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Research Paper

Validity assessment of a third-generation light-induced fluorescence device in detecting proximal and occlusal caries lesions: A cross-sectional study

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ABSTRACT

Objectives: The objective of this study was to evaluate the efficacy of a quantitative light-induced fluorescence (QLF) device (QrayCam Pro, AIOBIO, Seoul, Republic of Korea) in detecting and differentiating the severity of posterior proximal and occlusal primary caries.

Materials and methods: The study included a total of 120 teeth in 60 patients (of both genders, aged between 21 and 38 years) between January and March 2024, one carious tooth and one sound tooth were selected at random in each patient. All occlusal surfaces were evaluated in accordance with the International Caries Detection and Assessment System (ICDAS) Nyvad Criteria, using the visual tactile method. The ICDAS employs a scoring system ranging from 0 to 6, while the Nyvad Criteria employs a similar scoring system. Addionally, the depth of the proximal lesions was scored (0–6) using bite-wing radiography. The quantitative values representing the maximum loss of fluorescence (ΔFmax) and the maximum change in the ratio of red and green fluorescence (ΔRmax) were obtained using the Q-ray Clinical software v 1.45. To assess the validity, the sensitivity, specificity, and area under the receiver operating characteristics curve (AUROC) were calculated. Spearman correlation coefficient was used to investigate the correlation between the findings of the traditional and QLF examination methods.

Results: The AUROC values for both ΔFmax and ΔRmax were found to be excellent. The sensitivity of QrayCam Pro was found to be 84–88.6%, while the specificity was 100%. The correlation analysis demonstrated a strong correlation between scores obtained from the traditional examination and the QLF values.

Conclusions: Based on the findings of this study, QrayCam Pro exhibits potential as a valuable additional tool for not only detecting caries but also for assessing their severity and activity.

Clinical relevance: This study revealed that QrayCam Pro might be suggested as a precise tool for enhancing caries detection and assessment compared to traditional methods. By providing quantitative data on caries severity and activity, it enables more informed treatment decisions, potentially optimizing outcomes for patients.

1. Introduction

Dental caries is a prevalent oral disease characterized by the demineralization of tooth structure caused by acid-producing bacteria [1]. The development of dental caries is decreasing worldwide along with the increased use of fluoride and interest in oral health, whereas the relative prevalence of non-cavitated caries lesions is increasing [2]. Thus, detection of these caries solely with the visual-tactile method might be challenging for the clinician [3]. The International Caries Assessment and Detection System (ICDAS) is the commonly used method for assessing the severity and activity of caries lesions based on visual and tactile examination. While the visual-tactile method is widely used in dental practice, it has limitations in detecting early caries lesions, especially on occlusal and proximal surfaces. The reliance on visual and tactile methods alone may result in misdiagnosis or delayed diagnosis of caries lesions [4,5]. However, clinical signs usually appear in visual and radiographic examinations only after a lesion has progressed considerably into the dentin [3–5]. Visual-tactile examinations for identifying non-cavitated lesions present notable challenges due to considerable variations in sensitivity (ranging from 0.20 to 0.96) and specificity (ranging from 0.50 to 1.00), along with significant diagnostic discrepancies between different examiners [6]. Similarly, radiographic methods, demonstrate low sensitivity (ranging from 0.14 to 0.38) coupled with high specificity (ranging from 0.59 to 0.90) in detecting

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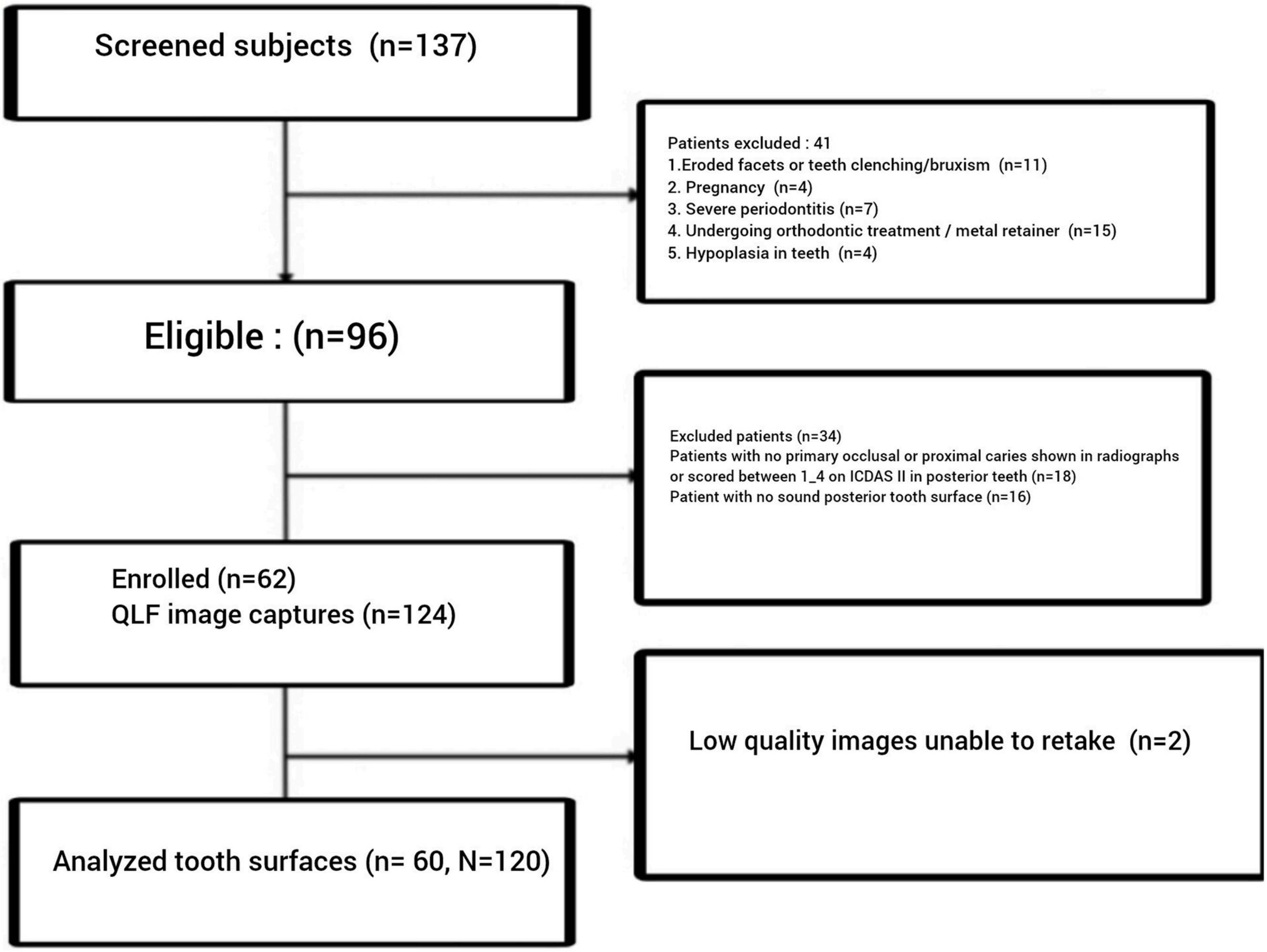

