

Methodology and Development of the Universal Visual Scoring System (UniViSS) for caries detection and diagnosis

Abstract

Given the limitations of adjunct diagnostic tools, e.g. imperfect reproducibility/ validity, the difficulties in controlling confounding factors, etc., it seems desirable to improve visual caries detection and diagnosis. Our work therefore aimed at systematising caries lesions as precisely as possible with one Universal Visual Scoring System (UniViSS). The development of UniViSS was influenced mainly by the publications of Ekstrand et al. [1998], Nyvad et al. [1999] and the recently introduced ICDAS criteria. More than 1500 photographs of different grades and stages of caries on occlusal and smooth surfaces were used to classify all kinds of lesions. UniViSS was systematically modified and improved using the authors' experience and the results of dental screenings of children in industrialised and developing countries. UniViSS is essentially a three-step evaluation procedure: (1) lesion detection and severity assessment (first signs, established lesion, microcavity, dentine exposure, large cavity, pulp exposure); (2) discoloration assessment (white, white-brown, brown, greyish translucency); and (3) activity assessment. UniViSS allows the classification of different types of caries lesions on occlusal and smooth surfaces in primary and permanent teeth with one setup under clinical, field and laboratory conditions. However, the validity and reproducibility of the system need to be further investigated.

Introduction

Visual caries detection and diagnosis is a key area of responsibility for dental practitioners, epidemiologists, clinical teachers and scientists. While the application of the DMF index [28] as a basic oral health measure will continue due to its worldwide acceptance, its convenience and the possibility to compare past dental data with future findings, the need to consider non-cavitated caries lesions in order to stay abreast of the changing clinical appearance of caries in industrialised countries is now being recognised. The development of the ICDAS criteria as the logical follow through of earlier studies carried out by Ekstrand et al. [3] and Nyvad et al. [23] has been a major step towards this goal. Being able to categorize non-cavitated lesions with only a few criteria while also indicating the caries stage is the ICDAS group's main aim. However, due to the fact that the clinical appearance of carious lesions is complex, a limited set of criteria seems to be unlikely to describe the clinical appearance as precise as possible. The ICDAS II criteria do no longer, for example, distinguish between white and brown discolorations [10, 11], which, in fact, provide important information about lesion activity [6] and are essential for comprehensive caries monitoring in longitudinal studies. The previously used differentiation according to Ekstrand et al. [3, 4] nevertheless proved useful and practicable in our own studies [9]. Further, the classification of lesions with both white opacities and brown discolorations on the other hand was difficult as well as distinguishing precisely between brown discolorations and microcavities. These clinical experiences as well as the fact that adjunct diagnostic methods, e.g. fluorescence measurements, electrical resistance measurements and quantitative light-induced fluorescence measurements do not perform as satisfactorily on non-cavitated occlusal surfaces as was hoped [7, 8, 16-18] constitute the main drivers for the favoured improvement of visual caries detection and diagnostic

approaches. It was hence the aim of the present work to improve visual caries diagnostics on occlusal and smooth surfaces in primary and permanent teeth that is universally applicable and takes into account all possible lesion stages. Additionally, the system should compensate inaccuracies of existing scoring systems, fulfil the current requirements for caries detection and diagnostic methods as well as be adjustable [24].

Material and Methods

Selection of criteria

The methodical development of the Universal Visual Scoring System (UniViSS) was mainly based on the WHO basic methods [28], the criteria of Ekstrand et al. [3] and Nyvad et al. [23], Ismails' [12] systematic review of published visual detection/diagnostic methods as well as on the recently introduced ICDAS criteria [10, 11]. This means that the system described here uses clinically accepted and validated criteria such as white and brown opacities, microcavities, occurrences of enamel breakdowns and grey translucencies. But with white-brown discolorations UniViSS adds a new criterion that appears for many lesions. Deep cavities with pulpal involvement were likewise considered since they are commonly associated with early childhood caries while also occurring with frequency in the permanent dentition of patients in developing countries, where caries remains often untreated. By matching them against our image database, which currently contains over 1500 high-quality photographs of very different carious lesions from occlusal and/or smooth surfaces of primary and permanent teeth, the criteria were generalised and summarised. For 117 occlusal surfaces histological findings from a preliminary study were also available in addition to the photographs. These data together with the results of previously validated

investigations [2-5, 14, 27] influenced mainly the systematisation of our diagnostic system.

