Microinvasive Dentistry
Clinical Strategies and Tools

John J Graeber
Tooth decay remains the most prevalent disease on earth. As Health Professionals, our goal is primarily to help heal our patients in need. This requires that we DO NO HARM.

In my opinion, we do harm when we do not avail ourselves of the most up-to-date devices and methods, which aid in the earliest possible diagnosis and intervene with the least invasive treatment, preventive or otherwise.

**Microinvasive Dentistry** is a series of manuscripts, which address prevention, management, early diagnosis, and treatment of caries – the most prevalent disease of mankind.

This book begins with a review of preventive techniques and current best practices with fluoride. The earliest signs of tooth decay can be treated with penetrating resins, sealants, and fluoride preparations when utilized early in the disease process.

Earlier diagnosis presents us with an opportunity to provide a better service, but only when we have the tools necessary for objective measurement and/or monitoring of the decay process. Several chapters of this book explain, in practical detail, devices, which far exceed the accuracy of the oldest dental instruments – the explorer and the dental bitewing X-ray.

The latest microbiological findings about caries are published here for the first time – shattering traditional concepts, not only in the discovery of novel causative species but also questioning current concepts of the anti-caries value of restorative materials. The potential of regeneration of dental materials is discussed by world-class researchers and clinicians.

Where caries has extended into the dental tissue, new methods of caries excavation and cavity preparation are explained and demonstrated in great detail by leading edge clinicians, based on years of real-life experience. The advantages of air-abrasives and all-tissue laser devices have been shown over the decades to be far safer on human teeth than the high-speed drills, which have been in common usage for the past 70 or so years. The time has arrived when we should be retiring the GV Black concepts designed for metallic restorations.

So, I invite you to read and study this book on **Microinvasive Dentistry** and challenge you to become part of the **New Age in Dentistry**.

John J Graeber
March 2020
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Introduction

The Canary System, developed by Quantum Dental Technologies (Figure 1) uses a low-power laser diode (<45 mW at the tooth surface) at 660 nm and modulated at 2 Hz\(^1\) to examine the tooth. Its unique energy conversion technology [photothermal radiometry and luminescence (PTR-LUM)] allows it to image and examine the crystal structure of the tooth. The PTR-LUM is able to measure and monitor two different phenomena: (1) modulated thermal infrared radiation (PTR), and (2) alternating current LUM.\(^2\) When pulses of laser light are shone on the tooth, the laser light is converted to heat (photothermal radiometry or PTR) and light (luminescence or LUM), which are emitted from the tooth surface in response to these modulated pulses.

Caries, cracks and erosion modify the thermal properties (PTR) and LUM of healthy teeth. As a lesion grows, there is a corresponding change in the PTR-LUM response signal. In effect, the heat confined or trapped in a region with crystalline disintegration (dental caries) increases the PTR and decreases the LUM response signal. As remineralization progresses and enamel prisms start to reform their structure, the thermal and luminescence properties begin to revert toward those of healthy tooth structure.\(^3\)-\(^7\) The Canary System detects very small changes in heat (<1–2°C), much less than that generated by a dental curing light. These pulses of laser light enable the clinician to examine lesions up to 5 mm below the surface.\(^8\)-\(^11\)

Research has demonstrated that Canary’s energy conversion technology (PTR-LUM) can detect, diagnose, record and monitor:

