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Review Article

How Valid are Visual Tactile Criteria for Diagnosing Initial Dental Caries?

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Abstract

Background: There is no global consensus on the criteria for diagnosing early carious lesions, despite a vast quantity of words on the subject. There are different traditions about defining a lesion in the grey area, where it is difficult to tell whether the disease is irreversibly established or not. Apart from inherent problem of diagnosing a borderline lesion, the major philosophical issue is how to score an early carious lesion that has not yet become cavitated when diagnosed clinically. Such a lesion appears as a discoloured fissure without loss of substance, as a 'white spot' on visible smooth surfaces. Because there are usually more non cavitated than cavitated lesions at any one time in both high – caries and low – caries populations, the decision as to whether to include or exclude them, and how to express them if included, can make a substantial difference in the oral health profiles obtained.

Aim: Critical review of visual and visuo tactile criteria to diagnose initial dental caries.

Keywords: Incipient Caries; Visual Criteria; Validity; Reliability

Introduction

During the last 100 years, the dental profession has made significant progress in reducing the burden of dental caries in economically developed countries [7]. The scientific and technological advances during the 20th century have profoundly revolutionized the dental practice and disease management. However, dental caries still represents the major chronic disease afflicting humans, the application of understanding of the dynamic process of caries development has not yet been widely incorporated into dental practice and research. Criteria systems used for the clinical detection of caries lesions have not yet been scrutinized according to standard protocols that are in use in social and clinical sciences i.e. inculcating social and clinical entities while applying for dental caries. The importance of the "first step" (i.e., detection and diagnosis) in caries management has not been widely recognized.

Visual examination is the most commonly used method for detecting caries, because it is an easy technique which is routinely carried out in clinical practice. Visual examination has been shown to have a high specificity (proportion of sound sites correctly identified) but low sensitivity (proportion of carious sites correctly identified) as well as low reproducibility, the latter because of the subjective nature of the procedure. The use of detailed visual systems could improve sensitivity and help to minimize subjectivity in individual examiners' interpretations of the varying characteristics of a lesion, thus improving reproducibility. Such systems may also describe the characteristics of all clinically relevant stages in the caries process, making them a cost-effective method of recording caries [7].

Terms such as early enamel caries, incipient lesion, and demineralization and non – cavitated lesion are synonyms for precarious lesions. This lesion represents an early stage in caries progression when remineralisation is possible. Non – cavitated enamel lesions retain most of the original crystalline framework that serves as a nucleating agent for remineralization. In the mouth a remineral-

ized lesion appears as a brown or discoloured spot. These discoloured, remineralized areas are thus more resistant to subsequent caries attack than the adjacent unaffected enamel [2].

It has been shown that diagnosis of caries at the cavitation level results in a significant underestimation of the actual caries experience in populations [3]. In the past recordings of non – cavitated caries lesions was deliberately avoided due to the belief that it is not possible to achieve a reliable diagnosis of precavitation stages of caries. Several criteria have been proposed to reduce the subjectivity, increase sensitivity and monitor lesions at an early stage (precavtation) and evaluate activity [4].

Use of caries diagnostic system which includes non – cavitated caries has the distinct advantage that the classical stages of the lesion formation, development of the cavitation through non- cavitated stages of caries may be reflected in the recordings. Measurement of the incipient or non- cavitated carious lesions increases the sensitivity and efficiency of the clinical trial. Also, given the wealth of information about the possibility of remineralization of the early carious lesions and how dental practitioners and patient can influence this protective process, diagnosis of early carious lesions is a necessary first step for the secondary prevention of dental caries. The necessity to detect lesions at the earliest is essential in realm of current cariology because, if detected early these lesions can be remineralized using non-interventional or preventive therapy [5].

The questions and challenges before us today require an examination of how one should manage dental caries in the future given our understanding of dental caries, its risk factors and prevention. The prevention of dental caries today must be based on appropriate detection of dental caries in its earliest stages; hence as dentists, we should not only detect cavities but also early signs of demineralization and disease activity. If the goal of management of dental caries is the preservation of tooth structure and promotion of oral health, then without doubt the early detection of pre- cavitated carious lesions is imperative for achieving it [6].

Hence the aim of the present review is to evaluate the validity and reliability of visual and visual – tactile criteria in initial caries detection.

Non cavitated lesion

A non-cavitated lesion is a caries/carious lesion whose surface appears macroscopically intact. In other words, it is a caries lesion without visual evidence of cavitation. This lesion is still potentially reversible by chemical means, or arrestable by chemical or mechanical means.

