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Accuracy of light fluorescence intraoral camera for detection of pit and fissure caries of occlusal surfaces. (An In Vivo study)

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Abstract
Objectives*: To assess the accurecy of fluorescence-based intraoral camera in relation to ICDAS II for diagnosis of occlusal surfaces.* ***Methods****: Twenty patients (9-12 years) were enlisted for this trial, using their permanent first molar to obtain 80 teeth involved in the study. Soprolife (DSL) was examined 400 point in (the lingual and buccal fissure regions, as well as the central, distal, and mesial portions of the central fissure) for each tooth. Then, the measurements were compared in reference to visual assessment method (ID) according to international caries detections and assessment system (ICDAS II criteria).* ***Results****: The value for the ICDAS categorization of scores 0, 1, and 2 as sound and initial caries that not cavitated was chosen as the cutoff value. The highest area under the ROC curve value, thus the highest overall ability to discriminate between "carious" and "non-carious," is achieved for the SOPROLIFE tool with AROC = 0.934±0.0128(SE). The SOPROLIFE tool had sensitivity (90.91%) and a specificity of (58.64%).* ***Conclusion:*** *Soprolife had high sensitivity and high area under the ROC curve. So Soprolife had the ability to differentiate between carious and sound tooth structures, but had low specificity.*

Keywords: *ICDAS II, SOPROLIFE, Caries.*

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I. Introduction

People are susceptible to dental caries, an infectious disease process, throughout their lifetime yet it is preventable and treatable. Around the world, dental caries continues to be a serious issue that affects (60–90%) of students and the large proportion of adults. Approximately 80% of people globally have it. Because of shape of their occlusal surfaces and the problem of removing plaque, molars and premolars are the teeth that are greater prone to carious lesions assault [(1)]. Even when carious lesions are still within enamel, many dentists still do interventions. In order to develop effective preventative measures and avoid premature tooth replacement, thorough preoperative evaluation of the depths of carious lesions and the initial lesions at occlusal surfaces identification are crucial [(2)]. All diagnostic equipment for the identification and measurement of dental carious lesions must comply with security laws, be user-friendly and cost-effective, be able to distinguish between shallow and deep lesions, and enable examination through accurate and numerical evaluation [(3)]. Traditional diagnostic methods can be used as visual, tactile, and radiographic; however, visual and tactile need experienced practitioners to avoid false positive and negative results.

Therefore, we employed two key methods in this study that are intended to aid clinicians in identifying caries on occlusal surfaces in relation to ICDAS II. These methods allow the clinician to identify caries at their initial stage and to determine the amount of mineral loss [(4)].

Firstly, by using the international caries detection and assessment system (ICDAS II), to detect and measure dental carious lesions visually. It is produced for use in research, therapeutic applications, epidemiological investigations, and dentistry education [(5-6)].

Regarding the fluorescence-based methods, it is worth mentioning that some synthetic and natural materials have the ability to fluoresce, which is when they absorb the energy with specific wavelengths, then reflect photons at longer wavelengths. The SOPROLIFE system in form of The Soprolife® (Acteon, La Ciotat, France) intraoral camera which based on the light-induced fluorescence evaluator which reported the phenomenon known as autofluorescence, which occurs when tooth structures are irradiated at a specific wavelength. The device was combining the benefits of visual inspections technique (high specificity) using a laser fluorescence device and a high-magnification oral camera (high discrimination and reproducibility) [(7)]. The

aim of this trial was to assess the validity of two fluorescence-based intraoral devices in relation to ICDAS II for examination of occlusal surfaces.

II. Methods

Study setting and population

The current study's protocol was registered in protocol registration. The Faculty of Dental Medicine, Al-Azhar University Ethics Committee granted final ethical approval (No.388/454/25/12/19). Each patient was informed of the study's methodology, consented to participate, and before to study beginning of the study, a consent form (written in a native language) was filled. The study was carried out on 9-12 years old Egyptian patients selected from the outpatient clinics, Department of Operative and pediatric Dentistry, Faculty of Dental Medicine, Cairo, Al-Azhar University.

