Functional Electromyography of the Temporal And Masseter Muscles in Class II, Division I Malocclusion and Excellent Occlusion

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Orthodontics has long separated normal and abnormal occlusion by anatomical tooth relations which is a static classification dependent upon bony architecture and tooth position. However, since the bony foundation which supports the teeth is powered and moved by muscle tissue the dynamic aspects of the oral cavity cannot be excluded from consideration.

Recognition of this functional concept gives rise to the question—is there a pattern of the functioning mandibular musculature which might possibly reflect the anatomical relationships of the teeth in their bony bases, i.e. does variation of tooth relationship result in characteristic patterns of muscle activity?

Muscle effects its function by contraction, i.e. it moves, holds, or produces tension by shortening or trying to shorten. Skeletal muscle contraction is accompanied by chemical, thermal, physical, and electrical changes.

The electrical feature of the contraction cycle has given physiologists an opportunity to precisely study some of the recondite phenomena of muscle tissue. These electrical changes just precede the contraction wave in the muscle and are termed action potentials.[1]

Recent advances in electrical research and electronic design permit accurate transmission, magnification, and reading of minute electric voltages such as those produced by voluntary muscle tissue.

The instrument designed for recording the electrical activity of heart action is called an electrocardiograph (E. K. G or E. C. G.). The electroencephalograph (E. E. G.) is used to study the electrical activity of the brain. An instrument derived from both of these is the electromyograph (E. M. G.) which is used to study the actions of (voluntary) muscle.

Electromyography is used to record the action potentials of voluntary muscle when it is excited. It has an honored history in the service of medicine and has been used successfully in the diagnosis and location of myopathic, myelopathic, and neuropathic lesions. More recent advances have given it a position in kinesiology—the study of muscle motivated movements. Recently this instrument has been used in dental research. The extent of its value to dentistry has not yet been fully explored and at the present time, only certain facets of its utility have been uncovered.

The principle of electrical activity in living tissue is related to the existence of polarized membranes at the cellular surfaces. The resting electrical charges in muscle, as in nerve, are positive on the external surface and negative on the inner surface. When tissues are activated these charges are reversed. It

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is this reversal of polarization at the tissue surface which produces electrical current, permits recording of some, and prompted early studies of the various tissues in function.

In electromyography there are two general methods of "picking up" these minute electrical charges. One is by means of subsurface or needle electrodes, and the other is with surface electrodes. The latter type of electrode is placed on the skin overlying the muscle to be studied and is utilized in studying large, poorly defined areas of muscle tissue. Diagnosticians use needle electrodes, inserted directly into the belly of the muscle in question, when studying the activity of a very small area.

Changes in electrical activity that are transmitted from the muscle to the point or surface of the electrode are very small. They are so small in fact that they must be amplified hundreds of times before recordings can be made. The present means of amplification is the vacuum tube or electron valve. These vacuum tubes are the principal organs in the anatomy of the electromyograph. They faithfully amplify the characteristics of the electric charges from the muscle to a controlled degree of recording. These magnified currents are then passed by electronic circuits to one or more recording devices.

It may be helpful to the uninitiated readers at this point to state that the action potenials usually occur in volleys. Of interest to the experimenter are: the number of spikes per volley, the frequency of spikes in the volley, the amplitude of the spikes, the duration of the spikes and the duration of the volleys. Also of interest is smoothness or lack of smoothness in the components of the volley. All of these can be detected by using the three recording devices available.

If a permanent inked record is desired, a crystograph or pen writing device is used. This device is similar to an ink writing barometer, and simultaneously records from one to eight muscles on a moving paper track. The electromyograph may also be traced on an oscilliscope making it possible to photograph electrical changes taking place. If spike form is of particular interest, this is the best method because it is inertia free. An audio unit, similar to the loud speaker on a radio, allows the operator to listen and record on tape any or all of the activity from one muscle or a group of muscles.

Attaching an EMG to a patient and taking a record does not constitute a study. A thorough understanding of the inter-dependent physiology and anatomy of nerve and muscle is of utmost importance. We should, therefore, consider certain of the fundamental theories of muscle-nerve physiology.

A voluntary muscle is composed of several anatomically distinct protoplasmic components. The basic member is the muscle fiber. This multinucleated cell is a group of myofibrils imbedded in a matrix of undifferentiated protoplasm, all of which are enclosed in a fine sheath, the sarcolemma. Muscle fibers occur in groups to form what are known as fasiculi. These, in turn, occur in bundles of variable number and size, which then constitute the muscles as we see them grossly.