White-spot lesion

This is a non cavitated caries/carious lesion that has reached the stage where the net subsurface mineral loss has produced changes in optical properties of enamel such that these are visibly detectable as a loss of translucency, resulting in a white appearance of the enamel surface. However, it must be noted that although initial lesions appear as a white, opaque change to the naked eye, not all white – spot lesions are either initial or incipient, as they may be presented for many years and may involve enamel and/or dentin.

Brown spot lesion

A brown spot lesion is a non-cavitated caries/carious lesion that has reached the stage where the net subsurface mineral loss in conjunction with the acquisition of extrinsic or exogenous pigments has produced changes in optical properties of enamel such that these are visibly detectable as a loss of translucency and a brown discoloration, resulting in a brown appearance of the enamel surface [13].

Differences between nonactivated and cavitated lesion (Nyvad., et al. 1999)

The typical characteristics of an active non-cavitated enamel caries lesion are those of a whitish/yellowish opaque surface with loss of luster, exhibiting a chalky or neon-white appearance. The surface feels rough when the tip of a sharp probe is moved gently across it. By contrast, in active enamel caries lesion are generally shiny and feel smooth on gentle probing. The color of inactive enamel caries lesions may vary from whitish to brownish or black, but color is not a reliable differential diagnostic characteristic.

The chalky opacity of an active non-cavitated enamel caries lesion related to two discrete phenomena. First, the opacity is explained by the increase in the internal porosity of the lesion due to subsurface demineralization. The second phenomenon is caused by dissolution of the outermost inter crystalline enamel spaces. When the surface is eroded the enamel loses its shiny appearance owing to diffuse back scattering of light. This is the very reason why an active enamel lesion may appear whiter, almost neon – like, than an inactive enamel lesion. If an active lesion is exposed to mechanical disturbances in the oral cavity the lesion gradually assumes a smooth surface; however, the internal opacity often persists.

The shape of the white spot lesion is determined by the distribution of the microbial deposits between the contact facet and the gingival margin, which results in a kidney shaped appearance. On the proximal smooth surface there will typically be an interdental facet surrounded by an opaque area extending in the cervical direction. The cervical border of the lesion is formed according to the shape of the lesion [2].

Visual characteristics of initial caries lesion

- **Loss of the gloss of the enamel:** The first and most early change detectable by means of visual observation. This criterion was there for a condition that triggers the carious process. The gloss loss is detected under dental plaque after cleaning and continuous drying and airing.
- **Loss of transparency:** The enamel loses its transparency. The condition is detected after the dental plaque has been removed and 5- second
- **Loss of smoothness:** The enamel surface of the lesion observed loses its smoothness. Becomes rough but without cavitation.
- **Borders of enamel lesion:** The link between the healthy enamel and the lesion. The borders can be clearly delineated, diffuse or unrestricted.

Discussion

It is unfortunate that the current standard for detection and assessment of dental caries in planning for dental public health programs in most countries is based on the World Health Organization (WHO) [1997] [8] or National Institute of Dental and Craniofacial Research (NIDCR) [Radike, 1968 [9]; NIDCR, 1987] criteria which measure dental caries at the cavitation or 'softness' level [10]. There are several criteria systems which detect the precavitated lesions. Some of them we have critically reviewed which are as follows:

Caries detection criteria by Nyvad's diagnostic system differentiate between active and inactive caries lesion. This system has been shown to have good reliability and also construct and predictive validity for assessment of caries activity [9]. In this system, if the lesion is active and cavitated, operative treatment is recommended. If active and non-cavitated, non-operative, preventive treatment is recommended. Up to now, the ability of the Nyvad system to estimate lesion depth has not been evaluated [11].

This system provides a better guidance on the appropriate management options for caries lesions. The use of these clinical criteria results in the detection of substantially more approximal caries lesions than the traditional bitewing radiographic method as shown in the studies by Machiulskiene V., *et al*. in 1999 and 2004 [12] and there by provides means for improving the non – operative management of caries. Studies have shown that inter examiner and intra examiner agreement can be high for the diagnosis of non cavitated lesions following extensive training and calibration of the examiners in the epidemiological surveys. The inter and intra examiner agreements were 0.70 and 0.69 respectively [13].

When we compare the Nyvad's criteria with def index we can see that the system proposed by Nyvad evaluates caries from initial or precavitated lesion, while the def index counts the disease only when it is in the cavitation state, thus underestimating the prevalence and severity of the caries [14].

