

REVIEWS

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KAMILA KOŁODZIEJCZYK^{1, B, C, D}, BEATA KAWALA^{2, E, F}, MACIEJ KAWALA^{3, A},
JOANNA BEDNARSKA^{1, B}, JOANNA ANTOSZEWSKA-SMITH^{2, E, F}

EMG vs Precision and Accuracy in Dentistry

EMG a precyzja i dokładność w stomatologii

¹ Students' Scientific Association at Department of Maxillofacial Orthopaedics and Orthodontics, Wrocław Medical University, Wrocław, Poland

² Department of Maxillofacial Orthopaedics and Orthodontics, Wrocław Medical University, Wrocław, Poland

³ Department of Dental Prosthetics, Wrocław Medical University, Wrocław, Poland

A – research concept and design; B – collection and/or assembly of data; C – data analysis and interpretation;
D – writing the article; E – critical revision of the article; F – final approval of article

Abstract

Global Electromyography is a technique used for evaluating the neuromuscular activity while making active movements, maintained muscle position (neutral, contraction or relaxation) as well as sports activity.

The aim of this work is to show the possibilities, the rules of the EMG exam, its advantages and disadvantages in measuring the precision of movements, which is vital for dentists. In this work there were discussed the structure and activity of hand muscles participating in holding dental tools as well as the techniques and standards of performing the EMG exam. In the study there is also raised the subject of the reliability of results and the affecting factors, i. e. the type, shape and electrode placement, the conditions during the signal registration, the level of muscle activation, the time of load maintainance as well as inner factors: thickness of the subcutaneous tissue, geometrical and anatomical properties of muscles and their physiology.

It follows from the work that a detailed analysis of the EMG signal allows to determine the order in which muscles were activated, the symmetry and fatigue of the muscle. Nevertheless, only unification of the manner and conditions of conducting the examination would make it possible to extend the list of indications with the measurement of the precision of movements in candidates for dental studies, students and dentists (**Dent. Med. Probl. 2015, 52, 4, 466–471**).

Key words: electromyography, muscles, motor skills, muscle tension, global electromyography.

Słowa kluczowe: elektromiografia, zdolności motoryczne, mięśnie, napięcie mięśniowe, elektromiografia globalna.

A good dentist, apart from the required knowledge, should be properly manually fit as this has a huge impact on quality and success of the conducted procedures [1]. It would be unsuitable to negate that written tests constitute large aid in assessment of the acquired knowledge and understanding skills; however, it is worth remembering that – unfortunately – they do not verify manual skills, so important in dental practise [2]. A dentist is expected to be a good diagnostician, to enter into contact with a patient skilfully and to act professionally and precisely, aiming at the highest priority – patient's welfare and health. So far, only mental aspects of applicants – the result of ma-

turity exam – were taken into account in the process of recruitment for dental studies in Poland. There were multiple attempts to introduce manual skills tests into the process of professional aptitude assessment. In the United States the manual skills of the recruits were assessed as early as in the 1950s [3]. To this day, no uniform way of manual dexterity assessment has been established [4]. Electromyography test, which enables the assessment of muscle electrical activity, seems promising in this regard. EMG test, owing to its advantage, i.e. easiness to conduct is commonly used in sport, rehabilitation, ergonomics and medicine. Despite the wide range of applications, electromyography

has never been used in the assessment of manual or precision skills. Electromyography could be a supplement to the process of recruitment of the future staff of dentists as it examines the tension correlating the motion precision. The result of correlation of the tension measured by an electromyograph allowing for movement precision test, would considerably help with establishing the skills of the recruited candidates and thereby with the assessment of predispositions to pursue the profession of a dentist. The aim of the paper is to present the principles of EMG evaluating technique, its advantages and disadvantages in terms of the precision of its measurements, and in particular: to direct attention to the possibility of applying the technique in high-quality assessment of manual skills of candidates for dental studies, students and dentists.

