Light Assisted Caries Detection: 21st Century Technology
A Peer-Reviewed Publication
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Abstract
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Educational Objectives
At the conclusion of this educational activity participants will be able to:
1. Discuss the limitations of manual and radiographic diagnostics for caries identification.
2. Describe the current equipment needed for caries diagnosis.
3. Access and restore carious lesions in a minimally invasive manner.
4. Describe cavitated and non-cavitated carious lesions.

Author Profile
Ian Shuman DDS, MAGD, AFAAID maintains a full-time general, reconstructive, and aesthetic dental practice in Pasadena, Maryland. Since 1995 Dr. Shuman has lectured and published on advanced, minimally invasive techniques. He has taught these procedures to thousands of dentists and developed many of the methods. Dr. Shuman has published numerous articles on topics including adhesive resin dentistry, minimally invasive restorative, cosmetic and implant dentistry. He is a Master of the Academy of General Dentistry, an Associate Fellow of the American Academy of Implant Dentistry, a Fellow of the Pierre Fauchard Academy. Dr. Shuman was named one of the Top Clinicians in Continuing Education since 2005, by Dentistry Today.

Author Disclosure
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Discussion
The traditional tools used for caries diagnosis are no longer considered the gold standard. Research has demonstrated that traditional methods and techniques for caries detection and diagnosis are inaccurate.1-3 Visual examination, probing with an explorer, and radiographs do not offer a complete representation of teeth that may be carious. The primary reason is due to the non-cavitated carious lesion phenomenon. Dentin caries can result in visually non-cavitated lesions, which present clinically intact enamel over the bodies of these lesions.4

The Non-Cavitated Carious Lesion
Historically, dental caries has been synonymous with the presence of cavitation. However, that paradigm is changing thanks to advancements in both the understanding of caries development and diagnostic modalities. The progress of caries can now be quantitatively and qualitatively measured and the clinical stages of the disease process that precede cavitation can be recognized and documented. There are a number of reasons and causes for the non-cavitated carious lesion also known as “Occult Caries” or “Hidden Caries”.5,6 This phenomenon may be due in part to natural anatomic defects in the enamel surface,7 especially pits and fissures.8 Often seen are diffuse opacities, which may be thin bridges of non-cavitated enamel overlying carious dentin. One implication may be due to over-fluoridation, which hardens the outer enamel surface, but does not penetrate sufficiently to prevent caries from occurring in the deeper layers of enamel and dentin.9-11

In response to these observations, The International Caries Detection and Assessment System (ICDAS) presented a new paradigm for the measurement of dental caries12 that was developed based upon the insights gained from a systematic review of the literature on clinical caries detection systems.13-18 That review found that while new caries detection criteria measured different stages of the caries process, there were inconsistencies in how the caries process was identified and measured.19

Visual Exam
It is difficult to determine whether a lesion is active or arrested simply by looking at the lesion.20 In a study by Assaf et al., it was determined that the visual/tactile method, with or without diagnostic adjuncts can diagnose cavitated lesions efficiently, but not non-cavitated lesions.21

Explorer
Physical diagnostic methods such as the use of an explorer for probing into pits and fissures will only reveal a “catch” if the defect is large enough to accommodate the explorer tip or soft enough to allow probing. In 1924, G.V. Black recommended treatment that would foreshadow the future of diagnosis and treatment of non-cavitated carious lesions: “A sharp explorer should be used with some pressure and if a very slight pull is required to remove it, the pit should be marked for restoration even if there are no signs of decay.”22 Dr. Black knew that a sharp explorer was not ideal for caries diagnosis. A new explorer has an average tip diameter of 30-40μm.23 After repeated use, the tip will dull to an average diameter of approximately 150μm. A physically undetectable enamel pit, fissure, or defect smaller than 30μm can accommodate a large bacterial population; therefore, caries detection by means of explorer examination is no longer considered a completely reliable diagnostic method.24-26 In addition, a false positive probing can result from the shape of the fissure, force of application, path of explorer placement and as mentioned, sharpness of the explorer.27

Caries-Staining Dyes
Chemical detection using caries-staining or caries-detection dyes lack accuracy. These dyes are most useful for detecting remaining caries following the initial preparation of a lesion. There also is a wide variation in the efficacy of the different caries dye materials currently available.28 Ideally, caries-detector dyes should stain only in a manner that permits proper discrimination between healthy and diseased tooth structures.29 Currently, none of the available caries-detection dyes is caries specific. Therefore, their routine use may lead to a profound degree of over-treatment.

