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Electromyography and its role in dentistry

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Abstract

Electromyography (EMG) is the subject which deals with detection, analysis and utilization of electrical signals emanating from skeletal muscles.(1)

The electric signal produced during muscle activation, known as the myoelectric signal, is produced from small electrical currents generated by the exchange of ions across the muscle membranes and detected with the help of electrodes. Electromyography is used to evaluate and record the electrical activity produced by muscles of a human body. The instrument from which we obtain the EMG signal is known as electromyography and the resultant record obtained is known as electromyogram.(2)

Keywords: Electrodes, Dental, Muscles, Orthodontics, Electromyograph

Introduction

Electromyography (EMG) is an experimental technique concerned with the development, recording and analysis of myoelectric signals. According to *Basmajian & DeLuca*(3) ***"Electromyography is the study of muscle function through the inquiry of the electrical signal the muscles emanate."*** Electromyograph is an instrument used to perform an EMG. The record which is obtained called an electromyogram. When the muscle cells are electrically or neurologically activated, EMG detects the electrical potential generated by these muscle cells. The signals can be analyzed to detect medical and dental abnormalities.(4,5) The structural basis of electromyography is the motor unit.

Motor Unit Action Potential (MUAP): Motor unit is the most fundamental functional unit of a muscle. It consists of a motor neuron and all the muscle fibers that are innervated by the motor neurons axonal branches. Activation of the muscle fibers of a motor unit produces electrical signal that are detected by electrode is known the motor unit action potential. The fundamental unit of the EMG signal is MUAP.(6)

Excitability of muscle membrane(6): The excitability of muscle fibers represents a major factor in muscle physiology through neural control. This phenomenon can be explained by a semi-permeable membrane model. Between the inner and outer spaces of a muscle cell, an ionic equilibrium forms a resting potential at the muscle fiber membrane (-80 to -90 mV approximately, when not contracted). Ionic pump maintain this potential difference which leads to formation of negative charge in the interior surface of cell as compared to exterior surface, which is positively charged. The conduction of the excitation along the motor nerve is produced after the activation of an alpha-motor anterior horn cell (induced by the central nervous system). An end plate potential is formed after the release of neuro transmitter at the motor end plates. Modifications are done in the diffusion properties of the muscle fiber membrane and there is flow of Na^+ ions inside the surface. This leads to Depolarization of the membrane which later leads to a process of Repolarization i.e. ions exchange in backward direction in the active ionic pump.

History

Francesco Redi's works in 1966 started the first documented experiments dealing with EMG. Redi discovered an electric ray fish with highly specialized muscle which generated electricity. Marey in 1890 made the first actual recording of this electrical activity, who also introduced the term EMG. To show the electrical signals from muscles Gasser and Erlanger used an oscilloscope in 1922.(7)

EMG electrodes and its types

With the help of EMG electrodes, inside the muscle of a human body the bioelectrical activity is detected. There are two types of EMG electrodes: surface electrode and inserted electrodes. Inserted electrodes further divided into two types: needle and fine wire electrodes. The three electrodes (surface, needle and fine wire) are explained as follows.

Needle electrodes

These are the widely used in neuromuscular evaluations. Needle electrode tip is bare and used as a detection surface. It contains an insulated wire in the cannula. The needle electrodes are comparatively improved from other available types in signal quality.

Advantages

- During relatively low force contractions individual MUAPs is detected by its small pick-up area that enables the electrode.

- The electrodes may be conveniently inserted within the muscle so that new tissue territories may be explored.[6]

Fine wire electrodes

From any small diameter, stiff wire with insulation, highly non-oxidizing, wire electrodes are made. Silver, platinum, nickel, and chromium alloy are used typically. Fine wire electrodes are extremely fine; easily implanted and withdrawn from skeletal muscles.[6]

Advantages

- Fine wire electrode is less painful but the cannula of needle electrodes remains inserted in the muscle throughout the duration of the test.

Surface electrodes

Surface EMG electrodes use a non-invasive approach for EMG signal measurement and detection. The current can flow into the electrode and the theory behind this; between the skin of the body and the detecting surface formation of chemical equilibrium takes place through electrolytic conduction.[8]

Advantages

- Simple and very easy to implement.
- Surface EMG electrodes require no medical supervision and certification.

Limitations

- They are generally used for superficial muscles only.
- With the skin their position must be kept stable; otherwise, the signal is distorted.

EMG Procedure

Skin preparation: Beforehand, application of surface EMG electrodes requires proper skin preparation. To obtain a good quality EMG signal, impedance of the skin must be considerably reduced. For this, removed the hair completely from the location where the electrodes are to be placed. Abrasive gel is advisable to reduce the dry layer of the skin.[8] There should be no moisture on the skin. In order to eliminate any wetness or sweat on the skin, the skin should be cleaned with alcohol.

