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REVIEW ARTICLE

METHODS FOR DIAGNOSING DENTAL CARIES LESIONS

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ABSTRACT

Tooth decay (dental caries) commonly occurs throughout the world and is one of the most widespread infectious diseases of lifestyle, globally affecting all age groups; up to 90% schoolchildren and almost 100% adults in both developing and developed countries. When left untreated, it can lead to disease outbreaks resulting in advere-health and life-threatening conditions such as endocarditis or sepsis. Undoubtedly, basic measures are thus required in both dental and GP practice to ensure that dental caries are detected early. This article presents the various diagnostic methods used to identify these disease outbreaks.

KEY WORDS: dental caries, diagnostics

INTRODUCTION

DIAGNOSTICS OF DENTAL CARIES

Oral disease poses a serious burden to human health and is a serious issue facing the world's population. The most common types occurring are tooth decay, periodontal disease and oral cancer that are largely due to the presence of microorganisms that variously bear pathogenic potential. There is therefore a need for them to be quickly identified and to detect changes so that progression of such oral diseases becomes limited.

Any dysbiosis in oral microorganisms leads to profound morphological changes in oral tissue structure as compared to normal conditions. A major cause of periodontitis is the colonisation of subgingival plaque by pathogens such as Porphyromonas gingivalis, causing microbial dysbiosis. It is also observed that components of gingival fluid, such as infiltrating inflammatory cells and tissue degradation products, greatly vary between people with and without inflammation. Changes in the microbiome and components of saliva and tissues can thereby be used as markers in studies on oral diseases, whilst Raman Spectroscopy can be considered a promising diagnostic method for their detection [1].

Dental Caries is the most common diagnosis made in oral disease at all ages. This is a disease of affluence (lifestyle/civilisation) and occurs throughout the world. Its status can be assessed by the Decayed, Missing and Filled Teeth index (DMFT) used to characterise both the extent of its prevalence and treatment requirements arising from disease progression. Although dental caries is recognised to be a globally widespread disease, its epidemiology is different in many countries and depends to what extent preventative measures have been adopted to try to effectively combat this disease over recent decades.

Poland is one of the few European countries where it has not been possible to reduce the incidence of dental caries in children, despite WHO recommendations for 2000 aimed at reducing the incidence of caries in 6-year-old children down to 50%. Indeed, the WHO recommendation for 2015 was to reduce such incidence down to 30% in 6-year-olds, (ie. to have 70% of 6-year-old children free of dental caries) [2].

It has been statistically estimated that a 12-year-old in Poland has 3.5 teeth affected by dental caries and that 40% of 18-year-olds have experienced losses to their permanent dentition arising from dental caries complications [3].

A study by Milewska et al. found that 87.6% of 6-year-old children had dental caries, whilst an incidence of 98.08% has been reported in 12-year-old children, with rates of 17.1% found in their permanent dentition (Fig. 1) [4].

Dental caries lesions have been shown to occur in over 40% of children aged 3 years and in 90% of those aged 18 [5], as reported by the latest epidemiological studies conducted under a Polish Ministry of Health programme entitled ‘Monitoring the oral health of Poland’s population during 2016-2020’. It has been proved that dental caries lesions present in children’s primary dentition are the strongest predictor of risk in their developing dental caries later in life. If dental caries occurs in children under 3 years of age, then there is also a high probability of permanent tooth disease [6].

Previous studies have indicated an alarmingly poor health condition of children's teeth in Poland. Such findings significantly contrast to the status observed, not only in the originally established EU countries, but also in those EU countries undergoing systemic transformation like Poland. The figure below shows the prevalence and severity of dental caries in 6-year-old children in Poland in relation to other selected countries [7].

A significant decrease has been observed in the aforementioned epidemiological parameters following the latest cross-sectional study on oral health in Germany, (DMSV-Fünfte Deutsche Mundgesundheitsstudie), performed in 2016. For example, between 1997 and 2016, the number of children without dental caries had doubled at the age of 12 years (from 41.8% to 81.3%), and the DMFT index in young adults had decreased by 30% to 4.9%. Furthermore, the DMFT for 13-14-year-olds dropped from 4.9% to 0.5%. It is also interesting to compare different social strata, where even though the better off achieve slightly more favourable results, improvements in oral health have been demonstrated in all social strata. A similar comparison has been seen between the regions of the former East Germany and West Germany. Oral health has almost been levelled within three decades. This thereby demonstrates how effective the preventive programs used in Germany are, and the usefulness of such a pro-health policy which promotes education, prevention and in rewarding patients when they are partially responsible for their own health [8].

One part of the pro-health German prevention system is to encourage patients to have twice yearly check-ups up to 18 years age and thence on once yearly. Patients meeting these criteria can not only count on having any pathological processes being thus detected early, but they can also benefit by being reimbursed if any treatment would be required.

