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Accuracy and Consistency of the Visual Diagnosis of Exposed Dentine on Worn Occlusal/Incisal Surfaces

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Key Words
Erosion · Enamel · Exposed dentine, diagnosis

Abstract
Most indices for the assessment of wear of various aetiologies include the distinction between 'enamel still present' and 'dentine exposed' for grading. Since the visual diagnosis of exposed dentine has not yet been validated, the present study is a first attempt to investigate its accuracy and consistency. Sixty-one examiners (23 scientists, 18 university dentists and 20 dental students) were asked to diagnose 49 tooth areas with different grades of wear and to decide whether dentine was exposed (positive test) or not (negative test). Afterwards, the teeth were histologically evaluated. In 44 areas, dentine (also in all cases with minor wear) was exposed, and in 5 areas enamel was present. Overall sensitivity was 0.65, specificity 0.88 and the proportion of correct diagnoses was 0.67. The diagnosis 'dentine is exposed' was about 5 times as likely and the diagnosis 'dentine is not exposed' half as likely to come from an area with exposed dentine than from an enamel-covered area. The closeness of the visual diagnosis to the histological findings was only fair ($\kappa = 0.27$), no significant impact of professional experience was found. For inter- and intra-examiner agreement, κ was 0.28 and 0.55, respectively. It was concluded that the diagnosis of exposed dentine is difficult.

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A number of indices for the clinical diagnosis of non-carious lesions are proposed, which more or less are modifications of the tooth wear index published by Smith and Knight [1984] or the erosion index suggested by Eccles [1979]. Some include items for the characterisation of the lesion shape intending a relation to aetiological factors, but most of them use two criteria for the three-dimensional quantification of hard tissue loss. The size of the area affected (parallel to the surface) is mostly given as the proportion of affected/sound tooth surface, and the depth of a defect (perpendicular to the surface) is measured either metrically or by using the criterion 'dentine affected or not'. Thereby, a relation between exposed dentine and amount of substance loss is implied.

The clinical (visual) detection of exposed dentine is made by estimating enamel loss by observing deviations from the original anatomical form or changes of optical properties. Exposed dentine is supposed to have a yellowish or brownish appearance and to be differentiated

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from enamel by differences in lustre. Even though widely used in epidemiological surveys, criteria for the diagnosis of exposed dentine are not clearly defined and the accuracy and consistency of the clinical differentiation between enamel and dentine have not yet been investigated.

The aims of the study were (1) to assess whether enamel and dentine could be differentiated by a visual examination (accuracy or closeness of the visual decision to histological findings) and (2) to investigate the extent to which multiple examinations agree with each other (inter- and intra-observer consistency).

Materials and Methods

Sample

From a pool of extracted human teeth stored in saturated aqueous thymol solution, 41 teeth with signs of tooth wear of various aetiologies were selected. Prior to the experiment, tooth tissue loss was quantified according to the criteria of Molnar [1971], modified by Ganss et al. [2002]. The respective modified index includes only morphological criteria for quantification but not the criterion 'dentine exposed or not'. For molars and premolars, substance loss was quantified depending on the presence or absence of main and accessory fissures, flattening of cusps and loss of crown height. The latter was the only criterion for grading incisors and canines. Sixteen teeth exhibited substance loss of grade 1 (minor), 23 of grade 2 (moderate) and 10 of grade 3 (advanced). Organic material and debris were removed with a scaler and with pumice, the teeth were embedded in white plaster blocks and kept in 100% humidity until assessment. Photographs were taken (magnification ×5), and the area to be diagnosed was marked on prints with a sticker. The sticker showed precisely the area to be diagnosed, but prevented examiners from diagnosing from the photographs rather than from the respective tooth area. On the 41 teeth, 49 incisal/occlusal areas were selected for examination.

Participants and Procedure

Sixty-one examiners (25 female, 36 male) took part in the study. The group consisted of 23 scientists (main field cariology; all of them participated during an international scientific congress), 18 university dentists and 20 dental students with clinical experience. The latter two groups were employees or students of the Dental Clinic, Justus Liebig University of Giessen. Professional experience was <2 years in 26 examiners, 2 to <5 years in 6, 5 to <10 in 8 and 10 and more years in 21 examiners. For all of them the same set-up was used. They received a short verbal instruction about the procedure, a form and a print-out of the photos. The embedded teeth were presented on a dark green cotton cloth and illuminated with a halogen lamp. The examination was made by visual inspection alone without magnification aid or probe. No instruction about possible diagnostic criteria was given. Examiners had to decide if dentine in the area of interest was exposed (positive test result) or not (negative test result). After each examination, the teeth were stored in 100% humidity. No air drying was used.