Structure and Function of the Muscles

The muscles of the hand are the main work tools of a future dentist. They took part in grips used in the practise for holding tools: two-finger, supported two-finger, three-finger, pen-grip, modified pen-grip, palm, palm-thumb, modified palm-thumb and reverse palm-thumb [5]. The most common of them is the pen-grip in which the following muscles are used: opponens pollicis, adductor pollicis, flexor pollicis longus, flexor pollicis brevis, flexor digitorum superficialis and flexor digitorum profundus [6]. Their efficiency depends on the construction, and, to be more precise, the number of motor units forming the muscle. The motor unit consists of muscle fibres innervated by one alpha motoneuron which transmits the signal from a motoneuron of the spinal cord or motoneuron in the brain stem [7]. The precision of the movement is increased along with the decline in the number of fibres in the muscular unit of an active muscle [8]. Muscles built of a small number of muscle fibres in a motor unit work the most precisely. The functioning of muscles depends not only on the number of fibres in a motor unit but also on their type. A hand consists of skeletal muscles built of white fibres which are more vulnerable to fatigue than red fibres in the walls of blood vessels and integral organs which need to work without breaks [9]. The anatomy of hand muscles causes the fact that they can maintain tension only for a short period of time [10] and, therefore, muscle strength, so important for a dentist, greater in the case of muscles of a larger diameter, i.e. with a larger number of fibres, is impaired.

The central nervous system fulfills an important role in the fluidity of movements, their accu-

racy and precision. Muscle activity occurs as a result of the information, which is transmitted by the nerve cells from the central nervous system. As a result of the flow of potential existing between the nerve cells, excitation and contraction of the sarcomere can take place [11]. Acetylcholine, which is secreted by a neuron, activates the motoneuron plate, i.e. connection of a nerve fibre with a muscle. Release of calcium ions from sarcoplasmic reticulum occurs as a result of activation. Due to the process, energy is released which allows for a contraction of actin and sliding it between the myosin fibres, and the contraction of muscles along with the movement of the hand [12]. In order to do this, the muscle must be characterised with electrical activity, i.e. resting potential which equals -70 mV and depends on the ion concentration in a cell.

As a result of increased potassium ion concentration in the extracellular space, the difference of the potential between the inside of the cell and the extracellular space is reduced, i.e. depolarisation occurs [13]. This causes the activity of a motor unit, while in the EMG picture not a single activity but the sum of potentials is registered. It follows that the higher value of the tension in the EMG recording the more motor units take part in the contraction, and higher number of motor units in the composition of the muscle means its capability to more precise movements.

EMG Exam

Techniques and Standards of Performance

The measure of precision is determined as a standard deviation of repeatability and reproducibility of movements [14]. An objective precision test should be sensitive, uncomplicated, repetitive and easy to interpret. It is difficult to analyse directly the number of muscle units that take part in the movement because of including, but not limited to, invasiveness and, therefore, it is best to make use of the fact that muscles generate tension during movement, which can be marked with the use of electromyography. There are two kinds of EMG which are differentiated by the technique of electrode fixing method: elementary and global. The more invasive technique is elementary electromyography. During the test, the electrode in the form of a needle is inserted into the patient's muscle. Unipolar needle electrodes monitor a more limited area of muscle activity than surface electrodes. Therefore, measurements performed by means of unipolar needle electrodes

are subject to an increased risk of error of the examined sample due to function-related division of muscles. Coaxial bipolar and unipolar needle electrodes allow for the examination of increasingly smaller areas of muscle function [15]. The second, global electromyography consists in placing the electrodes on the patient's skin, precisely over the muscle belly [16]. When applying coaxial bipolar and unipolar electrodes, we can record an electrical activity of a relatively large sample of muscles (some functions of the adjacent muscles are also often analyzed). The most significant factor which determines the limited diagnostic effectiveness of global electromyography – both in terms of accuracy and precision of the measurement – is the variability of the impedance of the measurement system which arises from the foundations of the physical model of acquisition of electric signals. Being advised of this fact enables constructive search for effective solutions, both at the level of measurement organization, and processing (extraction and estimation) of collected data.

The electrode in global electromyography consists of a reference electrode and two active electrodes which can be wire or wireless [17]. During the test, the activity of the motor unit over which an electrode is situated, is registered. An active electrode is placed over the place of the highest concentration of motor units. A grounding electrode placed on a tested limb most often takes the form of a band or a metal plate. It is important that electrodes used in re-examinations be made of the same material. Classically, chloride-silver electrodes – often in a round shape and diameter of between 0.5 and 1 cm, are used in the global electromyography [11]. Before each measurement, the skin shall be properly prepared and its condition shall be checked so that between the electrode and the skin the resistance is not too large because it influences the result of the test. The skin is disinfected with an alcohol swab, shaved and disinfected one more time [18]. Another method of preparing the skin is wiping it with abrasive paper (in order to remove the outer layer of the epidermis) after prior shaving and then disinfecting it with alcohol [19]. Electrodes should also be disinfected with alcohol and fixed to the skin surface with the use of a double-sided adhesive tape [18]. Gels or gel electrodes are the recommended method of decreasing the resistance. Due to the invasiveness, this type of test shall be conducted only in hospital conditions, in the presence of doctors because there is a particular risk of bacterial infection and many other complications. On the basis of the test, information about amplitude, shape and frequency of the signal is gained. The test does not provide information on the pain strength, the