A fundamental part of any dental examination of the oral cavity is in diagnosing dental caries. The most common method used is a medical examination, with aprobe, under adequate lighting and with the benefit of a dentist's personal experience (dentist's eye). This is a simple and quick method for determining whether teeth are healthy which does not incur any large financial outlays, but are subject to inherent disadvantages in such procedures. A frequently used manoeuvre to support any diagnosis is X-ray diagnostics that increases the sensitivity and specificity of this procedure, however the patient is inevitably exposed to ionising radiation and in bearing the increasing costs such examinations. The price for the patient ranges, depending on the method, from a dozen to about 100 PLN, whereas purchasing the diagnostic instrument would cost from 30,000 to 250,000 PLN.

Although this is the working equipment now used as standard-practice for the majority of dentists, it may still represent a limitation at smaller dental centres. Computed tomography examinations are much more expensive. Although they are not part of the standard diagnostic process for detecting dental caries, they are used in dental surgeries that posses more advanced procedures. Such services cost the patient from about 250 PLN, whilst buying the diagnostic instrument would cost several hundred thousand PLN.

An alternative to radiological examination is to use the techniques of transluminescence and fluorescence, for example that are present on-board the KaVo Diagnocam instrument. Exposure to X-rays, can thus be avoided which allows pregnant women to have their teeth diagnosed by these means. The higher cost of the Diagnocam procedure appears to be offset by its non-invasive nature and it can also be validated during checking. A problem is however that false positives and incorrect conclusions can arise due to a lack of operator experience. There are also additional costs that must be considered for patients and, of course, doctors. The instrument costs around 30,000 PLN and not forgetting that it requires installation into dental units. These facts would thereby indicate an association between higher expenditure on diagnostics with increased effectiveness in the early detection of dental caries. However, this is only one of the aspects that determine how successful the outcomes are of prevention policy. In Poland, dental health care was and still is largely in the private sector, which means that the burden of paying for treatment rests with the patient. In Germany, a large part of available dental heath services is free of charge to the patient and therefore the payer is the state. It is hardly surprising then, that the government (ie. payer) and health care regulator are interested in reducing the cost of treatment, thereby also increasing the role of pro-health prevention as being the cheapest form of treatment. Transferring this responsibility to patients in a system in which they themselves have to fully pay for it is, in authors' opinion, a very difficult task and explains why the set goals in reducing dental caries in Poland has proved unsuccessful.

Dental Caries is a localised pathological process caused by exogenous factors leading to decalcification of hard tooth tissue layers, followed by proteolytic decomposition of the thus exposed soft tissues. In Poland, it is diagnosed in over 85% of preschool children, including about 54% of 3-year-olds. The main contributing factors are an improper diet, lack of hygiene and an excess of microorganisms residing in the oral cavity, particularly Streptococcus mutans and Streptococcus sobrinus [9, 10]. These oral streptococci act on any available sucrose and produce tooth plaques containing water-soluble and water-insoluble extracellular polysaccharides called glucans (dextran and mutan) [11, 12]. When these bacteria enter the bloodstream, they can reach distant organs causing, inter alia, disease outbreaks. By such means, infections often arise in the joints, kidneys or heart as well as recurrent colds, pharyngitis and a slowing down of the healing process [13-15].

Research efforts should thus be focused on methods of prevention, including early detection of the first demineralization lesions. The most popular methods that can be employed at any clinic are the visual-contact method, X-ray image analysis and measuring tissue fluorescence [16].

Dental caries can be detected, usually at its certain stages of progression by basic diagnostic methods, such