Fig. 1. Flow diagram of the inclusion and exclusion process for teeth surfaces (n = number of subjects, N = number of tooth surfaces).

caries lesions [6]. These limitations underscore the inadequacy of current approaches to reliably diagnose dental caries and highlight the need for more reliable diagnostic tools and methods to improve patient care and outcomes [6,7]. The Quantitative Light-induced Fluorescence (QLF) technology enables quantitative assessment of mineral loss and bacterial activity, serving as an adjunctive technique for detecting subtle alterations in tooth structure. Its efficacy lies in its ability to harness tooth autofluorescence, a natural emission of light that occurs when certain molecules within the tooth are excited by external radiation. Specifically, QLF utilizes a wavelength of 405 nm visible blue light to irradiate the tooth surface, prompting the emission of auto fluorescent signals. These signals, which vary in intensity and pattern depending on the health and composition of the tooth, are then captured and analyzed by a software program. QLF technology has been widely used since the 1980s to observe fluorescence changes regarding mineral loss using visible light in the blue spectral range [8–11].

QrayCam (AIOBIO, Seoul, Republic of Korea) is a third-generation QLF device introduced in 2018.It features LED light sources, a CCD camera for image capture, and Inspektor glass filter, placed between the lens and the image sensor, covers the entire field of view. It enhances fluorescence image contrast by blocking background light and noise, thereby improving image clarity. A CMOS image sensor (FHD 1080p) and large FOV compared to previous generations [8]. Various types of devices based on QLF technology have been developed. The first-generation QLF system, Inspektor Pro (Inspektor Research Systems BV, Amsterdam, the Netherlands), was introduced in 2004 and comprises a 404 nm peak wavelength of light (with a full width at half maximum of 22 nm), a high-pass filter (>520 nm), and a micro-CCD camera. The second-generation device, the Quantitative Light-Induced Fluorescence—Digital Biluminator 2+ (QLF-D, Inspektor Research Systems BV), was introduced in 2012. It mainly uses a single-lens reflex (SLR) camera, with the Biluminator system containing 405 nm peak wavelength violet-blue light LEDs (with a full width at half maximum of 15 nm), white-light LEDs, and an Inspektor filter (a high-pass filter >480 nm combined with a pink filter to emphasize the 630 to 640 nm band). These various generations of QLF devices use visible light of the same wavelength but differ in their cameras, capturing methods, and filters [12].

The device allows simultaneous acquisition of both white-light and fluorescence images, overcoming the challenges of anatomical structures and debris often encountered when relying solely on fluorescence images to assess dental caries. The QrayCam Pro facilitates the detection of caries using the red fluorescence emitted by a substance produced by oral bacteria that infiltrates the tooth surface (porphyrin) and the loss of fluorescence emitted by the tooth structure, which correlates with mineral loss in the lesions [12]. To the best of our knowledge, only one study has evaluated the validity of QrayCam Pro in the detection of caries and showed low accuracies in the detection of proximal caries compared to the detection of occlusal caries [8]. Therefore, this study aimed to evaluate the validity of QrayCam Pro in the detection of non-cavitated caries lesions based on the visual-tactile method and bitewing radiography. The visual-tactile method included the ICDAS II and NYVAD scoring systems as the gold standard for the evaluation of occlusal caries, and bitewing radiography served as the gold standard for

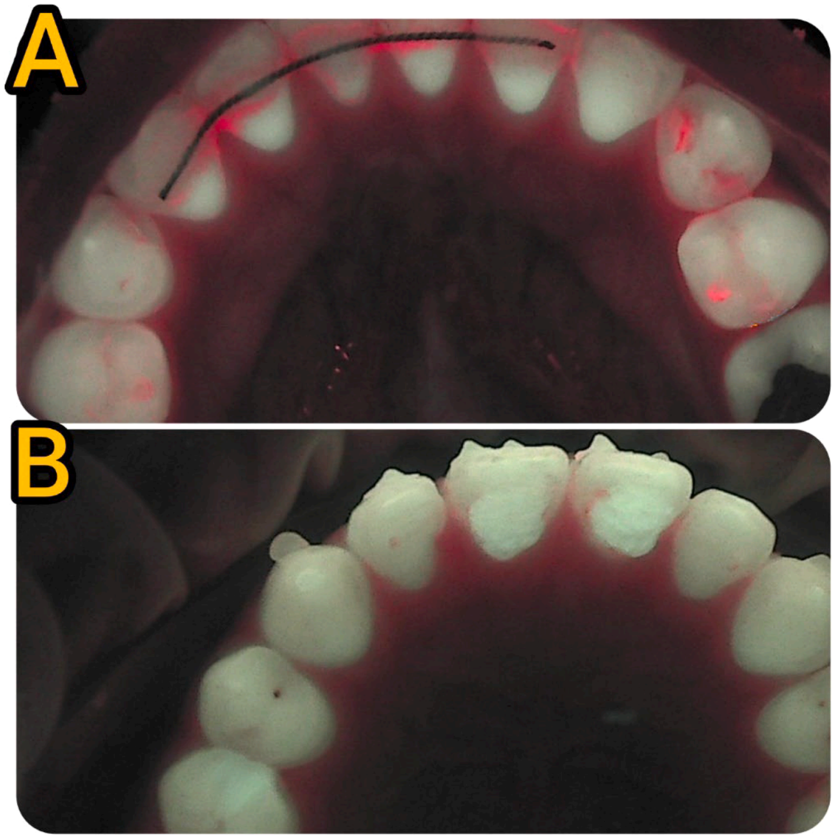

Fig. 2. (A) Patient was excluded due to metal retainer presenting possible misdiagnoses, (B) Patient with Invisalign orthodontic bracelets did not show misdiagnoses.

Table 1
Criteria used for QLF and radiographic scores in this study.

QLF score for proximal caries (QS-Proximal, Q0-Q3) [22]	QLF score for occlusal caries (QS-Proximal, Q0-Q3.) [32]	Radiographic score with ICCMS criteria (R0-R5) [13,22]
Q0: No dark shadow or red fluorescence was present.	Q0: No fluorescence loss or increase in red fluorescence was present in pits and/or fissures	0: No radiolucency
Q1: Irregular dark shadow with no red fluorescence.	Q1: Fluorescence loss and red fluorescence were present as lines or dots in pits and/or cracks.	1: Radiolucency in the outer 1/2 of the enamel
Q2: Pale red fluorescence present within one-third of the Bucco-lingual width.	Q2: Fluorescence loss and red fluorescence were around the pits and cracks.	2: Radiolucency in the inner 1/2 of the enamel (dento-enamel junction)
Q3: Strong red fluorescence present in more than one-third of the Bucco-lingual width	Q3: Widespread red fluorescence around pits and cracks with a dark shadow reflection from dentin.	3: Radiolucency limited to the outer 1/3 of dentin
		4: Radiolucency reaching the middle 1/3 of dentin
		5: Radiolucency in the inner 1/3 of dentin

the detection of proximal caries.

