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Case Report

Clinical utility of biofluorescence imaging for detecting secondary caries beneath esthetic restorations

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ABSTRACT

Secondary caries represents a major cause of failure in esthetic restorations; however, early lesions beneath restorations are difficult to detect using conventional visual and radiographic examinations. This case report presents two clinical cases in which Quantitative light-induced fluorescence (QLF) imaging with Qraypen C (AIOBIO, Seoul, Republic of Korea) was used to overcome the limitations of traditional diagnostic methods and to effectively diagnose and manage secondary caries beneath esthetic restorations. In the first case involving tooth #27 of a 34-year-old female patient, distinct red fluorescence in the QLF image corroborated the presence of deep secondary caries suspected on radiographs and facilitated the treatment planning for root canal therapy. In the second case involving tooth #16 of a 31-year-old female patient, localized red fluorescence detected exclusively on the QLF image guided early preventive intervention, confirming a previously undetectable subclinical lesion and preserving pulp vitality. QLF technology enables the early visualization of secondary caries that are difficult to detect clinically or radiographically, thereby improving diagnostic accuracy. By providing information on lesion activity, QLF supports clinical decision-making across a range of treatment strategies, from early intervention to endodontic therapy, and serves as a valuable tool for enhancing communication with patients.

1. Introduction

Secondary caries are lesions that develop adjacent to existing restorations and represent the most common cause of restorative failure [1]. In particular, composite restorations exhibit a higher incidence of secondary caries than amalgam restorations, largely because they are more susceptible to microleakage [2]. Recent literature reviews have reported that the incidence of secondary caries associated with composite restorations ranges from 3.5 % to 44 %, and that approximately half of all restoration replacements are attributable to secondary caries [3]. Secondary caries can continue to develop after restorative treatment, depending on the patient's oral environment and oral hygiene status, making prevention and early diagnosis essential. Once secondary caries develop, partial repair or complete replacement of the restoration is required, initiating the 'cycle of re-restoration' and resulting in additional tooth structure loss and increased patient burden [4]. Therefore, the early detection and minimally invasive management of initial lesions around restorations are important. The American Dental Association (ADA) recommends that radiographic examinations be prescribed based on individual patient needs, rather than performed routinely in asymptomatic or low-risk patients, to minimize unnecessary radiation exposure [5]. Accordingly, interest in non-invasive, sensitive adjunctive diagnostic technologies has increased.

Quantitative light-induced fluorescence (QLF) is a non-radiographic caries detection method that uses visible light to induce biofluorescence [6]. QLF primarily operates through two biofluorescence mechanisms. The first involves the inherent autofluorescence of the tooth, which enables the visualization of differences in fluorescence intensity between sound and demineralized enamel. Demineralized areas show reduced fluorescence and appear darker, allowing for the quantitative assessment and longitudinal monitoring of early carious lesions. In a study by Pretty et al. [7], artificial demineralization adjacent to various restorative materials was longitudinally evaluated at 72 and 144 h using QLF, and changes in fluorescence loss (ΔQ) enabled successful monitoring of the onset and progression of secondary caries. In addition to autofluorescence–based detection of enamel demineralization, QLF

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relies on a second biofluorescence mechanism: red fluorescence associated with bacterial activity within dental biofilm or carious lesions. This red fluorescence originates from porphyrins, metabolic by-products produced by oral bacteria, and allows the visualization of bacterial biofilm present in active carious lesions, mature plaque, and calculus [8]. Areas exhibiting red fluorescence indicate active bacterial processes and serve as auxiliary indicators of lesion activity and progression potential [9]. By simultaneously capturing and quantifying both the loss of tooth fluorescence and the increase in bacterial red fluorescence, QLF provides a comprehensive biofluorescence profile that supports the early diagnosis of secondary caries and facilitates timely, minimally invasive intervention.

Therefore, this case report presents two clinical cases in which QLF, a biofluorescence-based detection technology, was used to effectively diagnose and manage secondary caries beneath existing esthetic restorations. The first case describes deep secondary caries hidden beneath a composite restoration that was not detected early and ultimately required root canal treatment. The second case involved a patient with no specific symptoms and inconclusive radiographic findings, in whom early intervention was guided by red fluorescence, allowing prompt restorative management. Through these cases, we highlight the limitations of conventional diagnostic methods and discuss the clinical value of QLF in the early detection of secondary caries, treatment decision-making, and preventive patient education.