Study design

This study is a unicentered diagnostic accuracy study. Researcher was responsible for all activities associated with the study including recruitment of participants, Explaining and performing the procedures to them.

Eligibility criteria of the study

Inclusion criteria of selected patients include

Patient age range is 9 - 12 years. Sex had no gender restrictions. The children have bilaterally (upper and lower) erupted first permanent molars. Good oral hygiene and willing patients who can attend the study visits. [8, 9]

Exclusion criteria of patients include

Uncooperative or anxious children who were required behavior management techniques, History of abnormal Para functional activity, Unhealthy and bad oral hygiene [10]. Patients were had a severe or ongoing oral infection. Patients have a significant history of current or past medical issues. Patients with illnesses that could harm their oral flora or health (illnesses like diabetes, HIV, and heart disease that call for antibiotic prophylaxis) or using medication that could impact the flow of saliva or oral flora and inclusion in other trial at the moment [11].

Criteria of the teeth

Permanent molar teeth were with cavitated or non cavitated pit and fissure and without occlusal restorations or sealants [9]. Teeth with enamel anomalies, intrinsic or extrinsic staining.[12] Teeth without Amalgam filling, gold or steel crowns in adjacent teeth and large caries lesions on smooth and a proximal surfaces.[12]

Sample size calculation

The findings about the relation between DIAGNOdent and ICDAS II and Soprolife by the prior study's by **Rechmann et al., (2012)** [3], recorded mean ±SD values for 1 and 2 scores pre-cavitated enamel caries demonstrate DIAGNOdent values of (13±12) and the milled stained group was recorded(22±18). To disprove the null hypothesis that the population means of the experimental and control groups are probabilistically similar, a sample size of 20 per group will be required (power = 0.8). The Type I error probability (Alpha) for this null hypothesis test is 0.05, and the effect size was (78.4).

Grouping

Twenty patients were recruited for this study (10 men and 10 females, ages 9 to 12) using their permanent first molar teeth to obtain 80 teeth involved in the study. in every five fissure areas (the lingual and buccal fissure regions, as well as the central, distal, and mesial portions of the central fissure) were examined by certain diagnostic methods was light induced fluorescence camera Soprolife (DSL) Then compared the results in reference to visual assessment method (ID) represents ICDAS II criteria. Teeth were examined by two examiners El and E2.

Tooth Cleaning and Isolation

The 80 teeth were polished using a tool that contained sodium-bicarbonate powder (Air-Max, air-polisher with Prophy-Pen, ACTEON Group, France) prior inspecting the occlusal surfaces for five to ten seconds each tooth. Thoroughly washing was done with an air-water spray to eliminate any powder residue within fissures. Before conducting an examination, the roles of cotton were put, and briefly dry the occlusal surface with air (3 seconds each tooth) [13]

Assessment of Caries

Three separate caries assessments were carried out during this investigation. The evaluation results of the two evaluators (E1, E2) were hidden from one another. The evaluators discussed their results and came to an agreement on one score for each of the various parts of the tooth after independently rating for each [3].

Visual inspection and evaluation utilizing ICDAS II scores

All patients were reclined in the dental unit under operating light. And then they were examined visually with the aid of the light of dental unit lamp, air-water spray, dental mirror and CPITN (Community Periodontal Index

of Treatment Needs) probe. Based on the visible caries condition and intensity of plaque-free teeth as viewed moist and after being air dried, ICDAS II gives ratings to caries lesions [(14)].