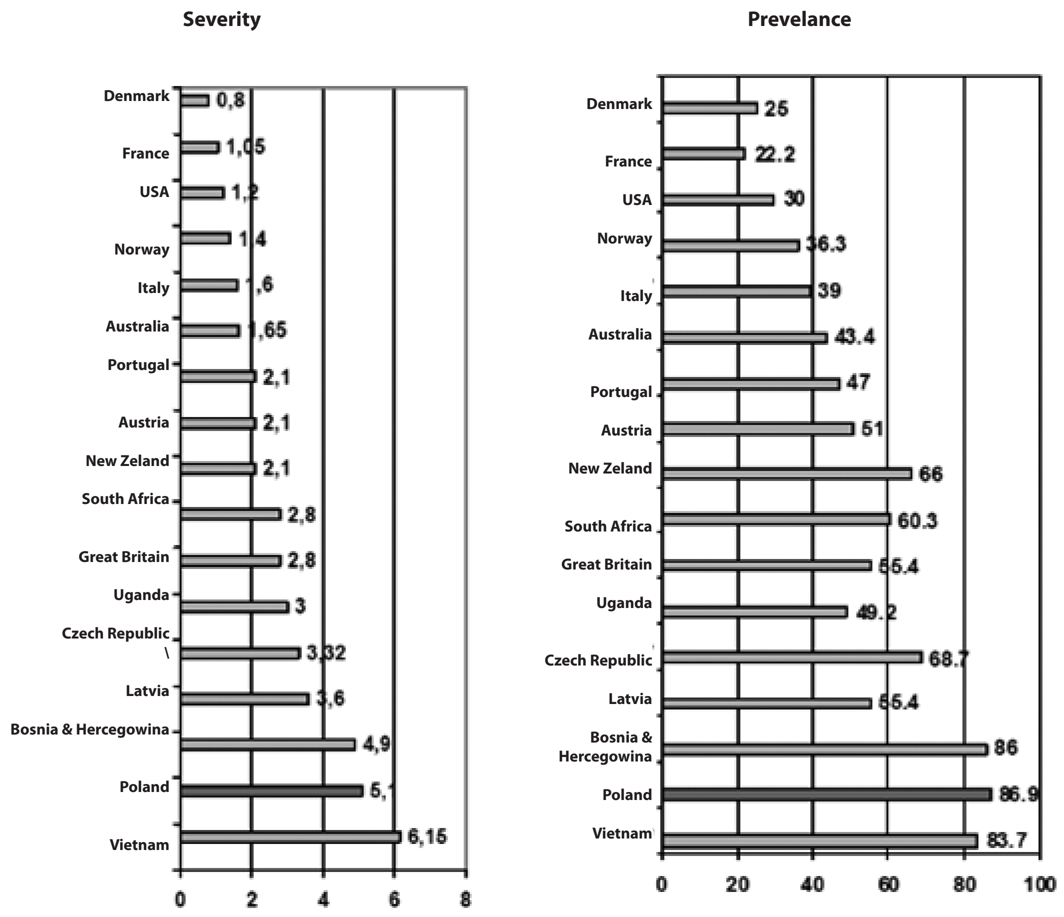


Fig. 1. The severity and prevalence of dental caries in 6-year-old children in Poland compared to other selected countries.

as intraoral examination with a mirror and probe, along with radiography. An early diagnosis enables remineralization treatment to be given without the need for mechanical intervention to the tooth tissues. In order to avoid invasive treatment, attempts have been made to use various physical phenomena for diagnostic purposes. These methods are based on light absorption and conduction, conductivity and electrical resistance, fluorescence or reflections of ultrasonic waves [17].

AIM

To review methods and techniques currently available for the early detection of dental caries outbreaks.

REVIEW AND DISCUSSION

OPTICAL METHODS

BASIC DIAGNOSTIC TOOLS

The oldest, but so far the most popular method for diagnosing dental caries is by visual inspection of the condition in tooth tissue. This is performed according to ICDAS II criteria (International Caries Detection and Assessment System) [18]. However, diagnosing dental caries using a probe and a mirror is not without its drawbacks. It is a subjective procedure based on the experience and skills of the examiner. Diagnosis can be greatly facilitated with the aid of magnifying glasses or a microscope, which are able to magnify the viewed area by up to 20 times. It is however difficult to determine the extent to which the condition has developed within time and to plan an effective method of management/treatment or remineralisation. This method only detects fairly advanced lesions. It is also worth noting that even small white spots can reflect surface instability which, when probed, can lead to the destruction of the enamel structure and prevent non-invasive treatment [16].

TRANSLUMINESCENCE

This method increases the effectiveness of intraoral examination. Illuminating the tooth with cold light using the fiber optic technique enables the sensitivity of intraoral examination to become closer to the X-ray method, however its specificity remains at a lower level [19].

X-RAY DIAGNOSTICS

X-ray diagnostics, especially those digital, allow diagnostic capabilities to be significantly extended and the use of digital image processing makes dental examinations more effective. In order to detect dental caries, intraoral bitewing and adjacent X-rays are taken as well as extraoral panoramic radiographs. Many authors however question the effectiveness of the latter. Even though taking X-rays increases the effectiveness of dental caries detection, it is still an ineffective tool for occlusal surfaces as it only shows advanced defects, nevertheless it is more useful for investigating proximal surfaces [20, 21].

The initial demineralisation as seen as a white spots are however imperceptible on an X-ray image [22]. When diagnostics are performed by both a probe and X-rays then the sensitivity and specificity are respectively 49% and 87% [23], which means that about half of the early lesions are undetectable and that dental caries was found in 13% of healthy teeth. In addition, ionising radiation adversely affects the human body. Because both methods have insufficient sensitivity and specificity, they are unable to describe/estimate how the dynamic process of re- and demineralisation develops [24]. This process cannot therefore be quantified by such means.

ELECTRICAL CONDUCTIVITY

Another diagnostic method is based on electrical conductivity (EC). Any material, including biological, possesses specific properties that define the flow of current. When the impedance of test tissue with a healthy standard is compared, then deviations from the norm can be detected. The porosity of the enamel increases in dental caries, resulting in increased amounts of fluid and electrolytes within this tissue which is reflected by increased conductivity but decreased resistance, thereby enabling dental caries to be diagnosed.