length of the muscle, the number of working motor units, the kind of contraction, the setting of joint or movement scope [11]. Global EMG is used for assessment of the neuromuscular activity during making active movements, maintained position of muscles (neutral, contraction or relaxation) and sports activity. Then, various forms of muscle work, e.g. eccentric, concentric, within an open or closed chain is tested [20].

The potential received by the electrode is different from the potential made during the muscle contraction. This is caused by the impossibility of gaining uniform conditions of the test or ways of EMG test each time, and, therefore, the results of tests of the same muscle groups can be different. Kind, shape and distribution of electrodes [21], conditions prevalent during the registration of the signal, the level of muscle activation, time of maintaining the load and internal factors: thickness of the subcutaneous tissue, geometrical properties and anatomical properties and physiology of muscles comprise external factors that have an impact on the test result. Individual factors connected with gender and age of the tested person are also meaningful [22]. In order to standardise conditions of the test in 2000 members of SENIAM (Surface Electromyography for the Non-Invasive Assessment of Muscles) organisation published guidelines concerning the construction and distribution of the electrodes, the way of registration, processing and also modification of EMG signals [23]. So far, they are the most often applied recommendations during the electromyographical test [24]. Guidelines of EMG tests were also recommended by ISEK (The International Society of Electromyography and Kinesiology) organisation [25].

Factors Affecting Reliability of the Measurement

Unfortunately, despite the implementation of the guidelines, the gained test results are not always repetitive. The actual electrical activity of muscles is modified by sociomedical and biological factors. They constitute a foundation of biological variance of electrical activity of muscles from the factors that burden the value of errors of the measurement method or measurement proceedings, such that are associated with the process of acquisition of electrical signals itself.

The EMG test result depends on the gender and age of the tested group. Women and men differ on the quality of muscles. This results from the changed properties of muscle fibres [10, 26]. Comparison of the test results of younger and older people is also unreliable. The number of mus-

cle cells decreases with age and as a result of the aging processes the diameter of muscle fibres also decreases. The response of muscles to nerve stimuli is impaired [27]. The frequency of action potentials also declines, which can be caused by reduced excitability of axonal membranes or decreased level of stimulation of nerve activation. Moreover, the synchronisation of frequency of individual motor units discharges due to the reduced number of common nerve inputs to the motor unit pool as a result of atrophy, reinnervation of motor units, creating new synapses is also decreased [26, 28]. Dendrites of a motor neuron create new connections with other neurons. Increasing number of synapses causes the emergence of the cochlear-synaptic-tinnitus. Neurotransmitters emitted as a result of depolarisation of presynaptic membrane of an axon situated near the dendrites cause presynaptic inhibition [29]. Therefore, the intensity of the contraction of motor units is higher in older people. The contraction time due to the hypertrophy of motor units is also longer. However, in tests by Sebastjan et al. [30], physically active older people gained better results of EMG than inactive people so training muscles can also change the EMG picture in each age of the patient.

Time of day during which the test is conducted is also meaningful. Minimum value of the amplitude of the effort record is reached in the morning. Then, it increases until 11:00 a.m. – 1:00 p.m. High values also occur in the afternoon and evening [10, 31]. The amplitude of the effort record reaches its maximum value about 6:00 p.m. [32]. Daily fluctuation of the temperature measured on the surface of the skin correlates visibly with the cyclical change of motor units efficiency. The higher internal temperature of muscles, the larger speed of conduction of action potential in muscle fibres and also: the higher energy transformations in the muscle tissue along with the decrease of muscle viscosity and increase in connective tissue elongation [10]. Daily rise in the temperature of the body causes the increase in the speed of nerve conduction, flexibility and strength of muscles by strengthened excretion of Ca^{2+} through sarcoplasmic reticulum [31].

Huber et al. [10] claimed in turn the effect of the menstrual cycle on the test results in early evening hours. Only in the luteal phase of the cycle, the muscle strength is correlated with the rise in the temperature of the body. According to Birch and Reilly [33], larger quantities of progesterone in this phase of the cycle have an impact on the rise in the temperature.