When the Nyvad's criteria was compared with Assessment of activity by the LAA (lesion activity assessment) system it was seen that in the Nyvad system, only one score can be attributed to all observed characteristics of the lesion, which is eventually classified as inactive or active. Therefore, in this system, if a lesion presents at least one feature compatible with an active lesion, the examiner should classify the lesion as active. Using the LAA, if a lesion presents with two clinical criteria that are compatible with an active lesion and another that is not, the first two criteria would weigh more than the single factor [15].

To propose an internationally accepted caries detection system, a new index for caries diagnosis, the International Caries Detection and Assessment System, was created in 2002 by a group of cariologists and epidemiologists, based on visual examination aided by WHO probe. The short name of this system is ICDAS. This system is modification of a previous visually ranked caries lesion scoring system that has been shown to detect occlusal lesions in permanent teeth and to assess their depth with acceptable accuracy and reproducibility [16].

The validity of ICDAS has been tested and expressed in many ways. For example, ICDAS has presented content validity i.e. the system is comprehensible for describing and measuring degrees of severity of caries lesions17. ICDAS is designed to meet the following concepts of content validity:

1. Measure stages of the carious process rather than just the 'decayed' stage

2. Provide, detailed exclusion criteria of non-carious lesions (staining, fluorosis, opacities)
3. Define the terms and descriptions used to measure the caries process.

Another method to validate caries criteria is based on the quantitative correlation between the clinical assessment of tooth surfaces with histological presence or extent of demineralization in enamel and dentin [17].

In primary teeth, ICDAS cannot distinguish accurately between lesions related to the outer or inner half of the enamel; this can be done accurately in permanent teeth. One explanation for this difference in performance is that the enamel in primary teeth is much thinner compared with permanent enamel.

ICDAS has discriminatory validity i.e. it can discriminate among groups of children and adults with different exposure to risk factors. ICDAS can discriminate between risk groups. For example, using dental caries data collected using ICDAS, Burt., *et al*. [18] reported that caries prevalence in adults was extensive with 82.3% of the adults having at least one cavitated lesion. They also found that dental caries severity assessed using the non cavitated, cavitated lesions, missing and filled tooth surface in bivariate analysis, was associated with frequency of soft drink consumption and presence of gingival plaque deposits. The ICDAS criteria discriminated between groups based on their different exposures to soft drinks as well as oral hygiene status. ICDAS has validity when overall severity is assessed in a population [16]. When ICDAS was used by examiners who had no previous experience in epidemiological dental examination it was seen that each one was able to reproduce it, thus showing the reliability of the caries detection system.

Initially ICDAS was devised as a detection system for primary caries. Adjunct criteria have recently been devised for activity assessment. Thus, the system can be used for caries lesion activity assessment (LAA) also [20]. The LAA is based on the combined knowledge of clinical appearance of the lesion, whether the lesion is in plaque stagnation area and the tactile sensation when a ball – ended WHO probe is gently drawn across the surface of the tooth. Such criteria related to activity receive an individual score based on predictive value in determining activity status, and the sum of these points is judged based on a cut – off point. These individual criteria have presented moderate to good intra and inter examiner reproducibility values as well as good reproducibility results for the system overall. This system also presented construct validity i.e. the system can reflect theoretical concepts regarding the caries process [13].

Two studies have already used the ICDAS + LAA system in caries activity assessment [13]. Results of both studies have suggested that use of this system could overestimate caries lesion activity status for primary teeth, because cavitated lesions invariably would be considered active, which is not certain in all cases.

Using ICDAS in combination with LAA criteria, it is possible to detect lesion, estimate its depth or severity and assess its activity, which are all fundamental prerequisites for the diagnosis and management of the individual lesion [13].

One of the purposes of ICDAS -2 system is to overcome this short fall, to characterize and describe the earliest visible changes due to caries on all coronal caries through to frank cavitation and how these stages relate to the histopathology of the disease. The ICDAS – 2 is a standardized approach to recording and characterizing carious lesions that relate to the histopathology of the disease, this system could be for use by researchers, epidemiologists, clinicians and teachers [17]

According to a study ICDAS – 2 is feasible in epidemiological surveys in preschool children. It was seen that the mean examination time with ICDAS -2 was almost twice as long as with WHO system and the longer examination time could be a limiting factor in using ICDAS- 2 in caries surveys. Though the above statements contradict each other, ICDAS – 2 has content validity of 0.9 in primary teeth, hence feasibility is good in preschool children [16]. ICDAS -2 demonstrates reproducibility and diagnostic accuracy for the detection of occlusal caries at varying stages of the disease process. The weighted kappa values for inter and intra examiner reproducibility for the ICDAS – 2 examination were 0.62 – 0.83 [18].