The first EC method is based on an ECM-electronic cars monitor using alternating current at a constant frequency of 23 Hz. The electrode applied to the tooth is in the shape of a probe / dipper, whilst the other is held by the patient. It is possible to test the point resistance or the impedance of the entire surface. Despite promising experimental results, physical factors such as tooth temperature [25], tissue thickness and hydration may affect the quality of the obtained data [26]. There are also doubts in assessing the advancement of lesions; it is not known whether total or partial surface porosity is being measured, whether the depth of defects is important nor whether their morphological complexity affects electrical conductivity. The ECM technique however gives hope that the effectiveness of dental caries diagnostics could be increased, but this requires further laboratory and clinical testing (Fig. 2).

Another instrumental technique that uses EC is EIC-Electrical Impedance Spectroscopy where an output series of current frequencies are scanned, that allows capacitance and impedance to be measured. This procedure enables a more accurate analysis of data and diagnosis of both the presence and the extent of dental caries lesions to be made [28].

LIGHT SCATTERING

A different analytical concept used for diagnosing dental caries is based on light scattering. Densely packed hydroxyapatite prisms, from which healthy enamel is built, create an almost translucent structure. Demineralisation becomes manifest as porosity forms, which causes spaces filled with air to occur that possess a completely different refractive index. Into these places, photons scatter (changing direction, without losing energy), and are seen as white spots. FOTI-fiber optic transillumination enhances this effect by using high-intensity white light, transmitted to the tooth via an optical fiber. Radiated light scattering disturbances are visible as shadows (Fig. 3 a-b).

This method is simple and relatively inexpensive, however assessing the results is subjective and there are insufficient studies that confirm its effectiveness, along with there being no way to record the results. DIFOTI, (Digital Imaging FOTI) allows diagnostic images to be recorded by computer, that permits the progress of dental caries to be compared and evaluated. There are however still no objective tools for evaluating images, and a subjective assessment needs to be carried out by the investigator.

FLUORESCENCE

Fluorescence occurs when light is emitted from an excited atom or molecule. This emitted light has a longer wavelength than the excitation light, arising from the principle of the conservation of energy. In applied dentistry, Quantitative Light-induced Fluorescence (OLF) uses visible light with a wavelength of 370nm, lying within the blue part of its spectrum. The resulting fluorescence is recorded by an intraoral camera at a 540nm wavelength range. The filtered radiation gives red and, above all, green light, which is characteristic of enamel. Demineralisation reduces the amount of fluorescence, which is calculated by the appropriate on-board software. The decreased fluorescence is highly correlated with enamel demineralisation, as confirmed by previous studies. Teeth fluoresce as a result of the enamel-dentine connection (EDJ), which contains fluorophores. A decreased intensity of fluorescence when decalcification occurs is due to the increased porosity of the enamel, because the light falling on the EDJ is scattered earlier and thus causes less excitation of the fluorophore molecules. Furthermore, the resulting radiation is once again scattered away, which in turn reduces the fluorescence [29]. An advantage of this technique is that images can be saved, thereby allowing comparisons to be made at subsequent follow-up visits and that the progress of dental caries can be objectively monitored/evaluated.

Specialised on-board software allows the surface of the examined tooth to be analysed and a 5% fluorescence reduction is qualified as evidence of demineralisation. By setting a 5% threshold, the computer recalculates the total healthy and demineralised area (as pixels) into deltaQ values and calculates the %deltaF fluores-

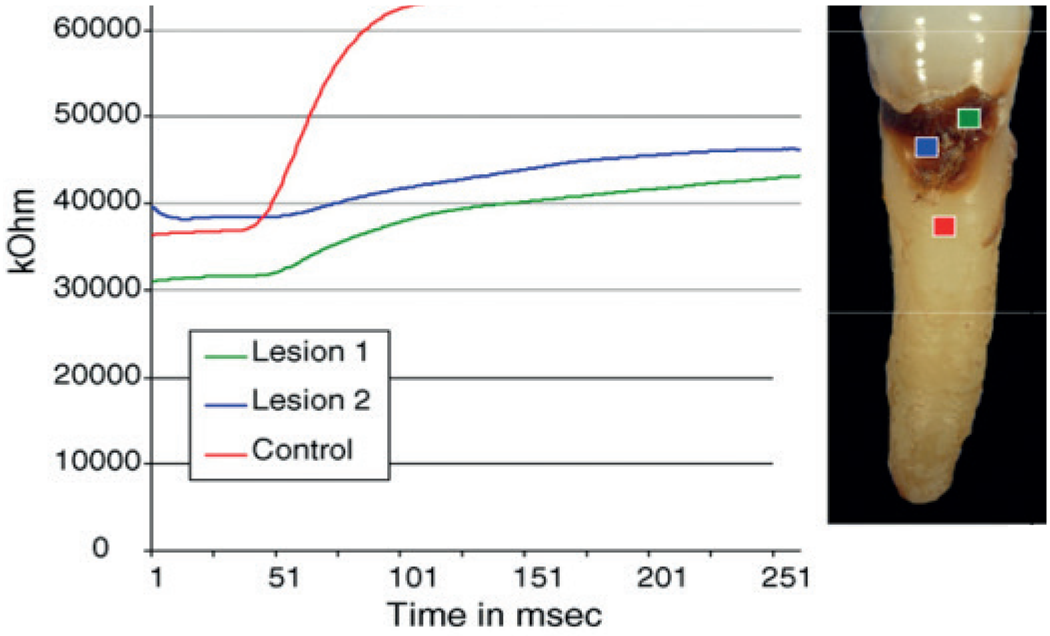


Fig. 2. An example of the ECM (electronic dental caries monitor) when used for diagnosing dental caries [27].