The basic functional unit of skeletal muscle is called the motor unit. Sherrington[2] has defined a motor unit as all of the voluntary muscle fibers supplied by one anterior horn cell or lower motor neurone. When such a nerve is adequately stimulated, all of the fibers of the individual motor unit contract. When the stimulus is inadequate none will. This is the all-or-none law of Keith Lucas.[3]

Hoefer[4] has stated that the ratio of nerve-to-muscle fibers in striated muscle supplied by the cranial nerves varies from 1:4 to less than 1:150. The lower ratios give fine graded activity as seen in the extrinsic muscles of the eye. Higher nerve-muscle ratios are found in the heavy work muscles like the cervical postural group. The nerve to muscle fiber ratio is not the only variable from one muscle to another. There are also differences in the fiber arrangement and muscle color.

Sicher[5] has skillfully shown that muscles depended upon primarily for movement have long chain like alignment of fibers. Muscles depended upon for sustained strong contractions and power have a penniform or parallel fiber arrangement.

Myoglobin, or the muscle hemoglobin content, varies from muscle to muscle according to the function of the muscle. This protein is the oxygen source for the chemical contraction cycle. Large amounts of myoglobin give a red color to the muscle and indicate a staying power in that muscle; this red coloration is found in the postural and heavy work muscles. Light colored muscles contain little myoglobin and are not capable of long sustained contractions; these muscles are designed for speed and are usually active in the initiation of movements.

The law of reciprocal innervation of voluntary muscles with antagonistic actions was stated in 1897. In that year Hering and Sherrington demonstrated "—electrical stimulation of certain points of the motor centers of the cortex cerebri of monkeys cause not only contractions of the corresponding muscles, but also a relaxation of the antagonists of these muscles." The functional aspect of this motor phenomenon is that it is one method at the disposal of the central nervous system for grading the speed, smoothness, and range of movement.

Activity of muscle is not limited to the production of movement. All muscles in producing movement act across joints and at times are called upon by the nervous system to stabilize the joint against external forces. Some muscles are utilized in the slowing or deceleration of movements already in progress. In performing this action, there is a lengthening of the muscle accompanied by the same changes which occur in shortening muscle.

Space is too limited to include all the aspects of recent electromyographic research. We should, however, take cognizance of some of the contributors in the field who have applied the method to dental problems. Moyers,[7] at the State University of Iowa, studied the activity of the temporomandibular musculature in normal occlusion and Class II Division I malocclusions. He found that none of the cases in the malocclusion groups demonstrated normal spike potentials (action potentials) from the musculature studied. Pruzansky,[8] in 1953, admirably described some dental muscle phenomena and suggested many possibilities for electromyography in dental research. Among his studies were unilateral recordings of gum chewing in normal subjects with an attempt to fractionate the activity of the temporal muscle.

The myofunctional exercises of A. P. Rogers, one of the first men to give muscle a place in orthodontics, were recently studied by Copeland.[9] With electromyographic tracings, he found that some muscular changes did exist immediately after the exercises but these were lost after a short time lapse.

The thoroughness of Swedish research design has been beautifully demonstrated by Carlsoo in his anatomical and electromyographical study of the musculature surrounding the temporomandibular joint. Carlsoo[10] found that the most important muscle in the habitual closing movement of the mandible appeared to be the temporal. He also stressed the temporal's importance in the "habitual rest-position."

Geltzer,[11] at Northwestern University, recently completed an electromyographic study of the temporal muscle. He concluded that from its myographic pattern, the temporal muscle has a stabilizing action on the mandible during forced closure. He also demonstrated that the EMG of a subject, doing the same exercise was statistically reproducible.

MacDougall and Andrew,[12] in England, studied the temporal and masseter muscles electromyographically and noted among other things that retrusion of the mandibles was accompanied by increased activity in the posterior fibers of the temporal muscles. This corrobrates some of Pruzansky's and Geltzer's findings.

The subjects for the study reported herein, were selected on the basis of the severity of their Class II, Division 1 malocclusion or upon the excellence of their occlusion. Models and functional, oral and cephalometric radiographic evaluations were made on each individual. The models of all subjects were examined by five competent orthodontists to ensure correct classification.

Surface electrodes were attached to the main belly of each masseter near the gonial angle of the mandible. Electrodes were also attached to the middle belly of each temporal muscle (Figure 1). These electrodes are attached by means of celloidin and must be held immobile until the celloidin drys to ensure proper positioning.

