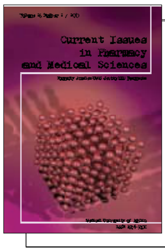

2013 © Curr. Issues Pharm. Med. Sci. Vol. 26, No. 3, Pages 344–346

Current Issues in Pharmacy and Medical Sciences

Formerly ANNALES UNIVERSITATIS MARIAE CURIE-SKLODOWSKA, SECTIO DDD, PHARMACIA
on-line: www.umlub.pl/pharmacy

AC-impedance spectroscopy and caries detection

RENATA CHAŁAS*, DOMINIKA PIĄTEK, ILONA WÓJCIK-CHĘCIŃSKA, JOANNA ZUBRZYCKA-WRÓBEL, TERESA BACHANEK

Chair and Department of Conservative Dentistry and Endodontics, Medical University of Lublin, Poland

ABSTRACT

Many studies have shown that the accurate diagnosis before cavitation occurs could reduce need for drilling and filling. Among many techniques, measurement of electrical resistance (impedance) of dental tissues looks promising. The role of AC-impedance spectroscopy in caries detection is discussed and a relatively new device CarieScan PRO™ based on this phenomena is described. Changes in tooth mineral density detected by this tool as numerical and color codes are distinguished.

Keywords: caries detection, AC-impedance spectroscopy, CarieScan PRO™

Detection and monitoring of the complex process of demineralization and remineralisation by the dental caries is a dentist's challenge. Even caries starting as a subsurface demineralization of enamel, may progress to the underlying dentine and, eventually, to cavitation of the surface [14]. Accurate diagnosis before cavitation occurs would permit targeted preventive treatment, thereby significantly improving dental health and reducing the need for expensive drilling and filling [10]. Conventional diagnostic methods involving visual inspection and the use of sharp dental explorer tools depend on subjective clinical criteria such as color, texture, softness and resistance to removal. These methods are good for the detection of larger or cavitated lesions. However, they are not suitable for the detection of early dental caries because of poor sensitivity and specificity. Routine dental radiographs also lack the ability to detect early carious lesions on enamel surface. Approximately 30-40% mineral loss is necessary before radiographs can detect the carious lesion. It can take a few months or longer for this extent of demineralization. Therefore, better diagnostic tools are needed to detect early carious lesions and help prevent dental cavities. Over the last years, various techniques have been explored to address the need for better detection tools to diagnose early dental caries. These techniques include magnifying loups, direct digital radiography, digital imaging fiber-optic transillumination, electrical conductance, quantitative light-induced fluorescence, laser-induced fluorescence, autofluorescence, multiphoton imaging, infrared thermography, terahertz imaging, optical coherence tomography, ultrasound, Raman spectroscopy and others [1,2,11,14,15,16]. In spite of numerous studies evaluating different tools with respect to caries detection, caries diagnosis continues to be a challenging task for the dental practitioner. Especially occlusal caries is a clinically difficult one due to the complex morphology of the fissure and fossa system and frequent presence of staining. Additionally, the extensive use of fluoride and remineralizing agents seems to delay cavity formation. Therefore, the accurate detection in the precavitation stages is very important for undertaking proper preventive and restorative procedures and avoiding unnecessary treatment.

Among alternative techniques, measurement of electrical resistance has shown the most promising. Caries diagnosis by electrical measurement was introduced into dentistry many years ago. Even in 1878, Magitot's first suggestion was to use electric current for caries detection [15]. The method is based on the phenomenon that dental enamel, consisting largely of hydroxyapatite, has a high electrical resistivity. This resistivity is reduced after demineralization, because this increases the size of the pores, which are filled with more conductive fluids. The porosities in the enamel tooth are filled with fluid from the oral environment that includes ions, resulting in decreased resistance and increases in conductance. Once the enamel has been lost locally and a cavity exists, the resistance of

Corresponding author
* Chair and Department of Conservative Dentistry and Endodontics, Medical University of Lublin, 7 Karmelicka Str., 20-081 Lublin, Poland
e-mail: renata.chalas@gmail.com

DOI: 10.12923/j.2084-980X/26.3/a.23

a tooth is determined by the dentine, which contains many dentinal tubules filled with fluid, and thereby has a relatively low resistivity. Electrical conductance measurement uses a single, fixed-frequency alternating current to measure resistance of the tooth structure. Electrical impedance is a measure of resistance to current flow through a given material. In AC – (alternating current) – impedance spectroscopy, the impedance of a tested material is represented by a parallel combination of resistor capacitor equivalent circuit containing an inductor. New electrical caries measurement device uses multiple frequencies (electrical impedance spectroscopy), as different substrates respond differently to the resistance test at different frequencies [3,4,5,6,7,8,13,17].