2. Case presentations

This case report follows the CARE guidelines and complies with the principles of the Declaration of Helsinki. Written informed consent was obtained from the patients for the publication of this report and any accompanying images. Institutional review board approval was waived because this report involved de-identified clinical data.

2.1. Case 1: Deep secondary caries with pulpal involvement

A 34-year-old female patient presented with the chief complaint of cold sensitivity in the left molar region. Her general health was unremarkable.

Intraoral examination revealed an old Class II (MO) composite restoration on tooth #27, and the patient reported discomfort during mastication in that area. Percussion and thermal sensitivity tests elicited mild responses in the patient. Periapical radiographs did not reveal a definitive periapical lesion; however, a localized radiolucency was observed beneath the mesial aspect of the restoration. Localized fluorescence imaging was performed using Qraypen C (AIOBIO, Seoul, Republic of Korea), a device based on QLF technology.

QLF imaging revealed decreased tooth fluorescence beneath the restoration, along with localized red fluorescence in the surrounding area (Fig. 1A). These findings, together with the radiographic features (Fig. 1D), were considered indicative of secondary caries beneath the restoration. Based on the patient's chewing discomfort and the thermal test responses, the potential need for root canal treatment followed by crown restoration was explained, and informed consent for the treatment was obtained.

After administering local anesthesia, the existing restoration was removed. Deep dentinal caries was confirmed at the mesial site, where red fluorescence was detected preoperatively, and strong red fluorescence was observed at the same location (Fig. 1B). The red fluorescence persisted throughout the caries excavation. Following complete removal of the lesion, pulp exposure occurred at the pulpal floor of the mesial

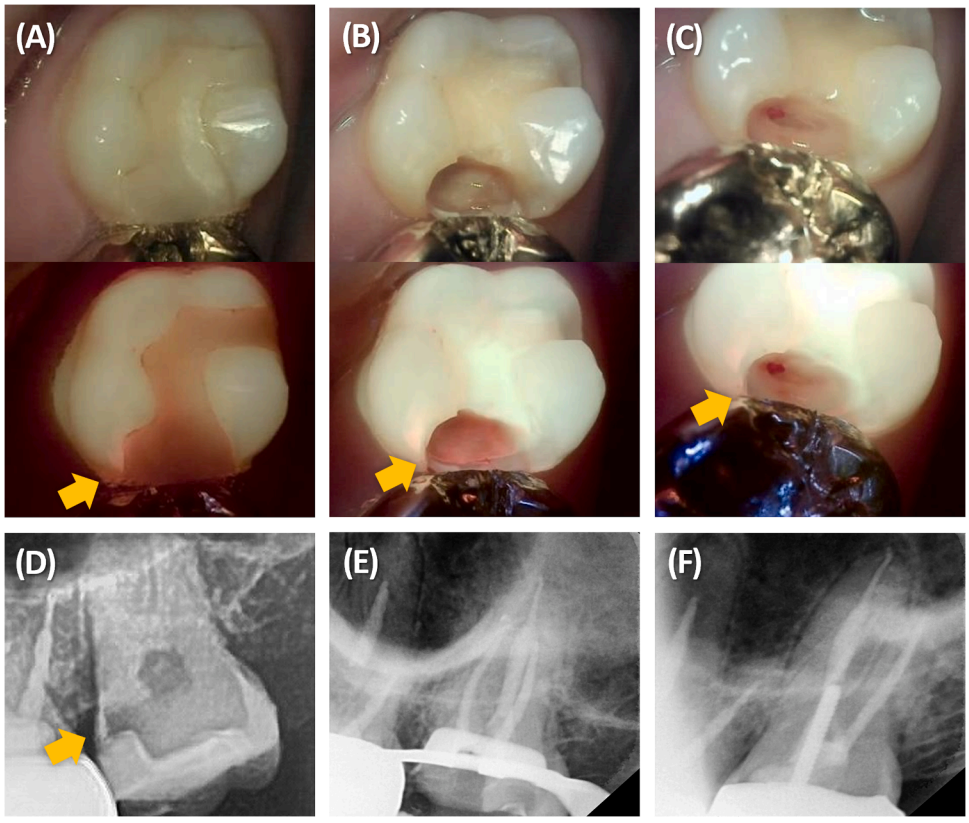

Fig. 1. Clinical images of Case 1: Deep secondary caries with pulpal involvement. (A) Initial clinical photograph and Qraypen C image of tooth #27 showing localized red fluorescence beneath the restoration (yellow arrow). (B) After removing the existing restoration, deep dentinal caries was confirmed at the same site where strong red fluorescence was observed (yellow arrow). (C) During caries excavation, pulp exposure occurred on the mesial pulpal floor (yellow arrow). (D) Preoperative periapical radiograph showing localized radiolucency beneath the restoration (yellow arrow). (E) Immediate postoperative periapical radiograph following root canal treatment. (F) Periapical radiograph taken 3 months after the prosthetic restoration.

