Assessing Caries Removal by Undergraduate Dental Students Using Quantitative Light-Induced Fluorescence

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Abstract: The purpose of this study was to compare detection of enamel and dentinal caries by dental students' and faculty members' visual inspection and by quantitative light-induced fluorescence (QLF). The overall aim was to determine whether QLF is an appropriate technique for use in clinical skills laboratories as a teaching aid for dental undergraduates to detect and assess the removal of enamel and dentinal caries. Sixty students who had no clinical experience with dental caries were asked to select suitably decayed teeth and mount them in plaster. After recording baseline QLF images, students removed caries according to instructions given by the clinical tutor. On completion of the exercise, the teeth were visually determined to be caries-free by the student, then confirmed by the clinical tutor. A fluorescein in alcohol solution was injected into the cavity for two minutes, rinsed, and dried before QLF images were captured. The images were visually analyzed by two examiners for the presence or absence of caries. From seventy-four images recorded, seventeen were excluded due to exposure of the pulp chamber. The remaining fifty-seven teeth, which by clinical visual examination were judged to be caries-free, were examined using QLF. Fifty-three percent were found to be caries-free, while 47 percent were carious. In this sample of fifty-seven teeth judged to be caries-free by both dental students and faculty members, QLF thus detected caries in almost half of these teeth. These findings suggest that QLF is a useful, noninvasive, nondestructive technique for the detection of caries and can serve as an adjunct to chair-side diagnosis and management of dental caries, which is typically accomplished by visual inspection. QLF may be useful and appropriate as an objective clinical teaching aid for the assessment of dental caries.

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Clinicians may acquire biased perceptions during their dental education that can affect decisions about treatment/management of dental decay. In a dental education setting, students reflect mainly the training program in their interpretation of enamel and dentinal caries.[1] Various diagnostic techniques are taught to dental students in caries detection classes. Routinely used methods in the clinical setting are visual, tactile, and radiographic methods. Bitewing radiographs are widely used, and dental students typically receive considerable instruction in this technique. These techniques still remain an important component of the diagnostic spectrum for carious lesions between contacting approximal surfaces.[2-4] Radiographs are the most widely available diagnostic aid for monitoring the extent and progression of carious lesions. They play a role in managing the progression of existing initial lesions and in assessing the outcome of preventive therapy.[5,6] Making treatment decisions based upon bitewing radiographs is not unusual;[7] however, using bitewing radiographs as the sole basis of diagnosis might lead to false negative decisions and thus result in considerable undertreatment.[4]

Research in cariology has led to altered views on how and when to treat carious lesions. The interpretation of research findings and the transfer of knowledge from teachers to students in dental schools have the potential to influence the practice of operative dentistry, but the interpretation and implementation of modern principles of caries treatment differ quite markedly from one dental school to another.[8] The need for dental and oral treatment in society is constantly changing. The graduating dentist should be aware of scientific progress and be able to apply this technology in future practice.[9] Snyman and Kroon[10] described a working model for integrating knowledge and skill as part of the dental school curriculum at the University of Pretoria. These authors noted that, in the management of a disease,

reversal of early lesions where possible and the successful management of advanced lesions of hard dental tissues were all part of the requirements to be met in an integrated curriculum protocol preparing dental students for future practice. Their preventive program for dental caries targeted such outcomes as the early diagnosis of caries and the design of a preventive treatment plan that included the reversal of early carious lesions.

Recently, newer and more sophisticated methods have become available for use in diagnosing dental caries, utilizing physical principles. These methods include digital image enhancement, digital subtraction radiography, tuned aperture computed tomography (TACT), optical caries monitor (OCM), quantitative fiber-optic transillumination, quantitative light-induced fluorescence (QLF), laser-fluorescence measurement (DIAGNOdent), electrical conductance measurement (ECM), electrical impedance measurement, and the ultrasonic caries detector. These devices and techniques have been reviewed extensively in the literature.[11]