Both the ICDAS caries detection systems 1 and 2 are valid and reliable for detecting caries and predicting the depth of the lesion at any coronal surface, as the ICDAS – scoring system have their origins devised for occlusal caries by Ekstarnd. Ekstarnd's criteria very clearly differentiate cavitated and non cavitated lesions in the following manner

- 0 = No or slight change in enamel translucency after prolonged air drying.
- 1 = Opacity (white) hardly visible on the wet surface, but distinctly visible after air drying.
- 1a = Opacity (brown) hardly visible on the wet surface, but distinctly visible after air drying.
- 2 = Opacity (white) distinctly visible without air drying.
- 2a = Opacity (brown) distinctly visible without air drying.
- 3 = Localized enamel breakdown in opaque or discolored enamel and/or grayish discoloration from the underlying dentin
- 4 = Cavitation in opaque or discolored enamel, exposing the dentin beneath).

The use of ICDAS system allows evaluation of both non cavitated and cavitated lesions. This helps to detect associations more sensitively during a short follow up period, thereby decreasing the duration of clinical trials [17].

The next system is the Dundee Selectable Threshold Method (DSTM) for caries diagnosis (PITTS and FYFEE, 1988)

- D0: Healthy enamel
- D1a: The earliest of the visually detectable lesions. It is found under a big quantity of plaque, usually cervical. The size coincides with the location of the tooth plaque. No pigmentation is seen. Becomes visible after tooth plaque has been removed by means of professional hygiene. Continuous drying and airing is needed. Only then the lesion becomes discernable from healthy enamel. Within the lesion the enamel has lost its gloss. Hardly detectable if drying has not been applied.
- D1b: White enamel lesion, clearly visible no cleaning and drying being conducted. It can be active, stationary or regressing. Depending on its activity the lesion can have the qualities of each of these types. It can also be combined. Must be studied for gloss, smoothness, borders and plaque. At this stage micro porosity can be discovered, but no enamel cavitation is found.
- D2: White enamel lesions within which one or a couple of small cavitations or one bigger and deeper can be seen. Around these cavitations a white diffuse active lesion is usually located. Zones of gradual transition to healthy enamel can be observed. The lesions are restricted and clearly delineated which is indicative of the lesions becoming stationary. Accordingly, the diffuse and broad lesions are indicative of progression of the lesion
- D3: Dentin caries
- D1a: Lesion is the border between the healthy and carious enamel.

The inter examiner agreement at the D_1 and D_3 diagnostic thresholds showed that kappa values were higher at the D_3 threshold for teeth and surfaces ($p < 0.01$). When the threshold criteria were used by novice examiner the mean sensitivity ranged from of 0.18 for identification of decayed surfaces at the D_3 level. When used by experienced examiners the mean sensitivity was 0.52 for decayed teeth at the D_3 diagnostic threshold than at the D_1 threshold. There is no consistent loss in the survey examiner ability to detect disease using the Dundee Selectable Threshold Method for caries diagnosis (DSTM) [20]. Mean specificity values for the diagnosis of caries using $D_1 – D_3$ threshold ranged from 0.93 to 1.00 and were significantly higher at D_3 than at D_1. The predictive value positive i.e. the probability of the tooth being carious when tooth has been recorded as carious, ranged from 0.48 to 0.93 and was consistently higher at the D_1 diagnostic threshold. The predictive value negative which gives the probability that a tooth or surface as caries free will be caries free, ranged from 0.58 to 1.00 and were consistently and significantly lower at D_1 than at D3 [19]. The important point to be made, however, is that although the individual examiners showed differences in intra examiner reproducibility according to the criteria, little difference were found in their ability to diagnose with similar level of reproducibility at each diagnostic threshold.

Using the DSTM it was demonstrated that the diagnostic threshold had a major impact on reported caries prevalence, indicating the level of underestimation of total caries levels as recorded at the D_3 diagnostic threshold. DSTM criteria emphasize the need for diagnostic threshold to be reported whenever caries prevalence data are discussed. It was also demonstrated that diagnostic threshold also had a major effect on dental health needs assessment and allowed identification and estimation of the proportion of the study population requiring preventive and restorative care. It is also possible to report at the D_2 diagnostic threshold which may be of value for those assessing caries diagnostic technologies but is of limited relevance to conventional dental epidemiology [20].

