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Case Report

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Shedding light on hidden caries detection with fluorescence enhanced dental loupes and radiographic examination: A case report

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Abstract

This study evaluated the effectiveness of newly introduced fluorescence-enhanced dental loupes ("Reveal") in facilitating the discovery of hidden and early carious lesions. Additionally, it compared fluorescence-based caries detection methods with traditional radiographic techniques. Traditionally, visual-tactile inspection and radiographs are used for caries detection. However, these methods have limitations, including operator subjectivity and exposure to ionizing radiation. Fluorescence-based devices aim to mitigate some of these limitations. Utilizing purple/blue light, physical and biological interactions occur between the light and tissues, allowing for early detection of enamel demineralization (through scattering) and the byproducts of bacterial activity (via red fluorescence). The report describes the examination of three patients with varying lesion types using the "Reveal" loupes, under dual white-light/fluorescence-light conditions. Photographic documentation was performed with a Nikon camera using a "Reveal" coated lens. Lesions were classified according to the ICDAS system, and treatments were tailored based on the lesion type and severity. The findings of the case report showed that fluorescence-light examination with the new device may enhance the detection of early occlusal and smooth surface caries. Notable red fluorescence from active caries lesions was evident, as well as identification of sub-surface dentinal lesions. The dual white-light/fluorescence-light approach was perceived as helpful in treatment guidance, and achieving treatment goal. While fluorescence techniques excelled in identifying surface and near-surface lesions, the traditional radiographic methods are still considered the gold standard in deep lesion detection and monitoring. In conclusion, the clinical use of fluorescence-enhanced dental loupes may increase caries detection sensitivity without compromising the high specificity of the traditional visual-tactile method. Adequately combining fluorescence-based detection methods with radiographic techniques can provide a comprehensive evaluation of dental health, suggesting a promising direction for enhanced clinical decision-making across various dental disciplines. Further research is needed to establish the definitive effectiveness of these devices.

Keywords: Dental loupes, Carious lesions, Radiographic technique, Clinical dentistry.

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INTRODUCTION

Screening for early signs of dental caries is an essential part of clinical dentistry, as it facilitates preventive therapies and allows for minimally invasive treatment [1,2]. To date, visual-tactile inspection is the most commonly used screening method for caries detection [3,4]. This approach relies on the clinician's expertise to detect changes in tooth structure indicative of caries. Some lesions, however, are concealed in non-reachable surfaces. In these regions, bitewing radiographs are typically employed, showing high accuracy for proximal and deep dentinal caries detection [4]. Visual examination, due to its subjective nature, tends to be specific (i.e., high proportion of correctly identified sound surfaces), but not highly sensitive (i.e., low proportion of correctly identified carious surfaces) [5,6]. Therefore, modern dentistry increasingly incorporated adjunct technologies for visual assessment, like fluorescence-based devices. These devices are sensitive for early lesion detection and avoid exposure to ionizing radiation [5-9]. When dental tissues are illuminated with energetic wavelengths of light (e.g. UV or blue light), they naturally emit fluorescence between 410-500nm, with a peak around 440nm (light blue) [10]. Under fluorescence-light, early enamel demineralization appears darker than healthy surroundings, due to localized light scattering from the porous surface [11]. At the presence of metabolically active bacteria, red fluorescence overlaying the tooth surface is visible [5-9]. The red fluorescence is attributed to the presence of porphyrin derivatives which are abundantly found in complex biofilms in caries and calculus [12-14]. Various fluorescence-based devices, such as fluorescence intraoral cameras or laser-induced fluorescence systems, are used in clinical settings [6,7].

Software algorithms analyze the fluorescence patterns, and provide visual feedback to the clinician from a display. Other devices provide direct visual feedback. Among the devices are hand-held light-emitting diode (LED) lamps (SIROInspect., Dentsply Sirona., Charlotte., NC., USA.), dual light-cure/diagnostic systems (D-light Pro., GC Corporation. Tokyo., Japan.), or fluorescence LED couplings (Fluoresce HD., Lares, Chico., CA, US.). A new class of hands-free devices was recently introduced, in which the fluorescence capabilities are integrated into magnification loupes with an optional camera (Reveal, Designs for Vision, Inc. NY, USA) [8,9]. In clinical decision-making, the choice between using fluorescence-based devices or radiographs depends on the specific diagnostic requirements and patient considerations. While exposing the patients to ionizing radiation, X-rays penetrate deep into the tissues and absorbed differentially by their mineral density. It makes them inherently sensitive for deep lesion detection in approximal surfaces [15]. Fluorescence techniques utilize light sources to stimulate fluorescence in the tooth and its overlying substances, without exposure to ionizing radiation. This can highlight surface and near-surface demineralization and bacterial activity or advanced lesions underlaying intact enamel. The aim of this case series was to assess the effectiveness of a hands-free fluorescence-enhanced dental loupes ("Reveal") in identifying hidden carious lesions. The device with its optional camera was said to provide the advantages of extensively researched digital systems, while allowing direct, hands-free use. Additionally, we discuss the drawbacks and advantages of radiographic and fluorescence-detection methods as clinical adjuncts.

