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Impedance Spectroscopy as a Tool for the Detection of Occlusal Noncavitated Carious Lesions

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Clinical Relevance

The diagnosis of caries in its early stages is important to allow minimally invasive treatments. Impedance spectroscopy may be useful for the detection of occlusal caries.

SUMMARY

A total 302 teeth (148 molars and 154 premolars) corresponding to 152 patients aged ≥18 years were evaluated for caries using the ICDAS (International Caries Detection and Assessment System), fluorescence (DD, DIAGNOdent) and electrical impedance (IMS, CarieScan PRO) systems. Fissurotomy and intraoral radiographs were used as the gold standard. Accordingly, 27.5% (n=84) of the teeth were classified as sound, while 26.9% (n=81) had enamel involvement and 45.6% (n=138) presented carious lesions reaching the dentin. Sensitivity (Se), specificity (Sp), and the area under the curve (AUC) were, respectively, 90.7%, 87.8%, and 0.954 (IMS); 92.4%, 92.7%, and 0.954 (DD); and 79.0%, 72.3%, and 0.756 (ICDAS). With regard to Se and Sp, there were significant differences between ICDAS and DD (*p*<0.001) and between ICDAS and IMS (*p*=0.01), but not between IMS and DD (*p*=0.07). In relation to AUC, there were significant differences between ICDAS and DD (*p*<0.001), and between ICDAS and IMS (*p*<0.001), but not between IMS and DD (*p*>0.05). The correlations between fissurotomy and each method were 88.7% (IMS), 89.7% (DD), and 77.1% (ICDAS). Within the limitations of this study, clinically, the electrical system is not useful for differentiating between sound teeth and truly incipient caries lesions by itself. The fluorescence or electrical systems are

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recommended with the ICDAS to detect carious lesions in their early stages.

INTRODUCTION

The early detection of occlusal caries can be complicated when the lesions are not cavitated.[1] Among other factors, this is due to the complex anatomy of the molars and premolars, and the use of fluoride products, which can increase enamel surface resistance and mask dentinal lesions.[2] In the last 20 years, many studies have attempted to evaluate the detection capacity of different systems, based mainly on fluorescence,[3-8] which involves the absorption of light of a short wavelength and the emission of light of a longer wavelength. The detection of caries, when the lesions are noncavitated and only affect the enamel layer, allows for more conservative management,[9-12] such as fluoride therapy[13] or ozone treatment,[11] which, in turn, implies less-expensive management and the preservation of more dental tissue, thereby, improving patient comfort and quality of life.[12]

The original visual criteria established by Ekstrand and others[14] are no longer regarded as suitable, since they do not contemplate all the stages of caries progression.[8,15] As a result, new visual criteria are being introduced. In this regard, the International Caries Detection and Assessment System (ICDAS) was presented in 2002,[15] allowing assessment of the caries process in each of its stages and determining caries lesion activity status.[16] The ICDAS is a clinical scoring system based on visual examination, optionally aided by a ball-ended probe. The system classifies the stages of the caries process based on histological extent and activity. Seven stages from ''sound'' to ''extensive distinct cavity with visible dentin'' are distinguished, based on the visual appearance of the tooth surface. Different studies support the validity of this system, finding it to be reproducible and precise.[17,18] However, there is great variation in the clinician-based diagnosis of hidden caries, and in this regard technological advances could contribute to improving the detection and diagnosis of caries in its early stages.[19,20] The ICDAS can be used in epidemiological studies, public health research, clinical research, clinical practice, and dental education. It is necessary to train and calibrate the examiners to ensure that the results obtained are comparable among different clinicians and useful, for example, in epidemiological studies.[21]