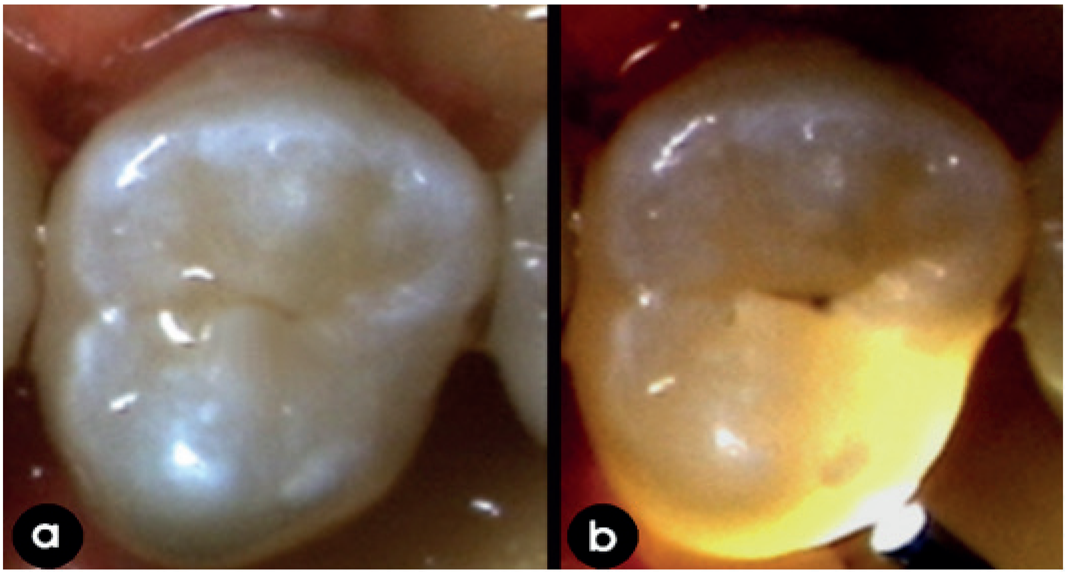


Fig. 3. An example of FOTI used for diagnosing caries: (a) a tooth image without signs of caries and (b), the same tooth illuminated by white light demonstrating a visible dental caries focus seen as a shadow [27].

cence loss. These two variables can be easily and objectively compared and serve as a good diagnostic tool (Fig. 4 a-b) [30].

LASER FLUORESCENCE

The DD-Diagnodent is an instrument that uses laser emitting light at a wavelength of 655nm lying within thered visible light range. It does not allow any image analysis, but provides numerical values that describe an examined tooth surface. Florescence in this case is generated by porphyrins which are metabolites of cariogenic bacteria (Fig. 5). Despite some promising research outcomes, there is a tendency for false-positive results to be made, (due to the presence of plaque and calculus) [31], which would thus raise questions as to the validity of using this diagnostic method in everyday practice [32].

The DIAGNOcam (KaVo) technology is based on irradiating teeth through gum tissue, bone or tooth roots using infrared radiation, (at a wavelength of 780 nm), which is scattered by dental caries tooth tissue.

Its efficacy is not dependent on how much teeth are cleaned from plaque or tartar and it is therefore more reliable than DD [25]. This test is also non-invasive and is body neutral as there is no emission of any ionising radiation so making it suitable for pregnant women. The method permits diagnosis of dental caries foci and it can detect secondary caries on all tooth surfaces, particularly on the occlusal and proximal surfaces of teeth. Additionally, it is more accurate than X-raying interdental surfaces [16].

OTHER OPTICAL METHODS

There are also several other methods for diagnosing dental caries that are still being researched and experimentally developed. These include, inter alia, optical coherent tomography-optical tomography, (OCT) using partially coherent light emitted by, for example, a superluminescent diode and also near infrared imaging spectroscopy (NIRS); ie. imaging with a laser emitting near infrared light. They enable a micrometer level of resolution to be achieved and penetrate into the tis sues, scattering the light. The spectrum of scattered light allows an analysis that gives hope as a potentially viable method of detecting early dental caries lesions [34].

ULTRASOUND

Ultrasonography is based on sound waves penetrating through gases, liquids and solids and the scattering and reflections at the boundaries lying between them. Tissue images are created by collecting and analysing the reflected sound waves. So as the sound waves can reach the tooth surface, they must pass through a 'coupling' medium which in dentistry is water or glycerin. A small number of studies have demonstrated the effectiveness of this method, for example when an ultrasonic dental caries detector (UCD) is used [35, 36], This holds promise, but does not yet confirm the effectiveness of the US method for diagnosing of dental caries lesions.