Radiography
Another traditional diagnostic tool, intraoral radiography, does not always reveal the presence of occlusal lesions because of the amount of healthy tooth structure surrounding the lesion, the small size of many lesions, and the variables in image quality related to radiographic exposure and development.30,31 Decay is difficult to detect in radiographs unless the lesion is larger than 2-3mm deep into dentin, or one-third the bucco-lingual distance. A systematic review was conducted by Schwendicke et
Modern caries detection using light

Because all teeth are translucent, they have specific optical properties and caries detection using a light source is not a new concept. In 1922, Dr. William John Cameron published his work: Diagnosis By Transillumination: A Treatise On The Use Of Transillumination In Diagnosis Of Infected Conditions Of The Dental Process. (1922) In it, he states, that this use of transillumination provides one of the most valuable aids in operative procedures. It can be used effectively for the detection of interproximal caries and intercoronal caries. Caries will at once evidence themselves by a distinct discoloration in the crown of the tooth covering the area affected or filled.

Transillumination is but one diagnostic technique that uses light for detecting hidden caries. Light source technology and result interpretation and recording has evolved to include laser caries detection through fluorescence, light emitting diode spectroscopy, fiber-optic transillumination, and optical coherence tomography among others.

Fiber Optics

Detection of a carious lesion is based on changes in scattering and absorption of light photons traveling through the carious lesion which can be observed by the clinician as a dark shadow. An intense light using fiber-optic technology greatly enhances detection ability. Methods using this intense light source are referred to as FOTI (fiber-optic transillumination) or DIFOTI (digital imaging fiber-optic transillumination), which operates under the same principle as FOTI but allows for the saving of digital images of the transilluminated tooth. In the literature, most studies have focused on transillumination as a method to replace radiographs with varying performance.

One device, the Microlux Transilluminator (Addent, Danbury, CT) is used for detecting anterior and posterior caries. Using a 2 or 3mm light guide, it also helps to visualize crown fractures, root canal orifice, and root fractures. The fiber optic probe is placed adjacent to the oral structure under examination and the passage of the light through the tissue is proportional to the translucency of each material. Caries, calculus, cracks, and the orifice of root canals do not transmit as much light as healthy enamel or dentin and appear darker.

Laser

There are a number of different devices for detecting caries through the use of lasers. The most popular devices detect caries through the use of fluorescence. Normal healthy tooth structure produces little or no fluorescence. Carious tooth structure will fluoresce proportionate to the degree of caries. Some of these early devices were highly sensitive to caries but had a low specificity. This low specificity meant that these devices would measure the fluorescence of anything. However, with contemporary advancements in laser technology, that specificity has improved and caries can be diagnosed in a more precise manner.

One of the first laser devices to detect caries was the Diagnodent® (Kavo, Alsip, IL) This unit employs a 655 nm laser that detects the fluorescence of decay in teeth on virgin smooth surfaces, and pit and fissures areas. A value is produced along with an increasing audio tone and digital readout indicating the presence of non-healthy tooth structure as well as other materials such as calculus and plaque.

Other devices (The Canary System®, Quantum Dental Technologies, Toronto, Ontario, Canada) use lasers that are absorbed in the tooth with luminescence conversion providing information on the presence and extent of tooth decay below the tooth surface. Another caries detection device uses Optical Coherence Tomography (OCT), which images both the teeth and periodontium. (Lantis Laser Inc., Denville, NJ). Cross-sectional images are then displayed allowing the device to detect decay associated with restorations.

LED (Light Emitting Diode)

LED technology has been used for caries detection. Midwest Caries I.D. (Dentsply, York, PA), measures the caries reflection signature for smooth surfaces, pits and fissures, and interproximal surfaces using LED. It is based on the concept that healthy tooth structure is more translucent than decalcified structure. The light reflected from the decalcified structures allows the device to distinguish between healthy and less translucent structures. A simple red and green indicator light and an alternating beeping sound indicate the presence or lack of caries. Other artifacts, present in or on the tooth, can interfere with detection.

LED Based Spectroscopy

Spectroscopy is the study of objects based on the spectrum of color they emit, absorb, or reflect. Certain bacteria are able to synthesize fluorescent compounds called porphyrins and can therefore be detected by sensitive fluorescence measurements in the red spectral region. Fluorescence of dental caries (and dental plaque) in the red spectrum is caused by oral bacteria such as Bacteroides and Actinomyces odontolyticus. This phe-
Caries Identification Using LED Based Spectroscopy

Caries detection utilizing a device that emits auto-fluorescent light and evaluates the fluorescing porphyrin byproducts of cariogenic bacteria such as Streptococcus mutans, Bacteroides, and Actinomyces odontolyticus. is also available (The Spectra System™, Air Techniques, Melville, NY). (Figure 1)

Using a 405nm LED, the device emits an auto-fluorescent light that is absorbed differently by various objects on and within a tooth. Porphyrin producing cariogenic bacteria have a unique spectral response to auto-fluorescence, producing a red color. In contrast, healthy tooth structure will fluoresce green. In a study by Lennon et al., it was determined that red fluorescence is well suited to detection of the bacteria that cause dentin caries. This has been substantiated and repeatedly demonstrated in numerous studies.

