Electromyography and its application in orthodontics

*Meenakshi Iyer and Ashima Valiathan**

All the muscles of the body are continually being remodeled to match the functions that are required of them. Any muscle that is used more than optimal level hypertrophies, and thus its total mass increases. Atrophy occurs when the muscle is not used causing a decrease in muscle mass. Electromyography is a record of the action current showing muscular activity under diverse functional conditions.

Electromyography and its applications in orthodontics

Electromyography is defined as the recording and study of the intrinsic electrical properties of skeletal muscle by means of surface or needle electrodes, to determine merely whether the muscle is contracting or not; by insertion of a needle electrode into the muscle and observing by cathode-ray oscilloscope the action potentials spontaneously present in a muscle or induced by voluntary contractions, as a means of detecting the nature and location of motor unit lesions; or by recording the electrical activity evoked in a muscle by electrical stimulation of its nerve. Electromyograph is the instrument used in electromyography. Electromyogram is the record obtained by electromyography (EMG). The structural basis of electromyography is the motor unit. The normal skeletal muscle fibers probably never contract as isolated individuals. Instead, several of them contract at almost the same moment, all being supplied by branches of the axon of one spinal motor neuron.

Motor unit potential

During the normal twitch of a muscle fiber, a minute electrical potential is generated, which is dissipated into the surrounding tissue. The duration of the action potential associated with this twitch is about 1–2 milli seconds, or even 4 milli seconds. Since all the muscle fibers of a motor unit do not contract at exactly the same time, the electrical potential developed by the single twitch of all fibers in the motor unit is prolonged.

A majority of these motor-unit potentials have an amplitude of around 0.5 mV. When displayed on a cathode-ray oscilloscope, the result is a sharp spike that is most often biphasic.

It was Einthoven[1] who discovered that a muscle contraction gives off an idiomuscular current. This is referred to as an action current or an action potential. The current generated is so small that it must be amplified many thousand times to be recorded. By means of an electromyogram one can get a relatively accurate picture of muscular activity under diverse functional conditions.

Peterson and Kugelberg[2] showed that the electrode types affect the recorded duration and amplitude of the action potentials. They demonstrated characteristic variation, e.g. the smallness of potentials in facial muscles as compared with those in muscles of the extremity. Under normal conditions, the smaller potentials appear first with a slight contraction. As the force is increased, larger and larger potentials are recruited, this being the normal pattern of recruitment.

Electromyographic technique

The types and construction of electrodes used in electromyography vary widely. The two main types of electrodes used for the study of muscle dynamics are surface (or ‘skin’) electrodes and inserted electrodes (usually wire or needle).

Both these electrode types have their advantages and disadvantages[3].

Needle electrodes. They are superior to surface electrodes, as the quality of the electromyogram is better. There are lesser technical artifacts, because distance between the muscle and the electrode remains more constant. There is a risk of infection associated with the use of needle electrodes. They may also be painful.

Surface electrodes. These are preferred because of their non-invasiveness and reduced risk of infection. Using a surface electrode always presents the possibility of

---

Meenakshi Iyer and Ashima Valiathan are in the Department of Orthodontics and Dentofacial Orthopedics, College of Dental Surgery, Manipal 576 119, India
*For correspondence. (e-mail: ashima-vip@zetainfotech.com)

loosening of the electrodes during nerve stimulation. Surface electrodes also give rise to errors when the distance between the electrodes and the muscle changes during muscle contraction. In a majority of cases, a technically satisfactory response can be obtained with surface electrodes.

The most important guideline for adequate needle insertion is to observe and palpate the muscle in contraction, while the test maneuver is being performed. This rule is applicable to almost all superficial muscles. After insertion of the needle, it is always important to confirm that the needle is correctly placed by asking the patient to contract the muscle being tested. If the needle is correctly positioned, this maneuver should easily produce crisp action potentials.

The electromyogram can be quantified by measuring either the height of the action potentials or the frequency of the individual action potentials. At high levels of activity, when action potential spikes are superimposed, frequency counts become inaccurate.

