at the D1 and acceptable at the D2 and D3 thresholds.

We expected higher performance of ICDAS for identifying enamel lesions at different depths as Az = 0.86 were previously found for permanent[14] and primary teeth[8] at the threshold D1. The differences in caries frequencies diagnosed using the gold standard and ICDAS may be attributed to the examiner's difficulty in visually differentiating healthy surfaces from those with early signs of enamel caries (ICDAS code 1). A great proportion of false-negatives were found in the present study. From the 16 healthy sites classified by the ICDAS, only 4 were confirmed by the gold standard. Furthermore, from the nine healthy surfaces identified by the gold standard, ICDAS identified five as carious lesions. Healthy sites may be classified as carious, likely because of areas of discoloration, fluorosis, or developmental defects. At the D1 threshold, false-positive rates have greater impact than false-negatives on treatment decision because implementing operative procedures at a healthy site would be the worst decision.

The Az at the threshold D3 was similar to that found in another validation study on permanent teeth.[14] However, in the present study, the frequency of deeper dentin lesions was 14.3%. The sample presented few obviously cavitated lesions and affected the performance of the method, as such lesions are easier to detect.

Detection of dental caries in the early stages is more prone to disagreement between examiners.[8] The visual exam may be impaired by difficulties in examining third molars because of their location and the patient's discomfort during longer exams.[18] Despite these aspects, the intraexaminer agreement regarding ICDAS severity was 0.61 in the present study, similar to that described in *in vivo* studies[19,20] with permanent molars. The exclusion of code 1 of the ICDAS from the analyses, which customarily generates greater disagreement, may explain the higher agreement values reported in a Colombian study.[21]

The correlation between the ICDAS and histologic exam was moderate and lower than that reported in a clinical study with primary teeth.[8] However, another *in vivo* study found lower correlation in permanent teeth.[14] A correlation coefficient of 0.7 or more would indicate a good correlation between the two methods.[14]

The variables evaluated in multiple teeth from one subject are not independent as the individual characteristics play a crucial role in caries development. Nevertheless, the ICDAS-LAA performance was similar when the unit of analysis was one subject or one tooth, resembling findings of previous studies. [6,8]

This study selected a convenience sample that could have included bias. However, the sample size was similar to that of other studies.[8,15] A power of 80% was found using type I error equal to 0.05 and a difference of sensitivities equal to 0.23 (0.93 from Diniz and others[14] compared with 0.70 from our study).[22]

The advent of systematic methods offers dentists the opportunity to enhance their diagnostic skills. However, the proper decision regarding the presence/absence of caries as well as the severity and likely activity of this condition, combined with sociobehavioral aspects of the patient, remains the responsibility of the dentist.

CONCLUSION

The ICDAS proved to be a reproducible method with good performance in detecting carious lesions in the dentin. The ICDAS-LAA criteria were reproducible to assess caries activity but had low accuracy.

Conflict of Interest

The authors have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

(Accepted 15 July 2014)