- Lesions and defects 5 mm below the enamel surface\(^1\)-\(^15\)
- Occlusal pit and fissure caries\(^8,13\)-\(^15\)
- Smooth surface caries\(^3,16,17\)
- Acid erosion lesions\(^7,18\)-\(^21\)
- Root caries\(^22,23\)
- Interproximal caries lesions\(^24\)-\(^29\)
- Caries beneath fissure sealants\(^30\)-\(^33\)
- Caries around margins of restorations and crowns\(^34\)-\(^40\)
- Caries beneath the intact margins of composite resins\(^37\)
- Caries beneath the intact margins of amalgam restorations\(^38,39\)
- Caries beneath the intact margins of resin modified glass ionomer & compomer restorations\(^39,40\)
- Demineralization and remineralization of early lesions\(^6,7,23,41\)-\(^45\)
- Caries beneath clear resin infiltrants\(^46,47\)
- Caries around orthodontic brackets\(^48,49\)
- Lesions and teeth treated with SDF (silver diamine fluoride)
- High inter and intra-examiner repeatability\(^33,40\)
- Detect and diagnose caries more accurately than radiographs\(^24\)-\(^26\)
- Detect and diagnose caries more accurately than fluorescence devices such as DIAGNODent or SPECTRA\(^13,17,30,33,37,39,40\)

Clinical trials

The Canary System has been investigated in three clinical trials. The first Health Canada-approved investigational study was completed in December, 2009. The trial involved 50 patients using the first
prototype in a number of clinical situations and found no safety issues.\textsuperscript{30,51} The second Health Canada clinical trial was a follow-on study designed primarily to help QDT define the Canary Scale and determine how to best integrate the system into a dental practice. The study involved 98 patients among four trial sites with 38 patients involved in multiple visits for monitoring the effects of remineralization therapy.\textsuperscript{52-55} The third clinical study was performed in 2014 at the University of Texas to investigate interproximal caries detection. The investigators found Canary was able to detect 92% of the lesions while radiographs only found 62%.\textsuperscript{26}

One could consider other caries detection systems but the critical question is what exactly are they detecting? Currently, on market there are three different approaches to caries detection – fluorescence (DIAGNOdent, SPECTRA and SOPRO), transillumination (CARIVU, FOTI and DIFOTI) and PTR-LUM (‘The Canary System’).

Fluorescence
Fluorescence is simply the emission of light from an object that has absorbed light at a specific wavelength.

These devices measure glow from the tooth surface when an LED or laser light is shone on the tooth. The literature indicates that the glow or fluorescence is from stain, bacterial porphyrins, tartar or food debris on the tooth surface.\textsuperscript{26}

**Transillumination**
Transillumination involves shining either visible light or near infra-red light through a tooth and measuring the scatter or disruption of the light. Sound enamel is composed of densely packed hydroxyapatite crystals which allow light to pass through them. When demineralization occurs, the light or photons are disrupted and the area will appear as a shadow. Shadows may indicate caries is present because demineralized areas of enamel or dentine scatter light more than sound areas. Therefore, caries appear as darker areas using FOTI,\textsuperscript{51} DIFOTI and CARIVU. These detection methods still rely upon visual examination of grey shadows on images to determine the presence of caries and measurement of changes in lesion volume may be challenging. Figures 2 and 3 provide a short summary of the clinical and technical characteristics of these systems.

**Method**
The Canary System has a voice which provides the Canary Number after each 4 second scan. This helps both the operator and the patient to understand what is being measured (Figure 4). The Canary System also has an intra-oral camera so images of the surface being examined can be shown to the patient. Using the detail scan mode the Canary Numbers are recorded on the image and a report can be generated for the patient showing the Canary Numbers and treatment.
Figure 4 The Canary Scale.

The key is to find the lesion and use technology to monitor the changes in the lesion as it undergoes remineralization.

**Integrating the Canary System into clinical practice**

The Canary System can be integrated into three paths in a dental practice.

1. As part of the dental hygiene recall exam
2. Evaluating the progress of a remineralization/prevention program
3. As part of the new patient exam

The chart below provides a summary of how the Canary System can be integrated into a dental practice (Table 1).