CarieScan PRO™ (Dundee, Scotland) is one of the recent examples of these technologies (Fig. 1). A proactive device using technology known as AC Impedance Spectroscopy Technique (ACIST) identifies decay much earlier than other methods, allowing for timely preventive and restorative treatment while being minimally invasive. This is innovative handheld dental device that enables the early detection and monitoring of hidden tooth decay. Developed at the universities of Dundee and St Andrews, the device is a safer and more accurate alternative to dental X-rays, with no radiation risks. Passing a tiny electrical current through the site, a measurement of the tooth's density is taken. This technique used in CarieScan PRO™ allows determining the mineral density of the dental substrate, meaning repeated measurements create an accurate and reliable picture of the remineralisation/demineralization of the tooth. It looks nice for the patient by design; it causes no pain, sensation, or ionising radiation – with each measurement taken in a very short time per site. The sensor tip (a small component) comprised of wire bristles allowing for multiple site readings per tooth, is simply touched on each suspected site giving the numerical reading supplemented by a colour. The CarieScan PRO™ remains accurate with a replacement sensor being used for each patient – an in-built system test for automatic calibration and accuracy – as well as eliminating potential cross infection issues thanks to using of disposable sleeves that wraps the unit, leaving the single-use sensor tip exposed. The full set contains sensors, sleeves, accessories, including lip hook cables, cable test adaptors, power supply units, and collars. To detect caries it requires the placement of a lip clip to complete circuit. When a lip hook is placed, the tooth should be dried by blowing dry air over the surface for five seconds to remove visible moisture. Then the CarieScan PRO™ sensing brush is moved over the pits and fissures of the tooth scanning for dental caries. The sensor tip easily bends after each application and this affects both the angulation and the pressure on tooth surface. From a clinical standpoint, care should be given not to push the sensor on tooth forcefully for the consistency of the readings [1,2,12,15].

Fig. 1. CarieScan PRO™

Application of a small alternating electrical signal, low voltage current (undetectable by the patient) through the tooth is monitored by the response of the sensor. The result as a numerical value between 0 and 100 is displayed on the LCD screen along instrument and the color-coded LED display that enables dental professionals to evaluate the depth of the carious lesion. By changing frequency of the applied signal, a spectrum is captured which provides valuable insights into the physical and chemical properties of the tooth. Additionally the classification reading of the 0-100 scale has also been further simplified into high, medium, and low probability categories, with specific advice for each identified category to help the dentist with caries treatment and intervention support. Interpretation of the obtained results allows possible treatment options recommended by the manufacturer. Green is associated with a reading of 0, indicating healthy tissues. With 1-50 and green/yellow bar code on the screen, there is a low probability of caries. Mild preventive care with usual caries prophylaxis, like good oral hygiene with use of fluoride toothpaste is advised. Yellow/orange color and number between 51 and 90 are interpreted as a medium probability of caries. Caries prophylactic methods like fluoride varnish, fissure sealant, and good oral hygiene, diet advice and personalized review with patient monitoring are recommended. Detected values 91-99 and intensive orange/red color on the display indicate a high probability of caries. Intensive prophylactic plan or possibly operative interventions are necessary to undertake. Information about the carious process affecting dentine is given by red color and value of 100. In this case with high probability of caries minimally invasive operative dentistry is necessary but the restoration should be as small as possible. With 92.5-94.8% accuracy in detecting caries and healthy tooth structure, the CarieScan PRO™ seems to be a reliable tool. Another option is using the CarieScan PRO™ RemoteView software, what allows to send data to the computer via Bluetooth, so these readings can be stored and compared over time [1,2,12].

