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Clinical, Radiographic, and Histological Changes in Enamel and Dentin, According to Caries Care International™ Evaluation, in Permanent Posterior Teeth: An Observational Study

Cambios Clínicos, Radiográficos e Histológicos en Esmalte y Dentina, Según Evaluación de Caries Care International™, en Dientes Posteriores Permanentes: Un Estudio Observacional

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SUMMARY: CariesCare International ™ practical guide is a tool for the comprehensive assessment and treatment of caries that synthesizes clinical and radiographic diagnosis and risk factors, classifying the severity, progression, and activity of lesions. The objective of this study was to analyze the validity and prediction characteristics of the proposed dental caries classification in the CariesCare International ™ practical guide as a reference through clinical and radiographic evaluation versus histological evaluation. Ninety-seven permanent posterior teeth were evaluated, and clinical and radiographic diagnoses were determined according to parameters defined in the CariesCare International ™ guide as a reference. Subsequently, histological evaluation was performed to compare each stage of dental caries progression, and statistical analysis was applied. When comparing the validity and prediction values between radiographic and clinical diagnoses in relation to histological evaluation, a low sensitivity and high specificity relationship was found. The sensitivity and specificity percentages between the clinical and radiographic methods show that the clinical method has a lower number of false negatives. Histological changes in dental tissue were evident from the earliest stages of lesions, even in those not related to the caries process, indicating that the dentist should be careful when deciding on a treatment plan and take into account all variables involved in the caries process, as proposed by the CariesCare International ™ guide.

KEY WORDS: Dental caries, Teeth, ICDAS, CariesCare International, Diagnosis.

INTRODUCTION

The coronal caries lesion begins in the enamel and can initially be observed as a small white lesion due to demineralization. When the caries extends into the dentin, cavity formation can be found, although there are cases with no visible cavity formation, which are known as underlying shadow lesions (Braun *et al*., 2017).

The visual method is the most commonly used in caries detection, but it should be combined with other methods for a more accurate diagnosis (Gimenez *et al*., 2015). Visual inspection combined with bitewing radiography is the most common method for caries diagnosis (Gomez, 2015).

During the last decade, the International Caries Detection and Assessment System (ICDAS), which identifies caries lesions by evaluating the visual appearance of dental tissues, has been shown to be accurate and reproducible in identifying early lesions and detecting changes in longitudinal follow-up (Gomez, 2015). When caries presence is histologically evaluated, the criterion used is the demineralization process of dental tissue seen from the enamel surface towards the pulp, which establishes the following analysis criteria: Code 0 or healthy tooth: No enamel demineralization is shown or involves a narrow zone of surface opacity. Code 1 or initial: Indicates enamel

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demineralization limited to the outer 50% of the enamel layer. Code 2 or moderate: Demineralization that affects the inner 50% of the enamel and the outer 1/3 of the dentin. Code 3 or severe: Demineralization involving the middle and inner 1/3 of the dentin (Ekstrand *et al*., 1998). This guide is considered the gold standard when using different criteria for caries lesion diagnosis (Chu *et al*., 2013). The objective of this research was to analyze the validity and prediction characteristics of the dental caries classification proposed in the CariesCare International ™ guide through clinical and radiological evaluation versus histological evaluation.

MATERIAL AND METHOD

In this observational, cross-sectional, and descriptive study, human teeth indicated for extraction were used, the which were donated for the study "Histomorphometric characterization of pit and fissure caries in permanent teeth", internal registration number 174-019, which has the approval of the human ethics committee of the health faculty of the Universidad del Valle, Colombia, verified in record number 018-019 of September 30, 2019.

A sample size of 97 teeth was determined using the PASS 15.0.5 software (For the statistical analysis, the statistical program MedCalc® Statistical Software version 20.100 (MedCalc Software Ltd, Ostend, Belgium; https://www.medcalc.org; 2022) PASS 2021 Power Analysis and Sample Size Software (2021). NCSS, LLC. Kaysville, Utah, USA), based on a two-tailed hypothesis with a 95% confidence level, a Kappa value of 0.8, a standard deviation of 0.25, and a confidence interval between 0.75 and 0.85 with a width of 1.