In recording action potentials from active muscle units a reference point of nearly indifferent electrical activity is necessary. This area must be near the units under study, and of necessity must be upon the individual being studied. Since the lobe of the ear was found to satisfy the above requirements,

Fig. 1.

two earring type electrodes were attached to the subject. Next, the person was placed in a copper screened room and after several preliminary exercises, was given a stick of chewing gum to chew.

The only instruction given was to chew the gum three times on the left side, roll it to the right, and then chew three times upon that side. The subject was also instructed not to swallow during the procedure. When the patient chewed, the electrical activity from the contractions of the masseter and temporal muscles was picked up by the surface electrodes. These electrical potential changes were relayed to the electromyograph for amplification and then recorded by the crystograph. So that the activity of any one muscle can be compared to another at any instant or interval, the pens of the crystograph are all set so they fall on a straight line drawn perpendicular to the margin of the record paper. This practice permits chronological as well as activity comparisons of all of the muscles studied.

Prior to any chewing, the patients' mandible was in the physiological rest position. Rest position in this study and on these records is an area of relative electrical inactivity. (It was not possible to record with surface electrodes any electrical evidence of tonus). A line was drawn perpendicular to the paper's margin and across the entire width of the record through the center of the physiological rest recording. This line then acted as a time base for each muscle unit record and related them all to a common source of reference.

Light pencil markings were made at 5 mm intervals along each of the four record lines. The total penwriter excursions for each 5 mm interval were measured in millimeters and recorded. A graph was then plotted with time the ordinate at 50 millisecond intervals and the amplitude for each 5 mm interval the abscissa. Different colored lines indicated different muscles, and thus through the study of the composite record, time duration, peake amplitudes, latency and other temporal relationships of each chewing stroke could be compared within each subject as well as from one subject to another.

Utilizing the methods just described the following features were noted on the transformed myograms of the normal occlusion subjects:
(Figures 2 to 6)

1. The temporal muscle of the functional or "working" side manifested action potentials before the opposite temporal or masseter.
2. There exists a great deal of synergy of peak amplitudes in all four muscles during function. Thus all muscles on both the working and nonfunctioning, or so called "balancing" sides of the occlusion, displayed maximal contraction at the same or nearly the same instant. This shows an apparent harmony and correlation of muscle activity when there are normal cusp and inclined plane relations.
3. The normal occlusion subjects displayed very little activity in the muscle units studied as the gum was rolled from one side of the mouth to the other. (Perhaps this is an indication of the dominance of the tongue in this function.)

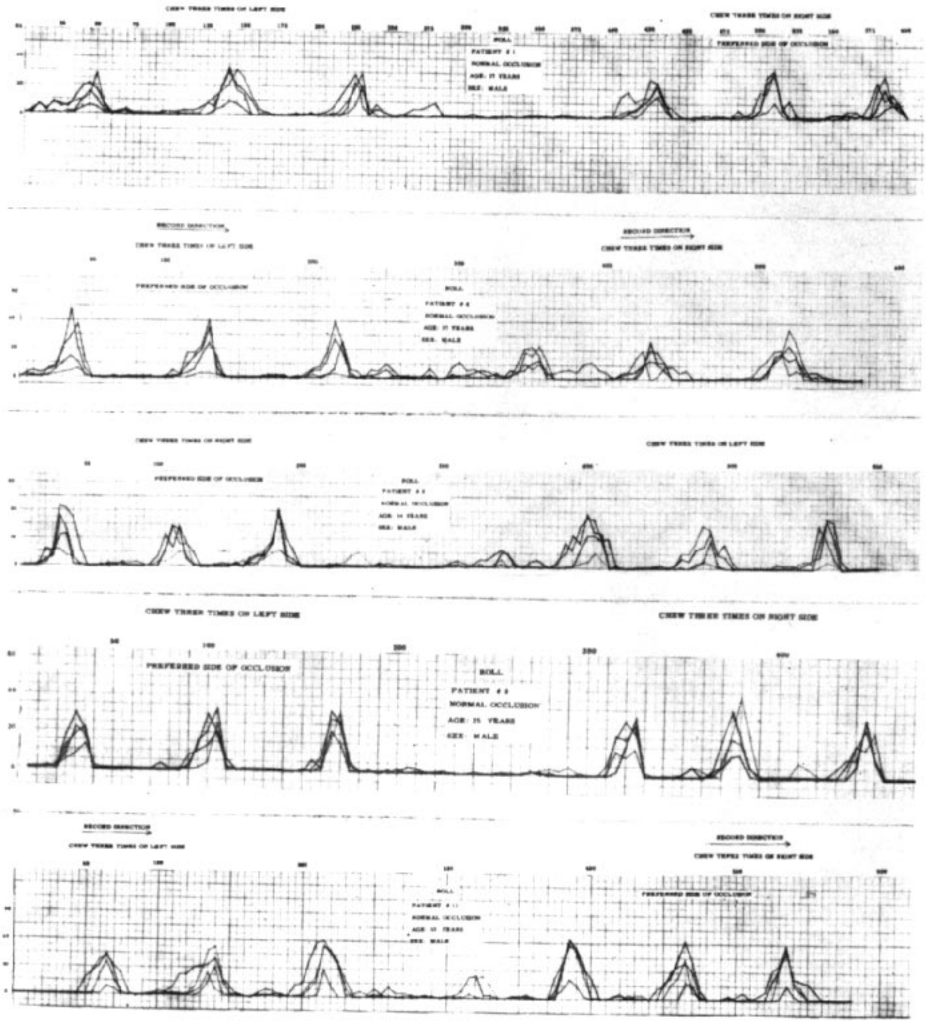
The following features were noted in the transformed myograms of the malocclusion patients: (Figures 7 to 12)