OTHER METHODS

Other diagnostic methods, such as Terahertz Pulse Imaging (TPI) or Time-Correlated Single-Photon Counting Fluorescence Lifetime Imaging (TCSPC-FLiM) are at present under preliminary development and are therefore not alternatives yet to the methods described above. Amongst the aforementioned methods described, optical techniques are the most promising. Tissue fluorescence analysis has already seen practical use in the form of the Diagnodent device by KAVO. As previously stated, studies have confirmed its effectiveness as a diagnostic tool, but however also suggest a tendency to give false positives.

SPECTROSCOPIC STUDIES OF TEETH

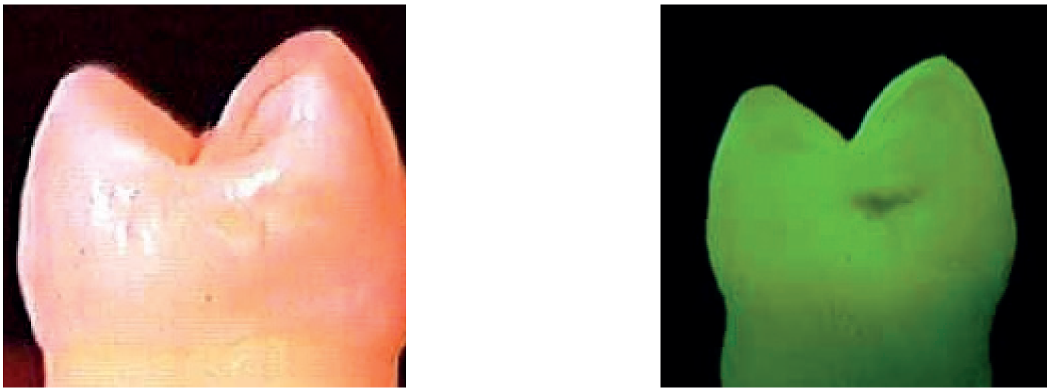
The technique of Raman spectroscopy is a latest attempt to find another technological application in dentistry in order to increase the effectiveness for making early detection and diagnoses of dental caries possible and to try to eliminate the errors/drawbacks inherent in previous methods. Raman spectroscopy is a type of scattering spectroscopy, based on a theory developed in 1925 by Kramers and Heisenberg; 'quantum-mechanical scattering theory'. The Indian physicist Chandresekhar Venkata Raman then lent support to experimentally confirm this theory in 1928 but also in the process, discovered a new phenomenon related to the scattering of light. Thus, a new type of spectroscopy was created for which he received the Nobel Prize in Physics in 1930 [37]. Raman microspectroscopy is a technique based on the Raman effect of measuring scattered radiation (Raman scattering, ie. the inelastic scattering of photons). The spectrum of scattered light always demonstrates a strong line corresponding to the wavelength of the incident radiation and there are also weak satellite bands present that are symmetrically located on both sides. The strong line corresponds to Rayleigh scattering, whilst the weak bands are due to Raman scattering. The weak bands shifted away from the excitation line towards longer wavelengths are termed the 'Stokes bands', whilst those shifted towards shorter wavelengths, 'anti-Stokes bands'. For a given substance, the position of the bands is constant and independent of the frequency of the incident beam, thereby constituting a unique 'chemical fingerprint' of a sample. The intensity of the Raman bands is however much lower, as much as 103-104 times, than that of the Rayleighband. Furthermore, the intensity of the anti-Stokes Raman band is much lower than the Stokes band, and so Raman spectrometry, in most practice, measures Stokes bands more often [38]. Raman scattering occurs during the interaction of electromagnetic radiation with a molecule. Electromagnetic radiation has corpuscular and wave properties (particle-wave duality) and therefore the origin of Raman scattering can be described in two ways. The first is based on the classical theory of electromagnetic radiation (wave description), and the second is based on quantum theory (corpuscular description).