2. Materials and methods

2.1. Study design

The principles of Declaration of Helsinki and the guidelines of Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) were followed. The study was approved by the University Ethical Committee under Protocol Number: XX-XXXX. All participants provided written informed consent prior to clinical examination.

2.2. Participants and sample selection

Potential participants (aged between 18 and 65) referred to Restorative Dentistry Department with at least one non-cavitated proximal or occlusal caries lesion were invited to the study between January 2024 to March 2024. Study flow chart is given in Fig. 1.

Patients with severe periodontitis, clenching/bruxism, metal retainer were excluded from the study, while patients with clean aligner appliances did not interfere with QLF image taking procedure (Fig. 2). Pregnancy was also an exclusion criterion regarding radiographic examination.

For standardization, preferably sound posterior teeth of the same type in the same jaw were examined as control, (e.g. mesial proximal surface of tooth number 25 with ICDAS score 4 and sound mesial proximal surface of tooth number 15).

2.3. Diagnosis by ICDAS II

Teeth were professionally cleaned using a rubber cup, and low speed handpiece prior to performing the clinical and QLF examinations. Since debris or plaque might affect the measurements, interproximal surfaces were cleaned using dental floss. The clinical examinations were performed by a single calibrated examiner, using the ICDAS II criteria [3], and were scored accordingly as follows:

1. indicated a sound tooth surface
2. enamel caries detectable only after prolonged air drying
3. obvious visual changes in enamel

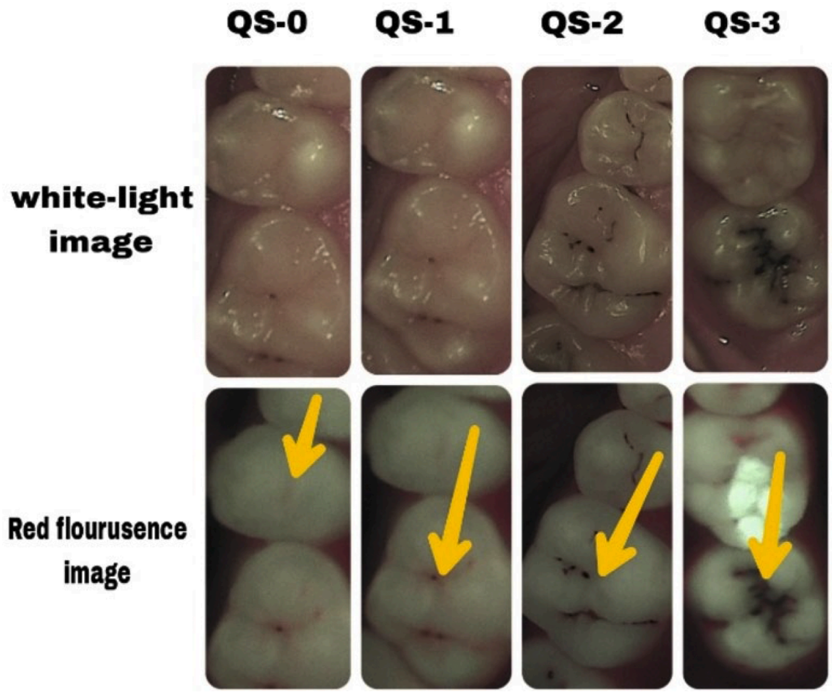

Fig. 3. QS occlusal score: Level 0: No fluorescence loss or increase in red fluorescence was present in pits and/or fissures; Level 1: Fluorescence loss and red fluorescence were present as lines or dots in pits and/or cracks; Level 2: Fluorescence loss and red fluorescence were around the pits and cracks; Level 3: Widespread red fluorescence around pits and cracks with a dark shadow reflection from dentin.

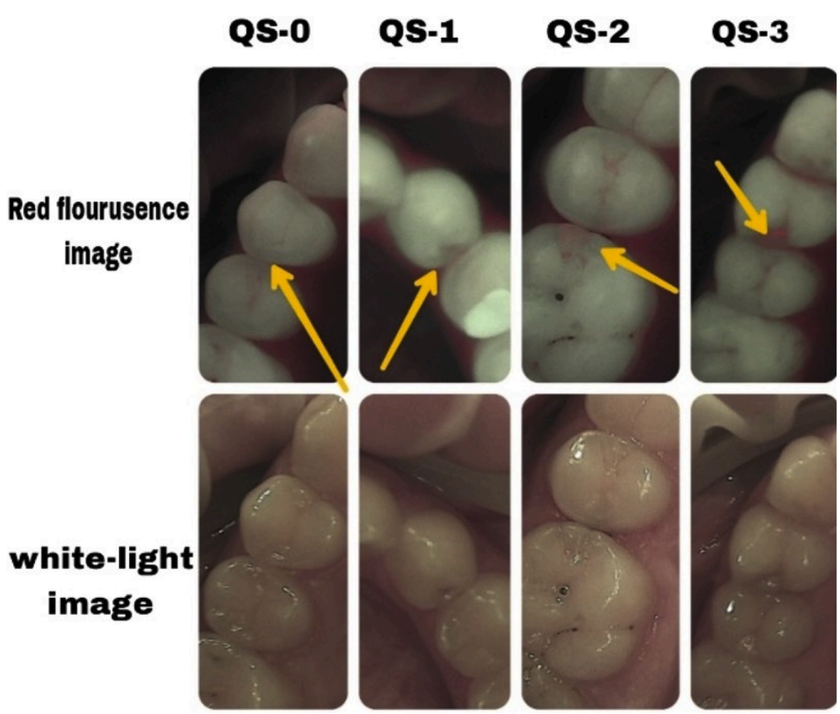

Fig. 4. QS score of proximal surfaces: Level 0: No dark shadow or red fluorescence was present; Level 1: Irregular dark shadow with no red fluorescence; Level 2: Pale red fluorescence present within one-third of the Bucco-lingual width; Level 3: Strong red fluorescence present in more than one-third of the Bucco-lingual width.

4. caries that did not reach dentin, showing localized enamel degradation
5. a dark shadow indicating dentin caries
6. cavitated dentin caries
7. dentin caries covering more than half of the tooth [3].

2.4. Radiographic examinations

Digital bitewing radiographic examinations were performed using x-ray device (Castellini Cefla s.c. Via Selice, 23/A, 40,026 Imola BO, Italy) and film holding instrument for bite-wing radiography (Kwik bite, Kerr corporation, Orange, CA, USA). Then the images were scored according