Table 1: ICDAS-II six codes

Score	Description
Code 0	A healthy tooth surfaces. After five seconds of air drying, there are no visible changes to the enamel's translucency (Figure 1).
Code 1	First change in enamel's appearance. There is no indication of a color change when the tooth is moist, but after five seconds of air-drying, discoloration or opacity of caries is visible that is isolated to the edges of the pit and fissures areas and independent to the clinical features of healthy enamel surfaces (Figure 2).
Code 2	Clear visual change in the enamel. A brown discoloration and/or opacity of caries is wider than the fissures when it is wet (the lesion is still visible when it is dry) (Figure3).
Code 3	Caries causes local enamel breakdown without visible dentin or underneath shadowing. A brown discoloration and/or opacity of caries is wider than the fissures when it is moist. Dentin is not visible in the base or walls of the discontinuity, but there is a losing of tooth structure because of caries inside, or beside the entrance to the pit or fissure/ fossa, lasting around 5 seconds. (Figure 4).
Code 4	A shade of brown dentin beneath the enamel, with or without break up of enamel. This carious lesion is characterized as a shade of discolored dentin that can be seen from an unbroken enamel surface and may or may not show evidence of regional disintegration. When wet, the darkened area is easier to see and can be blue, brown, or grey in color (Figure 5).
Code 5	Dentin very apparent in the cavity. The discolored or opaque enamel has cavities (Figure 6) which reveals the dentin beneath
Code 6	Distinct and extensive cavity with dentin that is visible. (Figure 7).


Figure (1)


Figure (2)


Figure (3)


Figure (4)

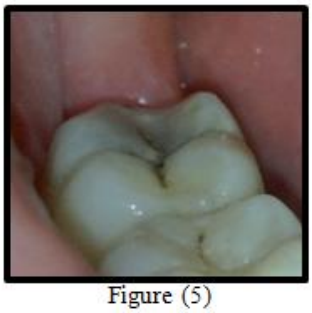


Figure (5)


Figure (6)

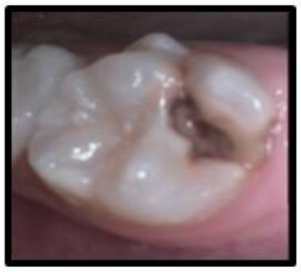


Figure (7)

Light induced fluorescence (LF)

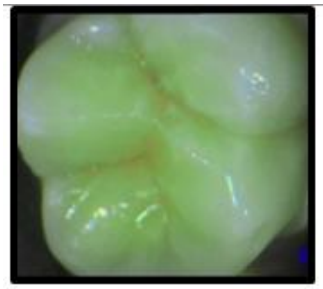
Soprolife intraoral camera:

It uses an intra - oral LED (light-emitting diode) camera that may detect and find variations in biological tissue's chemical composition, structure, and/or density. The Soprolife was light-induced fluorescence evaluation system (SOPRO. ACTEON Group. La Ciotat, France) which used for this investigation. The system was

utilized in the blue fluorescence mode, which employs four LEDs, and the magnification mode I. With the help of the SOPRO IMAGING programmed, the photos were captured.

Table 3: Soprolife® blue fluorescence mode score.

Score	Description
Code 0	Fissures display a glossy green tint, and the enamel appears sound and has undergone no noticeable modifications (Figure 12).
Code 1	It is possible for the small, narrow red glint in the pits and fissures system to partially complete its upward path through the slopes of the fissures. Without indication of red spots (Figure 13).
Code 2	There are evident heavier red areas confined to the fissures (Figure 14).
Code 3	Fissure areas are expanded by dark red lines that are still confined to the fissures. The much more lined red regions show some roughness (Figure 15).
Code 4	A wider area of deep red (or red orange) than the fissures' edges can be seen (Figure 16).
Code 5	With dentin clearly seen, significant enamel holes were seen (Figure 1).



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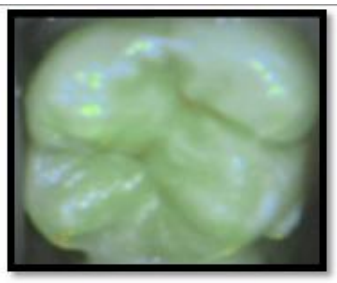

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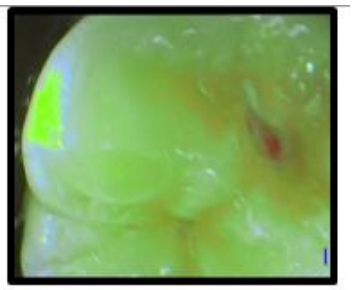