cavity (Fig. 1C), and the planned root canal treatment and crown restoration were completed (Fig. 1E). At the 3-month follow-up, the tooth remained functionally stable, and the patient reported no recurrence of discomfort (Fig. 1F).

2.2. Case 2: QLF-based detection of subclinical secondary caries

A 31-year-old female reported generalized dental discomfort and a previous suggestion of possible caries from another dentist. Her general health status was good, and her primary symptom was sensitivity in the maxillary right posterior region. Clinical examination revealed an old Class I (O-type) composite restoration on tooth #16; however, no definitive lesion was identified on visual inspection or radiographic assessment (Fig. 2D). No cervical abrasion or abfraction was observed.

For optical evaluation, localized imaging of the area was performed using Qraypen C. The Qraypen C image revealed fluorescence loss, appearing darker than the surrounding intact restoration, along with pronounced red fluorescence at the central and distal pits (Fig. 2A, yellow arrow). In the absence of clear clinical or radiographic findings, the QLF image was considered the primary objective indicator suggesting the presence of a potentially active lesion. The patient was informed of the possibility of secondary caries, the need for an inlay restoration, and the potential requirement for endodontic treatment, depending on the depth of the lesion. After obtaining informed consent, treatment was initiated for the patient.

Upon removal of the restoration, caries was confirmed at the exact site where red fluorescence was identified in the initial QLF image (Fig. 2B). As caries excavation progressed into the dentin, the intensity of the red fluorescence progressively diminished (Fig. 2C). Following the standard protocol, caries removal was completed until sound dentin was confirmed using a probe, without any pulp exposure. The tooth was subsequently restored using an inlay restoration. At the 3-month follow-up, the tooth remained clinically stable, with no recurrence of symptoms (Fig. 2E).

3. Discussion

This case report indicates that QLF imaging is useful for detecting secondary caries beneath esthetic restorations and that its clinical value may vary according to the stage at which the lesion is identified. These findings suggest that QLF can serve not only as an adjunctive diagnostic aid but also as a tool that supports clinical decision-making and facilitates patient communication.

Case 1 involved a lesion that had already progressed to a significantly advanced stage at the time of diagnosis. The patient's symptoms and radiographic findings were consistent with pulpal involvement, and endodontic treatment followed by full-coverage restoration was therefore anticipated. Notably, QLF imaging revealed pronounced red fluorescence beneath and adjacent to the restoration (Fig. 1A). Consequently, QLF plays a practical role in diagnosis, treatment planning, and shared decision-making with patients. After restoration removal, the location of dentinal caries corresponded to the area of preoperative red fluorescence, and strong red fluorescence persisted during excavation (Fig. 1B). These observations are compatible with the concept that QLF can capture not only optical changes related to mineral loss but also fluorescence signals associated with bacterial activity. The