The non-destructive method such as ACIST, has recently been applied in research conditions to early caries detection and to identify micro-leakage between tooth structure and filling materials. However, in vitro impedance measurements are affected by a number of external factors, like the size of electrode, repositioning at the electrode contact, surface area of the contact electrode, changes of temperature, changing concentration of fluid in storage solution and tooth structure like the thickness of enamel and dentine, their irregularities, distribution of minerals (ionic concentration), posteruptive mineralization, maturation time of the tooth in the oral environment, age of tooth, dentine age, presence of stain. In vivo studies, ac-impedance spectroscopy as a non-invasive method has been used safely to detect cracks and caries in enamel and dentine. This technique was also useful to investigate the effect of smear layer and dentine conditioners on dentine impedance, to identify micro-leakage between tooth and filling materials [1,3,4,6,7,8,9,14]. ACIST has the future potential for detecting changes in enamel, dentine, dental restorations, and even bone integrity of implants. Nevertheless, by using any new diagnostic technologies, it should be critical that they be used to dental health of our patients not to find more work in a dental office to perform.

REFERENCES

1. Ari T., Ari N.: The performance of ICDAS-II using low-powered magnification with light-emitting diode headlight and alternating current impedance spectroscopy device for detection of occlusal caries on primary molars. *ISRN Dentistry*, 2013.
2. Christensen G.J.: New caries detection systems: reliable and accurate. *Clinicians Report*, 4, 2, 2011.
3. Eldarrat A.H. et al.: Age-related changes in ac-impedance spectroscopy studies of normal human dentine. *J. Mater. Sci: Mater. Med.*, 18, 1203, 2007.
4. Eldarrat A.H., High A.S., Kale G.M.: Age-related changes in ac-impedance spectroscopy studies of normal human dentine: further investigations. *J. Mater. Sci: Mater. Med.*, 21, 45, 2010.
5. Huysmans M.C.D.N.J.M. et al.: Surface-specific electrical occlusal caries diagnosis: reproducibility, correlation with histological lesion depth, and tooth type dependence. *Caries Res.*, 32, 330, 1998.
6. Huysmans M.C.D.N.J.M. et al.: Temperature dependence of the electrical resistance of sound and carious teeth. *J. Dent. Res.*, 79, 1464, 2000.
7. Huysmans M.C.D.N.J.M. et al.: Impedance spectroscopy of teeth with and without approximal caries lesions – an in vitro study. *J. Dent. Res.*, 75, 1871, 1996.
8. Kaczmarek U. et al.: Charakterystyka właściwości przewodnictwa elektrycznego powierzchni zębowych metodą spektroskopii impedancyjnej – badania wstępne. *Czas. Stomat.*, 54, 559, 2001.
9. Longbottom C., Huysmans M.C.D.N.J.M.: Electrical measurements for use in caries clinical trials. *J. Dent. Res.*, 83, C76, 2004.
10. Longbottom C. et al.: Detection of dental decaay and its extent using a.c. impedance spectroscopy. *Nature Medicine*, 2, 235, 1996.
11. Meller C. et al.: Predicting caries by measuring its activity using quantitative light-induced fluorescence in vivo: a 2-year caries increment analysis. *Caries Res.*, 46, 361, 2012.
12. Miyasaki M.A.: Building your practice with caries management and CarieScan PRO. *Greater New York Dental Meeting*, 27, 2011.
13. Penkowski M. et al. Zastosowanie spektroskopii dielektrycznej do badania szkliwa ludzkich zębów. *Ann. Acad. Med. Gedan.*, 35, 23, 2005.
14. Pitts N. (editor): Detection, assessment, diagnosis and monitoring of caries. *Monographs in Oral Sciences*, vol. 21, Karger, Basel, 2009.
15. Rochlen G.K., Wolff M.S.: Technological advances in caries diagnosis. *Dent. Clin. N. Am.*, 55, 441, 2011.
16. Tassery H. et al.: Use of new intervention dentistry technologies in caries management. *Austr. Dent. J.*, 58, 40, 2013.
17. Woźniak J. et al.: The reproducibility of tooth impedance spectroscopy measurements: an in vitro study. *Dent. Med. Probl.*, 44, 11, 2007.