One of the existing fluorescence-based systems involving red laser (655 nm) measures the differences in fluorescence emitted by the healthy tissues and caries.[22,23] Part of the irradiated light is reemitted by bacterial porphyrins[2] as fluorescence within the infrared spectrum and can be quantified. This technique was introduced in 1998, and its detection ability has been extensively evaluated. Most reports are *in vitro* studies,[2,24-26] though some *in vivo* studies have also been published.[9,27,28] The sensitivity (Se) of the technique ranges from 44%-100%,[29,30] while its specificity (Sp) is reportedly 36%-100%.[31] The possible causes of such large variations in Se and Sp comprise a lack of consistency in defining the disease and variability in terms of the gold standard and analytical systems used.[32] Furthermore, it must be mentioned that fluorescence-based systems are prone to false-positive readings caused by different factors such as the use of silver amalgam, certain prophylactic pastes, resin composites, or calculus.[33,34]

Electrical impedance systems were designed to assess the extent of the lesion within the enamel,[35-37] and are based on the principle that materials can be characterized by their ability to conduct electricity to one degree or other. Such systems can be used in combination with visual criteria for the diagnosis and monitoring of noncavitated caries.[38] Their use in combination with visual criteria affords better diagnostic performance than visual criteria alone.[39] The system consists of a rechargeable device connected to a sensor that is placed in contact with the examined tooth and a lip clip that closes the circuit. The sensor is a disposable headpiece with a tip ending in a minute series of metal filaments that transmit the current to the tooth in order to obtain the measurements. The sensor is fitted to the upper part of the body of the device, which has a light display that indicates the different lesion degrees based on a luminous color code. A light-emitting diode (LED) screen in the central part of the device indicates the measured values, while the lower part houses the control buttons and an input for connecting the lip clip. The permeability of a tooth increases in the presence of a demineralization process.[40] Such permeability is related to the electrical resistance of the tooth; accordingly, the physical changes present in a carious process can be identified and quantified by measuring this electrical phenomenon. Enamel demineralization is associated with lower electrical impedance compared to sound tissue. Dentin, in turn, has lower impedance than enamel, but its porosity also increases due to dental caries resulting in a decrease in impedance.[41] Systems of this kind should not be used in patients with cardiac pacemakers or for the evaluation of secondary caries or root caries, or to detect the depth of a preparation[16]. These devices come with a screen showing the numerical value (0-100) obtained in the measurement and a color pyramid that lights up (green, yellow, and red), according to the numerical value obtained.[42] An algorithm, in turn, is used to establish the diagnostic score based on the bioimpedance values mapped against a clinical reference.

The cut-off point is the value used to divide continuous results into categories (typically positive and negative). In this case, positivity is the presence of caries, while negativity corresponds to a sound tooth. Agreement is lacking in the literature on the use of a cut-off point with the different detection systems, and the results of different studies can vary greatly depending on which cut-off point is used.[8,26-28] The differences among the cut-off points found in the literature preclude direct comparison of the different systems.[3,8,28,43]

There is no consensus in the literature regarding the detection capacity of the different diagnostic systems. The Se of the ICDAS II scoring system varies greatly among studies, from 5%-83% for grade D3 (outer half of dentin),[44,45] in the same way as its Sp. The systems based on fluorescence and electrical impedance also show disparate values for different degrees of involvement. Sensitivity ranges from 73%-100%[46,47] and 45%-92%[16,35] for fluorescence and electrical impedance systems, respectively. It is, therefore, essential to carry out more prospective *in vivo* studies involving large sample sizes and using fissurotomy to confirm the true extent of the lesion, as contemplated in our case. The objectives of the present clinical study were to evaluate the ability of impedance spectroscopy to detect occlusal caries, and to compare the technique against fluorescence and visual/tactile examinations. The null hypothesis was that there are no *in vivo* differences in the detection of occlusal caries of the permanent molars and premolars between the fluorescence and electrical impedance systems.

METHODS AND MATERIALS

Study Population

A prospective study was made of 152 patients in the Deparment of Dentistry (Dental Parhology and Therapeutics Unit), University of Valencia between January 1, 2009 and December 31, 2012.