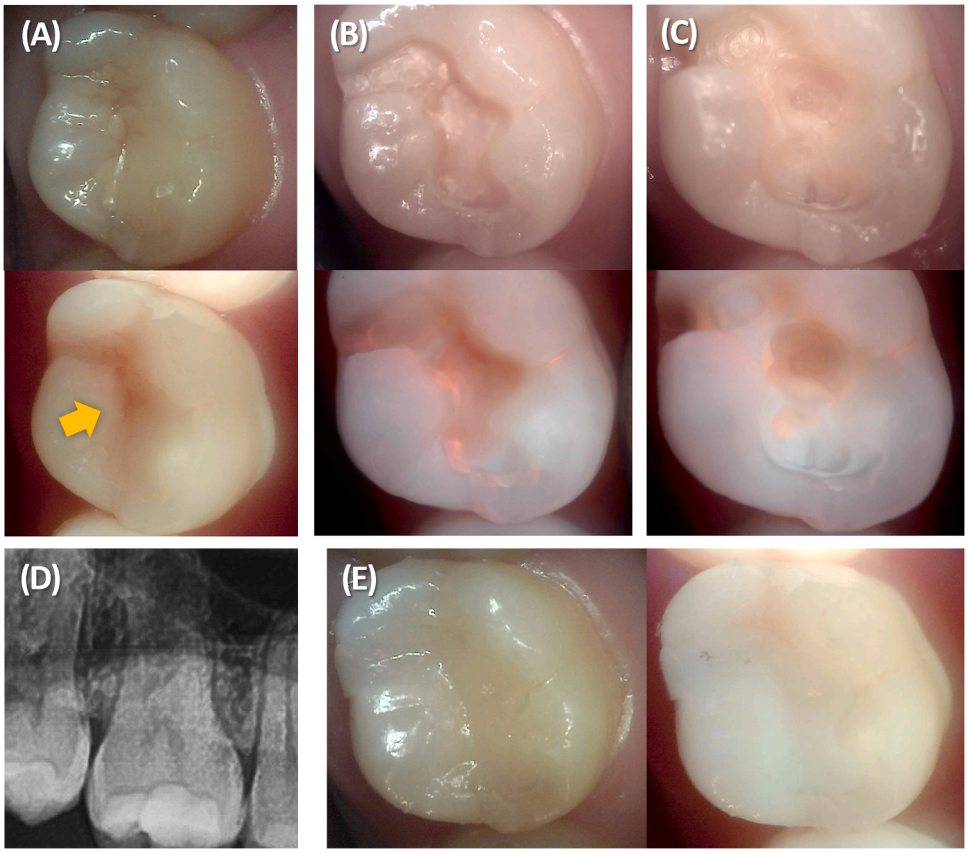

Fig. 2. Clinical images of Case 2: QLF-based detection of subclinical secondary caries. (A) Initial clinical photograph and Qraypen C fluorescence image of tooth #16 showing localized red fluorescence beneath the restoration (yellow arrow). (B) Clinical appearance and fluorescence image after removal of the existing restoration, confirming caries at the site corresponding to the initial red fluorescence. (C) Fluorescence image during stepwise caries excavation, showing diminished red fluorescence as the infected tissue was removed. (D) Initial periapical radiograph of tooth #16. (E) Clinical photograph and fluorescence image taken 3 months after the hybrid resin inlay restoration.

concordance among QLF findings, intraoperative caries location, and the radiographic radiolucency beneath the mesial aspect of the restoration (Fig. 1D) further supports the potential of QLF to provide clinically meaningful information for lesions concealed under esthetic restorative materials.

In Case 2, the patient reported non-specific discomfort. Both visual examination and radiographic assessment were inconclusive, making early diagnosis challenging when relying solely on conventional methods. In this context, the localized fluorescence loss and red fluorescence identified in the QLF image served as the primary objective findings that raised suspicion of secondary caries beneath the esthetic restoration and informed the decision to intervene. Consistent with Case 1, removal of the restoration confirmed the presence of a carious lesion directly beneath the area with red fluorescence. Moreover, as caries excavation progressed, a gradual reduction and eventual disappearance of red fluorescence could be observed in real time. These findings suggest that QLF imaging may function not only as a diagnostic tool for the presence of carious lesions but also as a visual guide for determining the extent of infected tissue removal, a role that has been consistently documented in previous studies [10].

A key difference between the two cases was the timing of diagnosis, reflecting the extent of lesion progression. In Case 1, the lesion had already advanced to a degree that necessitated root canal treatment and crown restoration. In contrast, in Case 2, early diagnosis and intervention guided by QLF imaging allowed the treatment to be completed while preserving pulp vitality. Accordingly, QLF may serve different clinical roles depending on when the lesion is detected, acting as a confirmatory tool in more advanced cases and as decisive evidence that enables early intervention in initial lesions. Importantly, in both cases, the lesion location visualized on QLF imaging corresponded closely with the actual site of caries, demonstrating the high sensitivity of QLF in identifying lesions beneath esthetic restorations and its value in providing meaningful diagnostic information.

Beyond lesion detection, QLF may contribute to patient-centered communication in clinical practice. Patients often find it difficult to understand caries activity or the extent of disease based solely on conventional explanations, which can hinder shared decision-making. By providing intuitive visual information—such as red fluorescence associated with mature biofilm or caries activity and fluorescence loss suggestive of demineralization—QLF may improve patient comprehension, acceptance of recommended care, and adherence to preventive behaviors [11]. Consistent with this, the patient in Case 2 reportedly experienced uncertainty after receiving inconclusive explanations elsewhere; however, visualization of the suspected lesion on QLF imaging appeared to facilitate understanding and acceptance of treatment. These observations align with previous reports indicating that visual contrast cues can enhance patient comprehension and the perceived persuasiveness of treatment recommendations [12]. In this regard, QLF may serve as an adjunctive communication and educational tool in preventive and restorative dentistry.