The teeth were fixed in buffered formalin for 24 hours, then washed with tap water and a medium bristle brush, and finally stored in sterile distilled water at room temperature until photographic, clinical, radiological, and histological examinations were performed. Photographic images of all teeth were taken using a Canon t6 camera (Digital SLR Camera, EOS 1300D - Rebel T6, Canon Inc. Tokyo, Japan), with a Youngno 60mm macro lens (Canon Inc. Tokyo, Japan).

For the clinical evaluation of teeth, it was ensured that the teeth were free of dental plaque and had clean surfaces, and the ICDAS criteria assessment protocol was followed. For the assessment of the severity of caries lesions, the CariesCare International ™ guidelines were followed, taking into account the ICDAS criteria of 0-6 and considering categories from 0 to 4, starting with a healthy tooth, initial lesion, moderate, and severe. Within the clinical assessment of teeth, surface lesions that were not carious lesions were also described, and they were coded according to the research group's criteria as follows: code 0 to identify healthy teeth, code 1 assigned to teeth with hypomineralization, code 2 for teeth with hypoplasia, and code 3 for teeth that presented surface dental pigmentation (da Cunha Coelho *et al*., 2019; Lygidakis *et al*., 2022) (Fig. 1).

Subsequently, digital coronal dental radiographs were obtained using a Kavo Focus 70K 7mA equipment with a total filtration of 2.0 mm and a focal point of 0.7 mm. The radiographic films used were number 2 photo-stimulable phosphor plates from Instrumentarium Express TM and an Instrumentarium Express TM digitalizer (Dental Instrumentation. Palo DEx Group Oy. Tussula. Finland), with a cone-to-tooth distance of 8.5 cm and an exposure time of 2.0 seconds with the direction of the X-ray beam in a vestibulolingual direction of the tooth. An ASUS Intel(R) Core (TM) i3-5005U CPU @ 2.00GHz 2.00 GHz computer (ASUS TeK Computer, Inc. Taipei, Taiwan) with a screen resolution of 1920 X 1980 pixels was used for the analysis of radiographic images. The information was qualitatively organized according to the progression assessment of the lesion indicated by ICDAS and the CariesCare International ™ guide, establishing ordinal categories of Code 0: Healthy tooth, no presence of

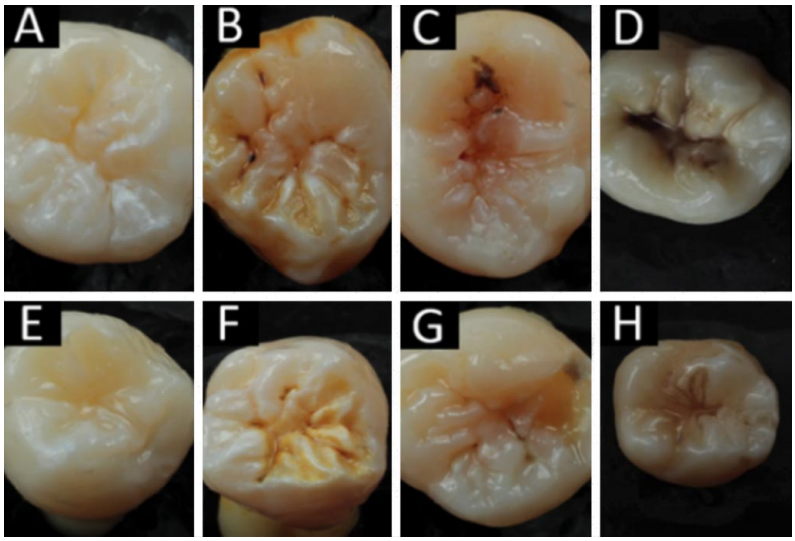

Fig. 1. Clinical assessment guide for carious (A-D) and non-carious lesions (E-F). A: Healthy tooth (Code 0). B: Initial lesion (Code 1/ICDAS 1 and 2). C: Moderate lesion (Code 2/ICDAS 3 and 4). D: Extensive lesion (Code 3/ICDAS 5 and 6). E: Without lesion (Code 0). F: Hypomineralization (Code 1). G: Hypoplasia (Code 2). H: Pigmentation (Code 3). Source: Authors.