CASE REPORT

For the clinical examination in the report, the operator was equipped with the "Reveal" 4.5x Panoramic loupes. The loupes telescopic lenses are coated with transparent coating protecting the clinicians' eyes from energetic light [Fig. 1]. After white-light examination, the operator switched to fluorescence-light examination. The transparent system enabled normal color vision under white-light, which did not require operator or photographic adaptations. The photographic documentation was carried out with a "Reveal" lens, attached to a Nikon Z-6 camera (Nikon Corporation, Yokohama, Japan) with a NIKKOR Z MC 105mm f/2.8 VR lens. The clinical assessment was supplemented with an X-ray, unless the lesion was deemed incipient, or in a buccal-lingual / buccal-palatal projection. The lesions were classified according to the ICDAS (international caries detection and assessment system) visual detection code and radiographic scoring system [16] followed by diagnosis and treatment protocol. The inclusion criteria were to be of legal age, natural/natural-restored teeth, capable of understanding the aims of the report and willing to sign an informed consent. The exclusion criteria were free from systemic or local condition which may affect their oral health and unusual dietary habits. 3 participants were included in the report.

Figure 1: "Reveal" fluorescence-enhanced-magnification-loupes

Case 1

A 51-year-old female patient with a high caries risk complained of tooth sensitivity to cold and sweets in her upper right premolar. Fluorescence [Fig. 2A] and white-light [Fig. 2B] examinations were conducted. White-light examination revealed a lesion on the mesial aspect of 25 (ICDAS code 4), and small lesions at the distopalatal groove and facially to the amalgam restoration on tooth 26 (ICDAS codes 1 and 2, respectively). Fluorescence-light examination revealed an optical occurrence of red fluorescence from within the cavity on 25, in the form of internal red fluorescence glow (IRFG), from the underlying dentin. On tooth 26, red fluorescence was observed along the distopalatal and buccal groove. The radiographic findings [Fig. 2C] were: moderate radiolucent lesion on 25, and two lesions at the distal surface of 26 and mesial surface of 25. A diagnosis of moderate caries was established for the lesion on 25, initial caries for the lesions on 26, and moderate caries for the two interproximal lesions. At the patient request, it was decided to treat only 25. Following initial cavity opening [Fig. 2D], caries removal was conducted under white-light [Fig. 2F] and fluorescence-light [Fig. 2G] to achieve a caries-free peripheral seal around the pulpal aspect of the lesion. The removal of caries tissue was confirmed by hard texture and absence of bacterial red fluorescence. Caries removal at the pulpal aspect was made with a dental excavator to firm/leathery dentin. The reconstruction procedure included the application of an ion-releasing biomaterial to the affected region (Harvard MTA Universal., Harvard Dental international., Hoppegarten., Germany). Riva glass ionomer cement conditioner (SDI., Bayswater., Australia) was used to prepare the surfaces of dentin and enamel prior to the application of Riva HV GIC, as an interim restoration prior to the final composite restoration.

Figure 2: (A) Fluorescence-light occlusal view (B) white-light view (C) Radiograph (D) White-light initial cavity opening (E) fluorescence-light cavity view (F) Selective caries removal under white-light (G) Selective caries removal under fluorescence-light

Case 2

A 22-year-old male patient with a high caries risk complained of vague cold sensitivity at the vicinity of 27. Percussion and palpation tests on 27 were negative and cold test was positive. White-light examination revealed extensive lesions on the distal and central fossae (ICDAS code 5 and 4 respectively). Fluorescence-light examination revealed an IRFG from the underlying dentin on the distal aspect of the tooth. A radiograph revealed an extensive radiolucency spanning from the

occlusal to the distal surface, bordering the pulp [Fig. 3C]. A cavity opening was decided, with a high probability for pulp exposure. Upon cavity opening, a soft, fluid-like infected tissue was encountered [Fig. 3D], with bright red fluorescence [Fig. 3E]. At the bottom, the presence of avascular pulpal tissue was encountered, establishing a diagnosis of pulp necrosis and bacterial infection, indicating the need for a root canal treatment.