**What should be scanned during a hygiene/preventive visit?**

- Status of pits and fissures on posterior teeth—helping to decide if sealants or restorations are required
- Status of the margins of restorations including composites, glass ionomers, amalgams, porcelain and metal crowns
- Stained marginal ridges to detect cracks
- White and brown spots on enamel or root surfaces
- Scan around orthodontic brackets to check for the development of white spots or caries beneath the bracket
- Interproximal areas to detect caries not seen on bitewing radiographs

Table 1

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>Canary System</th>
<th>DIAGNOdent</th>
<th>Spectra</th>
<th>SoproLife</th>
<th>CarliVu</th>
</tr>
</thead>
<tbody>
<tr>
<td>MANUFACTURER</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measures changes in the crystal structure of tooth</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Method Of Detection</td>
<td>PFL.U.M Photothermal Radiometry and Luminescence</td>
<td>Measures porphyrins from bacteria, an indirect way to detect caries</td>
<td>Measures porphyrins from bacteria, an indirect way to detect caries</td>
<td>Measures porphyrins from bacteria, an indirect way to detect caries</td>
<td>Passes near infrared light through tooth (transillumination)</td>
</tr>
<tr>
<td>Use with ADA Code D0600 and CDA Code 0420 for caries detection—meets the code definition</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Device output is quantifiable using a numerical scale</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Software is provided</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Patient and dentist reports provided—engages patients</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
<tr>
<td>Cloud storage with access to data, reports and analytics</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
<td>✔️</td>
</tr>
</tbody>
</table>

**Figure 3** Caries detection systems: Technical features.
Current report
Visit date: June 13, 2011
Patient: Bob Leigh
Dentist recommendations:
- 3M™ ESPE™ Clinpro™ 5000 1.1% Sodium fluoride anti-cavity dentifrice NPN80012416

Instructions:
- In-office treatment of 3M ESPE vanish every 3 months.
- Use 3M ESPE clinpro 5000 toothpaste at bedtime.
- Avoid soft drinks.

Next scan and treatment visit:
September 22, 2011 – 10:00 AM

The Canary System - www.thecanarysystem.com

One should simply pick a quadrant (3–5 teeth) of most concern and assess all posterior teeth at the end of the appointment or scan teeth that are of concern.

Who can use the Canary System?
Any member of the dental team can use the Canary System, including dental assistants, dental hygienists and dental therapists. Once the scans are done, the dentist can then review the information and develop a treatment plan. Our canary recommended treatment guide provides guidance on how to treat various clinical situations.

Clinical cases
Remineralization of brown spot lesions: A female patient, in her mid-twenties, had brown spot lesions along the gingival crest of the second molars and the mandibular first molars. A remineralization program was started 4 years ago in an attempt to stabilize the lesions and prevent cavitation. At that time, the lesion surfaces were brown in color but had some surface roughness. Results from monitoring the mandibular left second molar over the last 42 months are displayed in Figure 7. The remineralization therapy consisted of a combination of 3M ESPE Vanish White Fluoride Varnish applied every 3–4 months in the office and the home use of 3M ESPE’s Clinpro 5,000 toothpaste used nightly.

Initially, the patient started on the program and was able to decrease the Canary readout Number from “75” to “55” within the first 9 months of the program. There was no visible change but the patient was able to track their
Table 1 Integration of the Canary System into clinical practice workflow

<table>
<thead>
<tr>
<th>Examination type</th>
<th>Recall, re-care examination</th>
<th>Remineralization program</th>
<th>Full mouth examination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Details</td>
<td>Each scan takes 5 seconds. Scan 3–5 teeth and talk to the patient in under 4 minutes</td>
<td>Monitoring remineralization program using the Canary Book 15 minutes appointment to scan areas and apply remineralization product</td>
<td>A few offices book 45 minutes to 1 hour to scan the entire dentition. Some focus on the posterior teeth and discolored areas on anterior teeth</td>
</tr>
<tr>
<td>Suggested billing code</td>
<td>Included in recall examination or use ADA code in the US (D0600) or Canadian Code (04220)</td>
<td>Remineralization/fluoride varnish or CAMBRA codes</td>
<td>US – ADA D0600* Canada – Specific Exam Code® or Caries Diagnostic code 04220</td>
</tr>
<tr>
<td>Staff</td>
<td>Hygiene team</td>
<td>Hygiene team or dental assistant</td>
<td>Hygiene team or dental assistant</td>
</tr>
<tr>
<td>Patient message</td>
<td>A new system for accurately evaluating the health of the tooth</td>
<td>Monitoring how our home and office tooth decay reversal program is working</td>
<td>There are a number of areas of concern that we can't assess with dental X-rays</td>
</tr>
</tbody>
</table>