Regarding the practical aspects of clinical adoption, QLF imaging is a time-efficient procedure. As an adjunctive tool that complements conventional visual inspection, the overall examination time remains comparable to traditional methods. Furthermore, the captured images provide a permanent visual record, facilitating more efficient treatment planning. The diagnostic reliability of QLF is well supported by recent literature. A recent systematic review and meta-analysis reported a sensitivity of approximately 0.86 and a specificity of 0.82 for detecting caries, demonstrating high accuracy along with consistent and reproducible diagnostic performance across studies [13]. These findings support its reliability as a diagnostic tool for detecting secondary caries across different stages. In addition, as a non-invasive imaging technique that does not involve radiation exposure, QLF has the potential to reduce the overall treatment burden by enabling earlier detection and potentially reducing the need for more invasive and costly interventions, such as endodontic therapy.

QLF-based monitoring may be particularly beneficial for patients with multiple existing esthetic restorations or individuals at high risk for caries. Given its non-invasive and non-radiographic nature, the technology is well suited for longitudinal monitoring during routine dental examinations. Systematic assessment of biofluorescence changes may allow clinicians to identify subclinical activity at restoration margins before symptoms or radiographic changes become evident. As demonstrated in our cases, such early identification may enable more conservative management strategies and help interrupt the cycle of re-restoration.

The distinction between ‘early’ and ‘late’ detection can be understood in relation to lesion severity and the corresponding treatment approach. Early-stage lesions refer to cases in which conventional visual inspection and radiographic findings are inconclusive, while QLF imaging reveals fluorescence changes suggestive of demineralization or bacterial activity, allowing for timely intervention and conservative management that preserves pulp vitality. In contrast, late-stage lesions are characterized by both clinical symptoms (e.g., sensitivity or discomfort) and radiographic evidence of advanced caries, often requiring more invasive procedures such as endodontic treatment and full-coverage restoration. Based on this distinction, QLF may provide additional value in asymptomatic populations by enabling the identification of subclinical changes during routine examinations. Repeated monitoring of fluorescence patterns may further support the detection of lesion activity before the onset of symptoms or radiographic changes.

To apply QLF more reliably in diverse clinical settings, standardization and quantitative interpretation criteria are necessary. Intraoral fluorescence imaging can be affected by factors such as ambient lighting, oral moisture, and restoration polishing status; therefore, standardized imaging protocols that allow for the control of these variables are crucial. Additionally, previous studies have reported that fluorescence patterns may vary depending on the type of esthetic restoration [14], highlighting the need for research that quantitatively evaluates differences related to the restorative material type, thickness, and other characteristics. Establishing objective clinical cut-off values for fluorescence loss according to the lesion depth is also necessary. Because the presence of red fluorescence does not invariably indicate the need for invasive treatment, quantitative thresholds for interpreting red fluorescence intensity as a marker of lesion activity must be defined. Further studies correlating QLF findings with microbiological findings (e.g., bacterial counts and species composition) as well as histological assessments would strengthen the evidence base for interpreting QLF signals in secondary caries beneath esthetic restorations.

4. Conclusion

Through this case report, we confirmed that QLF, based on biofluorescence detection, can serve as a valuable adjunct for the early detection of secondary caries around esthetic restorations that may be difficult to identify using conventional examinations and for determining the appropriate timing of treatment. By visualizing fluorescence changes that reflect both enamel demineralization and bacterial activity, QLF supports evidence-based clinical diagnosis and facilitates effective communication with patients. However, complementary use with conventional diagnostic methods, such as radiographic examination, remains essential, and further research is needed to establish standardized guidelines that enhance diagnostic accuracy and support broader clinical applications.

CRediT authorship contribution statement

Gwen Woung Kang: Writing – original draft, Investigation, Data curation. **Sang-Kyeom Kim:** Writing – review & editing, Visualization, Methodology. **Eun-Song Lee:** Writing – review & editing, Conceptualization. **Baek-Il Kim:** Writing – review & editing, Supervision, Project administration.

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