The classical theory of Raman scattering describes interactions between the electron cloud of a molecule and electromagnetic radiation that cause inelastic light scattering. The Raman effect is observed when there are changes in the polarizability of a molecule, which is defined as the ability of an electron cloud to move relative to atomic nuclei in an electric field. The radiation-induced vibrating dipole moment is proportional to the polarizability of the molecule. Whilst classical wave theory describes the basic mechanism of inelastic scattering, it does not explain the changes in the position and intensity of the scattering bands of the Raman spectrum. Quantum mechanics can explain these changes based on graphs of energy levels. Molecules at the basic vibrational mode (zero level v=0) absorb energy, thus going into an excited state. When they relax, the radiation scatters and the molecule either returns to its initial state, by Rayleigh scattering, or to one of the higher energy vibrational levels by Stokes Raman scattering. Changes in the intensity of the bands occur due to the quantitative differences of the molecules in the excited and lowered energy states. At thermal equilibrium, the molecule population behaves according to the Boltzman dispersion state and is mostly at the fundamental energy level. Statistically, there are more molecules occupying the lowest energy levels and are thus capable of transitioning to the virtual (apparent/excited) state from the ground state, compared to those from the excited state. Thus, the Stokes band is more intense than the anti-Stokes band and it is the latter that is most often used in analysing Raman scattering spectra [39]. Many diagnostic methods are used to analyse biological material, some of which include Raman spectroscopy. Such methods enable studies with a spatial resolution of 0.6-1 µm and obtaining such high spatial capacity allows microstructural levels to be analysed for which infrared absorption spectroscopy is unsuited; this being another spectroscopy based on vibrational levels. In contrast to the latter, Raman spectroscopy has negligible sensitivity to the hydration state of the examined tissues. At present, the latest Raman method systems enable most biological tissues to be studied using a laser operating in the visible or near infrared range of the analytical setup. Using the latter, this allows fluorescence-related effects to be eliminated in the obtained Raman spectra that interfere in the analysis of spectral bands [40]. Both Infrared spectroscopy and Raman spectroscopy allow changes in chemical structure to be captured as well as those arising from mechanical damage or genetic defects. The high resolution of the instrumentation, (of the order of 1 µm), can facilitate the collecting of information on chemical processes such as remineralization.

Such spectra are recorded images of radiation broken down into individual frequencies, wavelengths or energies and are most often graphically presented by the intensity of the Raman band as a function of frequency. Although the recorded spectra should be composed of many narrow lines corresponding to dispersed energy quanta, in reality they are not in the form of lines, but in bands of different intensity and width. These band forms are due to the imperfections of the instruments recording them, as well as to the different widths of the energy states (Fig. 6) [41].

The main parameters characterising a given band when used for studying the structures of particles, molecules or crystals are:

- frequency, corresponding to the maximum height of the tested band contour;
- intensity, being the height of the band contour as measured from the background level;
- half width, being the width of the band contour, determined at the middle of its height;
- integral intensity, being the area bounded by the band contour of the band and the background.


a

b

Fig. 4. QLF. (source: Inspector Research Systems BV) - a) tooth in daylight, b) tooth highlighted.

Fig. 5. The Diagnodent system (source: DD KaVo Dental GmbH).

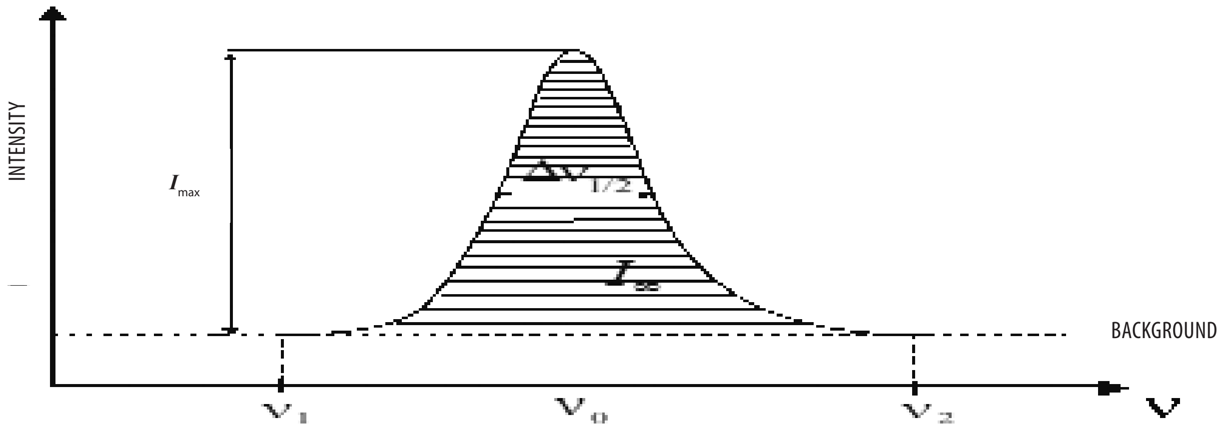


Fig. 6. A spectral band with descriptive parameters [41].

Fig. 7. Micro Raman system in Via (source: Renishaw).

THE INSTRUMENTAL SYSTEM FOR STUDYING RAMAN LIGHT SCATTERING

The classical study of Raman light scattering is performed by a spectroscope. In the case considered, a micro-Raman system is used equipped with the following elements:

- Excitation sources in the form of a laser.
- An optical system tasked with illuminating the sample, supplying excitation light and collecting the scattered radiation.
- A diffraction grating
- A diffuse radiation detector in the form of a CCD camera (charge coupled device).
- A signal recording and system control system (computer + specialised software) (Fig. 7).

Measurements with high spatial resolution at the micrometer level are made possible thanks to the confocal microscope on-board the instrument coupled with a measuring system, that allows the excitation light (laser) beam to be focused onto the test material, as well as collecting scattered light from a very small volume; in the order of several cubic micrometers.