Figures (15)

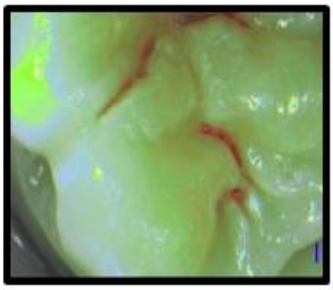
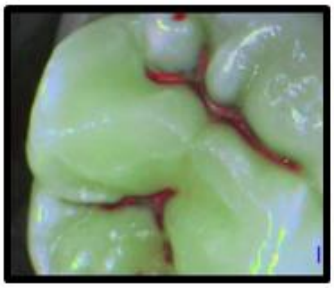


Figure (16)



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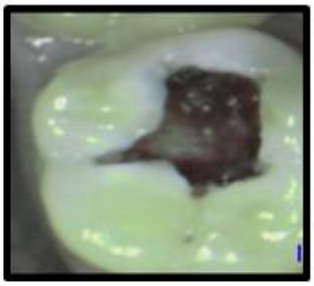

Figures (18)

Statistical Analysis

The normality was checked based on the Shapiro-Wilk Test. (α=0.05). The Kruskal-Wallis was used for the non-parametric distributed data. The Post-Hoc Dunn's test was used among the group pairs. Linear regression was used for the correlation between variables. ROC curve was used for sensitivity and specificity. The p-value threshold for significance was established at 0.05.

III. Results

This study evaluated Soprolife@ device (Light induced fluorescence intraoral camera) with the ICDAS II visual scoring by initial caries identification. In this study, 20 participants and a total of 80 teeth were assessed (40 permanent upper molars and 40 permanent lower molars) containing the (400) buccal and lingual fissures areas, as well as the distal, central, and mesial, portions of the fissures, were evaluated in the absence of restorations or sealants. The participants sample included ten male and ten female patients, with ages (9-12) years.

Scores distribution:

ICDAS II scores distribution:

172 locations on the 80 evaluated surfaces (400 locations) that were examined received a sound rating (code 0). A total of 346 pre-cavitated lesions were found, with 117 spots and 47 lesions receiving ICDAS II codes 1 and 2, respectively. ICDAS code 3 for early cavitations with first visible enamel disintegration, which was diagnosed in 32 cases, ICDAS code 4 for more advanced carious lesions, which presented in 19, ICDAS code 5 for 11 lesion, and ICDAS II code 6 for two lesions.

Table 1: shows the distribution of the ICDAS II score.

Variable	Score 0	Score 1	Score 2	Score 3	Score 4	Score 5	Score 6	P-value
No. of values ICDAS II	172	117	47	32	19	11	2	Total 400
%	43%	29.25%	11.75%	8%	4.75%	2.75%	.5%	100%