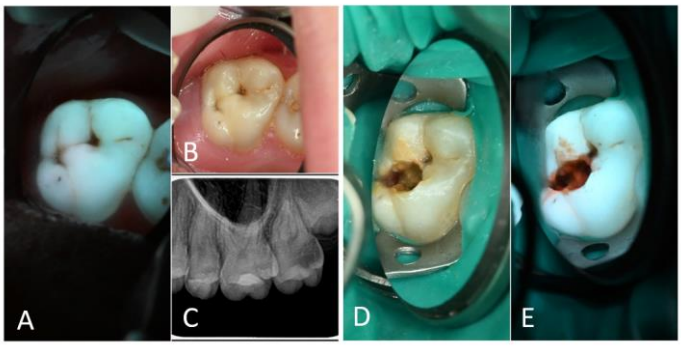

Figure 3: (A) Fluorescence-light occlusal view (B) White-light view (C) Radiograph (D) White-light cavity opening (E) Fluorescence-light cavity opening (F) Selective caries removal under white-light (G) Selective caries removal under fluorescence-light

Case 3

A 24-year-old male patient with a high caries risk attended a routine dental examination. White-light examination [Fig. 4A] showed substantial plaque deposits on the lingual aspect of 36 and an opaque region at the tip of the cusp. Visual changes in tooth enamel were observed under wet conditions (ICDAS code 2). Fluorescence-light examination [Fig. 4B] revealed a defined non-scrapable region with distinct red-fluorescence overlapping the region of the lingual lesion. At its periphery, a dark border was noticed at the gingival border, speckled patterns of red-fluorescence plaque were visible. No X-ray was conducted. A diagnosis of initial lesions was made. The lesions were treated non-operatively with a topically applied fluoride varnish (Bifluoride 10). Additionally, the patient was scheduled for a hygiene instruction session and cleaning.

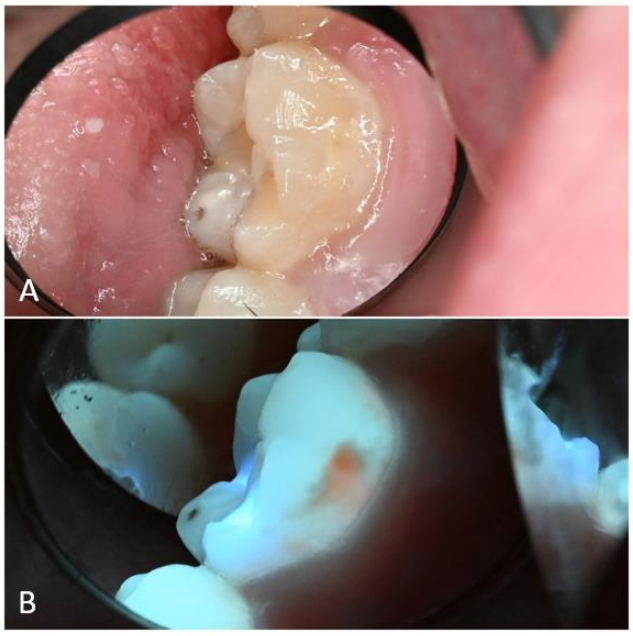

Figure 4: (A) Lingual view under white-light (B) view under fluorescence-light

DISCUSSION

Over the last few decades, several Biophotonics techniques, including fluorescence-based devices, have been introduced to improve early lesion detection without exposing the patients to ionizing radiation [5-7]. Recently, several systematic reviews and meta-analysis compared the accuracy of traditional caries detection methods to fluorescence-based methods [17-22]. The reviews focused on digital devices, emphasizing their capability for data enhancement and analysis [7]. "Simple" hand-held devices, where fluorescence-light is incorporated into a curing lamp or handpiece, achieved little attention, as they necessitated the operator to wear restrictive orange light shield and lack magnification [7]. In the current report we evaluated the capabilities of the "Reveal" loupes system to facilitate the discovery of hidden caries. Fluorescence-light examination consistently enhanced early caries lesion detection (ICDAS codes 1 and 2). Fluorescence-mode examination enabled visualization of active lesions with notable red fluorescence, along the grooves and pits. In advanced lesions, we were able to detect sub-surface dentinal lesions through an optical occurrence we referred to as "Internal red fluorescence glow" (IRFG). These were observed in cases 1-2. To the best of the authors' restricted knowledge, this phenomenon has not been previously documented through direct view. We speculate IRFG results from a heightened contrast between the bright cyan hue of healthy tissue and the red fluorescence emitted by the underlying bacterial contamination. It is important to mention that we were unable to detect IRFG in the deep lesion of tooth 26 of the case 1, despite it being readily identified through a complementary X-ray.