radiolucency; Code 1: Initial lesion, the radiolucency is confined to the enamel and outer third of the dentin; Code 2: Moderate lesion, the radiolucency is confined to the middle third of the dentin, and Code 3: Extensive lesion, the radiolucency corresponds to the inner third of the dentin and pulp chamber (Martignon *et al*., 2019) (Fig. 2).

To obtain histological images, the teeth were allowed to air dry, and then included in blocks of transparent polymethylmethacrylate, and progressive grinding of 1 mm was carried out with emery stone and constant irrigation with running water. Images were taken at 1X, 2X, 3X, and 4X magnification using a Motic stereoscopic microscope (Motic®.Richmond. Vancouver. Canada). The progression of the lesion was assessed based on Ekstrand's guidelines (Ekstrand *et al*., 1998), for histological diagnosis of caries, which were described previously in the introduction (Ekstrand *et al*., 1998) (Fig. 3).

The data obtained from this analysis were recorded in an Excel spreadsheet (Microsoft Excel 2019, version 17.0) and imported into the program MedCalc 20.0.4 (MedCalc Software Ltd.). The calculation of absolute and relative frequencies was performed for each diagnostic category of lesions according to the CariesCare International ™ and ICDAS guidelines; the distribution of caries levels among occlusal diagnoses was compared using the Kruskal-Wallis test and pairwise Wilcoxon post-hoc test. The confidence level was set at 95% and the significance level at 5%.

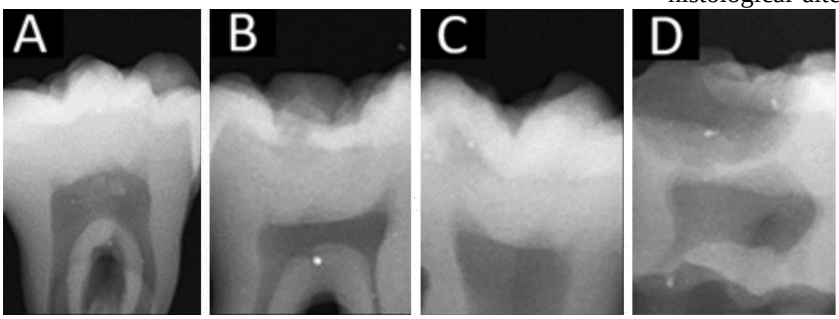

Fig. 2. Radiographic assessment guide for carious lesions. A: Sound tooth/Code 0. B: Initial lesion/Code 1. C: Moderate lesion/Code 2. D: Extensive lesion/Code 3. Source: Authors.

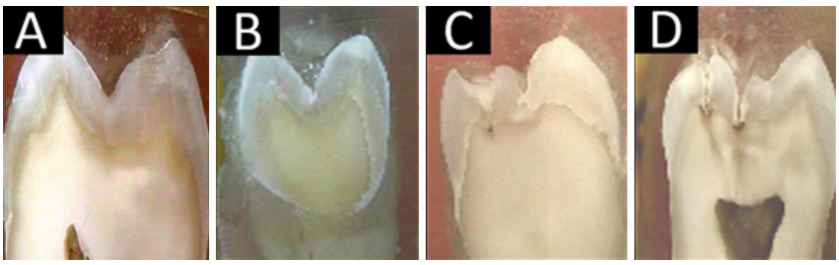

Fig. 3. Guide for histological evaluation of carious lesions. A. Code 0/healthy. B: Code 1/initial. C: Code 2/moderate. D: Code 3/severe. Own source

The calculation of the linear weighted kappa index (kappa) was performed to compare the diagnosis of caries among the different evaluation methods. Likewise, kappa index was calculated for dichotomized variables according to the identification or non-identification of caries. Concordance was classified according to Altman's proposal in 1990 (Altman, 1990)

In addition, the validity characteristics (sensitivity and specificity) and prediction characteristics (predictive values and likelihood ratios) of clinical and radiographic assessments were calculated using histology as the reference standard for initial and any carious lesions on coronal and proximal surfaces.