Although electromyography can give useful information on whether a muscle is active and define when the activity begins and ends in the muscle fiber sampled, it is impossible to know how much activity in the muscle is being missed. Movement cannot be inferred from the electromyogram alone, because antagonistic muscles may be working synergistically to control the movement or provide stabilization. Other instruments monitoring force, pressure, or position may be used in conjunction with the electromyogram to correlate muscle activity with effect.

Electromyography in orthodontics

The first effort to apply electromyography to dentistry was made by Robert E. Moyers[4]. He observed that the normal relations of teeth to each other in the same jaw and with those of the opposite jaw were influenced by muscular balance.

With relevance to orthodontics, the muscles of importance are the mandibular elevators, namely: masseter muscle, temporalis muscle, and the medial pterygoid muscle; and the mandibular depressor, i.e. the lateral pterygoid muscle. The genioglossus muscle also plays an important role in determining facial morphology. This muscle is responsible for the protraction of the tongue. Mentalis muscle and orbicularis oris muscle are also important.

Allen Brodie[5] said that, 'If we could learn to control the musculature through the critical period of growth, we might be able to expect that, in at least a proportion of the patients, there would be spontaneous unfolding of development, that we thought previously must be managed with orthodontic force'.

EMG activity in Class II malocclusion patients

Graber[6] points out that in contract to Class I malocclusion where the muscle function is usually normal (except for open bite cases), most Class II division 1 malocclusions involve abnormal muscle activity. In Class II division 2 malocclusion, there is compensatory muscle activity, with dominance of posterior fibers of both the temporalis and masseter muscles. Graber also added that in Class III and Class II division 1 malocclusions, the problem is that of dominant bone dysplasia with adaptive muscle function and tooth irregularity reflecting a severe basal dysplasia.

Pancherz[7] analysed the electromyographic activity in the masticatory muscles of patients with Class II division 1 malocclusion and normal occlusion. Recordings were made during maximal biting in centric occlusion and during chewing. The results revealed:

- During maximal biting in intercuspal position, the Class II exhibited less electromyographic activity in the masseter and temporal muscles than the controls.
- The reduction in electromyographic activity in the study group was most apparent for the masseter muscle.
- During chewing the Class II subjects showed less electromyographic activity in the masseter muscle than in the normals. For the temporal muscle, no differences were found between the two groups.
- High positive correlations were found between the electromyographic activity during maximal biting and chewing for both muscles of the two groups. The impaired muscle activity found in the Class II cases may be attributed to a diverging dentofacial morphology and unstable occlusal contact conditions.

Moyers[4] investigated electromyograms of children with Class II division 1 malocclusion and found dysfunction of the temporal muscle in habitual occlusion and at rest (increased activity in the posterior part of the temporal muscle). He asserted that this dysfunction might be an etiologic factor of post-normal occlusion.

Electromyographic findings in functional appliance treatment

The neuromuscular reactions seen in experimental monkey studies closely paralleled those often observed in patients wearing functional appliances on a full time basis. James McNamara Jr., called this response, which begins during the first few months after appliance placement, the 'pterygoid response'. The first indication of the pterygoid response can be observed quite easily in experimental animals, i.e. the increased tonic activity seen during the maintenance of the postural position of the mandible as well as during functional movements. During the first few hours after appliance placement, there was no change in the sequence of muscle activity. A distinct change in muscle activity occurred after the first few days or weeks of appliance wear. This change was characterized by a decrease in the activity of the posterior temporalis muscle, an increase in the activity of the masseter muscle, and most significantly an increase in the function of the lateral pterygoid muscle. The superior head of the lateral pterygoid muscle fired simultaneously with the jaw closing muscles in controls. In the experimental records, the superior head of the lateral pterygoid muscle not only fired when the elevator muscles were active, but also when the elevator muscles were not active. As the experiments progressed, the pterygoid response subsided and a gradual return towards the pre-appliance levels and patterns of muscle activities occurred.