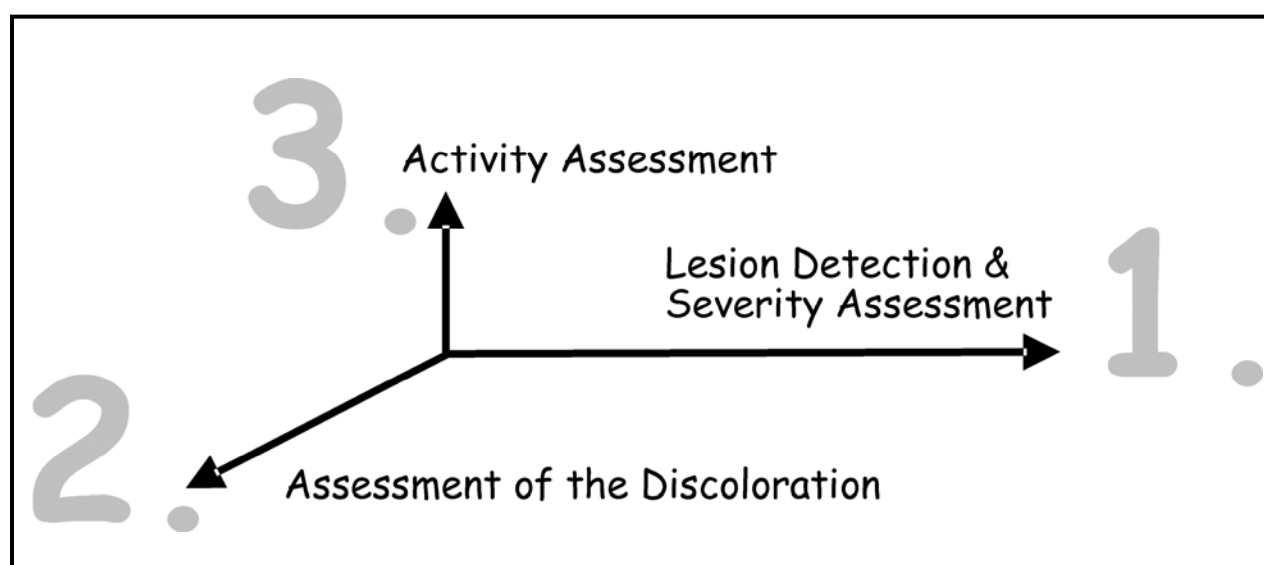
Systematisation of criteria

In difference 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: (1) severity assessment (the severity also determines the detection level, if a caries lesion is present); (2) discoloration assessment; and (3) activity assessment. For step 3 – analysing the activity of a caries lesion – lesion-related factors, e.g. discoloration, location on the tooth surface, presence or absence of plaque and superficial texture/ roughness play an important role in addition to patient-related factors such as age, individual caries risk, oral hygiene, nutrition and fluoride intake. White and white-brown coloured lesions, plaque coverage, roughness and the location in plaque retentive areas are strong indicators of a lesion which is active (Table 1). The lesion activity should be recorded as a Yes/No decision. As a whole, UniViSS can therefore be understood as a three-dimensional system of caries detection and diagnosis (Figure 1).

Table 1 Clinical indicators of inactive and active caries lesions on occlusal and smooth surfaces

Occlusal pits and fissures		Smooth surfaces	
Inactive	Active	Inactive	Active
Persistence of the lesions over years/decades	Detection within some years after tooth eruption	Persistence of the lesions over years/decades	Detection within some years after tooth eruption
No plaque coverage	Plaque coverage	No plaque coverage	Plaque coverage
Glossy, shiny appearance of the enamel surface after air-drying	Matt/ frosty/ rough appearance of the enamel surface after air-drying	Glossy, shiny appearance of the enamel surface after air-drying	Matt/ frosty/ rough appearance of the enamel surface after air-drying
No pathological enlargements	Microcavities	Lesions located in distance to the gingiva	White spots near the gingiva margin
Brown discoloration in enamel	White(-brown) discoloration in enamel	Brown discoloration in enamel	White(-brown) discoloration in enamel
Hard, dry, discolored dentine	Soft, wet, (un)discolored dentine	Hard, dry, discolored dentine	Soft, wet, (un)discolored dentine

Figure 1 Three-step procedure of UniViSS for detection and assessment of caries lesions.



Pre-clinical tests on practicability

The stepwise development of UniViSS happened over several years and was supported by repeated evaluations of the system to its present state. Each time, several experienced dentists assessed the system's status in terms of its practicability, consistence and design under different conditions. The evaluations were followed by an exchange of knowledge and ideas and discussions about possible improvements. The development status of UniViSS was then updated and approved. The following tests were carried out:

- Examination of 40 subjects at two different points in time as part of a general screening. The examinations were done by separate examiners (IG, SB, HS).
- Evaluation of the criteria under field conditions for 12-year olds as part of the standard school examination in a provincial town of the Philippines (RHW).
- Application and assessment in a dental office (TO).
- On-going review of the criteria set as part of patient care in university hospitals and the training of under- and postgraduate students and dentists (JK, RHW).