The proposal was approved by the research ethics committee of the Faculty of Health at Universidad del Valle, through record number 018-019 dated September 30th, 2019.

RESULTS

The clinical analysis showed occlusal caries lesions in 38.33% of teeth; additionally, non-carious lesions were diagnosed in 50.83% of the evaluated teeth, with the highest percentage being hypomineralizations. The results of the radiographic analysis showed that 20.83% had initial lesions with radiolucency in enamel and outer third of dentin. The histological study showed that 32.26% of the teeth had no changes in their mineral structure, 27.96% presented histological alterations in the initial stage, 33.33% in the moderate stage, and 6.45% in the extensive stage.

In the identification of occlusal caries, the agreement between the radiographic and histological diagnosis was slight (weighted kappa=0.18288; 95% CI [0.068474; 0.29729]). Similarly, the agreement between the clinical assessment and the histological assessment was slight (weighted kappa=0.19097; 95% CI [0.055705; 0.32623]). When measuring the agreement between the radiographic and clinical diagnoses for occlusal surface, it was found to be acceptable (Occlusal - weighted kappa=0.216; 95% CI [0.0433; 0.390]).

When performing the analysis of occlusal caries by filtering out those non-caries lesions, determined as hypomineralizations, hypoplasias, and

surface stains, an acceptable level of agreement was achieved between clinical and histological diagnosis (Weighted Kappa = 0.219; 95% CI [0.052; 0.385]). However, there was an acceptable level of agreement, but with undervaluation in the radiographic diagnosis in agreement with the histological diagnosis (Weighted Kappa = 0.201; 95% CI [0.063; 0.339]).

When analyzing the validity and prediction values between radiographic diagnosis and histological assessment, a low sensitivity of 36.5% with a high specificity of 70% was found. In addition, it was found that with a prevalence of caries lesions of 86.30%, the radiograph offers an 88% probability of diagnosing caries, meaning that the radiograph does not change the pre-test probability. It was also found that in this relationship, the negative predictive value is 14.8%, which means that the radiograph does not rule out the possibility that those diagnosed as healthy by this method may actually have caries.

When analyzing the validity and prediction values between clinical diagnosis and histological evaluation, it was found that this relationship has a low sensitivity of 47.61%, which is more sensitive than the radiographic diagnosis, and a high specificity of 80%. This indicates that the probability of diagnosing a caries lesion with the clinical method in relation to histological evaluation is still low, but compared to the radiographic method, it is better. Additionally, it is more likely that the clinical method will identify healthy teeth when they are actually healthy according to histological evaluation, with a false negative value in caries diagnosis of 52.4% and false positive of 20%. Moreover, it was found that with a prevalence of 67.7% of caries lesions, the clinical diagnosis offers an 83.3% probability of diagnosing caries, meaning that the clinical diagnosis could change the pre-test probability of having caries lesions.

When analyzing the validity and prediction values between the clinical diagnosis and histological assessment, but excluding non-caries lesions, it was found that sensitivity increases considerably and improves the probability of diagnosing a caries lesion by the clinical method from 47.61% to 60.8%, and specificity decreases from 80% to 75%. This indicates that the probability of diagnosing a caries lesion with the clinical method validated with histological assessment, without considering those non-caries lesions that may cause confusion at the moment of diagnosis, improves towards the positive side.

When analyzing the same comparison between radiographic diagnosis and histological evaluation, similar results were found. Sensitivity and specificity increased from 36.5% to 41.30% and from 70% to 87%, respectively. This indicates that the probability of diagnosing a caries lesion with the radiographic method compared to histological evaluation, without taking into account those non-caries lesions that may lead to misinterpretations, also improves towards the positive. In addition, it was found that in the presence of a caries lesion prevalence of 65.7%, radiography offers an 82.3% probability of diagnosing caries and a negative predictive value of 50%, indicating that the radiographic method does not exclude the possibility that those diagnosed as healthy by this method may actually have caries.

