SCIENTIFIC REPORT

Fluorescence-assisted caries diagnostics

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As part of the continual developments in dentistry, a new method for detecting and monitoring carious lesions has managed to establish itself in the last few years – fluorescence-assisted diagnostics, which is based on fluorescence spectroscopy. Essentially, spectroscopy is a specialism normally reserved for scientists coming from physics and chemistry. For this reason, this article is intended to explain the most important aspects of fluorescence spectroscopy with respect to caries diagnostics. It provides the dentist applying the product with more detailed information in order to give him/her an even broader understanding of the topic and as such to promote informed use of this innovative diagnosis option.

Cold light materials and systems

The material property of the fluorescence is a special form of "cold light", so-called luminescence. Generally speaking, luminescence describes the optical radiation of a system which occurs during the transition from an excited to the ground state. In addition to fluorescence, there are also a number of further types of luminescence. The following table provides an overview of the most important types of luminescence along with common examples.

Type of luminescence	Excited by	Examples
Triboluminescence	Friction	Sugar crystals, self-adhesive envelopes
Electroluminescence	Electrical current	Light diodes
Chemoluminescence	Chemical reaction	Luminol as evidence of blood
Bioluminescence	Chemical reaction in living organisms	Deep-sea fish, fireflies
Phosphorescence (photoluminescence)	Photons (light particles)	Glow-in-the-dark watches and clocks
Fluorescence (photoluminescence)	Photons (light particles)	Monitors, **medical diagnostics**

As can be seen in the table, phosphorescence and fluorescence are both types of photoluminescence. Photoluminescence describes the radiation of a system following excitation as a result of interaction with light particles (photons). The excitation process is called absorption. Humans perceive the colours when the system returns to its ground state. This process is called emission. Whether humans can see the colour depends on the length of the excited state. This can easily be demonstrated using a phosphorescent clock face as an example: Firstly, the photons (light particles) are absorbed from the daylight or artificial light. This excites the phosphorescent material on the clock face and charges it up so to speak. At night, when the light source is no longer present, the emission process begins. The phosphorescent material returns to its ground state whilst emitting (usually green) light.

Fluorescent substances

In **fluorescence**, in contrast, the excitation lasts considerably shorter and is only for approx. 10 ns (ns = nanosecond, 1 second = 1,000,000,000 nanoseconds). Consequently, the human eye can only see fluorescence directly under certain conditions. Illumination is only visible, if the source of the excitation is permanently present and activates the material. If the photon source runs out, the fluorescence must be detected indirectly via spectroscopic procedures and then visualised.
Systems or materials displaying fluorescent properties are known as fluorophores. There are a number of examples of common fluorophores:

- Quinine as a colourant (in drinks, dragées)
- Signal colours in our surroundings
- Fluorescent colours in pens and clothes
- Amino acids (tryptophan, tyrosine, phenylalanine)
- Metabolic products of caries (porphyrins)

For a material to fluoresce, it must be excited. This excitation originates with a radiation source emitting light at a certain wavelength. Depending on the fluorophore, the material is excited either by UV light, daylight or infra-red light. A good example of this is the use of black lights (UV light) in nightclubs, which make drinks containing quinine and fluorescent colours in clothing shine. Signal colours (e.g., on traffic signs or in text markers) work using a similar principle. The fluorescence of these materials is largely activated by natural daylight, but also by the UV light which is contained in a proportion of natural light.

Fluorescence-assisted caries diagnostics in dentistry

In terms of the fluorescence-assisted diagnostics possibilities in dentistry, the metabolites of caries bacteria play a decisive role. These metabolites belong to a group called porphyrins. Porphyrins and porphyrin-related compounds are chemical substances which form the building blocks for human proteins. At the same time, however, porphyrins boast sophisticated fluorescent properties, which can be exploited for caries diagnostics via fluorescence spectroscopy. To this end, technical devices were developed which comprise a laser unit and a detector. The laser emits light at a specific wavelength to excite the fluorescence of the caries bacteria. This fluorescence is then determined by the detector with reference to the dental hard tissue and visualised.
Well-known manufacturers of this type of diagnostic devices are, for example, Dürr Dental AG (model: Vista Cam iX Proof) and KaVo (model: DIAGNOdent 2095). The excitation is performed by a laser emitting light at a specific wavelength. Both the Vista Cam iX Proof (wavelength λ = 405 nm) and DIAGNOdent 2095 (λ = 655 nm) excite the fluorescence with light in the visible spectrum (400 - 800 nm). The wavelength of the light that the devices emit is responsible for its colour: The Vista Cam iX Proof emits purple light (405 nm). In contrast, the light of the 665 nm wavelength emitted by the DIAGNOdent 2095 appears red-orange. Figure 1 shows the spectrum of visible light (400 - 800 nm) with the corresponding colours for comparison.

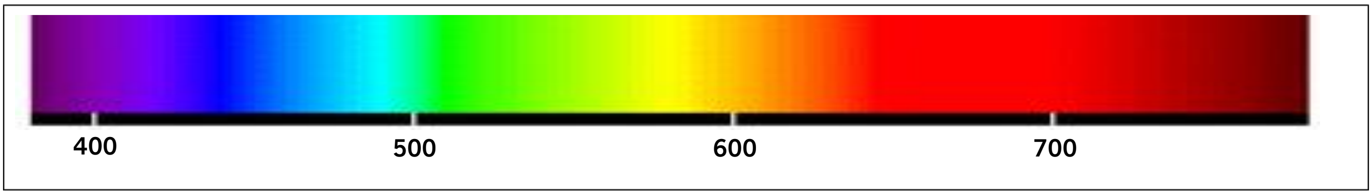

Figure 1: Spectrum of visible light (400-800 nm)

The main advantage of employing fluorescence-assisted caries diagnostics in dentistry is the fact that there is the possibility of keeping a tooth caries-free and thus healthy for longer. Highly filled, transparent fissure sealants such as Control Seal from VOCO, for example, allow the monitoring of a fissure through the sealant material. This makes it possible to check and ensure teeth are caries-free using fluorescence-assisted diagnostics. Any small caries fissures can be sealed air-tight with a transparent sealant. This first of all halts the progression of the caries. The dentist is then able to monitor its progress using fluorescence-assisted caries diagnostics.

All in all, laser fluorescence-assisted caries diagnostics is a non-invasive method which protects the dental hard tissue and as such ensures the long-term health of the complete dentition.

Conclusion: Laser fluorescence-assisted caries diagnostics in dentistry utilise the basic principles of fluorescence spectroscopy. Today, developments in the field of spectroscopy are so technically advanced that it is possible to include highly developed technology in a device which the treating dentist can use as an essential tool in his daily work. Laser fluorescence-assisted caries diagnostics is risk-free and safe for the patient and dentist alike. As such it contributes decisively to keeping the teeth free from caries for longer as well as to a reduction in loss of dentition in the long run.