Results

Our efforts finally led to the development of a visual system for the detection and diagnosis of caries that is universally applicable and adaptable (Figure 2 and 3, detailed descriptions of each criteria can be taken from the electronic supplementary material). The clinical use of the system is very flexible and may be adjusted as required. It is not only possible to choose the most appropriate and goal-oriented criteria set for each case but the examination conditions can also be modified according to what is intended to be achieved. Table 2 summarises the typical parameters. For a better comparability of results and tests the selected examination

details should be specified in each study protocol. The standard examination equipment consists of the CPI probe and the dental mirror. The CPI probe is used to help the metric differentiation between established lesions and microcavities as well as for the pressureless tactile examination of the tooth surface.

Table 2 Summary of possible conditions for the usage of UniViSS

Study type	Tools	Illumination	Tooth cleaning
Field	Cotton rolls	Head lamp	Patient brushed him/herself
Clinical	Magnifying glass/ loop	Examination lamp	Professional tooth cleaning with a bristle brush etc.
Laboratory	Dental unit with air syringe	Operating light of the dental unit	Professional tooth cleaning with air polishing

Figure 2 Criteria of the Universal Visual Scoring System for pits and fissures (UniViSS occlusal).

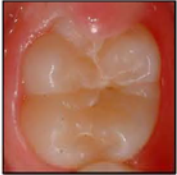



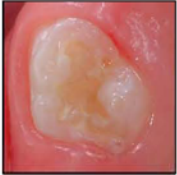













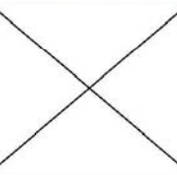



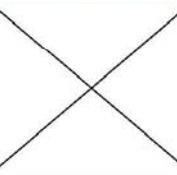
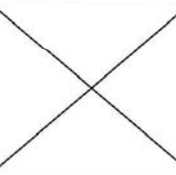

















Universal Visual Scoring System for pits and fissures (UniViSS occlusal)						
Second step: Discoloration Assessment	First step: Lesion Detection & Severity Assessment					
	First visible signs of a caries lesion	Established caries lesion	Microcavity and/or localised enamel breakdown	Dentin exposure	Large cavity	Pulp exposure
	Score F	Score E	Score M	Score D	Score L	Score P
Sound surface (Score 0)	No cavitations or discolorations are detectable.					
White (Score 1)						
White-brown (Score 2)						
(Dark) Brown (Score 3)						
Greyish translucency (Score 4)						

Figure 3 Criteria of the Universal Visual Scoring System for smooth surfaces (UniViSS smooth).

Universal Visual Scoring System for smooth surfaces (UniViSS smooth)						
Second step: Discoloration Assessment	First step: Lesion Detection & Severity Assessment					
	First visible signs of a caries lesion	Established caries lesion	Microcavity and/or localised enamel breakdown	Dentin exposure	Large cavity	Pulp exposure
	Score F	Score E	Score M	Score D	Score L	Score P
Sound surface (Score 0)	No cavitations and/or discolorations are detectable.					
White (Score 1)						
White-brown (Score 2)						
(Dark) Brown (Score 3)						
Greyish translucency (Score 4)						

Discussion

Our universally applicable visual detection and diagnostic system should allow a precise description of non-cavitated and cavitated caries lesions alike. It also shows the clinical diversity of lesion stages from the point of view of the dental practitioner, the epidemiologist and the dental researcher, respectively. The development of UniViSS was influenced by the empirical data obtained during the pre-clinical tests on practicability as well as by the results of epidemiological and diagnostic caries studies by the authors [7, 9, 15-21]. This way, the inaccuracies of existing visual diagnostic systems mentioned in the beginning were compensated. Another advantage worth stressing is the consistency of the criteria for occlusal and smooth surfaces, which means that the system can non-restrictively be used for the examination of both primary and permanent teeth. For smooth surfaces the system's availability extends to the freely accessible vestibular and oral as well as to the approximal surfaces. It also enables the visual detection and evaluation of caries-related cervical defects in older patients.

To make examination data comparable UniViSS was developed following WHO and ICDAS criteria. In this context, UniViSS should mainly be understood as an addition to these two methods, used to visually describe the clinical appearance of (non-)cavitated carious lesions more precisely. According to the authors, it is only under this assumption that: (non-)cavitated lesions can be detected reliably by visual inspection, the diagnostic performance of visual methods can be improved, changes of carious lesions can be detected as part of caries monitoring and caries activity can be assessed more accurately.

In order to assess the activity of carious lesions with UniViSS the degree of discoloration as well as the circumstances from Table 2 need to be taken into account.