All of the patients were over 18 years of age and presented American Society of Anaesthesiologists' (ASA) classification score I-II. A total of 302 teeth (148 molars and 154 premolars) out of 1758 posterior teeth were analyzed. The teeth were diagnosed with caries amenable to restoration based on the ICDAS system (code 3 or higher), and were also examined with the fluorescence and electrical systems. A bitewing radiograph was subsequently used to confirm lesion extension. The exclusion criteria were teeth with sealants or previous restorations, hypoplasia, or teeth with fluorosis or amelogenesis, in accordance with the recommendations of other authors.[3,8,48]

Clinical Analysis

All the detection procedures were carried out by the same examiner (MM) who was trained and calibrated for all the systems used. The occlusal surfaces were first cleaned using pumice mixed with water and a nylon prophylactic brush (Dentaflux, Madrid, Spain) at low speed. The visual examination was performed under no magnification, as recommended by the ICDAS II code system.[3,15] The tactile examination to check the surface was performed using a TU 17/23 Hu-Friedy exploratory probe (Chicago, IL, USA), moving it over the explored surfaces without applying pressure. The fluorescence system (DD: DIAGNOdent 2095, KaVo, Bibberach, Germany) was used following the recommendations of the manufacturer. Since these were occlusal surfaces, we used the previously calibrated A probe positioned perpendicular to the occlusal surface being examined. In all cases we recorded the highest value obtained.[36] Lastly, the electrical impedance system (IMS: CarieScan PRO, CarieScan Ltd, Dundee, Scotland) was used. The tooth was rehydrated with water from the system syringe for 5 seconds in order to facilitate electrical conductance. We then dried the tooth for another 5 seconds following the recommendations of the manufacturer. The soft tissue clip was placed on the lip of the patient, avoiding contact with any metal restorations present in the mouth. The sensor, in turn, was placed on the occlusal surface of the tooth to be examined, and the "enter" button was pressed to start measuring. Four tones can be heard during the measurement process before the result appears onscreen. The end of measurement is indicated by a long sequence of "beeps" and the classification appearing on the color display.[35] The highest value obtained was recorded. The operating principle is shown in Figure 1.

The true extent of the carious lesions was determined by fissurotomy using round diamond drills measuring 0.5 mm in diameter at high speed (Komet, Gebr Brasseler GmbH & Co, Lemgo, Germany)[8,26] by one operator (MM). The final lesion depth was assessed visually and with the tip of the exploratory probe, evaluating the hardness of the bottom of the fissure. This technique was used as the gold standard in our study. After fissurotomy, bitewing radiographs were obtained to confirm lesion extension, recording the true extent for posterior statistical analysis.[48] The following criteria were used to classify lesion extension: D0 (sound), D1 (outer half of the enamel), D2 (inner half of the enamel), D3 (outer half of dentin), and D4 (inner half of dentin).[16,50]

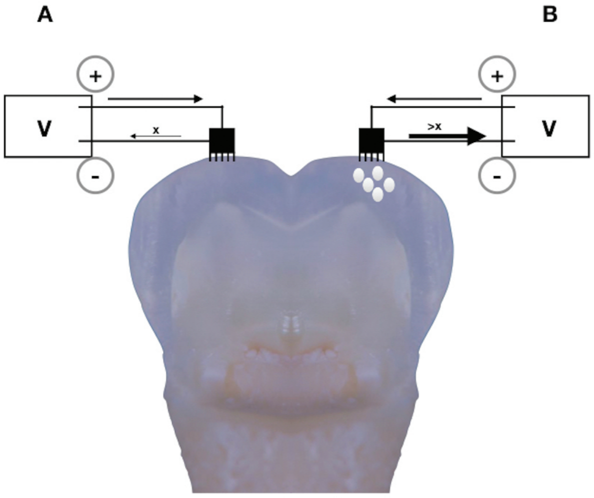

Figure 1. Schematic representation of the electrical impedance system.