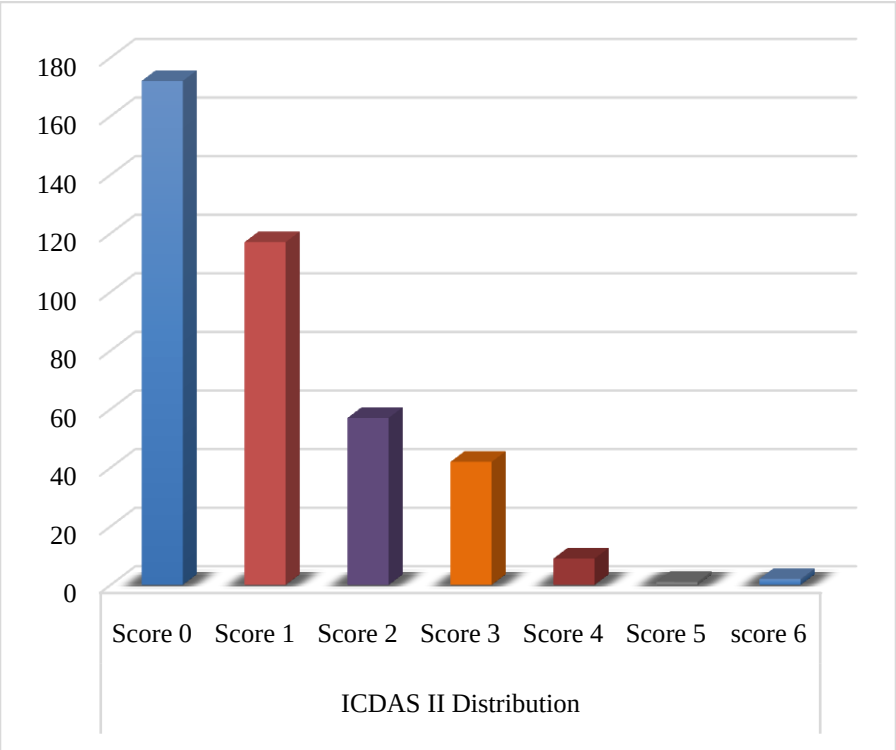

Figure 1: Diagram shows the distribution of the ICDAS II score.

SOPROLIFE scores:

From 80 evaluated surfaces (400 locations). 154 times a score of zero was given, 93 times a score of 1 was assigned, and 51 times a score of 2, 39 times a score of 3, 30 times a score of 4, and 19, 14 times a score of 5, 6 were given respectively.

Table 3: shows the distribution of the Soprolife score.

Variable	Score 0	Score 1	Score 2	Score 3	Score 4	Score 5	Score 6	P-value
No. of values ICDAS II	172	117	47	32	19	11	2	Total 400
%	43%	29.25%	11.75%	8%	4.75%	2.75%	.5%	100%
No. of values Soprolife	154	93	51	39	30	19	14	Total 400
%	38.5%	23.25%	12.75%	9.75%	7.5%	4.75%	3.5%	%

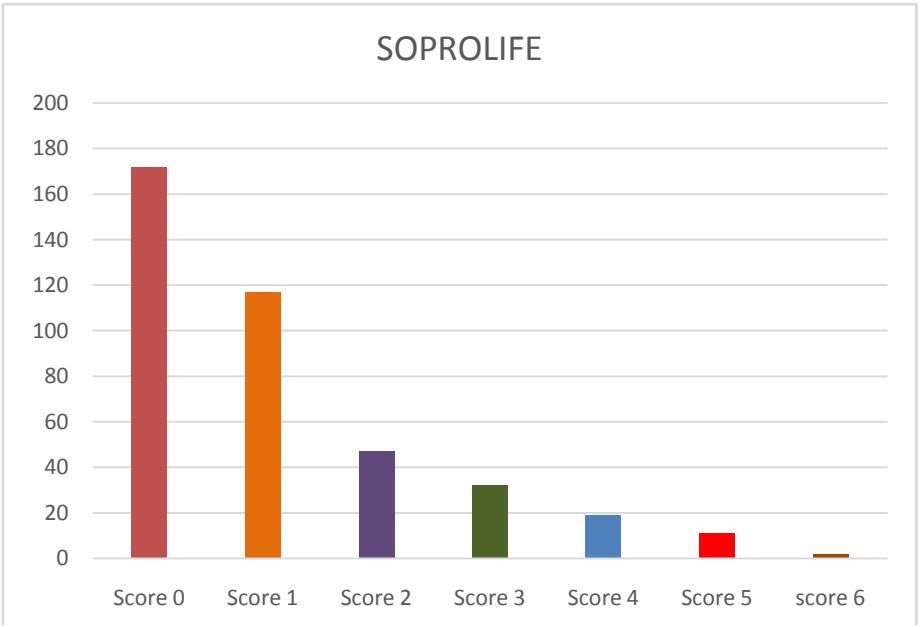

Figure 3: Diagram shows the distribution of the SOPROLIFE score.