The fluorescing substrate in and/or on the captured image of a tooth is converted to both colors and numbers via live video feedback. A graphic display showing varying colors on the tooth is produced. For patient education, this has often been referred to as a “Doppler” type image, especially useful for immediate comprehension of familiar technology often used by weather reporters. Next to each color variance is a quantitative numerical display. (Figure 2) One of the benefits of this device is that the graphic image can be saved to imaging software and the patient’s chart, enhancing the ability to monitor the development of caries and chart the progression of remineralization of tooth structure over time. In addition, the visual image provides the patient with an interactive point of reference. This is a powerful tool that allows the patient to co-diagnose their caries, understand the problem, and often initiate the dialogue regarding treatment.

Figure 2.

"DOPPLER RADAR" FOR CARIES DETECTION

LED based spectroscopy device images color scale and diagnostic value

This technology has been demonstrated to be highly effective. (Figure 3) In a study by Buchalla, emission spectra from noncavitated enamel caries with different degrees of discoloration under a wide range of excitation wavelengths were compared. Freshly extracted human molars with white spot, light discolored and dark discolored, brown spot enamel caries were selected. Rectangular blocks were cut from the carious area and a corresponding sound area of the same tooth. Emission spectra were recorded from carious lesions and the corresponding sound areas using a fluorescence spectrophotometer at excitation wavelengths from 360 nm up to 580 nm in steps of 20 nm. Emission spectra of all types of carious lesions were shifted towards longer wavelengths (red shift) when compared to the spectra of the corresponding sound enamel. The red shift was highest for dark brown spot lesions and lowest for white spot lesions. Distinct fluorescence bands within 600-700 nm typical for porphyrin compounds were strongest for excitation wavelengths from 400 to 420 nm and present in most of the lesions investigated.
The patient, a 35-year-old male presented for initial examination. Existing carious lesions were charted, however there were several areas in the occlusal pits and fissures that were not cavitated to the point where an explorer would stick. A lower right second premolar exhibited such signs. (Figure 4) These areas of discoloration are common, yet many are not properly diagnosed. After polishing and then drying the occlusal surface, the LED spectroscopy device was used to obtain more in-depth information regarding the status of caries presence. (Figure 5) The areas of concern were accessed using a minimally invasive bur (Fissurotomy Bur™, SS White, Lakewood, NJ) (Figure 6) and the site was reevaluated for the presence of remaining caries using the LED caries detection device. (Figure 7) These areas were additionally confirmed with an explorer and were confirmed to be soft, carious dentin. The caries was carefully removed (Figure 8) using a round bur on a slow speed handpiece at 250 rpm, and the site reevaluated with the same device.
(Figure 9) Showing no signs of any further lesions, confirmed with an explorer the cavity preparation was restored. (Figure 10)

Conclusion:
With technology able to now detect the undetectable, caries diagnosis and treatment has evolved from the need for "extension for prevention" to a minimal intervention model. This advancement in caries management has been further strengthened by the advancements in adhesion dentistry, which together encourage preservation of tooth structure. Despite these changes, the ultimate goal lies with the prediction of GV Black: “The day is surely coming... when we will be engaged in practicing preventive, rather than reparative, dentistry.”

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Questions

1. A new explorer has an average tip diameter of:
   a. 10-20μm
   b. 20-30μm
   c. 30-40μm
   d. 40-50μm

2. A false positive probing can result from the:
   a. Shape of the fissure
   b. Force of application
   c. Path of explorer placement
   d. All of the above

3. The International Caries Detection and
   - Assessment System review found that while new caries detection criteria measured different stages of the caries process, there were inconsistencies in how the caries process was:
   a. Identified
   b. Measured
   c. Located
   d. Both a and b

4. According to several studies, one possible cause of non-cavitated lesions may be due to:
   a. Well water
   b. Recession
   c. Over-fluoridation
   d. None of the above

5. Historically, dental caries has been synonymous with the presence of:
   a. Candida albicans
   b. Cavitation
   c. Balancing contacts
   d. All of the above

6. The non-cavitated carious lesion is also known as:
   a. Occult caries
   b. Shadow caries
   c. a and d
   d. Hidden Caries

7. Dentin caries can result in visually non-cavitated lesions, which present as clinically intact:
   a. Dentin beneath enamel bridges
   b. Enamel and dentin
   c. Enamel over the body of the lesion
   d. None of the above