Statistical Analysis

A descriptive analysis was made, calculating the Se and Sp values, and the area under the curve (AUC) for each of the systems used. The 95% confidence interval (95% CI) of the AUC was calculated, based on the contrast test AUC=0.5. The inferential analyses included the Mann-Whitney U-test for two independent samples in order to determine whether the distribution of the values of a diagnostic test is homogeneous in two groups. The Kruskal-Wallis test for more than two independent samples was used to determine whether the distribution of the values of a diagnostic test was homogeneous in several groups. The McNemar test was used to compare predictions between the two tests, while the Spearman correlation coefficient was used to estimate the correlation between two at least ordinal variables. The significance level considered was 5% (α=0.05). The statistical power of the study (n=302) was 96% for a two-tailed test, with a level of significance of 5%. The SPSS version 15.0 statistical package (SPSS Inc, Chicago, IL, USA) was used throughout. We used the cut-off points suggested by the manufacturer for both the devices (fluorescence and electrical impedance). In the former system, values from 0 to 14 indicated sound tooth, 15-20 corresponded to D1-D2 lesions, and finally values over 21 corresponded to D3-D4 caries. In the latter system, 0 indicated sound tooth, 1-50 corresponded to D1 caries, 51-90 to D2 lesions, 91-99 to D3 lesions, and 100 indicated D4 caries.

RESULTS

A total of 302 teeth (148 molars and 154 premolars) corresponding to 152 patients with a mean age of 39.1 ± 14.3 years were included. The prevalence of caries in the sample was 72.5% (after fissurotomy).

The fluorescence system provided continuous values. The cut-off points used were those suggested by the manufacturer: D0=17.1% of the sample, D1-D2=10.3%, and D3-D4=72.6% of the lesions. The optimal cut-off point obtained in this study was 23.5. The values referring to diagnostic validity varied according to the real extension of the caries as shown in Table 1.

In relation to the electrical impedance system, the results were classified according to the parameters proposed by the manufacturer: There were no cases with a value of 0, so according to this system there were no sound teeth. Specifically, 46.5%, 20.9%, 0.7%, and 32% of the sample corresponded to D1, D2, D3, and D4 lesions, respectively. The values referring to the diagnostic validity of this system vary according to the degree of extension of the lesion. Other cut-off points (24.5 and 33) were analyzed, and the results are shown in Table 2.

The Se values were D0=27.7%, 96.2%; D1=51.4%, 82,9%; D2=52.3%, 95.2%; D3=94.6%, 98.2%; and D4=95.7%, 100% for ICDAS and DD, respectively. No case was classified as D0, according to the IMS; the Se in this case, therefore, was D1=100%, D2=52.3%, D3=40%, and D4=83.8%. The correlation between the real extension of caries and DD/IMS was 0.911 and 0.904, respectively (p<0.001). The kappa index was 0.50, with 95% CI 0.42-0.67. The Spearman correlation coefficient was 0.911 (r=0.676/ranges), indicating a moderately strong correlation for DD. In the case of IMS, the kappa index of linearly weighted concordance for the complete ordinal classification was 0.59, with 95% CI 0.55-0.63. The Spearman correlation coefficient between the exact value given by the system based on IMS and the actual range of the lesion was r=0.904 (r=0.806/ranges), suggesting a fairly strong correlation. For the AUC estimations, no significant difference was recorded between IMS and DD (p<0.05). However, there were differences between ICDAS and IMS (p<0.001) and between ICDAS and DD (p<0.001). This information is summarized in Table 3. The values corresponding to Se, Sp, AUC, and correlation with fissurotomy of the different methods are presented in Table 4.

DISCUSSION

The present study tested the hypothesis that there are no differences in Se and Sp between the visual and tactile systems and the fluorescence and impedance techniques in detecting occlusal caries of the permanent dentition. Based on the results obtained, the null hypothesis of our study was accepted. In order to establish the true extent of a carious lesion, a biopsy

Table 1: *Results of the Fluorescence System According to Real Extension of the Caries*