*Refer to the specific billing codes used in the US and Canada.

progress by accessing their reports on the Canary Cloud.

From month 12 to month 36 the lesion did not decrease in size and this was due to poor compliance with the remineralization program. No surface cavitation developed nor was there any pain on temperature change or exposure to sweet carbohydrates.

From month 36 onward, the patient decided to try to improve her Canary Numbers and did follow the simple home care regime. The Canary Numbers dropped to “25” and remained stable going forward. The tooth surface became smoother and no cavitation developed. Visually, there are no signs of remineralization or color change since initially this is mostly a sub-surface
phenomena. The ICDAS II ranking has remained at “4” throughout this process since it could not detect any sub-surface remineralization. Using the Canary System, we were able to monitor remineralization of the lesion. The patient was able to follow the remineralization process by accessing her reports on the Canary Cloud and listening to the voice on the Canary System as each scan was taken. This allowed the patient to take ownership of the management of her oral health.

Clinical example of early caries detection using visual exam and radiographs

In this clinical situation, a 40-year-old female patient with minimal caries risk and only two pre-existing restorations was complaining of pain in the maxillary left first molar. The pain was low grade, not stimulated by chewing or cold. A routine bitewing radiograph (Figure 8) and visual examination revealed no sign of pathology, and both marginal ridges appeared intact with no signs of any radiolucency. Scanning the mesial contact area with the Canary System, however, indicated that a lesion was present beneath the occlusal aspect of the marginal ridge but toward

Figure 7 Monitoring the remineralization of a brown spot on mandibular second molar.
(Courtesy: Quantum dental and Dr Stephen Abrams)

Figure 8 Bitewing radiograph showing no interproximal lesions on the left side.

the buccal surface (Figure 9). Preparation of the tooth for a conventional composite restoration (Figure 10) confirmed caries on the mesial contact area as indicated by the Canary System. This clinical example illustrates situations where radiographs and visual examination may not be able to detect lesions due to their placement beneath a hard intact shell of radiopaque enamel – but treatment was required.
Advantages

- Ability to detect lesions far earlier than with visual or radiographic methods
- Ability to measure objectively changes in lesion demineralization
- Cloud and audible options aid the patient’s motivation in remineralization efforts
- Virtual Training and online videos are available for training new staff

Disadvantages

- Cost for equipment which is competitive with other technologies
- Time required for training/familiarization by the entire clinical team
- Time required for extensive testing of all suspected areas of demineralization

Conclusion

Caries a common oral disease treated in clinical practice. Treatment of the disease does not involve placement of restorations but the detection and monitoring of changes if one is placing restorations or remineralizing lesions. The Canary System detects monitors and measures the changes in the crystal structure of the tooth which means it can be used as diagnostic device for the detection and monitoring of caries in clinical practice.

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readings. International Association of Dental


The clinical appearance of caries has changed since the widespread use of fluoride in most populations. Diagnostic instrumentation and treatment protocols have not kept pace.

Technology developed in the past 30 years has made evidence-based diagnosis simple and objective. The advent of Adhesive Dentistry requires traditional technique changes.

Caries management and treatment need an overhaul to make early diagnosis and microinvasive treatment a reality.

The contents of this book will challenge and enlighten Dental Professionals as to many of these new developments which preserve dental tissues to the maximum extent possible.