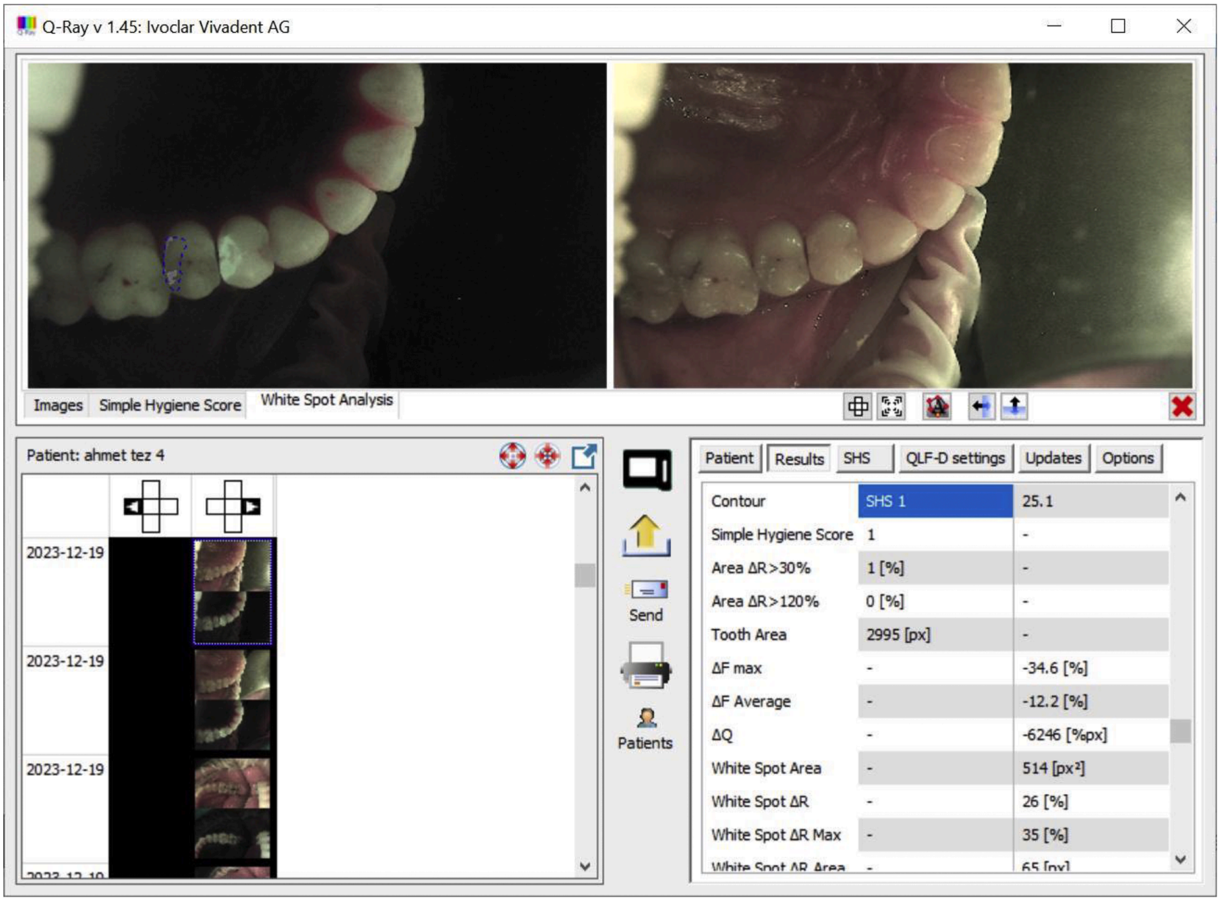

Fig. 5. This figure shows the environment where the pictures were taken, each time the device took two photos simultaneously, the designated area was highlighted according to manufacturer's Instructions, and the readings showed values of ΔRmax and ΔFmax.

Table 2
Sensitivity, specificity, and area under the receiver operating characteristic curve (AUROC) for QLF parameters in detecting occlusal caries lesions.

	Cut-off	Sensitivity (% 95 CI)	Specifity (% 95 CI)	AUROC (% 95 CI)
ΔFmax	<−34	84 (63.9–95.4)	100 (86.2–100)	0.946 (0.843–0.989)
ΔRmax	>0	92 (73.9–98.8)	96 (79.6–99.3)	0.942 (0.838–0.988)

to International Caries Classification and Management System (ICCMS) (13) (Table 1).

2.5. Acquiring of QLF images and the readings of QrayCam pro device

All QLF images were taken by one single trained and calibrated evaluator in the same dark room with as little ambient light as possible. Additionally, the cheek and lips were retracted using OptraGate (Ivoclar-Vivadent AG Schaan, Liechtenstein). After selected teeth were graded according to ICDAS II and ICCMS (as the gold standard), QLF images were captured using the third generation QLF Device (QrayCam, AIOBIO, Seoul, Republic of Korea). The fluorescence properties (fluorescence loss and red fluorescence) of selected teeth in the fluorescence images were recorded.

2.5.1. QS scoring of occlusal and proximal surfaces

The common characteristics were categorized into four stages to yield a quantitative light-induced fluorescence score for the occlusal and proximal caries (Table 1). Subsequently, a score system was applied to record the QS score of the occlusal surfaces (Fig. 3) and proximal surfaces (Fig. 4) prior to further analysis.

2.6. Analysis

2.6.1. Analyzing of QLF images

In accordance with manufacturer recommendations, an analysis area was determined by drawing a border that encompassed sound parts without caries lesions or pits and fissures. The fluorescence changes of occlusal and proximal surfaces were calculated by the Q-ray Clinical software v 1.45 (Fig. 5), ΔFmax, ΔRmax and ΔR values were measured.

2.6.2. Statistical analysis

The visual examinations and image classification were performed for sound or non-cavitated occlusal surfaces independently. The normal distribution of the data was examined using the Shapiro-Wilk test.

For validity assessment area under the receiver operating characteristic curve (AUROC), sensitivity, and specificity were calculated for two categories as carious and sound. The relationships between clinical and radiographic scores and device measurements were assessed using Spearman rank correlation analysis. A statistical significance level of $P \leq 0.05$ was accepted, and calculations were performed using the SPSS (ver. 23) program.

3. Results

Out of 137 patients, 120 surfaces of 60 patients aged between 21 and 38 (35 males, 25 females; mean age: 24.13 years) were included in the study. The sample was divided into two groups (proximal and occlusal)