Table 1. Number of areas with exposed or unexposed dentine (as evaluated histologically) with regard to different grades of substance loss (criteria of Molnar [1971] modified by Ganss et al. [2002])

Tissue loss	Dentine exposed	Dentine not exposed	Total
Grade 1	16	–	16
Grade 2	20	3	23
Grade 3	8	2	10
Total	44	5	49

Histological Evaluation

After the assessment of the surface, the teeth were ground on a Knuth-Rotor polishing machine with silicone carbide paper of grain size 60 μm under constant tap water cooling.

Progression of the grinding process was repeatedly checked under the microscope (magnification ×10). When the periphery of the test site was reached, papers of grain sizes 30, 18 and then 10 μm were used. The centre of the test site was polished with 5-μm paper. Under a magnification of ×50, the presence and thickness of enamel was then assessed (Leica, M 1000, Cambridge, UK).

Statistical Analysis

Using the histological results as the true state, sensitivity, specificity, positive and negative predictive values (PPV, NPV) and the likelihood ratios for a positive or a negative test were calculated. For a positive test, likelihood ratios of >10 have a large, 5–10 a moderate, <5–2 a small and <2 a tiny impact on the likelihood of disease (exposed dentine); for a negative test result, the respective ranges are <0.1, 0.1–0.2, >0.2–0.5 and >0.5. Likelihood ratios of around 1 indicate that no useful information has been produced from the findings.

The closeness of the visual diagnosis of exposed dentine to the respective histological state (accuracy) was determined using Cohen's κ. For a subgroup (18 university dentists), the inter- and intra-examiner agreements were assessed also using Cohen's κ. The following qualitative terms were attached to κ coefficients: 0–0.2 = 'slight', 0.2–0.4 = 'fair', 0.4–0.6 = 'moderate', 0.6–0.8 = 'substantial' and 0.8–1.0 = 'almost perfect' [Sackett et al., 1991].

For assessing the impact of professional experience on sensitivity, specificity, PPV and NPV, one-way analysis of variance was used.

Results

The histological findings revealed that in 5 areas (3 in teeth with substance loss of grade 2 and 2 in teeth with grade 3) enamel was present, whereas in 44 dentine was exposed (table 1). In cases of unexposed dentine, the mean thickness of the remaining enamel was 0.64 ± 0.16 mm (range 0.46–0.87 mm).

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Table 2. Sensitivity, specificity, PPV, NPV and κ value for accuracy (closeness of the visual diagnosis to the histological finding) for all examiners as well as for subgroups (mean ± SD)

	Sensitivity	PPV	Specificity	NPV	Accuracy (κ)
All (n = 61)	0.65 ± 0.19	0.98 ± 0.03	0.88 ± 0.19	0.26 ± 0.12	0.27 ± 0.17
Scientists (n = 23)	0.66 ± 0.18	0.98 ± 0.03	0.85 ± 0.24	0.25 ± 0.13	0.26 ± 0.19
Dental students (n = 20)	0.66 ± 0.15	0.98 ± 0.03	0.90 ± 0.18	0.26 ± 0.09	0.28 ± 0.14
University dentists (n = 18)					
1st assessment	0.61 ± 0.24	0.99 ± 0.02	0.91 ± 0.14	0.27 ± 0.15	0.27 ± 0.19
2nd assessment	0.61 ± 0.26	0.99 ± 0.03	0.91 ± 0.23	0.27 ± 0.15	0.28 ± 0.21
Experience <2 years (n = 26)	0.65 ± 0.15	0.98 ± 0.03	0.89 ± 0.18	0.25 ± 11.2	0.26 ± 0.16
Experience 2 to <5 years (n = 6)	0.73 ± 0.21	0.99 ± 0.02	0.90 ± 0.17	0.34 ± 0.14	0.38 ± 0.18
Experience 5 to <10 years (n = 8)	0.55 ± 0.23	0.98 ± 0.02	0.90 ± 0.15	0.23 ± 0.14	0.22 ± 0.20
Experience ≥ 10 years (n = 21)	0.65 ± 0.21	0.98 ± 0.03	0.87 ± 0.24	0.27 ± 0.13	0.27 ± 0.17

The pretest likelihood of exposed dentine was 0.89. Sensitivity, specificity, PPV and NPV as well as κ coefficients for accuracy are given in table 2. The overall proportion of correct diagnoses was 0.67. The overall likelihood ratio was 5.4 for a positive and 0.4 for a negative test.