The management of caries lesions in the report, was customized according to their location, classification, and radiological extent. Fluoride varnish was employed for the treatment of initial active lesions, for its remineralization properties [1,2]. Moderate lesions were treated with tooth preserving operative care. The infected tissues were excavated up to firm/leathery dentin under fluorescence light guidance. Complete removal of caries tissue surrounding the pulpal aspect was confirmed by the hard texture and absence of red fluorescence, to allow for a quality seal [1,2]. The choice between complementary radiographic or fluorescence method throughout the clinical cases, depended on the specific tooth-surface in question, as well as patient-individual considerations. The main differences between the two methods are highlighted in Table 1. In recent years, several systematic reviews and meta-analysis were conducted to compare between the methods. Kapor et al [17] reviewed the methods for occlusal surface caries, Janjic et al [18] for proximal surfaces, and Serban et al [19] for deep dentin caries. In non-cavitated lesion detection, Gomez et al [20] and Thanh el al [21] included both in-vitro and in-vivo studies, while Foros el al [22] included solely in-vivo studies. Considerable variations in the sensitivity and specificity values were observed due to experimental setting heterogeneity. Nevertheless, some clinical recommendations can be considered, taking into account the different tooth surfaces:

- Non-cavitated lesion diagnosis might be enhanced by using a combination of visual and fluorescence based-devices.
- Fluorescence-based devices showed better diagnostic accuracy sensitivity and specificity for early occlusal surfaces.
- For proximal surfaces diagnosis and lesion monitoring, the radiographic method presents higher overall accuracy.

The limitations of the case series report should also be discussed. As the device evaluated in the study is new, scarce information was available. These include a review [8], a quantitative study [23] and a previous case report [9]. Additionally, some authors suggested that results obtained with other devices, may not necessarily reflect the abilities of others with the same working principle [24]. However, a systematic review and meta-analysis by Gimenez et al [25], showed similar results of accuracy were observed among laser fluorescence, fluorescence cameras and QLF

[25]. Other systematic reviews also supported the conclusion [19,22]. The majority of the reviews also mentioned, the high need for qualitative and quantitative standardized studies to draw robust conclusions regarding the definite effectiveness of the devices.

Table 1: Comparative Description of Radiographic vs. Fluorescence-Based Detection

Features	Radiographic Detection	Fluorescence-Based Detection
Principle of Detection	Relies on differential X-ray absorption to produce an image of tissue mineral density	Utilizes light emission from endogenous dental fluorophores or as porphyrins in carious lesions, upon excitation
Safety	Involves exposure to ionizing radiation, eliciting concerns regarding cumulative dose effects, particularly among pediatric patients	Not involving exposure to ionizing light, making it safer for repeated or routine use
Imaging Depth	Penetrates deep into the dental tissues, from enamel to dentin and pulp	Primarily targets the surface and subsurface layers, limiting the diagnosis of the deep tissues
Diagnostic Time	Involves processing time for film or digital image generation	Provides real-time or near real-time results
Early Lesions	Limited sensitivity due to mineral content below the detection threshold	High sensitivity to initial demineralization and bacterial contamination.
Occlusal Detection	Low contribution in early and non-cavitated lesions	High sensitivity, specificity and accuracy
Interproximal Detection	Appropriate for identifying dentinal lesions and cavities in proximal areas	Not as extensively supported by studies as radiographic results
Technology Integration	Digitally evolving. Offering potential AI integration for improved analysis and diagnostics	Integrates with digital platforms for data storage, analysis, and potential inclusion in electronic health records
Main Limitations	• Exposure to ionizing radiation • Inability to distinguish between active/arrest lesions. • Low sensitivity for early lesions	• Limited depth of detection • Susceptibility to false negatives/positives, due to extrinsic staining and other local factors

CONCLUSION

In summary, using fluorescence-enhanced loupes for conventional and fluorescence assessment may increase caries detection sensitivity without compromising the high specificity of the traditional method. Additionally, combining between the fluorescence and radiographic methods for different scenarios can provide a more comprehensive evaluation of dental health and pave the way towards enhanced clinical and operative decision making. The fluorescence-enhanced operative ability, should also be investigated among other dental disciplines, to facilitate the discovery of bacterial contamination in periodontology, implantology and endodontics.

Conflicts of Interest

Gal Hiltch and José Antonio Poli de Figueiredo Declares no conflict of interest. Liviu Steier owns IP rights and touches royalties on Reveal.

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