The quantitative light-induced fluorescence (QLF) technology is an established technique in early caries detection and diagnosis.[12-17] Its use has been reported in several in vitro and in vivo studies and applied to the physical properties of enamel, measuring changes involved in the caries process. It has developed from use in vitro to use in situ and in vivo by researchers and clinicians alike to monitor caries progression. There is an enhancement of the fluorescence contrast between demineralized lesions and sound enamel by at least ten times when compared with visual inspection. QLF provides quantitative data for an area of demineralization and mean loss of fluorescence from the lesion. The latter has been correlated with mineral loss measured using the destructive techniques of transverse microradiography.[14,15] The QLF system comprises a camera handpiece device (intra/extraoral) connected to a computer fitted with a frame grabber (Comet, Matrox Electronics Systems Ltd., Quebec, Canada), onto which the QLF software (Inspektor Research Systems BV, Amsterdam, The Netherlands) is installed. To visualize and capture the tooth image, white light from a special arc lamp (Philips BV, Eindhoven, The Netherlands) based on xenon technology is filtered through a blue-transmitting band pass filter with peak intensity of λ=370nm and bandwidth of 80nm to provide illumination of the tooth with blue-violet light with an intensity of 13mW/cm^2. With the aid of a charge coupling device (CCD) sensor (Sony LS-1P, Tokyo, Japan), which has a yellow transmitting (λ=520nm) filter (Phillips BV, Eindhoven, The Netherlands) positioned in front of it in order to filter out all reflected and back scattered light, the fluorescent image of the tooth is then recorded and digitized with the QLF software. This image can then be analyzed quantitatively with the QLF software.

Recent studies have shown that the results obtained using QLF are reproducible[18-20] and valid.[21] Repeatability and reproducibility studies have been carried out on the QLF device in relation to assessment of demineralization and early caries detection. QLF is a noninvasive, nondestructive, and patient compliant technique, which is ideal for use in vivo, in situ, and in vitro for the longitudinal detection and quantification of early hard tissue mineralization changes over time.

Previous generations of dentists have been taught diagnosis by teachers whose experience was gained under circumstances and assumptions other than those pertaining today.[22] Studies of dentists' diagnostic behavior have shown wide individual variation in their accuracy of caries diagnosis from radiographs. Caries recognition and removal exercises are taught regularly to students as part of the cariology course at the University of Liverpool dental school. The aim of this study was to determine whether QLF is an appropriate method for use in operative technique (clinical skills) laboratory sessions to detect and assess the removal of enamel and dentinal caries with the view of it being used in the future as a teaching aid. The methodology for making this determination was to compare detection of enamel and dentinal caries by students' and faculty members' visual inspection and by QLF.

Materials and Methods

A total of sixty students in their second of five years of dental training and with no clinical experience of caries removal participated. Four groups of fifteen students were asked to select decayed teeth (n=74) and mount them in plaster. A suitability criterion was based on the presence of occlusal caries on the teeth; therefore, premolars and molars were used. Baseline QLF images using the Inspektor Pro system (Inspektor Research Systems BV, The Netherlands) were recorded prior to caries removal.

Students removed caries as instructed by their clinical tutor using a high-speed bur to gain access if necessary and slow-speed rose head bur and spoon

excavator. On completion of the exercise, the teeth were visually determined to be caries-free by the student, then confirmed by the clinical tutor. In order to enhance fluorescence, a fluorescein in alcohol (0.2 g/L) solution was injected into each prepared cavity for two minutes, then rinsed and dried before QLF images were captured. The QLF images were stored and visually analyzed later by two examiners for the presence or absence of demineralization. No quantitative analysis was carried out using QLF.

Results

A total of seventy-four teeth judged to be caries-free by both students and faculty members had QLF images recorded. Seventeen of these were excluded because the pulp chamber had been exposed (Figure 1). Of the remaining fifty-seven teeth judged to be caries-free by clinical visual examination, 53 percent (twenty-nine teeth) were found to be caries-free by QLF examination, while 47 percent (twenty-eight teeth) still exhibited demineralization (Figure 2).

QLF detected caries in almost half of the teeth that had been found to be caries-free by both students and clinical tutors. Using the Fishers exact test, this level of caries detection was significantly different from the visual examination ($p<0.0001$). For the QLF images viewed separately by two examiners, a kappa test was carried out to assess for interexaminer agreement. The score was 0.783, indicating good agreement.