The anterior temporal muscle showed dominant activity during maximal clenching, but after the 3-month stage, a significant decrease was noted. The results show that treatment with an oral shield caused a decrease in orofacial muscle activity during oral functions.

Lacouture *et al.*[8] studied the action of 3 types of functional appliances on the activity of the masticatory muscles. The appliances used were – Herbst, Frankel and simulated Twin block. The authors found that the use of these appliances in non-human primates was associated with a statistically significant decrease in functional activity of the jaw muscles. This study was used to test the 'lateral pterygoid hypothesis', which states that postural and functional activity of the superior, and inferior heads of the lateral pterygoid muscle increases after the insertion of a functional appliance. This increased activity, especially in the superior head of the lateral pterygoid muscle then acts to stimulate increased condylar growth.

The electromyographic activity of the masseter, digastric, superior and inferior heads of the lateral pterygoid muscles were monitored and were found to decrease with functional appliance treatment. This study did not support the lateral pterygoid muscle hypothesis. An earlier study by Sessle *et al.*[9] found similar results.

Ingervall and Thüer[10] studied temporal muscle activity during the first year of Class II division 1 malocclusion treatment with activator. They found no evidence of decrease in the postural activity of the posterior temporal muscle, although such a decrease has been described as a sign of forward displacement of the mandible during treatment with a functional appliance.

EMG studies done on Class III subjects

It is believed that correction of the anterior crossbite in Class III patients increases the electromyographic activities of the masseter and anterior temporal muscles, or improves coordination of the bilateral masseter and anterior temporal muscles. A study by Deguchi and Iwahara[11] tested this hypothesis. They used chin cup therapy for Class III patients and found a decrease in masseter muscle activity on both the working (chewing) and balancing sides, with no improvement in the coordination of bilateral masseter and anterior temporal muscles. It has been reported that the integrated electromyographic activity of the masseter and temporal muscles in Class III cases is less than in normal occlusion subjects.

Electromyographic activity during swallowing

The electromyographic activity of the facial muscles shows characteristic differences during normal and abnormal swallowing. In the normal mature swallow, the mandible rises as the teeth are brought together during the swallow, and the lips touch lightly. The facial muscles do not show marked contractions. The temporal muscle contracts as the mandible is elevated. During the teeth-apart swallow, no contraction of the temporal muscle is seen. Here mentalis muscle and lip contractions are needed for mandibular stabilization.

Winders[12] studied the forces exerted on the dentition by perioral and lingual musculature during swallowing. He concluded that the buccal and labial musculatures do not contract during swallowing unless there is an anterior open bite with accompanying antero–posterior skeletal dysplasia.

All the muscles of the body are continually being remodeled to match the functions that are required of them. Any muscle that is used more than optimal level hypertrophies, and thus its total mass increases. Atrophy occurs when the muscle is not used causing a decrease in muscle mass.

In tongue thrust swallowing, the tongue activity is increased. The tongue has to come more forward than normal to produce an oral seal to help initiate the swallowing procedure. Therefore, the tongue muscle, especially the genioglossus muscle (which is responsible for protrusion of the tongue), hypertrophies.

Virtually all muscle hypertrophy results from increase in the number of actin and myosin filaments in each muscle fiber, thus causing enlargement of the individual muscle fiber[1]. This is called fiber hypertrophy. This usually occurs in response to contraction of a muscle at maximal or almost maximal force. Another type of hypertrophy occurs when muscles are stretched to a greater-than-normal length. This causes new sarcomeres to be added at the ends of the muscle fibers where they attach to the tendons.

Whenever a muscle hypertrophies, its electromyographic activity increases relative to the normal. This is because of increased motor units being activated during muscle contraction. This applies to the tongue muscle as well.

When the tongue is retrained and the tongue habit is corrected, the muscle remains shortened continually to less than its normal length. Thus sarcomeres at the ends of the muscle fibers disappear, and the amount of actin and myosin decreases. Therefore, there is a relative atrophy of the muscle fibers. The electromyographic activity after habit correction returns to normal levels. It is by this process that muscles are continually remodeled to have an appropriate length for proper muscle contraction.