Calculation of area under the ROC curve for SOPROLIFE:

Total Cases: 400

Positive Cases: 140

Negative Cases: 260

The highest area under the ROC curve value, thus the highest overall ability to discriminate between "carious" and "non-carious," is achieved for the SOPROLIFE tool with AROC = 0.934±0.0128(SE). Using the grouping of ICDAS II code 0-1-2 as "healthy" results in the highest area under the ROC value for the Soprolife diagnostic method. The Soprolife method received an area under the curve value (0.934), which is regarded as a "very good" overall sensitivity of this diagnostic method.

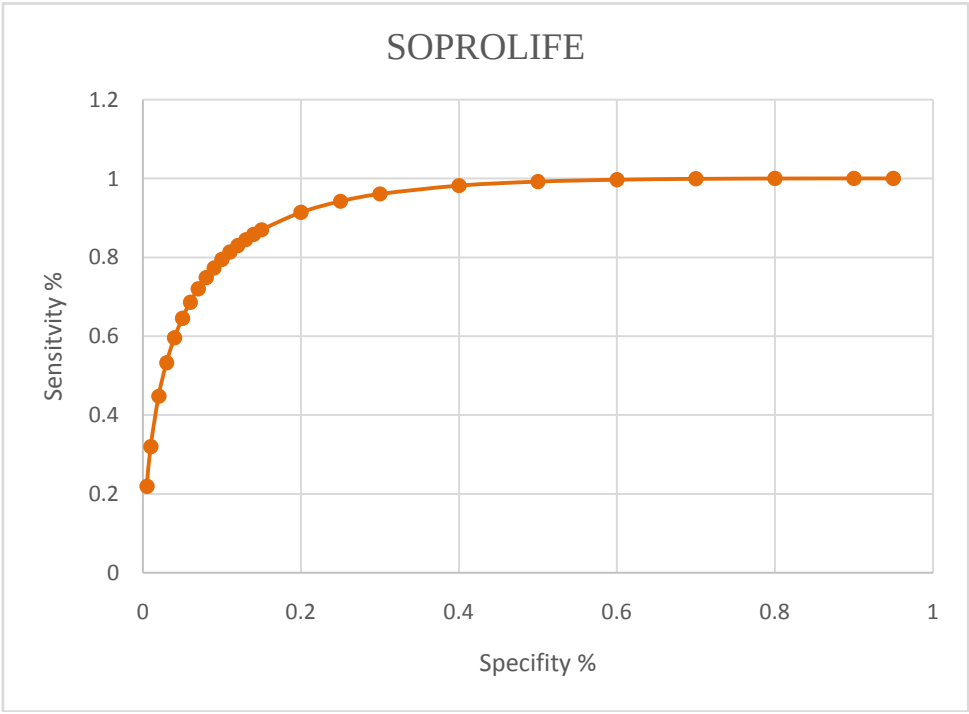

Figure 10: AROC curve for the SOPROLIFE method

Sensitivity and Specificity

As a cutoff point, the corresponding value for ICDAS grouping of scores 0, 1, and 2 together as healthy and non-cavitated lesions was chosen. The value for grouping ICDAS codes 0, 1, and 2 are chosen as the cutoff point for the sensitivity calculation and Specificity.

Sensitivity and Specificity calculation for the SOPROLIFE Diagnostic method:

If the value for grouping ICDAS codes 0, 1, and 2 is chosen as the cutoff point for the sensitivity calculation, the average value for DIAGNOdent is 1.27with a corresponding sensitivity of 90.91% and a specificity of 58.64%.