SPECTROSCOPY IN THE ANALYSIS OF ENAMEL

Thanks to Raman studies and infrared absorption, it is possible to characterise molecular tissue components, such as primary and secondary amides, calcium ions and carbonates, where the results serve as a framework for evaluating pathological changes within the tooth and its surface. Analysing selected Raman bands is particularly useful for distinguishing between healthy and pathologically altered teeth. Even subtle changes in the molecular structure of dental caries material (tissue) cause detectable changes in vibration states, as reflected in the spectral appearance of new bands, a changed location or changes in the intensity of those bands responsible for specific vibration states.

The recorded spectra show changes in the intensity of the bands in places associated with dental caries where there is increased background (increased intensity of Rayleigh scattering), a lack of structural order in the enamel damaged by caries, changed anisotropy of polarizability at the site of caries and increased carbonate to phosphate bands ratios at the lesion sites. Using many of these indicators, (like carbonate to phosphate band ratio intensities), confers on them the potential to be spectroscopic markers. Modern diagnostic methods must be harmless, easy to use, repeatable, capable of being archived and compared and inexpensive. Raman spectroscopy (RS) aspires to such criteria.

Although the first studies using Raman spectroscopy for dental examinations had already been done the 1960s, this technique was not extensively described in the scientific literature until almost the end of the 20th century; mainly due to the complexity and unwieldiness of spectrometers and fluorescence interference [42-53]. It was not until the NIR-FTR technique (near-infrared Fourier transform) had been developed, which eliminated the dominating background fluorescence, that interest in using RS revived for diagnosing dental caries at the end of the 20th century.

Raman spectroscopy enables vibrational spectra to be obtained of mineral structures by analysing the light scattered by a monochromatic laser. Molecular vibration bands can thereby be obtained of biological materials such as tooth enamel. When the positions of Raman bands are known that are characteristic for individual chemical groups, Raman spectra can be used for chemical identification and quantitative analysis [46]. It is therefore expected that Raman spectroscopy will not only be a tool to confirm the presence of caries but, above all, it will permit qualitative assessment of enamel and allow any early interventions to be made together with evaluating how effective preventive measures had been [55-57].

The present scientific literature describes the usefulness of Raman spectroscopy for detecting dental caries on the interproximal surfaces of molars and premolars that are difficult to clean [58, 59]. This paper presents the concept of using the above technique to assess the quality of enamel in the area of orthodontic brackets. However, the presence of orthodontic brackets and, above all, any additional elements such as elastic chains, springs, hooks, additional intra- and extra-aural appliances makes it difficult to maintain oral hygiene. This is a new look at the diagnostic possibilities of PSR, and gives hope for avoiding any complications during orthodontic treatment.

CONCLUSIONS

The driver behind the progress that has been achieved in medicine is the development of modern technologies.

New diagnostic capabilities has allowed a better understanding of disease mechanisms, to detect health threats earlier than before and treat them more effectively. The situation is similar in dentistry. Dental caries is nowadays still an unresolved problem, even though dental caries was described in ancient times, (mentioned in the writings of both Aristotle and Hippocrates) [60], and cavities had been found in homo-sapiens teeth since the time of Australopithecus. It is now so widespread that it deserves to be labelled a disease of affluence (lifestyle/civilization). According to the WHO, the DMFT index for 12-year-olds is 1.2-4.4 in developed countries whilst this is 9-13.9 for 35-44-year-olds [61].

In recent decades, the growing role of focal diseases in cardiology has become increasingly noticed.

Currently, mainstream orthodontic treatment for both children, adolescents and adults can lead to decalcification as a result of inadequate tooth cleaning, whichis initially manifested as white spot lesions (WSL). Numerous studies have pointed out the threat from WSL: Lovrov et al. at 25% [59], Pancherz, Mühler at 29% [62] and Jost-Brinkmann at 17.5% [63]), whilst according to some the risk is even at 60.9% [64] or 72.9% [65]. Despite this wide range of results, it can be clearly stated that the risk of WSL is high and poses a serious health and aesthetic problem. The increased risk of dental caries requires the use of specialised prophylactic, diagnostic and therapeutic measures to ensure treatment safety, such as using preparations containing fluorine compounds, chlorhexidine, cetylpyridinium chloride or selenium.

Thanks to the high sensitivity of the new methods, it can be possible to intervene at early stages of demineralization and stop or even reverse the dental caries process. Preliminary results suggest that, in the future, it will become necessary to supplement diagnostic tools or even change procedural standards to thereby increase the effectiveness of detecting pathological changes. This would so allow principles of prophylactic treatment to be developed in patient care and possibly force through legislative changes [66].

Despite the promising outcomes of studies using the aforementioned diagnostic tools, objectively determining which one might prove to be the new diagnostic 'gold standard' remains elusive. Making any objective comparison on the effectiveness of the above methods is not possible at present, because most such studies were conducted in-vitro and any evaluation of results have, as yet, still not been standardised, thereby making a meta-analysis impossible to perform [27].

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CONFLICT OF INTEREST

The Authors declare no conflict of interest.

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