The next criteria we are going to discuss is about the WHO + Initial Lesion (IL) diagnostic threshold. When WHO diagnostic

threshold was compared with WHO + IL diagnostic threshold under epidemiological conditions, there were significant differences in caries detection for all age groups [20]. 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 decayed surfaces, to 95.64% for the dmfs. There were significant differences between the WHO threshold and WHO+ IL threshold when performed under clinical setting for all age groups. The percentages of observed epidemiological examination outcomes with the clinical setting examination outcomes as a reference varied from 76. 15% for decayed surface to 99.09% for the dmfs [20].

Mean inter examiner agreement measured by kappa statistics was 0.88 for the WHO+IL threshold. However, the relevant errors were related to IL diagnosis, mainly those isolated and contiguous to sealants. One of the reasons for the low results for IL is that they are the results of crossroads among all the examiners in relation to each specific dental condition.

Higher Kappa results could probably obtain if a smaller group of examiners participated in the study. The poor IL diagnosis may be justified because of the inherent difficulties in diagnosing IL, mainly under epidemiological conditions. For these reasons, new training sessions that include the use of extracted teeth with IL lesions, as well as use of artificial light during examinations, should be recommended in order to improve the examiners' diagnosis under these specific conditions [21].

When compared with the threshold based in the diagnosis of cavities (WHO), the inclusion of IL in surveys clearly has a major effect on the assessment of dental health needs, as it allows the proportion of the studied population requiring preventive and restorative care to be identified and estimated. Its use should be appropriately indicated, as there are some situations in which the inclusion IL would enhance the value of the survey data, and others in which additional cost would not be offset by additional benefits. It may be beneficial, for instance, to include IL in studies that involve the natural history of caries and its treatment. To demonstrate differential affects between different formulations of caries preventive agents, like fluoridated toothpastes; and in clinical trials or in surveys being conducted to plan oral health programs. The inclusion of ILs within epidemiological surveys is likely to establish a clearer relation between the epidemiological estimates of dental caries prevalence and the treatment needs. As the ILs require preventive treatment and not restorative, its inclusion in epidemiological surveys establishes a relation between the caries prevalence and the treatment needs. On the other hand, including IL in national surveys only to obtain descriptive information on the populations dental health would not only be very expensive, but it would also be of less apparent value [22].

The most recent criteria for diagnosing initial dental caries is Universal Visual Scoring System (UniViSS) should be understood as an addition to existing methods, used to visually describe the clinical appearance of non- cavitated carious lesions as precise as possible. Different to existing visual systems for caries detection/diagnosis, which are essentially a sequence of criteria from healthy to severely decayed, UniViSS uses a three - step diagnostic procedure to classify in detail the complex clinical appearance of carious lesions. These three steps are:

- Severity assessment (the severity also determines the detection level, if caries lesion is present)
- Discoloration assessment
- Activity assessment

Due to the meticulous classification of all possible stages of the caries process UniViSS can register logically the clinical appearance of all kind of carious lesions. UniViSS uses clinically accepted and validated criteria such as white and brown opacities, microcavities, occurrence of enamel breakdowns and grey translucencies. But with white-brown discolorations UniViSS adds a new criterion that appears for many lesions in the clinical practice.

Conclusion

- Effectiveness of a visual tactile caries examination depends strongly on the caries diagnostic level used.
- Visual tactile caries examination is quick and easy to perform in both clinical and epidemiological set up as it does not require expensive equipment and prevents unwarranted radiation exposures.

Visual tactile criteria by Nyvad., *et al.*

- Have predictive value for lesion activity, which means that they are highly relevant for clinical decision making.
- Reflect the current evidence-based management options for different stages of carious lesion
- Can be applied for all entities of caries including root surface caries and recurrent caries.

ICDAS

- Can be used *in vitro* studies as well as clinical studies (validation study, secondary caries, epidemiology, study on caries risk factors and clinical trial), in different dentitions (primary and permanent teeth), in different age groups (children, teenagers, young adults, adults) and by multiple examiners with different backgrounds as well as previous exposure and experience with the criteria.

DSTM criteria

Useful in cariology research studies, for it permits identification of lesion initiation, progression and regression.

Universal visual scoring system (UniViSS)

Useful in epidemiological setting as the procedure is simple and practicable and each carious diagnosis can be linked with distinct treatment strategy.

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Volume 3 Issue 10 October 2019