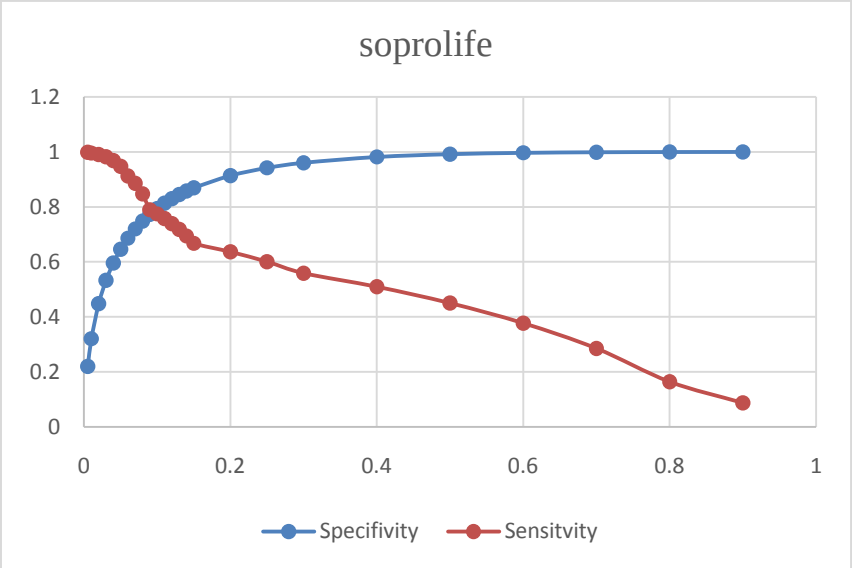

Figure 20: Sensitivity and specificity of the SOPROLIFE.

Table 10: Summarizes the specific tool cutoff values for grouping ICDAS 0 with 1 and 2 as "healthy," the sensitivity and specificity at this cutoff point.

Total	Cutt-off point	Sensitivity %	Specificity %
SOPROLIFE	1.27	90.91%	58.64%

IV. Discussion

Epidemiological studies have shown that molars are considered the most susceptible teeth for caries susceptibility, due to the morphological structure of their occlusal surfaces, and the uneasiness in plaque elimination [(15)]. For these reasons, the current study was carried out to evaluate the diagnostic accuracy of a light-induced fluorescence intraoral camera in comparison with the visual–tactile assessment technique using the ICDAS-II scoring system in the detection of initial occlusal caries in molars. Central to the vision of awareness of preventive therapies is the ability to spot caries lesions at a primary stage, and to measure the extent of mineral loss, guaranteeing a suitable interference [(16)].

This study showed a strongly correlation between the measurements Of both ICDAS Il and Soprolife with P-Value less than 0.05 which shows a significant correlation between ICDAS II and soprolife that is positive, and direct which means that as the reading Of ICDAS- Il increases, the Soprolife, measurement increases, and vice versa.

Table (1, 2 and 3) figures (1, 2, and 3) showed that: ICDAS showed lower prevalence of scores (2), (3), (4), (5) and (6) than corresponding of DIAGNOdent and Soprolife values,

For ICDAS II score 2 was 11,75 % while in Soprolife was 12.75 % while score 3 was for ICDAS 8 % in Soprolife was 9.75 %, for score 4 it was for ICDAS 4.75 % and for Soprolife was 7.5 % , for score 5 it was for ICDAS 2.75 % while Soprolife was 4.75 % and for score 6 it was for ICDAS .5 % and Soprolife was 3.5

% . Soprolife showed lower prevalence of Scores (0) and (l) than ICADS II. ICDAS II score 0 was 43 % while in Soprolife was 38.5 %, while score 1 was for ICDAS 29.25 % in Soprolife was 23.25 %.

This could be explained by **Lussi et al. 2004** [(17)], who stated that white-spot lesions formed in vivo do not produce a significant increase in fluorescence compared with sound surfaces. Distinct fluorescence of the caries process in more advanced stages leads to the assumption that, besides light scattering, bacteria. or their metabolites could contribute to the fluorescence of these lesions. Carious material had an intense fluorescence maximum in the red spectral region, containing mainly porphyrin (by products). Thus, molecules that contribute to the signal obtained from caries were identified. Also **Mendes et al, 2004** [(18)], Showed that laser fluorescence device reflects organic changes in carious lesions rather than mineral loss with the progression of the carious process. There is an increase in the amount of fluorescent light. These results were in agreements with **Alzayyat NAA et al 2021** [(19)], and **Gomez et al, 2012** [(20)].