DISCUSSION

A comprehensive systematic review with meta-analysis aimed at evaluating the overall accuracy of the visual method in detecting caries lesions demonstrated that the visual method has good accuracy, but the performance was better for more advanced stages of the carious process (Gimenez *et al*., 2015). Similarly, in a meta-analysis and systematic review that included 117 studies, it was found that in the diagnosis of initial caries lesions, there were low sensitivities but moderate to high specificities; for dentin lesions, sensitivities were higher, as were those for proximal cavitated lesions compared to occlusal lesions, while specificities remained high (Schwendicke *et al*., 2021). Likewise, in a study by Michalaki *et al*. in 2016 (Michalaki *et al*., 2017), it was determined that each enamel change characterized by the ICDAS code 1 or higher was classified as caries. At this diagnostic threshold, sensitivity was high (100%) and specificity was low (47.06%). At a diagnostic threshold of 3, where enamel changes its characteristics and codes higher than 2 are used, they were considered caries, with high sensitivity (100%) and high specificity (93.62%).

In daily practice, caries progression is evaluated complemented with radiographic evaluation; some studies have shown that radiographic evaluation underestimates the size of occlusal caries lesions compared to histological evaluations (Gomez, 2015).

In this study, by performing radiographic evaluation, it was found that 23.23% of the teeth studied had caries, mostly corresponding to early stage caries lesions. However, histological validation showed that more than half of the sample had some degree of demineralization. Kapor *et al*. (2021), describe that in the early stages of occlusal caries, dental anatomy produces overlapping images on the radiograph, showing the limitations of radiography as a diagnostic method for initial occlusal lesions (Crispin *et al*., 2021). In an in vitro study where they measured the validity of the radiographic examination compared to a standard in histological sections, they found that there is a high probability that the measurement of the

individual lesion by the radiographic method is overestimated, or underestimated compared to the true depth of the lesion (Jacobsen *et al*., 2004).

The results of this work are consistent with other studies where it is indicated that visual examination of pits and fissures is not perfect and should be accompanied by additional diagnostic methods (Crispin *et al*., 2021).

CONCLUSIONS

The histological changes in dental tissue are evident from the early stages of lesion development, even in those not related to the caries process. Therefore, caution must be exercised when deciding on a treatment plan and all variables involved in the caries process should be taken into account, as is not proposed in the CariesCare International ™ guidelines.

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RESUMEN: La guía práctica CariesCare International™ es una herramienta para la evaluación y tratamiento integral de la caries que sintetiza el diagnóstico clínico y radiográfico y los factores de riesgo, clasificando la gravedad, progresión y actividad de las lesiones. El objetivo de este estudio fue analizar la validez y características de predicción de la clasificación de caries dental propuesta en la guía práctica CariesCare International™ como referencia a través de la evaluación clínica y radiográfica versus la evaluación histológica. Se evaluaron noventa y siete dientes posteriores permanentes y se determinaron diagnósticos clínicos y radiográficos según parámetros definidos en la guía CariesCare International™ como referencia. Posteriormente se realizó una evaluación histológica para comparar cada etapa de progresión de la caries dental y se aplicó análisis estadístico. Al comparar los valores de validez y predicción entre los diagnósticos radiológicos y clínicos en relación con la evaluación histológica, se encontró una relación de baja sensibilidad y alta especificidad. Los porcentajes de sensibilidad y especificidad entre el método clínico y radiográfico muestran que el método clínico tiene un menor número de falsos negativos. Los cambios histológicos en el tejido dental fueron evidentes desde las primeras etapas de las lesiones, incluso en aquellas no relacionadas con el proceso de caries, lo que indica que el odontólogo debe tener cuidado al decidir un plan de tratamiento y tener en cuenta todas las variables involucradas en el proceso de caries, tal como propone la guía CariesCare International™.

PALABRAS CLAVE: Caries dental; Dientes; ICDAS; CariesCare International; Diagnóstico.

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