1. There was no single muscle unit which appeared to initiate consistently the chewing cycle in the same patient or within the group.
2. The malocclusion subjects had very little synergy of contracting units. In all patients there was an inconsistent multipilicity of amplitude peaks and a "searching" pattern in the contraction units. This is possibly the result of tooth interferences in closing to the occlusal position.
3. In malocclusion subjects all units acted in some degree in the rolling of gum from one side of the occlusion to the other. Thus it would appear that the mandible is active in shifting the gum from one occlusal segment to another.

It was evident in both the normal and malocclusion cases the greatest synchrony and harmony of the peak amplitudes occurred on the preferred side of the occlusion. The preferred side in this study was indicated by the subject prior to the experiment.

Some of the more significant findings of this particular study were noted in the preceding paragraphs. At this point, a consideration of the possible "How" and "Why" of these differences is attempted.

Sicher[5] has classified the temporal muscle as fast acting because of its physiological and anatomical construction. In the studies of the normal occlusion cases the temporal muscle of the working side was the first muscle to

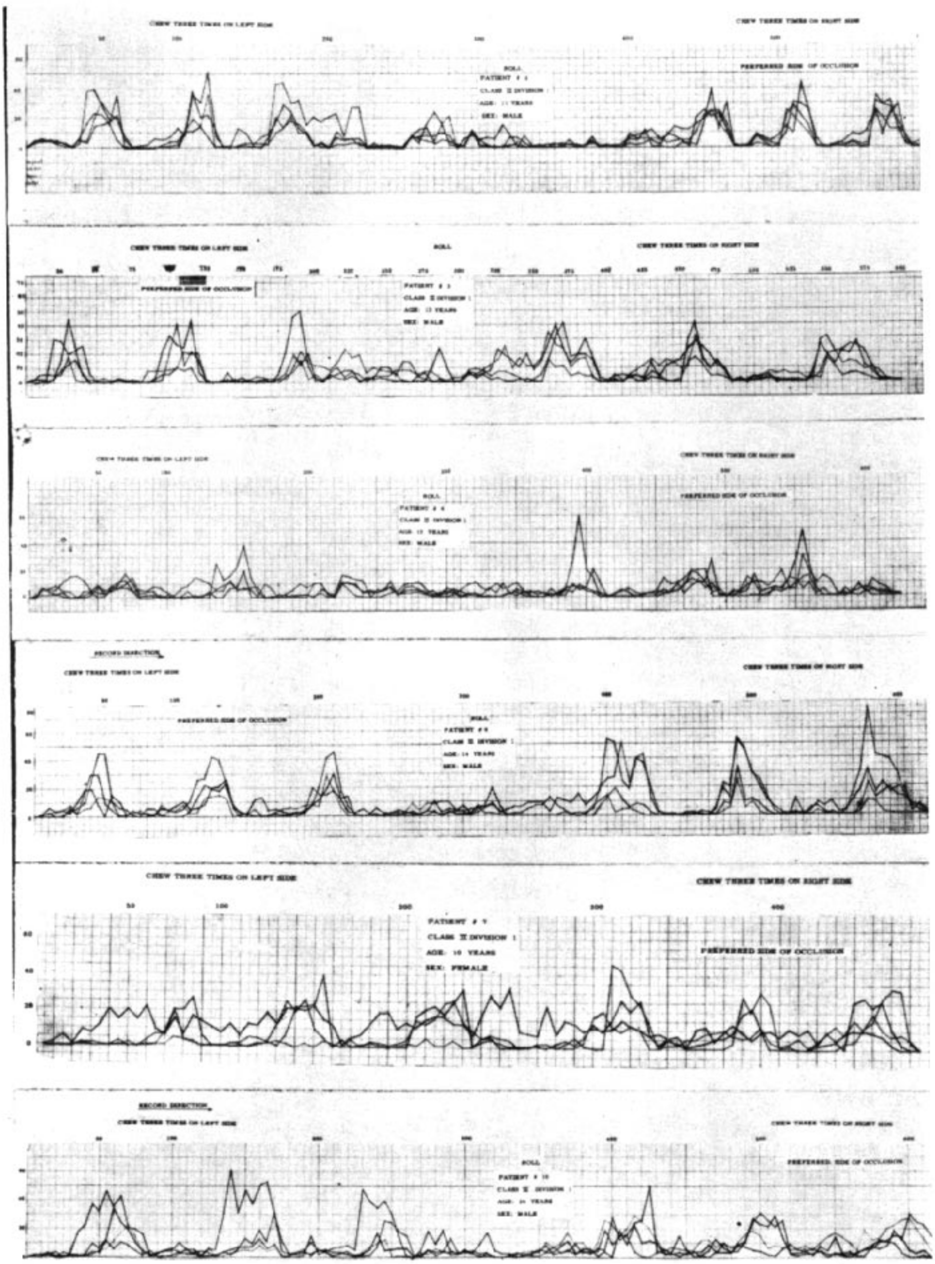


Figs. 2-6.

emit recordable action potentials in mandibular closure from rest to occlusal contact. There was no clear hesitation or demarcation between the occlusal movement and the very slight lateral movement necessary for near end-to-end occlusal contact.

It was difficult to ascertain the extent of the temporal's action in the closure to cuspal contact, but it is apparent that the temporal on the masticating side in the normal occlusion subjects acted prior to the opposite temporal or either masseter. The electromyographic evidence seems to validate the role of this muscle as a fast or initial mover adding functional proof to its physiological appointment. Following the initiatory action of the masticating side temporal, the opposite temporal and two masseters displayed action potentials. There was no evidence of sequential firing by these units.