These results are in disagreements with **Zeitouny et al, 2014** (21), who found an almost perfect agreement among the two methods for caries detection with no statistically significant differences between scoring with visual examination and LED fluorescence. This indicated that the diagnosis made with visual examination was roughly the same as the diagnosis made by Soprolife. The contradiction might be related to the small sample size (21 patients).

The figures (8) showed that, The highest area under the ROC curve value, thus the highest overall ability to discriminate between "carious" and "non-carious," is achieved for the SOPROLIFE tool with AROC = 0.934±0.0128(SE). The Soprolife method received an area under the curve value (0.934), which is regarded as a "very good" overall sensitivity of this diagnostic method. The findings agreed with **Alzayyat NAA et al 2021** [(19)], revealed AUC 0.909 and **Gomez et al. 2013** [(22)], who showed AUC •0.98 for Soprolife and **Alkahtani A et al 2021** [(23)], revealed AUC 0.0.93 for Soprolife. On the Other hand, **Unal et al, 2019** [(24)], revealed AUC 0.86 for Soprolife blue fluorescence tool and 0.91 for DIAGNOden and **Muller-Bolla et al. 2017** [(25)], found (AUC - 0.87) for Soprolife.

The figures (9) showed that, If the value for grouping ICDAS codes 0, 1, and 2 is chosen as the cutoff point for the sensitivity calculation, the average value for Soprolife is 1.27with a corresponding sensitivity of 90.91% and a specificity of 58.64%.

Soprolife showed high sensitivity value (90.91%) which indicates a strong ability to detect caries lesions when they are present. And low specificity (58.64%) which indicated to the device had moderate ability to detect the non cavitated carious lesion. This high sensitivity for the two devices reflected their ability to be reproducible and reliable devices. This outstanding performance of the device could be explained by the fluorescence signal and expression are most probably triggered and modified by bacteria and bacteria byproducts. The blue light transmits through healthy enamel and evokes a green fluorescence of the dentin core. The green fluorescence light coming back from the dentin core then leads to a red fluorescence from bacteria and bacterial byproducts like porphyrins [(3)].

The low specificity could be explained by white-spot lesions and non-cavitated lesion formed in vivo does not produce a significant increase in fluorescence compared with sound surfaces. Distinct fluorescence of the caries process in more advanced stages leads to the assumption that, besides light scattering, bacteria or their metabolites could contribute to the fluorescence of these lesions. Carious material had an intense fluorescence maximum in the red spectral region, containing mainly porphyrin (by products). Thus, molecules that contribute to the signal obtained from caries were identified. [(17)]

The results of this study show agreement with **Rechmann et al 2012** who found that, At a cutoff point grouping healthy teeth and precavitated lesions together, DIAGNOdent shows a sensitivity of 87% and specificity of 66%, followed by SOPROLIFE daylight with sensitivity to specificity 93% to 63%, SOPROLIFE blue fluorescence with 95% to 55%, and Spectra Caries Detection Aid with 92% to 37% [(3)].

The results of this study show disagreement with **Theocharopoulou A et al 2015** [(26)], the sensitivity of Soprolife was 0.43 (95% CI: 0.23- 0.66) and its specificity was 1.0 (95% CI: 0.76-1.0) compared to ICDAS. The sensitivity of DIAGNOdent was 0.62 (95% CI: 0.39-0.81) and its specificity was 0.81 (95% CI: 0.54-0.95) compared to ICDAS. This could be explained as in this study the sample size was 37 point on occlusal surfaces (13 on primary molars 24 on permanent molars) and ICDAS (cut-off value 3). The sample size used in this Study were 400 point on 80 occlusal surface where as ICDAS cut-off value 0, 1, 2.

V. Conclusion

The Soprolife had the ability to differentiate between carious and sound tooth structures**.** Soprolife have high sensitivity and low specificity. A high sensitivity indicated that the device was appropriate for caries detection, while owning moderate low specificity, mean that device having some difficulty in detecting non cavitated lesions and there are more instances of false positive outcomes. Consequently, it is advised to combine alternative approaches ICDAS II with Soprolife.

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