Discussion

Identification of occlusal or pit and fissure caries is a diagnostic challenge for clinicians, and with the increasing use of fluoride dentifrices, the occurrence of frank cavitations has reduced and the diagnostic complexity of caries increased.[23] The traditional methods of caries recognition and detection have long been taught to dental students worldwide. Recent advances in diagnostic research have introduced the use of other methods such as transillumination, laser, and light-induced fluorescence. The use of

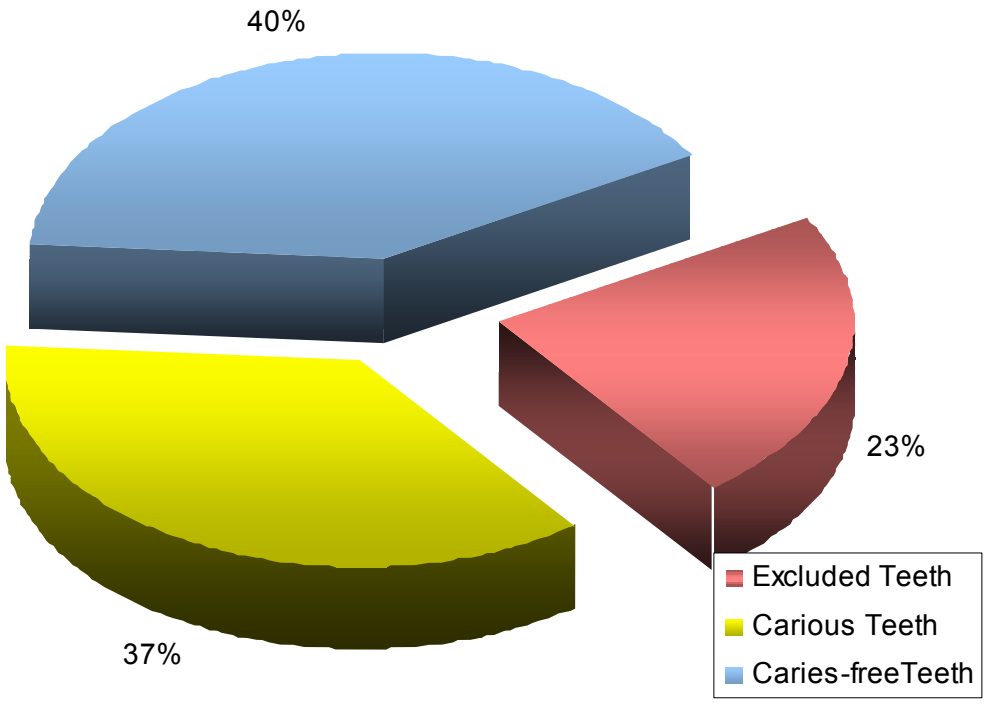

Figure 1. Percentages of carious teeth, caries-free teeth, and excluded teeth detected by QLF

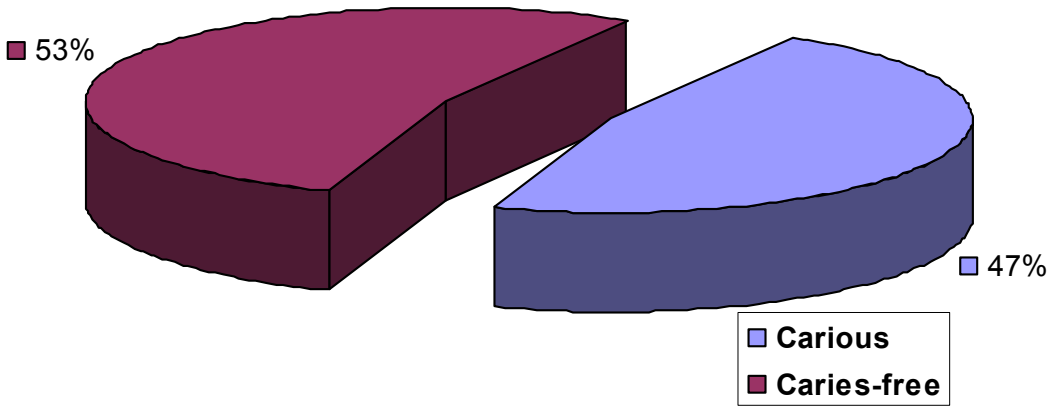

Figure 2. Percentage of caries-free teeth and carious teeth detected by QLF

these methods, in addition to the traditional methods taught to students, may help them to achieve better and more accurate diagnoses of caries and thus has the potential to improve the management of caries and preventive practices for patients.

The results obtained from this study demonstrated that QLF enhanced by fluorescein dye detected caries in almost half of the teeth that by visual means had been judged to be caries-free. However, there was no standardization between the type and extent of the lesions that the students had worked on. Some of the lesions were quite extensive, resulting in pulpal exposure. Future investigations will attempt to standardize the type of lesions examined, so that the variation in extent may be reduced.