In the grinding movement the buccal



Figs. 7-12.

inclined planes of the mandibular teeth slide from an end-to-end or near end-to-end contact (depending upon the extent of the oblique gliding movement) on to the lingual inclined planes of the buccal cusps of the maxillary teeth. As the mandible approaches the occlusal position, the muscles are contracting isotonically, and they shorten. With this movement, the electromyogram of the contacting side musculature and the noncontacting side musculature display relatively equal amplitude increases.

The importance of the balancing side musculature in this functional movement, despite the absence of tooth contact on that side,[13] could possibly be a protective force. This would prevent movement of the noncontacting side of the occlusion around a pivot on the masticating side occlusion. The temporal and masseter muscles of the nonoccluding side must necessarily display a contractile force nearly equal in intensity and duration to that of the occluding side. This is the only reasonable mechanism which could prevent undue vertical stresses on the temporomandibular joint of the balancing side.

Sicher[5] has mentioned the spheno-meniscus head of the external ptyergoid as a means of assistance in the balancing of this joint in the horizontal plane. These studies suggest that the vertical fibers or middle belly of the temporal muscle and the masseter muscle have a similar role in protecting the joint on the noncontacting or nonoccluding side of the individual.

As the occlusal position is reached, the amplitude of spike potentials increases. There is an instant when the occlusion is attained that isotonic contraction becomes isometric, i.e. tension without shortening. The occlusal position marks the peak amplitudes of both the working and the balancing side musculature obtained under the conditions of these experiments.