	Fluorescence System					Fluorescence System Using Cut-off Value 23.5				
	D0	D1	D2	D3	D4	D0	D1	D2	D3	D4
Sensitivity (Se), %	96.2	82.9	95.2	98.2	100	92.4	74.3	85.7	98.2	100
Specificity (Sp), %	51.2	51.20		49.7		92.7	72.6	57.2	42.8	31.5
Positive (+) predictive value, %	83.5	20.0		62.3		97.0	97.0	84.0	66.0	38.5
Negative (–) predictive value, %	84	84		98.8		82.6	92.4	98.9	100	100
Concordance, %	83.6		61.3			92.4%		—		
Kappa	0.54 (0.42-0.66)		0.50 (0.42-0.57)			0.82 (0.75-0.89)		—		
Correlation fluorescence-real extension		$r = 0.911$ ($p<0.001$)					$r = 0.911$ ($p<0.001$)			
Correlation range fluorescence-real extension		$r = 0.676$ ($p<0.001$)					$r = 0.755$ ($p<0.001$)			

is needed (in the case of *in vitro* studies) or a fissurotomy must be performed (in the case of *in vivo* studies).[51] It should be noted that not all studies use histology as the gold standard. This is the case of Theocharopoulou and others[52] and Rechmann and others,[53] who used ICDAS as the reference standard. For this reason, not all the published results can be compared. In our *in vivo* study, fissurotomy was taken to be the gold standard for establishing the true extent of the lesions, in concordance with other publications.[8,27,37,54]

Table 2: *Results of the Impedance System According to Real Extension of the Caries*

	Impedance System				Impedance System Using Cut-off Value 24.5					Impedance System using Cut-off Value 33.0				
	D1	D2	D3	D4	D0	D1	D2	D3	D4	D0	D1	D2	D3	D4
Sensitivity (Se), %	100	52.3	40.0	83.8	90.2	44.4	100	100	100	89.8	38.9	100	100	100
Specificity (Sp), %	0	96.6	95.7	93.1	87.8	78.0	56.8	42.4	31.0	96.3	85.6	62.3	46.5	34.0
Positive (+) predictive value, %	41.6	95.2	100	70.5	95.1	95.1	87.3	65.8	39.0	98.5	98.5	91.3	68.9	40.8
Negative (–) predictive value, %	—	82.6	77.5	93.6	78.3	100	100	100	100	78.2	100	100	100	100
Concordance, %		39.4			89.8		—			91.5		—		
Kappa		0.59 (0.55-0.63)			0.76 (0.67-0.84)		—			0.80 (0.73-0.88)		—		
Correlation fluorescence-real extension		$r = 0.904$ ($p<0.001$)				$r = 0.904$ ($p<0.001$)					$r = 0.904$ ($p<0.001$)			
Correlation range impedance-real extension		$r = 0.860$ ($p<0.001$)				$r = 0.760$ ($p<0.001$)					$r = 0.814$ ($p<0.001$)			

Table 3: *Results of the Studied Systems According to Real Extension of the Caries*

	ICDAS	DD	IMS
Sensitivity (Se)	79.0%	92.4%	90.7%
Specificity (Sp)	72.3%	92.7%	87.8%
Area Under the Curve (AUC)	0.756	0.954	0.954
Correlation with fissurotomy	77.1%	89.7%	88.7%

Abbreviations: ICDAS, International Caries Detection and Assessment System; DD, DIAGNOdent; IMS, CarieScan PRO.

We performed visual examination using the ICDAS criteria, in the same way as other authors,[2,8,23] in order to compare the results obtained with those of other publications. In the present study, the Se of ICDAS was seen to increase with caries lesion depth (51.4%-95.6%). Other investigators have recorded similar results. In one study, the Se of ICDAS was found to be 48%-83% in D3 lesions, though in D1 lesions Se performance was found to be 59%-73%.[44] Zaidi and others obtained similar results, with sensitivities of 65% (D1 lesions) and 59% (D3 lesions).[54] Pourhashemi and others[25] found the lowest Se of ICDAS to be 25%, and the highest 61.4% depending on the observer. In another study[45] the Se of IDCAS was 8%-76% (for D1 and D2 lesions) or 5%-78% (for D3 and D4 lesions). The authors reported that clinical performance was not significantly improved when the detection level was moved to the inner enamel layer. Diniz and others,[28] in turn, obtained specificities and sensitivities for enamel and dentin caries versus only dentin caries of 60%-93% and 77%-52%, and similar results were recorded by Jablonski-Momeni and others.[42] There are minor variations between the visual signs associated with each code.[55] Kockanat and Unal[16] reported the highest Se (97-86%) and Sp (96%-93%) at D1 and D3 thresholds of ICDAS. Lower figures were obtained by Singh and others,[56] with a Se of 77.78% and a Sp of 75%. The important differences recorded in the Se of ICDAS can be attributed to the fact that dental caries is a dynamic process in which early lesions undergo demineralization before becoming clinically manifest.