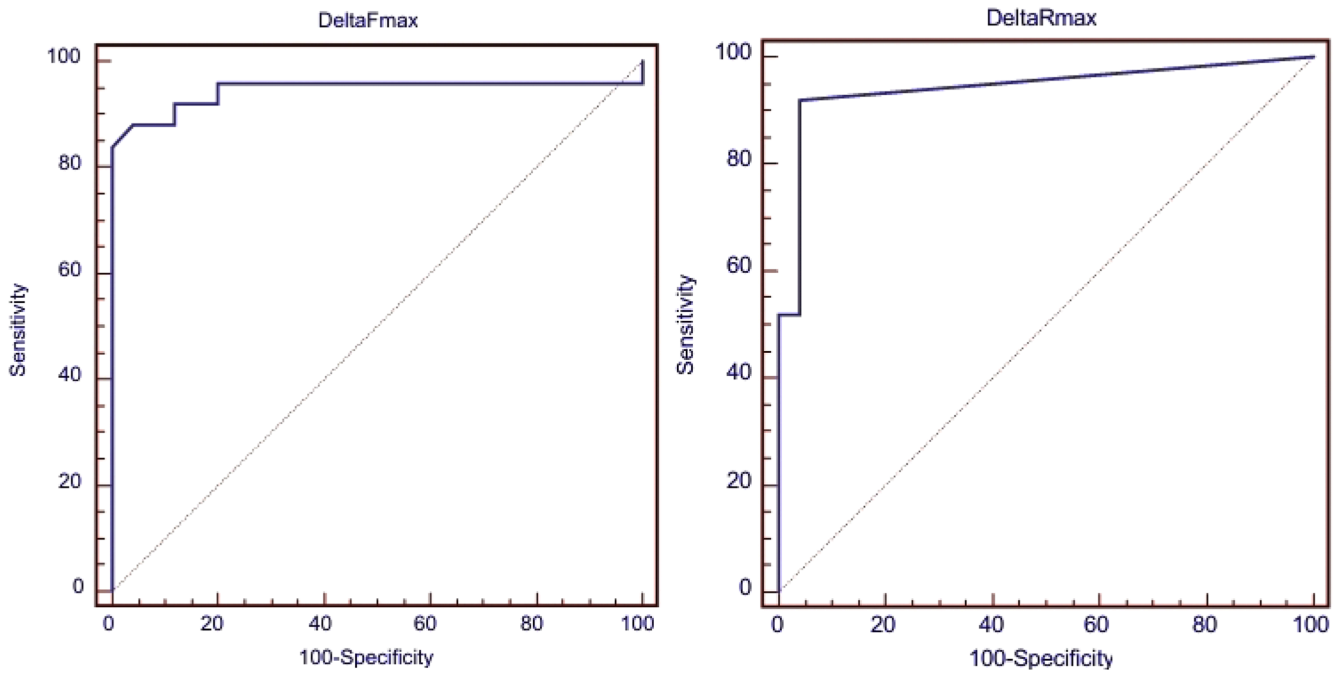

Fig. 6. Sensitivity and specificity ROC Curves for ΔFmax and ΔRmax of analysed occlusal surfaces.

Table 3
Sensitivity, specificity, and area under the receiver operating characteristic curve (AUROC) for QLF parameters in detecting proximal caries lesions.

	Cut-off	Sensitivity (% 95 CI)	Specifity (% 95 CI)	AUROC (% 95 CI)
ΔFmax	≤−25	88 (73,2–96,7)	100 (89,9–100)	0,969 (0,897–0,995)
ΔRmax	>0	92 (73,9–98,8)	100 (89,9–100)	0,929 (0,841–0,976)

Table 4
Distributions of QS-proximal and Nyvad and ICDAS scores according to the severity of the proximal caries lesion based on radiographic scores.

	NYVAD SCORE				ICDAS SCORE				QS SCORE			
ICCMS SCORE	0	1	2	3	0	2	3	4	0	1	2	3
3 ($n = 14$)	0	11	2	1	1	0	1	12	0	1	7	6
4 ($n = 5$)	0	3	1	1	1	0	0	4	0	1	2	2
5 ($n = 2$)	0	1	1	0	0	0	0	2	0	0	0	2

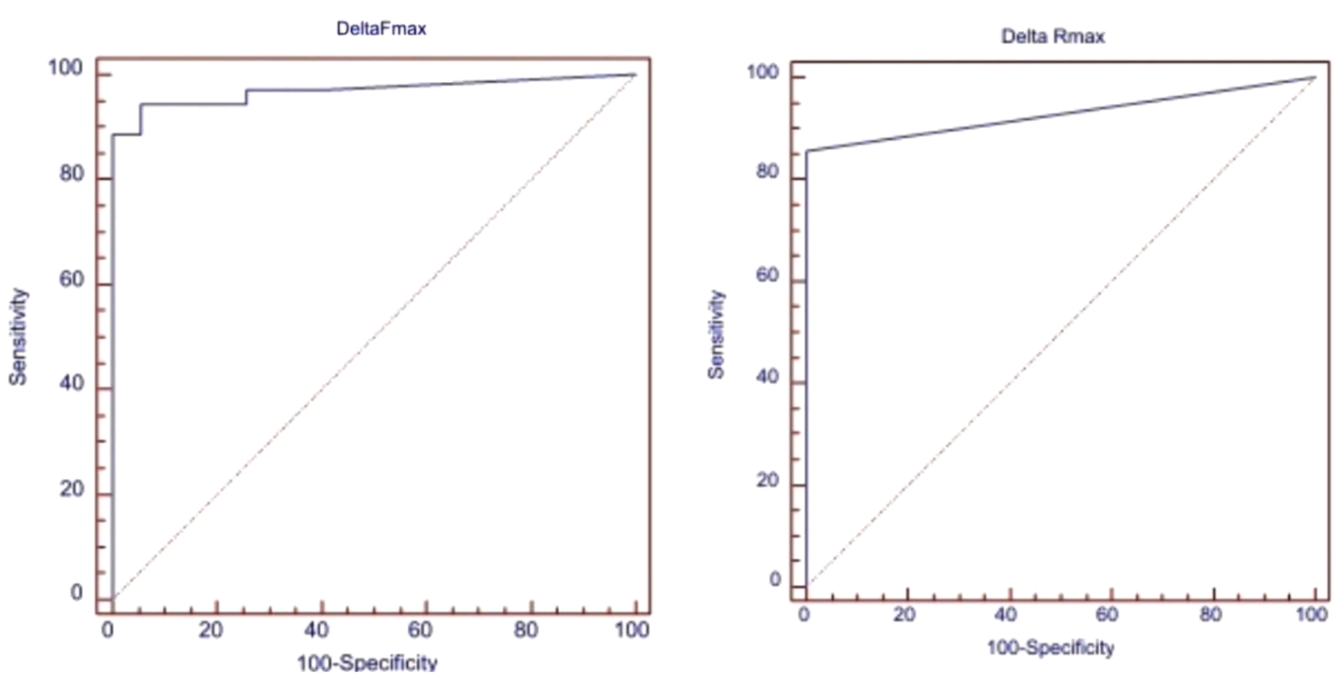

Fig. 7. Sensitivity and specificity ROC Curves for ΔFmax and ΔRmax of analysed proximal surfaces.