EMG electrode placement: Between the tendinous insertion and the motor unit of the muscle, the surface EMG electrodes should be placed, along the longitudinal midline of the muscle.[9] Between the center of the electrodes or detecting surfaces the distance should be only 1-2 cm. The longitudinal axis of the electrodes should be parallel to the length of the muscle fibers.

EMG in Dentistry

- Action potentials in actively contracting lingual and masticatory muscles can be studied.
- It is used in the management of Myofacial Pain Dysfunction (MPDS) and its procedure is called Auditory or Visual electromyographic feedback, concerning to the muscle activity, it supplies information to the patient.
- Biomechanics of jaw and facial muscle functions can be studied.
- EMG is useful for identifying the results of the therapy and judging the asymmetry of muscle action.
- Nocturnal bruxism and jaw muscle tracking can be monitored.
- To evaluate muscle asymmetries or possible postural disturbances and significant muscle fatigue.[4,5,10,11,12,13]

Electromyography in Orthodontics

Robert E. Moyers made the first effort to apply electromyography in dentistry.[14] He observed that the normal relations of teeth were influenced by muscular balance within the same jaw and those of the opposite jaw. The mandibular elevator muscles are important in context of orthodontics namely: temporalis muscle, masseter muscle, the lateral pterygoid and medial pterygoid muscle. To determine facial morphology, the genioglossus muscle also plays an important role.

Allen Brodie said that, ‘Through the critical period of growth, if we could learn to control the musculature, we might be able to expect that, in at least a proportion of the patients, there would be unfolding of development, that we must be managed with orthodontic force.[15]

Porrit (1960) concluded that a change in the pattern of masticatory muscle contraction and the pattern of symmetrical muscle contraction is due to single occlusal interference and restored by removal of occlusal interferences and during movements of the mandible, that interferences could inhibit muscle activity. After the occlusal interferences were placed, mandibular adaptation was generally accomplished in a short time. To change in muscle contraction patterns, the location of the interference (tooth) appeared to be more responsible than the location of the tooth in the mouth. The masseter muscle appeared less sensitive to interferences than the temporal muscle.[16]

Grossman et al (1961) felt that the problem in orthodontic therapy was not purely mechanical since muscular factor were considered as an etiology and they influenced the end result stability in a major way. They also stated that prior to commencement of treatment an exact assessment of the muscle behaviour would enable the orthodontist to make a comparison and due to treatment assess any changes that might have occurred.[17]

Ahlgren et al (1973) observed in the masseter and temporal muscle that the post normal occlusions expressed less EMG activity as compared to normal occlusions during swallowing. During swallowing, longer duration of the activity seen in the posterior part of temporal muscle as compared to anterior part whereas normal occlusion was seen in the reverse condition.[18]

Vittiet al (1975) analyzed the circumoral muscles and the activity of tongue and in eleven individuals with normal occlusion. Only slightly increased activity occurred in the buccinator muscle but a marked EMG response occurred in both orbicularis oris and genioglossus muscles during aberrant oral activity (such as thumb sucking). These findings helped to explain the role of muscles in the aetiology of malocclusions such as tongue thrusting and thumb sucking.[19]

Moss (1975) investigated the muscle activity patterns of normal subjects and the subjects with malocclusion before and after orthodontic treatment. He concluded that specific pattern of muscle activity seen in normal occlusion subjects and among each groups, masticatory muscle activity was high and children and adults showed a difference in their muscle pattern. Muscle patterns changed during treatment such as normal pattern of activity observed, once they were out of retention. To assess the position of the jaw, the muscle activity could be palpated. Following orthodontic treatment, muscle activity give a sign of the stability of the end result and states whether occlusal equilibration is needed or not.[20]

Pancherz et al (1978) observed masticatory activity in 9 patients with relapse of overjet and 10 patients without relapse of overjet following the application of activator. Masticatory efficiency was related to the number of intermaxillary tooth contacts and was evaluated by chewing test and EMG activity of the temporal and masseter muscles. The results indicated reduced masticatory efficiency which was related to fewer intermaxillary tooth contacts and less EMG activity of the masseter and temporal muscles. Masticatory efficiency and muscle activity was reduced in patients with relapse of overjet in comparison with patients without relapse.[21]