As a general assumption, white and white-brown lesions are associated with more active caries lesions, while brown and black lesions normally indicate a slower disease progression. Apart from discolorations, plaque is another aetiological factor that also provides clues to the activity of a caries lesion. Location plays a part here, too. The natural plaque stagnation areas [2], e.g. the vestibular surfaces near the gingival sulcus, the lingual surfaces of the molars in the lower jaw, or the approximal spaces, are difficult to reach with the tooth brush and therefore more likely to be caries susceptible. Whether roughness will gain significance as a valid caries predictor in the future remains to be seen [2].

Since every diagnosis should be linked to specific treatment strategies [25], the clinical consequences of different UniViSS results will be outlined in the following. While active treatment is not considered necessary as such for sound tooth surfaces, the intensification of preventive dental care at home remains the goal for caries risk patients. First visible lesions as well as established lesions should be treated with professional measures, i.e. topical fluoridation and the sealing of pits and fissures, in addition to a more comprehensive home prophylaxis program, to stop caries progression. On microcavities – when the radiograph shows an involvement of the dentine and indicate a bacterial infection – appropriate filling treatment seems to be indicated in most of the cases [26]. Otherwise, the complete sealing of the microcavity constitutes a possible therapeutic option [6, 13, 22]. Restoration is clearly indicated for carious lesions with dentine exposure, greyish translucencies or gross cavitations. The decision between endodontic therapy or extraction after pulp exposure should be carefully weighted based on the individual dental status dentition, the need for follow-up treatment and patients preferences. The measures listed here represent mainly the preventive and therapeutic spectrum for industrialised countries, whereas

fundamentally different strategies might be applicable for similar diagnostic findings in developing countries with limited resources.

Due to the meticulous description of all scores it includes, UniViSS is particularly suited to detailed studies on the clinical appearance of carious lesions. However, by grouping the various criteria its use can be simplified significantly, e.g. for the purpose of epidemiological surveys. For clinical application, the following principles exist:

1. By visual examination the dentists first of all aims to detect and diagnose caries lesions. Secondly, there is a need to decide whether those lesions may be treated with non-invasive/ invasive measures. The classification according to the treatment strategies suggested by Pitts [25] – non-active care advised, preventive care advised and operative care advised – is therefore sufficient. The same applies to the (post)graduate dental teacher.

2. The use of all UniViSS criteria for in vitro studies is always possible thanks to the optimum study conditions. This is also true for well-designed clinical studies.

3. Epidemiological studies normally require a simple and practicable procedure to ensure that the several tests can be carried out efficiently under field conditions, too. The easiest way of doing this is to group all non-cavitated lesions under the same category (Scores F, E, M) apart from registering the cavitated caries lesions (Scores D, L, P = D-component of the DMF index) and to record them as one score for the respective tooth surface. Thus, at least any carious processes that can be observed visually will be captured. While it requires more effort, each of the three diagnostic steps mentioned above (1. severity assessment, 2. discoloration assessment, and 3. activity assessment) may also be included in the study design. In order to ensure the reproducibility of the results the teeth should be cleaned and the examiner(s) should

have received a calibration training prior to the study. The oral cavity needs to be sufficiently illuminated.

Statistical tests of the intra- and inter-examiner-reproducibility should report at least three agreement measures in accordance with the main scores (severity, discolorations and activity) used. Determination of the discoloration and lesion severity can be made with weighted kappa statistics, while Kappa is proposed as the most suitable measure of the reproducibility of the activity (Yes/No decision). In case the diagnostic system is used with more than two examiners, it is advocated that (weighted) kappa values be averaged across all pairs of examiners.

The validity could be evaluated according to the sensitivity, specificity, positive and negative predictive values as well as to the area under the ROC curve (Az). As this procedure lacks by reason of defining clear cut-off values for the diagnostic method we recommend to validate UniViSS with the new developed Caries-Extension-Index [1]. Furthermore, with our current level of knowledge and understanding, it seems hardly possible to validate the activity with standard histological methods as it is primarily a clinical diagnosis, which in addition depends on a lesion progression per definitionem [5]. This means that the activity could be validated by repeated, non-invasive examinations over a specified period of time only.

The present development state of UniViSS seems to allow the precise recording of the entire spectrum of caries lesions with just one visual diagnostic system. After the systematisation of UniViSS is now effectively complete, further studies on its validity and reproducibility are needed.

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UniViss was developed by Jan Kühnisch¹, Inka Goddon², Susanne Berger², Helga Senke², Thomas Oehme³, Reinhard Hicel¹, Roswitha Heinrich-Weltzien⁴

(¹Department of Conservative Dentistry and Periodontology, Ludwig-Maximilians-University of Munich, Munich, Germany, ²Health Department of the Ennepe-Ruhr-District, Schwelm, Germany, ³Dental practice, Lichtenstein, Germany, ⁴Department of Preventive Dentistry, University of Jena, Germany)