The size, shape and distance between the electrodes play an important role in gaining repetitive results of the tension tests, and paying attention

to the distribution of the electrodes in the same place during subsequent tests decreases the possibility of measurement error [10].

Repetitiveness of the test can be also gained when the tested persons perform commands in the same rhythm, on the same plane and with the same load. Application of a metronome is a simple method of setting the pace of performed movements [34]. Inertial sensors IMU (Inertial Measurement Unit) placed near EMG electrodes can be used for the control of the plane in which the motion is performed. IMU enables setting the rotation in a joint during performance of motion activity which gives more comprehensive information on the scope, character and repetitiveness of performed activities to researchers [35].

When it comes to the burden, the frequency of repetitions of movements should be inversely proportional to the value of the burden [36], as illustrated by, e.g. holding a dental handpiece. Furthermore, as the speed of movement is an additional load for the muscles, if the muscles are already tensed as a result of holding a given dental instrument, the pace of work should be slower during the assessment. Application of larger load is also connected with faster fatigue of the muscles. In order to avoid the reading of muscle fatigue, it is necessary to take breaks between subsequent tests [37]. Non-invasive methods of EMG measurement enable identification of fatigue of muscles, which increases during long-term exercises. Muscle fatigue causes an increase in the number of activated muscle units and tension amplitude [38]. In turn, an increase in the number of measurements leads to the lowered measurement uncertainty.

Data Processing and Difficulties in Interpreting the Results

The analysis and processing of the test results can also be different. Roman-Liu and Bartuzi [18] analyses chosen sections of the EMG signal and divided them into parts. Out of them, they chose 3-second sections with the most stable value of the amplitude. In order to eliminate the impact of individual factors, they conducted normalisation of the amplitude, mean and median of the frequency of each measurement in relation to maximum measurements of muscle contraction. Such a detailed analysis of EMG signal allows for the assessment of the impact of activation of a given muscle or muscle group on the course of the motion activity – allows for setting the order in which muscles, symmetry and muscle fatigue is activated [11].

Registration of activity of adjacent muscles can also distort the reading [15]. Then, there is a distortion while sending the electromyograph-

ic signal (crosstalk) – value of algebraic sum of action potentials of motor units from the area adjacent to the measuring electrode is changed [8]. The EMG amplitude is the higher the shorter muscle is and it becomes lower when the muscle is more relaxed. It also decreases when the muscles are being stretched [34]. Higher amplitude of the tension is characteristic to more shaped and stronger muscle groups [10]. Some muscles on the right side have larger amplitude than on the left side of the body which is probably connected with the majority of society being right-handed [39]. This all makes it necessary to conduct EMG evaluation in homogenous groups of patients and under precisely determined conditions to obtain credible and repetitive data.

Summary

Muscles along with the skeletal system form a closed kinematic chain and, therefore, direct measurement of the contraction force is impossible. Electromyographic signal as an electrical record of the muscle activity during the contraction enables assessment of the force level indirectly. Global EMG is a painless, easy to apply method. Additionally, registration digital techniques shorten the time of testing and enable statistical anal-

ysis of a lot of parameters. These facts direct attention to the possibility of the application of the technique in high-quality assessment of manual skills of candidates for dental studies, students and dentists.

Reliability of the measurement can be achieved by gaining uniform conditions. The group of tested people shall be chosen in respect to age, gender and the testing itself shall be conducted at the same time of day and in the same phase of the menstrual cycle at women. Commands should be performed in the same rhythm, on the same plane and with the same load. Using breaks between subsequent tests prevents reading muscle fatigue. For the results of the study to be credible, it is necessary to conduct the study under some specific conditions.

Despite difficulty in gaining repetitiveness of the test, the advantages of EMG test considerably prevail over its disadvantages. If it is possible to harmonise the method of conducting analysis of global electromyography results, an extension of application of this test would be possible. The electromyographic test of candidates for dental studies would make it possible to choose and train even better specialists and as for the students, it could constitute the form of learning progress assessment as skill is the basic attribute of a good craftsman – dentist.

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Address for correspondence:

Kamila Kołodziejczyk
Department of Maxillofacial Orthopaedics and Orthodontics
Wrocław Medical University
Krakowska 26
50-425 Wrocław
E-mail: kamila.kolodziejczyk@gmail.com
Tel.: +48 500 211 130

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