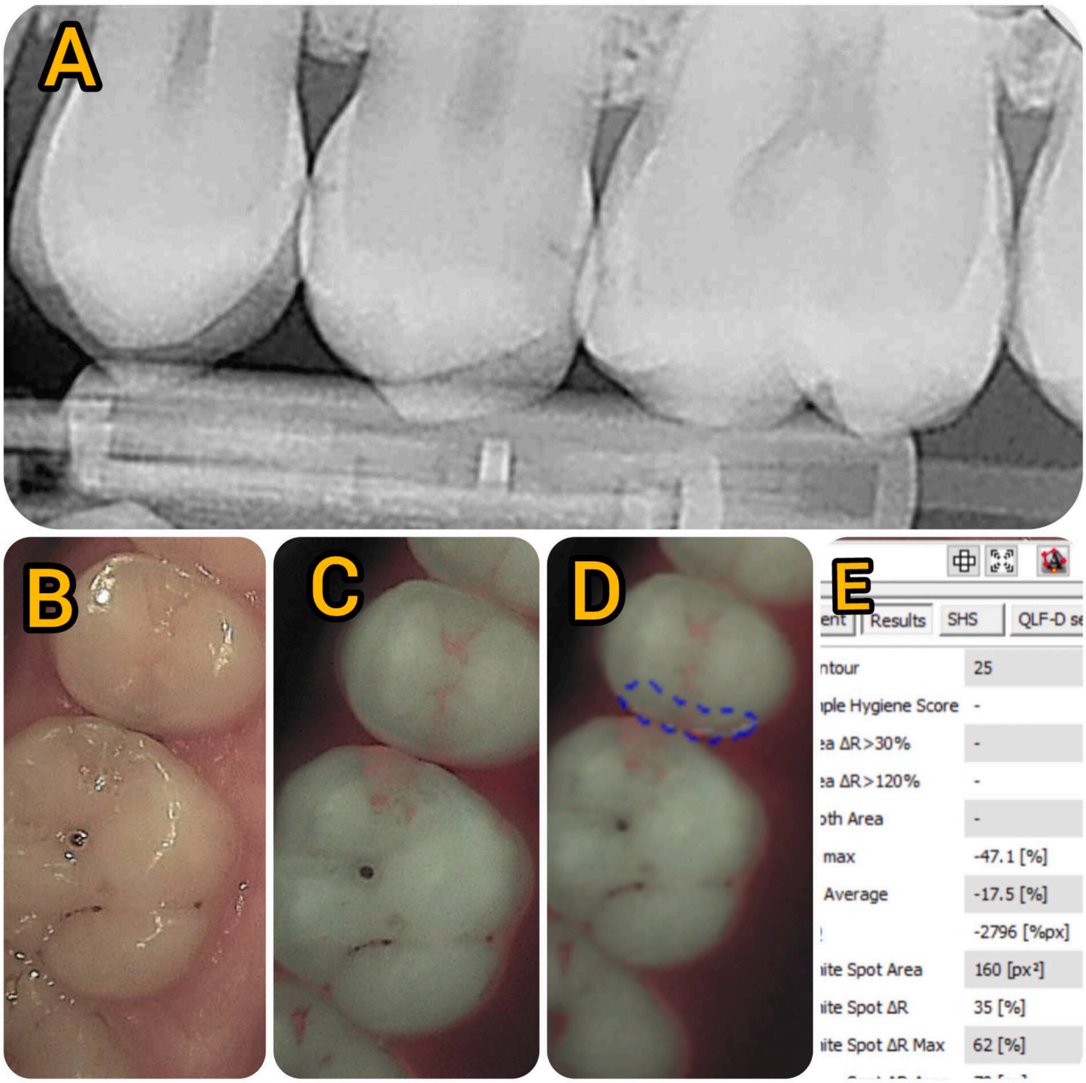

Fig. 8. (A) shows distal caries on tooth number 25 Below the contact area with ICCMS score of 3 (B) focused photo of the occlusal surface of the tooth after using dental floss in the interproximal area (C) fluorescence image of the previous picture shows QS score of 2 (D) drawing the border on the surface according the manufacturer's instructions (E) analysis of designated surface showing mineral loss and bacterial activity.

based on the examined surfaces.

3.1. Results of occlusal surfaces

For the occlusal surfaces, measurements were taken from the occlusal surfaces of a total of 50 teeth, with 2 teeth from each of 25 individuals. One of these teeth was carious, and the other was healthy. The ages of the 25 individuals ranged from 21 to 31 years, with an average age of 24.04 ± 2.35 years. Of the 25 individuals, 14 (56%) were male.

3.1.1. Assessment of QLF parameters for occlusal caries detection

The results demonstrated a strong correlation between the ICDAS score and the ΔFmax ($r = -0.749$; $p < 0.001$). Additionally, a very strong correlation was observed between the ICDAS score and the ΔRmax ($r = 0.890$; $p < 0.001$).

Table 2 shows the values of the QLF parameters in the detection of occlusal caries lesions. For ΔFmax, a cut-off value of less than or equal to −34 resulted in an 84% sensitivity (95% CI: 63.9–95.4), a 100% specificity (95% CI: 86.2–100), and an AUROC of 0.946 (95% CI: 0.843–0. For ΔRmax, a cut-off value greater than 0 resulted in a sensitivity of 92% (95% CI: 73.9–98.8), a specificity of 96% (95% CI: 79.6–99.3), and an AUROC of 0.942 (95% CI: 0.838–0.988). Fig. 6 shows receiver operating characteristic curves for ΔFmax and ΔRmax of the analyzed occlusal surfaces.

3.1.2. Assessment of QLF score for occlusal caries detection

The results showed a very strong correlation between ICDAS score and QS occlusal score $r = 0.833$;($p < 0.001$).

3.2. Results for proximal surfaces

For the proximal surfaces, measurements were taken from a total of 70 teeth, with each of the 35 individuals contributing two teeth. One of these teeth was carious, while the other was sound. The ages of the individuals ranged from 21 to 38 years, with 21 of them (60%) being male. The average age of the total 35 individuals was found to be 24.2 ± 3.56 years

3.2.1. Assessment of QLF parameters for proximal caries detection

The results demonstrated a strong correlation between the ICCMS score and ΔFmax ($r = -0.777$; $p < 0.001$). Additionally, a very strong correlation was observed between the ICCMS score and ΔRmax ($r = 0.863$; $p < 0.001$).