As occlusion was reached in the normal occlusion subjects there was a high degree of synchrony of peak electromyographic amplitudes in the four muscles of all the subjects studied. The greatest synchrony was noted in subjects with low rounded cusp forms and few occlusal fillings. It is interesting to note here that cusp forms of the most synchronous and smoothly developed amplitudes displayed patterns of natural or physiological attrition which may have contributed to the reduced cuspal forms. A contributing factor to the achievement of this synchrony may well be the near perfect occlusal position which allows some balancing occlusion immediately before the centric position is attained. This additional "guiding" by the occlusion of the balancing side could participate in the peak contraction synchrony patterns noted between the balancing and working sides of the occlusion.

In the malocclusion patients studied, there was no evidence of initial activity on the part of the working side temporal in four of the six cases. The two subjects displaying initiatory temporal activity did so only in one or two of six chewing movements. These two subjects showed the same activity in the remaining chews as did the majority of the malocclusion group. The first muscle to give recordable action potentials in the remaining individuals with this type of malocclusion was the masseter instead of the temporal of the masticating side. A suitable explanation of this phenomena is difficult to find. Perhaps the steeper curves of Spee and potential retrognathic mandibles might necessitate a forward thrust of the mandible to obtain a more functional occlusion.

The pattern of the chewing cycle in these subjects does not exhibit the cadence and harmony which is seen in the normal occlusions. The ascension of amplitude of the individual units is not smooth and the relationship of amplitude is not similar. Peak amplitudes have a longer time duration relative to those of the normal occlusion subjects. The individual units approach peak amplitudes in some cases, with a series of plateaus or ragged peaks. This indicates an irregular contraction pattern of the muscle with the relaxations interspersed; wherein the normal occlusions had a continual graded contractile response. The muscles seem to be guiding the mandible in a "searching" effort for a suitable occluding position. Since the Class II Division I subjects of this study were selected for their severe malocclusions cuspal interferences were abundant and seemed likely to be involved.

It appears reasonable, teleologically, to assume that these premature, erratic cuspal contacts initiated irregular neuromuscular reflex interferences in the individuals volitional activity. The proprioceptive nerve endings surrounding the teeth and those in the temporomandibular joint are the sensory components of a reflex arc to the musculature. Their purpose being to grade and control the mandibular movements. Therefore, it may be presumed in these subjects, as the mandible closes from rest to occlusion premature contacts prevent contraction reflexly from increasing (thus the plateaus) or causes a relaxation of the musculature followed by a new contractile attempt to carry it further into occlusal position (the irregular jagged peaks).

The balancing musculature in these patients does not mimic the masticating side musculature as perfectly as it does in the normal occlusions. Some of the true balancing effect of the muscles is lost because of the absence of synergy. It seems likely that with irregular contact on the working side and uncoordinated activity of the balancing musculature the imposed stresses on the temporomandibular articulation could be detrimental. Whether the injurious nature of this asynchrony would invoke its greatest damage under willful control or when the higher centers are at low ebb is not certain. It is apparent that the irregular balancing and working patterns over a period of time could injure the articulation.

In the few malocclusion cases whose contractile amplitudes increased relatively smoothly, the severity of tooth interference was observed to be relatively less than that of the remainder of patients in this group. Sicher[5] has referred to the adaptability of the masticatory mechanism and this may well be an example of achieving efficiency within a limited system. Perhaps part of the neuromuscular system has partially adapted itself to the existing disharmonies and now exhibits some degree of harmonious activity.

It is apparent from this and other unpublished findings that variation and alteration of the natural dentition has an effect upon the functional activity of the stomatognathic musculature system. The practice of dealing with individual components of the stomatognathic system with total disregard of the other components is no longer tenable. There should be no such thing as a analysis of an occlusion without due consideration of that occlusion while in operational movement.

The possibility of individual variation within a normal group is not to be denied but still this variablity will have a range and as demonstrated, the consistency and harmony of synchrony is at its highest level in the near perfect occlusion subjects.

It has been considered but deemed unlikely that the abnormal muscle activity preceded the abnormal anatomical relations observed in the Class II, Division 1 malocclusions studied. Work is now under way in an attempt to prove this. This statement does not mean to imply that abnormal neuromuscular function cannot lead to abnormal anatomical relation; subsequent communications will present some such cases.

In orthodontics one endeavors to alter faulty tooth relations in order to improve the health, function and esthetics of the dentition. Ideal occlusal relationships of the teeth have been the objective. The scope of orthodontics is being enlarged to include the evaluation and treatment of the entire stomatognathic system. The evaluation of muscle function may some day be every bit as important as observing the intercusping of the opposing teeth in occlusion.

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The Angle Orthodontist

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Vol. 25, No. 1 January, 1955