It is difficult to establish comparisons between studies of fluorescence systems, since no consensus regarding the cut-off points can be found in the literature. Each point on a Se-Sp curve corresponds to a cut-off value, and is associated to test Se and Sp. Locating the cut-off point thus requires a compromise between both the parameters. In some cases, Se can be more important than Sp, though in other circumstances the opposite may apply. If there is no preference between Se and Sp, or if both parameters are the same, a good approach would be to maximize both the rates. Different studies have calculated their own cut-off points, seeking to obtain maximum Se and Sp. This is the case of Rodrigues and others, who determined point 30 to be the most suitable cut-off point in terms of Sp.[3] Ghoncheh and others[46] determined three different cut-off points: 8.5, 9.5, and 10.5, with Se values of 73%-92% and Sp values of 57%-82%. In our study, the maximum values for Se and Sp were obtained with a cut-off point of 23.5. Fluorescence system measurements at a single site are reproducible when the device is calibrated according to the instructions of the manufacturer.[57] The classification of a tooth as either presenting caries or being sound or healthy is not conditioned by operator bias, since this is an objective technique

Table 4: *Sensitivity (Se), Specificity (Sp), Area under the Curve (AUC), and Correlation with Fissurotomy of the Different Methods*

		D0	D1	D2	D3	D4
Sensitivity (Se)	ICDAS	27.70%	51.40%	52.30%	94.60%	95.70%
	DD	96.20%	82.90%	95.20%	98.20%	100%
	IMS	—	100%	52.30%	40%	83.80%
Correlation	DD	0.911 (*p*<0.001)				
	IMS	0.904 (*p*<0.001)				
Kappa	DD	0.50 95% CI, 0.42-0.67				
	IMS	0.59 95% CI, 0.55-0.63				
Spearman	DD	0.911 (*r*=0.676/ranges)				
	IMS	0.904 (*r*=0.806/ranges)				

Abbreviations: ICDAS, International Caries Detection and Assessment System; DD, DIAGNOdent; IMS, CarieScan PRO.

that produces a numerical reading of the inspected site. Nevertheless, the importance of the cut-off point and the influence according to some authors of stains in fissures and cracks are clear. Such stains could be a source of high false-positive rates obtained with light fluorescence, with a consequent decrease in the Sp values recorded.[24,58] The high incidence of false-positive results produced by laser fluorescence devices not only reduces the Sp values but is also partially responsible for higher Se values.

The Se obtained with the fluorescence system lies within a narrow range (79%-100%).[51] However, the Sp reported for this system in the literature is lower than that obtained in our study, where the range was seen to be 53%-72%.[3,59,60] When caries affects dentin, the Se of the technique is close to 100%. However, in the case of D1 and D2 lesions, the Se values are lower. The Se of the system was seen to increase with the severity of the lesion (82.9% in D1 lesions versus 100% in D4 lesions). Our results are consistent with those of other studies.[26,43] Some authors consider that fluorescence readings reflect changes in the organic material rather than in the inorganic content of the teeth. Oral bacterial metabolites affect the signal, and an increase in fluorescence is due more to changes in the organic content of carious lesions than to mineral disintegration.[61,62]