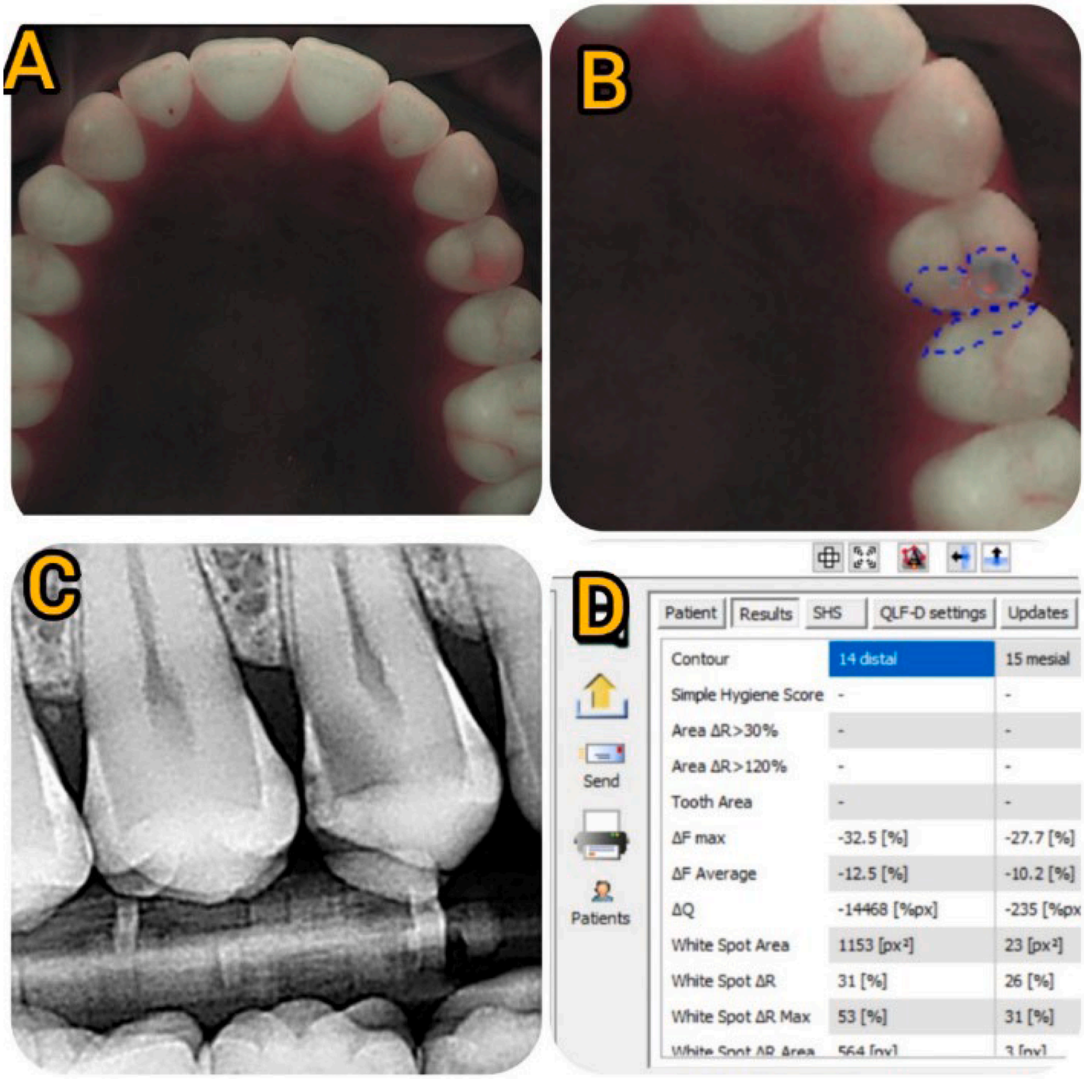

Fig. 9. (A)The distal surface of tooth number 14 had QS score of 3, while the mesial surface of tooth number 15 had QS score of 1, (B) drawing borders according to manufacturer's instructions (C) tooth number 14 exhibiting an ICCMS score of 5 and Tooth Number 15 had score of 3 with Radiolucency on the dento-enamel junction (D) both analysed surfaces showed ΔRmax values that had good readings of lesions depth the readings on tooth number 15 were not affected by the adjacent tooth high ΔRmax value.

Table 3 illustrates the values of QLF parameters in the detection of proximal caries lesions. For ΔFmax, a cut-off value of less than or equal to −25 was found to result in a sensitivity of 88% (95% CI: 73.2–96.7), a specificity of 100% (95% CI: 89.9–100), and an AUROC of 0.969 (95% CI: 0.897–0.995). For ΔRmax, a cut-off value of greater than 0 resulted in a sensitivity of 92% (95% CI: 73.9–98.8), a specificity of 100% (95% CI: 89.9–100), and an AUROC of 0.929 (95% CI: 0.841–0.976). Fig. 7 shows the receiver operating characteristic (ROC) curves for the analyzed proximal surfaces for both ΔFmax and ΔRmax.

3.2.2. *Assessment of QS proximal score for proximal caries detection*

The results showed very strong correlation between QS proximal score and ICCMS ($r = 0.851$; $p < 0.001$), and ICDAS score and ICCMS ($r = 0.828$; $p < 0.001$). Table 4 shows the comparisons and distributions of QS-proximal, Nyvad and ICDAS scores according to the severity of the proximal caries lesion based on radiographic scores for dentine caries.

4. Discussion

The results of this study demonstrated the efficacy of QrayCam pro in the detection of non-cavitated caries. One study, which employed the same third-generation device, QrayCam pro, indicated lower sensitivity and specificity for proximal caries detection compared to occlusal caries detection. However, the results for proximal caries detection were deemed to have a reduced reliability due to the limited number of analyzed proximal surfaces [8]. The present study demonstrates good sensitivity and specificity for the detection of both proximal and occlusal caries lesions, with 70 analyzed proximal and 50 analyzed occlusal surfaces.

As previously mentioned, porphyrin-induced metabolites from oral microorganisms give rise to red fluorescence, which is evident in dental caries [14]. QLF devices are capable of assessing the severity of dental caries by detecting red fluorescence, as well as oral bacterial structures such as plaque and calculus. These methods facilitate the evaluation of bacterial metabolic activity by detecting increased red fluorescence levels [11,15,16]. Consequently, in some cases, dental plaque and stains may result in misreading, suggesting the need for more than the average cleaning. This illustrates that while QrayCam Pro can facilitate the diagnosis of patients in many cases, the classic visual-tactile method may be a more time-efficient approach in instances of severe dental plaque and stains.