Effect from pain from orthodontic treatment on EMG activity

Pain has been shown to have an effect on muscle activity even when it does not originate in the muscle itself or in the related joint. The effect of pain from archwire adjustment on jaw muscle activity is unclear.

Goldreich *et al.*[13] evaluated the effect of orthodontic archwire adjustment pain on masseter electromyographic activity. The electromyographic levels during function decreased significantly after treatment started. The results suggest that orthodontic pain on teeth tend to reduce muscle activity during function.

Ngan *et al.*[14] assessed masticatory muscle pain and EMG activity before, during, and after treatment with orthopaedic protraction headgear. In general, 800 g of orthopaedic force is used to protract the maxilla and 75% of this force is transmitted to the temporomandibular area via the mandible. The results of the study demonstrate no significant increase in masticatory muscle activity or muscle pain associated with orthopedic treatment using maxillary protraction headgear.

Lip and cheek activity in sucking habits

Ahlgren[15] electromyographically studied lip and cheek activity in sucking habits. He found that profound lip and mentalis (perioral) activity was developed during thumb and dummy sucking. Cheek (buccinator) activity was less evident, showing light to moderate activity. Lip and cheek activity was more noticeable during dummy sucking than thumb sucking. Activity at rest in perioral muscles was pronounced among thumb and dummy suckers, while buccinator activity was negligible. Lip and cheek activity was substantially less, both at rest and during sucking, in a control group of children who were not thumb suckers.

EMG activity in cleft lip and palate patients

Li *et al.*[16] evaluated the characteristics of masticatory muscle activity in operated unilateral cleft lip and palate patients with anterior crossbite compared with normal individuals. Electromyographic activity of the masseter and anterior temporalis muscles were recorded bilaterally. Results showed that patients with unilateral cleft lip and palate demonstrated:

- A higher activation level of masseter and temporalis muscles in rest position.
- Lower potential function of masseter and temporalis muscles.
- Inharmonious activity of the masticatory muscles during mandibular border movements.
- Higher asymmetry index of masseter and temporalis muscles.

Conclusion

The role of musculature in malocclusion is very important. As dentists, we tend to think of certain of our muscles primarily as masticating elements. The dental student learns first that the masseter and temporal, external and internal pterygoid muscles are 'muscles of mastication'. This is only part of the picture. These muscles as well as other facial muscles with which they are intimately associated, have other functions that are equally important, or more so. The average person eats three meals a day, but he swallows all day long, and he breathes constantly, and talks a good part of the time. In addition to these is an even more important role of the musculature – that of posture. As electromyographic studies have shown, even at postural resting position muscles are apparently at function, maintaining a status quo of soft tissue and bony elements. Premature occlusal contacts and compensatory muscle activity during active function produce departures from the normal. Such activity can change bony morphology, accentuating the malocclusion.

If there is a malrelationship between the maxilla and mandible, making normal muscle function difficult, an adaptive activity of the muscles may occur. Nature usually tries to work best with what it has, so that a compensatory muscle functional activity is established to handle the demands of mastication, respiration, deglutition and speech. Good examples of this compensatory activity are seen in Class II and Class III malocclusions. After orthodontic therapy, adaptations to the new morphologic relationship are clearly seen.

The dentist seldom has access to and rarely needs equipment, which provides electromyographic records.

But, knowing the importance of muscle activity and the effect of abnormal muscle function on the dentition, there are times when such records are of value.

In a severe Class II division 1 malocclusion, it can be seen clinically that the mentalis muscle is hyperactive and the upper lip is hypofunctional, while the lower lip strongly extends upwards and forward during swallowing to force the maxillary incisors labially. Electromyographic studies verify this clinical observation. In addition, they indicate that the buccinator muscle may contract excessively. In Class II division 1 malocclusion the posterior fibers of the temporalis muscle seem to exert greater influence than with a normal occlusion.