Professional experience in terms of years in profession or field of work (scientist, university dentist, student) had no significant impact on sensitivity, specificity or on PPV or NPV.

The overall interexaminer agreement was fair: 153 combinations from 18 participants revealed a mean (± SD) κ coefficient of 0.28 ± 0.15 (range 0.01–0.89). Intraexaminer agreement was moderate (mean κ = 0.55 ± 0.19; range 0.1–1.0).

Discussion

Up to now, the clinical diagnosis of exposed dentine was mostly relevant in the frame of grading tooth wear of various aetiologies. Since wear from the clinical view is a surface and not a subsurface phenomenon and changes in anatomical form, colour or lustre appear to be easy to observe, details of grading rather than the accuracy or consistency of the diagnosis of exposed dentine are currently under discussion. The present study, however, revealed that the differentiation between enamel and dentine at a given tooth surface is difficult (fig. 1). As to the accuracy of the visual diagnosis, 65% of areas with exposed dentine, 88% of areas with enamel present and 67% of all areas examined had been diagnosed correctly. As to a given clinical diagnosis (predictive values), in 98% of a positive test dentine was also histologically exposed, whereas only in 25% of a negative test enamel was histologically present. PPV and NPV depend on the pretest probability (prevalence) of the target disorder. Since the pretest probability for exposed dentine was surprisingly high, the observed high PPV and, vice versa, low NPV could be expected. In terms of likelihood ratios, which are not dependent on pretest probabilities, the diagnosis 'dentine is exposed' was about 5 times as likely and the diagnosis 'dentine is not exposed' half as likely to come from an area with exposed dentine than from an enamel-covered area. Likelihood ratios of 5.4 and 0.4, however, have only a moderate to small impact on likelihood of disease.

Looking at κ values, the results are not encouraging either. The overall κ value was only 0.27 and also the more experienced examiners did not perform better than the beginners. A comparably low κ was also found for the accuracy of diagnosing fissure caries [Lussi, 1991] which can be attributed to the limited visual and tactile accessibility of carious lesions. Since the tooth surface is easy to observe, fair κ values for the diagnosis of exposed dentine might be merely due to a lack of defined criteria for diagnosis. Further, the problem of diagnosing exposed dentine has been sparsely discussed in the scientific community and has not been introduced in daily clinical work. For both aspects, examiners were possibly confronted with a diagnostic problem they had not been aware of before and therefore had made their decision from instinct rather than from evidence.

The inter- and intra-examiner agreement was fair to moderate which was also observed for the diagnosis of occlusal caries [Lussi, 1991]. This reflects a well-known problem and emphasises the general need for training and validation of diagnostic procedures in general as well as for appropriate calibration procedures in epidemiological surveys in particular.

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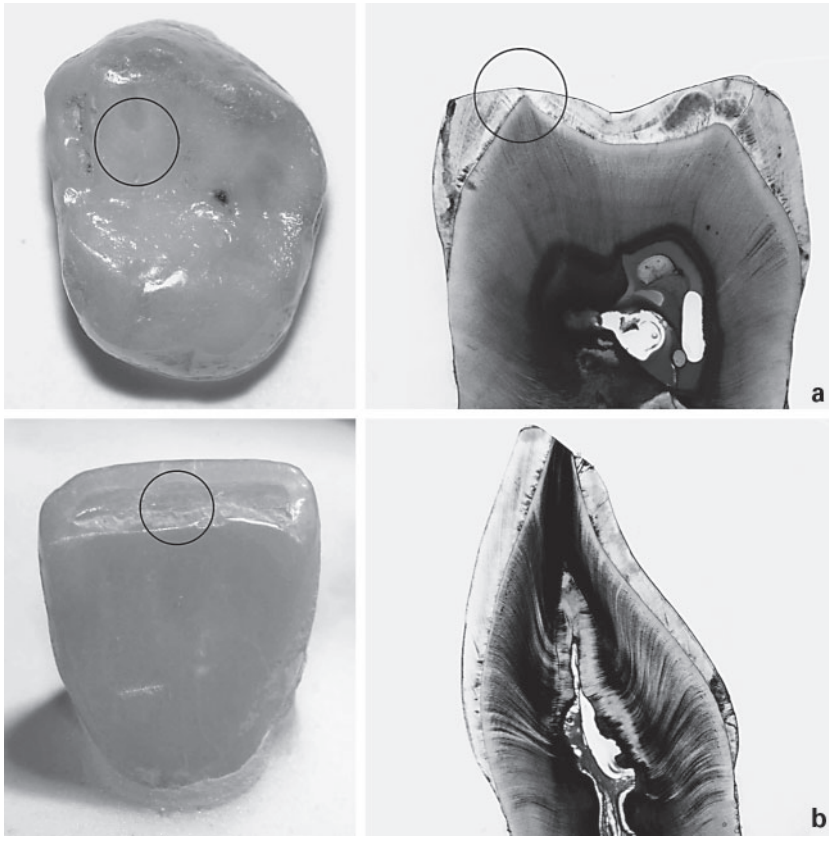