Ingervallet al (1979) studied the activity of temporal muscles and masseter muscles in individuals with dual bite. The subjects with dual bite had low postural activity of temporal muscle possibly indicating a protruded postural position of the mandible. The activity of the posterior temporal muscle was low during maximal bite in the intercuspal position and the same was true for the masseter activity during biting in the retruded position. Neither of the two mandibular positions examined gave a balanced activity during maximal bite in all three muscles examined. They also found that the muscle activity duration in the individual chewing cycles was shorter in controls than the subjects with dual bite. This could be due to stability of the occlusion. Retruded mandibular position was used during chewing, it indicate the pattern of muscle activity. To create a stable occlusion in the retruded mandibular position it was therefore functionally beneficial.[22]

Lacouture et al studied the action of 3 types of functional appliances(Herbst, Frankel and simulated Twin block) on the activity of the masticatory muscles. Statistically significant decrease in functional activity of the jaw muscles when use of these appliances in non-human primates. Heinserted the functional appliances to test the ‘lateral pterygoid hypothesis and found increased postural and functional activity of the inferior and superior heads of the lateral pterygoid muscle. Increased condylar growth was observed as a result of stimulation in the superior head of the lateral pterygoid muscle. The EMG activity of the digastric, masseter and lateral pterygoid muscles were also monitored and found to be decrease with treatment by functional appliances.[23]

A study by Deguchi and Iwahara for Class III patients chin cup therapy is used, decrease in masseter muscle activity on both the balancing sides and working (chewing) is found with no improvement in the coordination of bilateral temporal and masseter muscles. The integrated electromyographic activity of thetemporal andmasseter muscles in normal occlusion subjects is more than Class III cases has been reported.[24]

Goldreich et al evaluated the effect of pain on masseter activity from adjustment of orthodontic arch wires. After treatment, the electromyographic level is significantly decreased. The results suggest that the orthodontic pain on teeth reduce muscle activity during function.[25]

Nganet al assessed EMG activity and masticatory muscle pain before, after, and during treatment with orthopaedic protraction headgear. In general, to protract the maxilla, 800 g of orthopaedic force is used and 75% of this force is used for the temporomandibular area. The results of the study demonstrate no significant increase in muscle pain or masticatory muscle activity associated with orthopaedic treatment using maxillary protraction headgear.[26]

Li et al compared normal individuals with an operated unilateral cleft lip and palate patients with anterior cross bite to observe the characteristics of masticatory muscle activity. Bilaterally electromyographic activity of the temporalis and masseter muscles were recorded. Results showed that patients with unilateral cleft lip and palate demonstrated:

- A higher activation level of temporalis and masseter muscles in rest position.
- Lower potential function of temporalis muscles and masseter muscles.
- Masticatory muscles activity is inharmonious during mandibular border movements.

- Higher asymmetry index of masseter and temporalis muscles.[27]

Winders observed the forces exerted on the dentition by lingual and perioral musculature during swallowing. He concluded that during swallowing the labial musculatures and buccal musculatures do not contract unless there is an antero-posterior skeletal dysplasia with accompanying anterior open bite. To match the functions that are required of those all the muscles of the body are continually being remodelled. Total mass increases if any muscle that are used more than optimal level hypertrophies. Decrease in muscle mass when the muscle is not used causing atrophy. The tongue activity is increased in tongue thrust swallowing. To produce an oral seal, the tongue has to come more forward than normal to help initiate the swallowing procedure and hypertrophy of the genioglossus muscle occurs. Increase in the number of filaments (actin and myosin) in each muscle fiber results muscle hypertrophy, thus causing enlargement of the individual muscle fiber. This is known as fiber hypertrophy. Contraction of muscles occurs usually at maximal force when muscles are stretched to a more than normal length. This causes new sarcomeres which are added to the ends of the muscle fibers where they attach to the tendons. Electromyographic activity increases in muscle hypertrophies, because increased motor units being activated during contraction. This applies same for the tongue muscle. When the tongue habit is corrected, the muscle remains short than its normal length. Thus the amount of actin and myosin decreases and sarcomeres at the ends of the muscle fibers disappear. Therefore, there is a relative atrophy of the muscle fibers. After habit correction the electromyographic activity returns to normal levels. By this process muscles are continually remodelled to achieve proper length for proper muscle contraction.[28]

Conclusion

In the past, orthodontists depended mainly on static and stable records in the form of plaster models and head films for diagnosis and planning. Since Orthodontists have moved from a stable to a dynamic and functional concept of occlusion, it is mandatory that orthodontist knows how a muscle functions. In this context, thorough knowledge of physiology of skeletal muscle contraction is mandatory for an orthodontist. It is possible to record even minute electrical activity of biologic tissues.

Sometimes, orthodontic clinicians may have to resort to the use of EMG for diagnosis and assessment of cases under treatment.

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