REFERENCES

1. Ölmez A, Tuna D, & Oznurhan F (2006) Clinical evaluation of DIAGNOdent® in detection of occlusal caries in children *Journal of Clinical Pediatric Dentistry* **30(4)** 287-291.
2. Toraman Alkurt M, Peker I, Arisu HD, Bala O, & Altunkaynak B (2008) In vivo comparison of laser fluorescence measurements with conventional methods for occlusal caries detection *Lasers in Medical Science* **23(3)** 307-312, http://dx.doi:10.1007/s10103-007-0486-2.
3. Diniz MB, Rodrigues JA, Hug I, Cordeiro RCL, & Lussi A (2009) Reproducibility and accuracy of the ICDAS-II for occlusal caries detection *Community Dentistry and Oral Epidemiology* **37(5)** 399-404, http://dx.doi: 10.1111/j.1600-0528.2009.00487.x.
4. Ismail AI, Sohn W, Tellez M, Amaya A, Sen A, Hasson H, & Pitts NB (2007) The International Caries Detection and Assessment System (ICDAS): An integrated system for measuring dental caries *Community Dentistry and Oral Epidemiology* **35(3)** 170-178, http://dx.doi: 10.1111/j.1600-0528.2007.00347.x.
5. Nyvad B, Machiulskiene V, & Baelum V (1999) Reliability of a new caries diagnostic system differentiating between active and inactive caries lesions *Caries Research* **33(4)** 252-260, http://dx.doi: 10.1159/000016526.
6. Ekstrand KR, Martignon S, Ricketts DJ, & Qvist V (2007) Detection and activity assessment of primary coronal lesions: A methodological study *Operative Dentistry* **32(3)** 225-235, http://dx. doi: 10.2341/06-63.
7. Murakami K, Kitasako Y, Burrow MF, & Tagami J (2006) In vitro pH analysis of active and arrested dentinal caries in extracted human teeth using a micro pH sensor *Dental Materials Journal* **25(3)** 423-429, http://dx.doi.org/10.4012/dmj.25.423.
8. Braga MM, Ekstrand KR, Martignon S, Imparato JCP, Ricketts DNJ, & Mendes FM (2010) Clinical performance of two visual scoring system in detecting and assessing activity status of occlusal caries in primary teeth *Caries Research* **44(3)** 300-308, http://dx.doi: doi: 10.1159/000315616.
9. Internacional Caries Detection and Assessment System (ICDAS) Coordinating Committee (2009) *Criteria Manual. International Caries Detection and Assessment System (ICDAS II)*; Retrieved online December 7, 2011 from: http://www.icdas.org/
10. Landis JR, & Koch GG (1977) An application of hierarchical kappa-type statistics in the assessment of majority agreement among multiple observers *Biometrics* **33(2)** 363-374.
11. Ekstrand KR, Ricketts DN, Kidd EA, Qvist V, & Schou S (1998) Detection, diagnosing, monitoring and logical treatment of occlusal caries in relation to lesion activity and severity an in vivo examination with histological validation *Caries Research* **32(4)** 247-254.
12. Zandoná AF, AL-Shiha S, Eggertsson H, & Eckert G (2009) Student versus faculty performance using a new visual criteria for the detection of caries on occlusal surfaces: An in vitro examination with histological validation *Operative Dentistry* **34(5)** 598-604, http://dx.doi:10.2341/08-082-L.
13. Altman DG, & Bland JM (1994) Diagnostic tests 1: Sensitivity and specificity *BMJ* **308 (6943)** 1552.
14. Reis A, Mendes FM, Angnes V, Angnes G, Grande RHM, & Loguercio AD (2006) Performance of methods of occlusal caries detection in permanent teeth under clinical and laboratory conditions *Journal of Dentistry* **34(2)** 89-96, http://dx.doi.org/10.1016/j.jdent.2005.04.002
15. Diniz MB, Boldieri T, Rodrigues JA, Santos-Pinto L, Lussi A, & Cordeiro RCL (2012) The performance of conventional and fluorescence-based methods for occlusal

caries detection. An in vivo study with histologic validation *Journal of the American Dental Association* **143(4)** 339-350.

16. Kuhnisch J, Berger S, Goddon I, Senkel H, Pitts N, & Heinrich-Weltzien R (2008) Occlusal caries detection in permanent molars according to WHO basic methods, ICDAS II and laser fluorescence measurements *Community Dentistry and Oral Epidemiology* **36(6)** 475-484, http://dx.doi: 10.1111/j.1600-0528.2008.00436.x.
17. Ekstrand KR, & Bjørndal L (1997) Structural analyses of plaque and caries in relation to the morphology of the groove-fossa system on erupting mandibular third molars *Caries Research* **31(5)** 336-348.
18. Novaes TF, Matos R, Raggio DP, Imparato JCP, Braga MM, & Mendes FM (2010) Influence of the discomfort reported by children on the performance of approximal caries detection methods *Caries Research* **44(5)** 465-471, http://dx.doi:10.1159/000320266.
19. Bailey DL, Adams GG, Tsao CE, Hyslop A, Escobar K, Manton DJ, Reynolds EC, & Morgan MV (2009) Regression of post-orthodontic lesions by a remineralizing cream *Journal of Dental Research* **88(12)** 1148-1153, http://dx.doi:10.1177/0022034509347168.
20. Zandoná AF, Santiago E, Eckert G, Fontana M, Ando M, & Zero DT (2010) Use of ICDAS combined with quantitative light-induced fluorescence as a caries detection method *Caries Research* **44(3)** 317-322, http://dx.doi: 10.1159/000317294.
21. Cadavid AS, Arango-Lince CM, & Cossio-Jaramillo M (2010) Dental caries in the primary dentition of a Colombian population according to the ICDAS criteria *Brazilian Oral Research* 24(2) 211-216, http://dx.doi.org/10.1590/S1806-83242010000200014.
22. Obuchowski NA, & McClish DK (1997) Sample size determination for diagnostic accuracy studies involving binormal ROC curve indices *Statistics in Medicine* **16(13)** 1529-1542