While QLF devices allow for the objective quantification of lesion

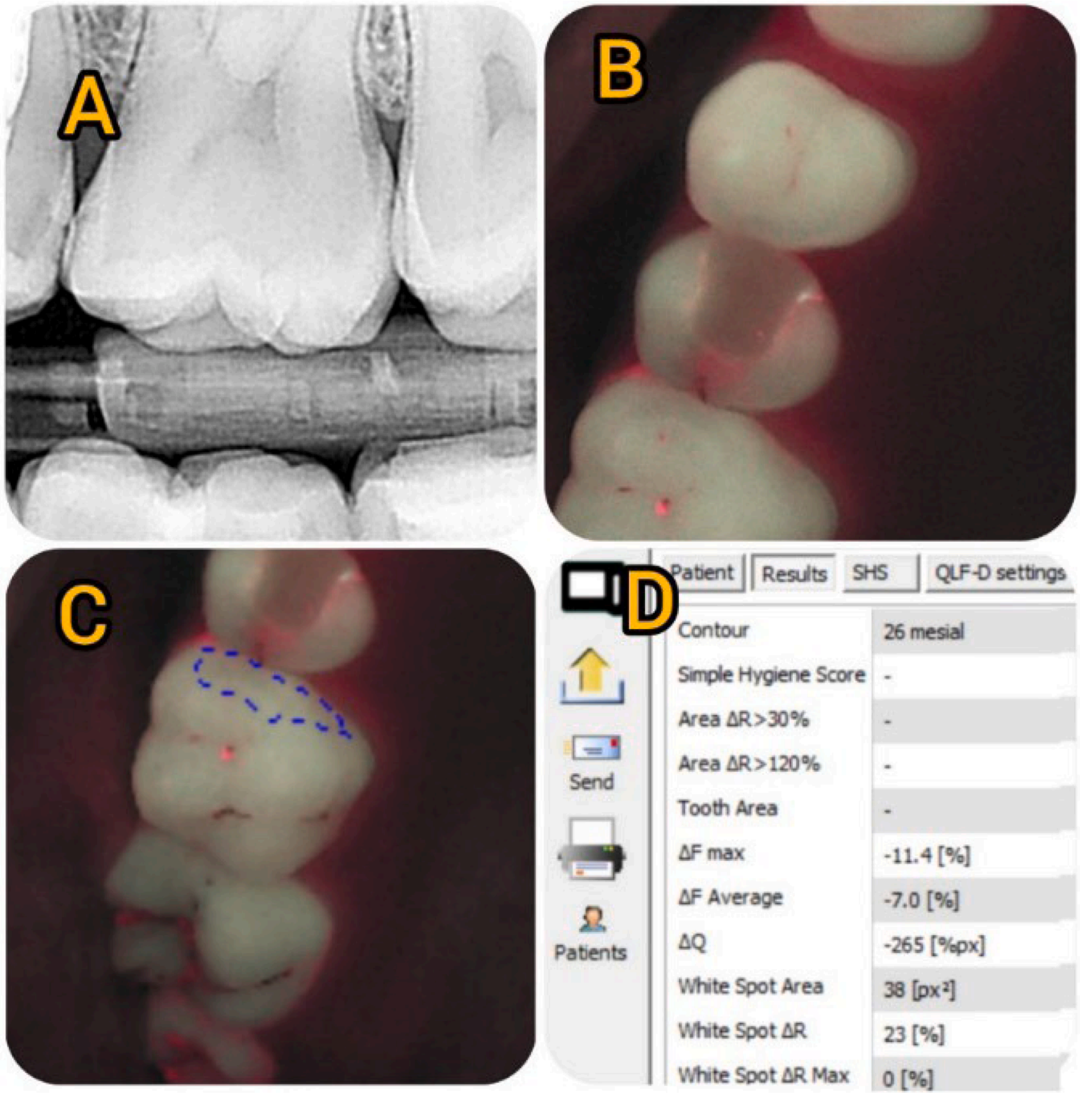

Fig. 10. (A) shows ICCMS score of 1, Radiolucency below the contact point but has not extended to the 2nd half of the enamel on tooth number 26, tooth number 25 shows ICCMS score of 4 (B) the distal side of tooth number 25 had QS score of 3 while tooth 26 has QS score of 0 with no grey color on the contact area (C) tooth 25 was not analysed because it had a restoration,(D) analysis of tooth number 26 showed values of ΔR but not of ΔRmax.

status using QLF parameters (e.g., ΔF and ΔR) calculated by supplied software [17–19], there are still limitations in terms of cost and time when utilizing specialized software in a busy clinic to obtain precise quantitative values for each lesion [20].

Interpreting the status of caries lesions in clinics can be difficult, requiring a simplified scoring system. Large-scale surveys with limited examiners visiting multiple sites are costly and time-consuming. Acquiring clinical data through image capture and evaluation by other dental professionals could overcome these challenges, making easier data accumulation without space or visit limitations for both clinical and educational purposes [21,22]. In this study, the QS scores were highly aligned with ICDAS scores, suggesting that QS scores are a reliable measure for assessing dental caries, and in proximal caries the correlation between QS proximal score and ICCMS score was even slightly higher than correlation coefficient between QS proximal score and ICDAS score. These findings indicate that QLF technology significantly reduces the likelihood of misdiagnoses encountered when assessing non-cavitated early caries lesions solely through visual and radiographic examinations. Such high correlation and agreements underscore the technology's efficacy in providing consistent and reliable diagnostic outcomes, thereby enhancing the accuracy and precision of dental caries detection and management [8].

Considering the typical features of occlusal caries, the maximum loss of fluorescence (|ΔFmax|) and the maximum percentage of red fluorescence increased at the lesion site compared to red fluorescence of normal enamel (ΔRmax) were used to represent pit and fissure lesions, because they show an inverted V-shape with a narrow entrance and a progressively wider area to the dento-enamel junction. In general, tooth fluorescence is stronger in the dentine than in the enamel and is brightest at the dento-enamel junctions [23].

Recent studies have suggested that ΔR is better for distinguishing lesion depth [24], while previous studies have demonstrated that ΔFmax (reflecting the degree of mineral loss) is an index that accurately reflects the histologically measured depth of a lesion [12]. Caries lesions exhibit both red and green fluorescence. They generally contain lower mineral content and higher levels of organic matter and water compared to a healthy tooth surface [25,26]. Bitewing radiographs provide a two-dimensional image of the teeth, allowing visualization of interproximal caries that may not be visible during a visual examination. However, bitewing radiography has its own limitations, including radiation exposure [12,24]. Earlier research suggests that radiography is not suitable for detecting non-cavitated caries lesions due to its low reported sensitivity (0.17–0.83) [24]. Other studies assessing proximal carious and sound surfaces used fluorescence images captured from the occlusal surface. This indirect evaluation faced challenges in confirming the relationship between lesion depth and fluorescence parameters [27, 28]. However, another study demonstrated that QLF (Quantitative Light-induced Fluorescence) technology can effectively serve as a screening tool and a reference to detect proximal dental caries before resorting to further examination [22,29].Another study suggested limitations of QrayCam pro claiming that obtaining images perpendicular to the occlusal surfaces (at 90°) was less effective for detecting caries compared to images taken at other angles [30]. Moreover, a previous *in vitro* study assessing proximal caries in three directions (buccal, lingual, and occlusal) reported that detecting caries was more possible in the buccal and lingual directions compared to the occlusal direction [31].

Fig. 8 shows patient with ICCMS score of 3 on tooth number 25 distal proximal surface, after using dental floss in panel, the device was able to measure ΔRmax; which has been used in other research as a value indicating the depth of the lesion [24].

While another study showed lower sensitivity and specificity when it comes to QrayCam detecting proximal caries

The device proved to be a good screening tool for early diagnosis of tooth surfaces adjacent to deep carious surfaces where in (Fig. 9) tooth 25 was accurately diagnosed and analysed, even in a more superficial lesion in (Fig. 10) tooth number 26 had an ICCMS score of 1 and the device showed QS score of 1 and showed values of ΔR and of ΔRmax was 0 when the surface was analyzed, ΔRmax scoring 0 while ΔR scoring $<$ 0 is an indicator of low lesion depth and low bacterial activity [24].

Previous studies have employed ICDAS II and radiography scores as gold standards [22,24,31]. Additionally, other research has utilized histological analysis to accurately determine lesion depth, thus reaffirming the validity of QLF parameters and providing evidence for the diagnosis of early dental caries [12,31,32], However, *in vitro* experiments are limited because they do not accurately reflect the actual clinical setting. Remains of Dental plaque and stains remaining on the tooth surface even after thorough cleaning before QLF imaging may have affected the results of this study. this is one of few studies to assess the validity of the newest version of the 3rd generation QLF device in detecting both proximal and occlusal non-cavitated caries simultaneously and assessing the nature of it and the challenges it is still facing all while considering the actual clinical process.

5. Conclusions

This study shows that QrayCam pro can be used as a reference and a screening tool with a good validity in early diagnosis but it's still technique sensitive and requires specific environment and criteria to achieve better diagnosis.

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CRediT authorship contribution statement

Ahmad Bittar: Writing – original draft, Visualization, Validation, Software, Methodology, Formal analysis, Data curation, Conceptualization. **Tuba Çetin:** Writing – review & editing, Visualization, Validation, Data curation. **Gizem Meva Başyiğit:** Writing – review & editing, Validation, Data curation. **Burcu Gözetici-Çil:** Writing – review & editing, Supervision, Project administration, Methodology, Conceptualization.

Declaration of competing interest

The authors did not have any commercial interest in any of the materials used in this study.

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