The use of fluorescein with the QLF technique had been previously reported by Pretty et al.[24] as dentinal lesions fluoresce more than enamel lesions. Carious lesions in dentine are notoriously difficult to detect using optical techniques. It was observed in this study that fluorescein enhanced fluorescence of the stained tissues and materials such as the dental stone that the teeth were embedded in. This can be viewed in Figure 3, in which the intensity of fluorescence progressively increased.

QLF has been used in vitro and in vivo to detect very early carious lesions before they are visually and radiographically detectable. While QLF can detect early lesions that are in tens of microns in depth, radiographs are unable to detect lesions until they are at least 300µm deep and progressing towards the dentine.[25] The bacterial activity in the lesions can also be assessed using QLF as active lesions may fluoresce red.[26-28] While this area was not investigated in this

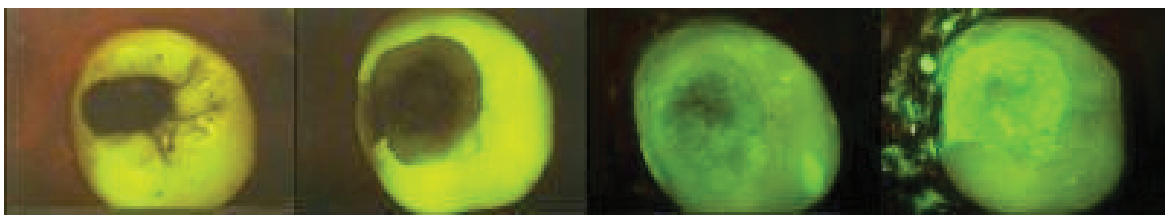

Figure 3. An example of QLF images captured as caries was progressively being removed from this tooth (from left to right)

study, there is a potential for its use in assessing the activity of carious lesions, since the decision on how much softened dentine to leave in a cavity during caries management is largely subjective and based on operator experience. The ability to gain information regarding the bacterial activity of a carious lesion via the use of QLF might prove an important adjunct in decision making.

QLF is available as a chair-side device for cavity inspection (Inspektor Pro version) that is convenient and easy to use. There is a short learning curve, and images are achievable that can be used in the monitoring of lesions and teeth in patients over time. Inspektor Pro employs a non-ionizing blue light system, the major advantage of which is that the patient is not exposed to additional amounts and doses of radiation as would be the case with traditional radiographic methods.

This study indicates there is a need to integrate new technologies into the training received by dental students especially as pertains to detection and diagnosis of caries. Assessment by QLF revealed there were teeth that were still carious even after caries was thought to have been completely removed by the students. The earlier students are taught to use a combination of traditional and new methods in caries recognition and diagnosis, the more likely they will be able to embrace and implement informed management decisions in clinical practice. In this study, QLF was used as a method to provide visual feedback to undergraduate dental students on their caries removal skills. Although feedback information was not recorded, verbal feedback from students to the authors was positive, suggesting enhancement in their understanding of dental caries diagnosis and management. Future research will aim at objectively assessing the students' understanding before and after using QLF technology as an adjunctive tool in caries management, and also will measure student and faculty members' perceptions about the value of QLF as a diagnostic device and a method for providing feedback to students on their clinical skills.

The kappa scores between examiners indicated that there was a good, but not perfect, agreement between examiners and that, overall, the method was reliable. This is consistent with findings from previous studies by Tranæus et al.[16,19] and Pretty et al.,[18] which suggested that QLF was a reliable tool for caries detection. While the use of kappa scoring is controversial, it is one measure of interobserver agreement. Although there are other methods of assessing interobserver agreement, it is the most commonly reported measure in the medical literature and thus was chosen for this study. Kappa makes no distinction among various types and sources of disagreement, and because it is affected by prevalence, it may not be appropriate to compare kappa between different studies or populations. Nonetheless, kappa can provide more information than a simple calculation of the raw proportion of agreement.[29]

Conclusion

QLF detected caries in almost half of the teeth judged by visual means to be caries-free in a caries recognition and removal session. The findings suggest that QLF can be a helpful tool for providing feedback to students on their caries detection and recognition skills and also may be useful as an objective clinical teaching aid to help dental students learn the skills associated with assessment of dental caries. Based on the findings derived from this study and previous research, we conclude that QLF is a useful, noninvasive, nondestructive technique in the detection of caries and serves as an adjunct to the visual chair-side diagnosis and management of dental caries.

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