Fig. 1. Teeth No. 22 (**a**) and 41 (**b**) with the crown preserved and after histological preparation – the area of interest is indicated with a circle. **a** Substance loss grade 3; 89% of the examiners visually diagnosed 'dentine exposed'; however, 0.5 mm enamel was still present histologically. **b** Substance loss grade 1; 80% of the examiners visually diagnosed 'enamel present', but histologically dentine was unambiguously exposed.

An additional, although not systematically studied aspect was that in the present sample there was no relation between exposed dentine and the amount of wear. Unexpectedly, the percentage of teeth with exposed dentine was high and in all teeth with minor substance loss dentine was exposed, whereas enamel was still present in teeth with wear of grades 2 and 3. Similar results were found in a study of primary teeth [Al-Malik et al., 2001]. In 31 teeth with visually diagnosed wear, only 3 had enamel present histologically. In 14 teeth, enamel was diagnosed visually, but in 11 of them dentine was histologically exposed. Even in 1 of 10 teeth, in which no wear was diagnosed visually, the histological examination revealed exposed dentine. In the present sample, dentine was exposed in all cases of cupping or grooving even if only minor substance loss occurred. Most erosion indices use cupping/grooving as diagnostic criterion and grade the severity of a given lesion using the distinction between exposed and enamel-covered dentine [Linkosalo and Markkanen, 1985; Lussi, 1996; van Rijkom et al., 2002]. If cupping is assumed to be basically related to dentinal exposure, present grading of initial and advanced occlusal lesions should be reassessed.

Regarding the difficulty of diagnosing exposed dentine correctly, as well as the possibly high prevalence of exposed dentine even in cases of minor substance loss, the criterion 'dentine affected or not' used in current indices should be discussed.

Diagnosing exposed dentine, however, could be important for the therapeutic approach in cases of erosion or as a prognostic factor with respect to the progression of erosive, abrasive and combined wear. Contrasting findings are published regarding the susceptibility of enamel and dentine to erosive mineral loss. In some studies, dentine appears to erode to a similar or lower extent than enamel [Ganss et al., 2000; Hunter et al., 2000b], whereas others found dentine to be much more prone to erosive mineral loss [Hunter et al., 2000a]. However, with increasing demineralisation, the amount of organic material exposed increases, thus retarding the progression of dentine erosion whereas enamel erodes linearly. The relative susceptibility of dentine therefore probably depends on the stage of erosive demineralisation and the resulting

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variability would explain the contradicting results published. Dentine, however, is more prone to 2- or 3-body abrasion [Koczorowski and Wloch, 1999; Hooper et al., 2003] since its microhardness is much lower than that of enamel [Meredith et al., 1996] and probably also more susceptible to tribochemical wear [Mair, 2000; Ganss et al., 2002].

Wear of any aetiology, however, is to a various extent a physiological phenomenon. Criteria for pathological wear were suggested by Smith and Knight [1984], who regarded tooth substance loss as pathological if the teeth do not function effectively, seriously mar appearance or are unable to survive the individual's expected life span if wear continues at a given rate. Therefore, the clinical relevance of exposed dentine as a prognostic factor for wear progression should be further assessed.

In conclusion, the visual differentiation between enamel and exposed dentine appears difficult. The accuracy of the diagnosis of exposed dentine was poor and the inter- and intra-examiner agreement was fair to moderate. Further, the prevalence of exposed dentine even in cases of minor wear was high. For both aspects, the use of the criterion 'dentine is exposed or not' in indices assessing wear of any aetiology should be discussed. As suggested earlier [Ganss et al., 2002], modified new wear indices could possibly include morphological criteria for analytical epidemiological purposes and grade the amount of wear by assessing deviations from the original anatomical form rather than by diagnosing exposed dentine.

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