Usefulness of AC-impedance spectroscopy technique in occlusal caries determination – own investigations

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ABSTRACT

Exact caries detection and monitoring over time are important in modern clinical caries management. Especially the detection before cavitation occurs and the control of initial lesions are of significance because an accurate diagnosis can reduce the need for drilling and filling. Among many techniques, impedance spectroscopy technique is one of the proposed. The aim of the study was to determine dental caries clinically and characterize its bio-impedance to gain detailed information about the progression of the process. Human extracted permanent premolars and molars were used in this *in-vitro* experiment. The teeth were unrestored and undamaged, except of caries. Their occlusal surfaces were examined by dentists according to Universal Visual Scoring System and assessed with CarieScan PRO™. The statistical analysis of obtained results revealed that clinical examination and AC-impedance spectroscopy measurements showed differences in impedance depending on changes and stages in caries progress. Preliminary results from this research indicate that the device using AC-impedance spectroscopy may be a useful additional aid for caries diagnosis together with clinical examination.

Keywords: *in-vitro* tests, caries detection, AC-impedance spectroscopy, CarieScan PRO

INTRODUCTION

Detection of early stage caries when it can be reversed, i.e. before the creation of the lesion in the hard tissues of the tooth as well as monitoring its progress, is now an important goal of clinical dentistry, because accurate diagnosis may reduce the need for invasive treatment [12]. Difficulties in proper diagnosis and monitoring the progress of caries of occlusal surface of posterior teeth result from the anatomical structure and the fact that caries most often develops on the side walls of the grooves. Among many methods of caries detection most commonly used by dentists are visual, physical and radiological examinations [10,12]. According to the literature, only 12% of the initial caries of grooves can be detected by visual examination [13]. In addition, visual and physical (tactile) methods for detecting caries (using probe) are considered highly subjective [1,14]. Radiological examination is a valuable diagnostic tool in the detection of caries, but the useful-ness of this test in the diagnosis of occlusal surface of caries is limited because this examination can detect only such a process, which has already covered the dentin [12].

Difficulties in the detection of initial caries of grooves made the researchers look for new, objective and increasingly sophisticated methods of diagnosing carious lesions. In this process the knowledge of detailed morphology of the hard tissues of the tooth and the changes that occur in these structures in the carious process, proved to be extremely helpful [9]. Currently available diagnostic methods aiding the detection of dental caries of tissues on the occlusal surface employ the phenomenon of light absorption and dispersion, conductivity and electrical resistance, reflection of sound waves and photoluminescence [2,8].

One of the new devices launched to the market in recent years is CarieScan PRO™, the operation of which is based on the utilization of impedance spectroscopy for the detection of caries. The starting point for the electronic measurement of the tooth hard tissues is the knowledge of physical properties of the enamel. Healthy tissue exhibits high electrical resistivity due to enamel crystals tightly laid out. Under the influence of demineralization of dental enamel in caries process, the increase of the porosity of the tissue occurs, and reduction of the dimensions of the

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prisms and extending of intergranular voids filled with water, which results in a decrease in the electrical resistance of the enamel [4,7,11]. According to the manufacturer, the device is characterized by almost 95% sensitivity and about 93% specificity.

The aim of the study was to compare caries detection under *in vitro* conditions using conventional methods (visual) and modern, advanced electronic method (CarieScan PRO™) based on AC-impedance spectroscopy technique.

MATERIAL AND METHODS

An *in vitro* examination was performed on 48 human premolars and molars without fillings, which were not broken during extraction. Occlusal surfaces of teeth with caries were assessed by dentists according to Universal Visual Scoring System (UniVISS) for occlusal and smooth surfaces lesions, which can be used for primary and permanent teeth, as well under clinical, epidemiological, public health and laboratory conditions [10], and by means of a CarieScan PRO™ using the phenomenon of impedance spectroscopy. Measurements were made according to the procedure of repeatability of examinations in a specially designed holder (Fig. 1, 2). The measuring holder was made of a material having a high dielectric constant. It consisted of two components: the tooth-mounting bracket and the base with copper electrode on which a sponge impregnated with a conductive gel was placed. The sponge with gel formed a model of gingiva, lips, and periapical tissues. The thickness of the sponge was chosen empirically so that the resistance measured
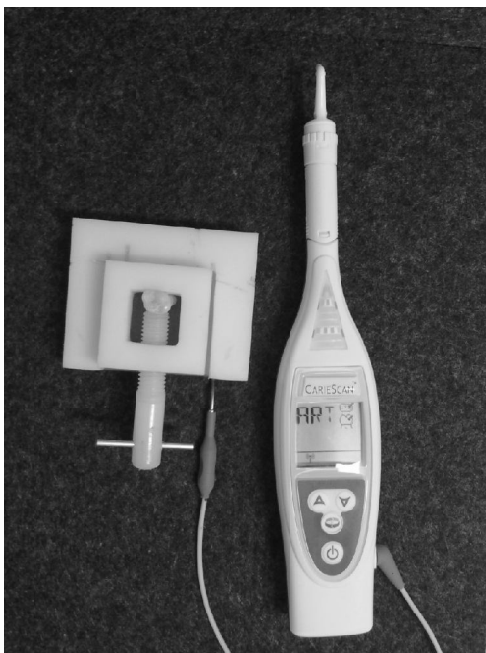
between the tip of the copper electrode and the surface of the sponge was 450–550 kΩ. This value was measured empirically using the DMM accuracy class of 1.5 ± 1 digit in the oral cavities of patients with the use of two electrodes of "Liphook" placed in opposite corners of the mouth. The design of the holder ensured the repeatability of measurements. By using the appropriate procedure of fixing the tooth, dipping the roots in a sponge to 0.5 mm ± 0.2 mm was achieved.
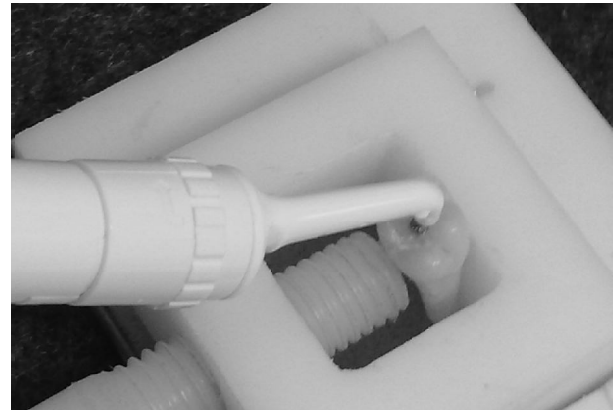