8. Thin bridges of non-cavitated enamel overlying carious dentin may present as:
   a. Diffuse opacities
   b. Green phosphorescence
   c. A violet isthmus
   d. All of the above

9. Which of the following determined that the visual/tactile method, with or without diagnostic adjuncts can diagnose cavitated lesions efficiently, but not non-cavitated lesions?
   a. Farley
   b. Hartman
   c. Assaf
   d. Radner

10. After repeated use, an explorer tip will dull to an average diameter of approximately:
    a. 50μm
    b. 100μm
    c. 150μm
    d. 200μm

11. Chemical detection using caries-staining or caries-detection dyes:
    a. Lack accuracy
    b. Are highly accurate
    c. Offer a definitive diagnosis
    d. Are inaccurate 98% of the time

12. Decay is difficult to detect in radiographs unless the lesion is larger than:
    a. 2mm to 3mm deep into enamel
    b. 1mm to 2mm deep into enamel
    c. 1mm to 2mm deep into dentin
    d. 2mm to 3mm deep into dentin

13. Which of the following conducted a systematic review aimed at evaluating the accuracy of radiographic caries detection for different lesions at different locations?
    a. Berkowitz
    b. Raider
    c. Shipman
    d. Schwendicke

14. Some laser devices detect caries through the use of:
    a. Fluorescence
    b. Optical mirroring
    c. Trans-translation
    d. Bioluminescence

15. Some of the early laser devices were highly sensitive to caries but had:
    a. High gravity
    b. Low specificity
    c. A defined gradient
    d. An average median

16. Low specificity meant that these early laser devices would measure the fluorescence of:
    a. Specific dentinal anomalies
    b. Enzymatic viral byproducts
    c. a and b
    d. Anything

17. There are now caries detection devices that image both the teeth and periodontium using:
    a. Optical Coherence Tomography
    b. Infrared Coherence
    c. Sonography
    d. Refractive Guided Telemetry

18. The LED based spectroscopy caries detecting device uses an LED at a wavelength of:
    a. 680nm
    b. 820nm
    c. 405nm
    d. 360nm

19. Porphyrins fluoresce differently than other tooth structures and restorations and will fluoresce:
    a. Red
    b. Green
    c. Violet
    d. Indigo

20. One compound emitted from caries-producing bacteria that is detected with fluorescence is:
    a. Lactin
    b. Casein
    c. Oxydoreductase
    d. Porphyrin

21. A visual image of their tooth can provide the patient with an interactive point of reference and is a powerful tool that allows them to:
    a. Code diagnose
    b. Understand the problem
    c. Request treatment
    d. All of the above

22. Over-fluoridation hardens the outer enamel surface, but does not penetrate sufficiently to prevent caries from occurring in the deeper layers of:
    a. Enamel
    b. Cementum
    c. Dentin
    d. Both a and b

23. Using the LED based spectroscopy caries detection device, healthy tooth structure will fluoresce:
    a. Lavender
    b. Green
    c. Red
    d. Cobalt blue

24. Which of the following researchers determined that red fluorescence is well suited to the detection of bacteria that cause dentin caries?
    a. Lennon
    b. Green
    c. Lynch
    d. Martin

25. Normal healthy tooth structure produces:
    a. Little or no fluorescence
    b. High fluorescent values
    c. Little or no phosphorescence
    d. High phosphorescence values

26. According to a review by McComb, the routine use of caries staining dyes:
    a. Is an excellent method for removing caries
    b. Should be completely avoided
    c. Is a definitive diagnostic tool
    d. May lead to a profound degree of over-treatment

27. Radiographic caries detection is highly accurate for all but which of the following lesions?
    a. Crevicular proximal lesions
    b. Carious lesions within the dentin larger than 2-3mm
    c. Non-cavitated lesions
    d. Highly advanced caries lesions

28. Diagnostic techniques that use various forms of light to detect hidden carious lesions include:
    a. Transillumination
    b. Lasers
    c. LED spectroscopy
    d. All of the above

29. Which of the following researchers studied the effect of metalloporphyrins on red and green fluorescence from oral bacteria?
    a. Chase
    b. Volgenant
    c. Martin
    d. Short

30. LED caries detection is based on the concept that:
    a. Decalcified teeth are more translucent than healthy teeth
    b. Healthy teeth are opaque
    c. Healthy teeth are more translucent than decalcified tooth structure
    d. None of the above
**Light Assisted Caries Detection: 21st Century Technology**

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**Educational Objectives**

1. Discuss the limitations of manual and radiographic diagnostics for caries identification.
2. Describe the current equipment needed for caries diagnosis.
3. Implement the materials and steps required to access carious lesions in a minimally invasive manner.
4. Be able to restore a tooth using a variety of composite bonding agents and resins.

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