With the fluorescence technique, the differences among the cut-off points found in the literature preclude direct comparison of the systems studied. We used the cut-off points proposed by the manufacturer, but other cut-off points have also been studied, and the findings have been presented in the Results section. Teo and others[34] included different cut-off points. The D1 cut-off point (21) was a matter of concern, even when the second chosen cut-off point (51) represented deeper lesion extension into the inner-third of the enamel layer. In the same study, with the mentioned cut-off point of 21, the Sp was 81.7% and increased to 100% with the other two cut-off points (51 and 91, proposed by the manufacturer, as in our case). In the last two cases, Se decreased to 71.6% and 45%, respectively. The overall values in the study by Teo and others were 95% for Se and 44% for Sp. The high Se obtained by these authors suggests that the system is able to detect correctly (enamel and dentin) but is hampered by low Sp that does not allow it to distinguish between caries and healthy dental tissue. In D2 lesions and deeper lesions, the results clearly improved. This system yielded the highest Cohen's kappa coefficients in the study published by Katge.[37] On the other hand, Kockanat and Unal, in primary molars, reported higher Se for D1 lesions (89%-92%) than for D3 lesions (47%-73%).[16] This difference can be explained because more than lesion depth is responsible for the result or value obtained by the system. In an *in vitro* study of 10 posterior teeth subjected to electrical impedance measurements and microcomputed tomography scans, the analysis of the images revealed a complex morphology of occlusal caries in terms of density. The authors concluded that lesion morphology is an important factor to be taken into account in assessing the capacity of electrical impedance spectroscopy to detect caries or conduct follow-up of carious lesions over time.[63] This may explain the high values obtained in our study, even though lesion depth was smaller than in other cases where the numerical reading obtained was lower. It is also important to note that the histology of a tooth changes with advancing age—with significant differences in measurements between young and mature teeth. The formation of peritubular dentin over time causes the tubular lumen to gradually narrow and even become obliterated.[40] A study in which electrical impedance measurements were obtained from 99 healthy first molars every 6 months found impedance to increase in the posteruptive period.[64] For this reason, and in the same way as there are differences between the deciduous and permanent teeth, the values obtained with this system cannot be generalized to all ages when establishing a treatment plan.[35]

Some studies have found electrical impedance systems to be more sensitive in detecting occlusal caries than visual, tactile, or radiographic techniques. Katge and others[37] found the Se of this system to be 97%, versus 93% in the case of ICDAS. However, Sp was lower (82%) for electrical impedance, though other authors claim the opposite.[16,48,65] The lower Se values reported by some investigators underscores the importance of this system in monitoring lesions confined to dentin and healthy teeth. Jablonski-Momeni,[42] in a study of 292 teeth, recorded high *in vivo* reproducibility but only moderate correlation to the findings of the visual system. The authors considered the system to be useful for monitoring caries not subjected to invasive treatment but questioned its validness in detecting lesions limited to the enamel—visual examination being considered more useful in this case. This differs from our own findings, in which electrical impedance yielded better results than ICDAS in D2 caries (Se 100% versus 52.3%). The lack of a gold standard in the above-mentioned study for validating the results may be the cause of this difference. Also, Jablonski-Momeni and others conducted their study in adults over a broad age range (18-68.5 years), and hence the results may differ from those obtained in our study.

Identifying the initial stages of demineralization is essential in order to allow noninvasive therapies such as fluoride therapy. According to the clinical practice guidelines referred to nonrestorative treatments for carious lesions of the American Dental Association,[66] clinicians should prioritize the use of sealants plus 5% NaF varnish applied every 3-6 months, or sealants alone over 5% NaF varnish alone, or 1.23% APF gel applied with the same frequency. As an application at home, 0.2% NaF mouth rinses once per week are strongly recommended.

With regard to the limitations of our study, it must be mentioned that due to ethical concerns, the examined teeth were diagnosed with caries amenable to be restored based on the ICDAS system. Furthermore, the study design did not allow us to determine whether any of the evaluated detection methods are useful for detecting truly incipient caries lesions.

CONCLUSIONS

Clinically, the electrical system on its own is not useful for differentiating between sound teeth and truly incipient caries lesions. The fluorescence or electrical systems are recommended with the ICDAS to detect carious lesions in their early stages.

Regulatory Statement

The study and experimental protocol were reviewed and approved by the Institutional Review Board of the University of Valencia (IRB00010108) and were conducted in accordance with the guidelines of the Declaration of Helsinki. Informed consent was obtained from all the participants included in the study.

Conflict of interest

The authors declare that they have no proprietary, financial, or other personal interests of any kind in relation to any product, service, and/or company cited in this article.

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