Fig. 2. Measurement of tooth impedance in *in-vitro* conditions

The results obtained were coded and recorded in the minutes of research. Coding was based on assigning the values of obtained measurements: visual and impedance to one of four groups (classes) due to the recommended therapeutic effects. The results were statistically analyzed assuming 5% significance level.

RESULTS AND DISCUSSION

The results of the assessment of teeth occlusal surface, and the likelihood of carious lesions, assumed all the values of the entire measuring range (1–100). Statistical analysis showed that the clinical examination and measurements with CarieScan PRO™ showed differences in impedance depending on the severity of lesions and stages of caries development. The results of visual examination obtained by of various researchers have shown a statistically significant correlation. A statistically significant correlation was also obtained in comparison to the results of visual examination of individual researchers (Examiner 1, 2 and 3) and the results of impedance spectroscopy reading (positive correlation) – Table 1.

Table 1. Results from CarieScan Pro reading with accordance of examiners

Parameters	R-Spearman	p level
Examiner 1 vs CarieScan Pro	0.437	0.0030
Examiner 2 vs CarieScan Pro	0.517	0.0003
Examiner 3 vs CarieScan Pro	0.546	0.0001

p<0.05 statistical significance threshold

Fig. 1. CarieScan PRO and designed tooth holder

Unfortunately there are not many published materials for the performance of AC-impedance spectroscopy technique because CarieScan PRO is a quite new and modern device used for caries assessment of hard tissues of the tooth [3,5-7,9,15,16]. Thanks to different hydration of dentin and enamel, resistance of these tissues is differentiating. High electrical current characterizes healthy enamel, mainly composed from hydroxyapatites. When the demineralization occurs, the level of liquid is increasing in pores of enamel, so conduction is growing and resistance is decreasing. After enamel breakdown when the cavity is created, the tooth resistance is relatively low and conditioned by the properties of dentin [7]. Actually, reports comparing impedance spectroscopy assessment results with visual inspection of teeth are limited. Some of reported *in-vivo* and *in-vitro* studies are based on examination of deciduous and permanent teeth. Ari and Ari [3] used CarieScan PRO for caries detection of deciduous teeth together with ICDAS clinical criteria. They found relatively low intra- and interexaminer repeatability. They did not find statistic correlation between CarieScan PRO indications and clinical examination. Woźniak et al. had different observations. They noted high reproducibility of impedance spectroscopy measurements in *in-vitro* conditions of permanent teeth [16]. Hall et al. found similar results about intra- and interexaminer repeatability in *in-vivo* study [6]. Teo et al. performed examinations of both deciduous and permanent teeth. They noticed that CarieScan PRO is unsuitable for caries detection in deciduous dentition because of very small validity in *in-vivo* examination and lack of correlation between *in-vitro* and *in-vivo* results [15]. In our preliminary study, the agreement between visual examination of every investigator was observed. In addition, the positive correlation in clinical inspection and CarieScan PRO measurements was noted. And this is in agreement with Cohen's research [5]. His results of the study on 125 molar human teeth indicate relationship between CarieScan PRO scores and development of carious process.

CONCLUSIONS

Preliminary results from this experiment within the limitations of the *in-vitro* study indicate that CarieScan PRO can be helpful in caries detection of occlusal surface but only histopathological examination could confirm the real depth of the lesion. Clinicians should keep in mind that this device is only an additional tool for early caries diagnosis and it should always be used in line with visual inspection. Continuing clinical research is advised.

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