Vertical dimension problems are also amenable to electromyographic study. Overclosure, with concomitant retrusive posterior temporalis and deep masseter activity can create antero–posterior discrepancies. It is a simple matter to check muscle fiber group contractions. Advanced technology provides equipment that is now available in a number of medical laboratories. The dentist should develop a connection with the laboratories to obtain information not available in his/her own office. With progress in electromyographics, more definitive studies are possible that may give a clue to solving many malocclusion problems.

1. Best, C. H. and Taylor, W. B., *Physiological Basis of Medical Practice* (ed. West, J. B.), Williams and Wilkins, Baltimore, 1985, 11th edn.
2. Peterson, I. and Kugelberg, E., *J. Neurol. Neurosurg. Psychaitr.*, 1949, **12**, 124–128.
3. Oh, S. J., *Electromyography: Neuromuscular Transmission Studies*, Williams and Wilkins, London, 1988.
4. Moyers, R. E., *Am. J. Orthod.*, 1949, **35**, 837.
5. Brodie, A. G., *Angle Orthod.*, 1953, **23**, 71–77.
6. Graber, T. M., *Am. J. Orthod.*, 1963, **49**, 418.
7. Pancherz, H., *Am. J. Orthod. Dentofac. Orthop.*, 1980, **77**, 679–688.
8. Lacouture, C., Woodside, D. G., Sectakof, P. A. and Sessle, B. J., *Am. J. Orthod. Dentofac. Orthop.*, 1997, **112**, 560–572.
9. Sessle, B. J., Woodside, D. G., Bourque, P., Gurza, S., Powell, G., Voudouris, J., Metaxas, A. and Altuna, G., *Am. J. Orthod. Dentofac. Orthop.*, 1990, **98**, 222–230.
10. Ingervall, B. and Thuer, U., *Am. J. Orthod. Dentofac. Orthop.*, 1991, **99**, 361–368.
11. Deguchi, T. and Iwahara, K., *Angle Orthod.*, 1998, **68**, 419–424.
12. Winders, R. V., *Angle. Orthod.*, 1958, **28**, 226–235.
13. Goldreich, H., Gazit, E., Lieberman, M. A. and Rugh, J. D., *Am. J. Orthod. Dentofac. Orthop.*, 1994, **106**, 365–370.
14. Ngan, P. W., Yiu, C., Hagg, U., Wei, S. H. and Bowley, J., *Angle Orthod.*, 1997, **67**, 433–437.
15. Ahlgren, J., *Swed. Dent. J.*, 1995, **19**, 95–101.
16. Li, W., Lin, J. and Fu, M., *Cleft Palate Craniofac. J.*, 1998, **35**, 415–418.

Received 21 September 2000; accepted 17 November 2000

Neural stem cell research: A revolution in the making

P. N. Tandon

Existence of stem cells capable of differentiating in all types of haemopoietic cells, red blood cells, white blood cells, platelets has been known for the last one decade. These have been isolated from bone marrow cultured and made to differentiate into specific cell types. It is, however, only in the last couple of years that totipotent cells isolated from human embryo at the blastocyst stage, have been shown to retain the potentials to differentiate into any type of adult cells including neuronal series. More or less simultaneously it was demonstrated that contrary to the prevailing belief, neurogenesis continues throughout life even in humans, at least in certain regions of the brain. Not surprisingly, this has lead to active research in the field with the hope of exploiting this knowledge for replacement of lost or degenerating neurons. This review is an attempt to summarize the current knowledge and future areas of research.

TWO independent publications[1,2] in November 1998 heralded the isolation of the human embryonic stem cells (ESCs) using two different approaches. These cells can not only differentiate into all types of tissue, but can, under carefully controlled conditions, be maintained continuously as undifferentiated cells in culture[3]. A year later Floyd Bloom[4] hailed it as the breakthrough of the year arguing that 'without question, the potential of embryonic stem cells again fulfills our definition of a breakthrough as a rare discovery that profoundly

---

P. N. Tandon is at the All India Institute of Medical Sciences, New Delhi 110 029, India
e-mail: nbrc@icgeb.res.in