An Electromyographic Study of The Temporal and Masseter Muscles In Cleft Palate Patients with Insufficient Maxillary Development*

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INTRODUCTION

Considerable literature has accumlated which demonstrates that congenital clefts of the hard palate frequently result in retarded or insufficient maxillary growth in all planes of space, i.e. anteroposterior, lateral and vertical. This retardation is markedly increased when certain types of surgical correction are attempted. Mandibular growth, however, is apparently unaffected or only slightly affected by the retardation of maxillary growth, (Case, 1915; Graber, 1940, 1949, 1950; Slaughter and Brodie, 1949; Thompson, 1949). The result is the concave face and the abnormally large interocclusal clearance observed clinically in this group of cleft palate patients. The anteroposterior insufficiency of the maxilla is evident at both the rest and occlusal positions of the mandible. The vertical insufficiency is apparent only when the mandible is carried to an occlusal relation with the maxilla. This gives the patient the typical edentate appearance commonly associated with them.

The accepted treatment for these cleft palate patients has been the construction of a prosthesis to restore the maxilla to its proper anteroposterior, lateral and vertical relationship to the mandible. (Slaughter and Brodie, 1949; Graber, 1949; Thompson, 1949, 1952; Cooper, 1953; Howard, 1952).

With the development of radiographic cephalometric technics and the kinesiological concept of mandibular positioning, considerable progress has been made in determining the proper relationship of the mandible to the maxilla and the production of functionally sound prostheses. (Brodie, 1942; Thompson, 1943, 1946, 1949; Rickets, 1952).

Boos (1940), using an intermaxillary gnathodynometer, demonstrated an optimum relationship of the mandible to maxilla where the mandibular elevators were in a position to deliver a maximal force. Any deviation from this position markedly reduced this force. Boos related this position of maximal force to centric relation. Graber (1949), using a radiographic cephalometric technic, demonstrated that the postural muscular balance of the head and neck region is fundamentally intact in cleft palate patients.

Electromyography has recently been adapted to the study of these problems in neuromuscular balance of the stomatognathic system. (Meyers, 1949, 1950; Pruzansky, 1952; Carlsoo, 1952; MacDougall and Andrew 1953; Geltzer, 1953).

The physiologic unit of muscular action is the motor unit which is composed of a motor cell, its axon process and the group of muscle fibers which it innervates. The ability of a muscle to deliver a maximal contraction is di-

* Thesis submitted in partial fulfillment of the requirements for the master of science in dentistry degree from Northwestern University, Chicago, Illinois.

rectly proportional to the number of motor units capable of contraction at any one time. (Sherrington, 1925) Upon contraction of a muscle fiber a small portion of the energy liberated appears as an electrical discharge or action potential. The registration and evaluation of this action potential can be employed as an index to the number and pattern of motor units contracting. It can also be used to determine the functional integrity of the neuromuscular complex. (Wiggers, 1946; Moyers, 1949; Pruzansky, 1951).

Piper (1907) and Buchanan (1908) were the first to describe the bioelectric phenomena associated with the contraction of voluntary muscle. Adrian and Bronk (1929) were the first to study the frequency response of the individual motor units of voluntary muscle. They could not demonstrate electric activity in a completely relaxed muscle.

Moyers in a series of two papers reported on a technic for recording and analyzing the activity of the muscles of the temporomandibular articulation. In 1949 he concluded from the electromygraphic findings on 16 patients exhibiting Class II Division I malocclusion, that none of the subjects studied showed a normal spike potential. He further concluded that the spike potential is alterable by orthodontic therapy, and that aberrant muscle function patterns can result from malocclusion of the teeth.

In a second paper (1950) Moyers reported on the electromyographic analysis of the normal temporomandibular musculature in various functional movements. On the basis of his electromyographic findings he assigned the functional responsibility of the various components of the mandibular elevators and depressors. He pointed out the interaction of these components to produce a specific movement.

Kendall et al., (1951) reported on the present status of electromyography as a diagnostic tool. They outlined the objectives of electromyography and discussed the advantages of the group approach to the complex problems confronting electromyographers. They reported permanent electromyographic records and also advocated the analysis of peak amplitude responses as a diagnostic criterion as taken from the cathode ray oscilloscope.

Pruzansky (1952) reviewed the principles of electromyography as well as the types of recording equipment in current use. He outlined several areas of promise for electromyography in the dental field and presented preliminary electromyographic findings on several neuromuscular lesions involving the masticatory musculature.

Carlsoo (1952) included electromyographic analysis of the activity of the mandibular elevators in a monograph on the *Nervous Coordination and Mechanical Function of the Mandibular Elevators.* The data was collected on a string oscillograph and camera using concentric needle electrodes. He concluded from his findings that the temporal muscles were the primary muscles used in closing from rest to occlusion and that they appeared to be responsible for maintaining mandibular posture or rest position. He divided the temporal muscle into two functional portions, a ventral (anterior) and dorsal (posterior). The ventral portion was found to be more active in rotational movements and the dorsal portion in lateral movements.

MacDougall and Andrew (1953) in an electromyographic study of the temporal and masseter muscles on a series of twelve subjects found that upon incision the activity centered over the masseter while upon occlusion the activity was more or less equal over the masseter and temporal muscles. They also found that protraction produced considerable action over masseter and that retraction against resistance resulted in activity over the posterior fibers of the temporal muscle. A further finding was the activity produced in the temporal and masseter muscles by extreme mouth opening. They attributed this activity to a protective or splinting action of the muscle to protect the temporomandibular articulation.

Gelzer (1953) outlined an electromyographic technic by which reproducible results might be obtained. The data was collected on an Offner Type A electroencephalograph with crystographic penwriter using surface electrodes. He stressed the need for standardization of technic and the elimination of as many variables as possible. He demonstrated that with the use of reference points to facilitate electrode placement and a carefully controlled procedure, sufficient accuracy might be obtained in tracings to permit serial quantitative evaluation. He demonstrated three functional components of the temporal muscle an anterior, middle and posterior belly.

Statement of the Problem

The purpose of this problem. was (1) to study the neuromuscular response of the temporal and masseter muscles when called upon to carry the mandible from rest to occlusal contact; (2) to compare the normal response through an average interocclusal clearance with the response through the excessive interocclusal clearance exhibited by certain cleft palate patients; (3) to evaluate this response by a comparison of the electromyographic findings in a suitable number of cleft palate patients with an equal number of normal subjects.

Materials and Methods

The electromyographic equipment employed in this study (Fig. 1) was manufactured by Offner Electronics Inc., Chicago, Illinois. The subject was placed within a grounded Faraday cage and was seated in a comfortable straight backed chair with the head oriented to Frankfort horizontal. The electrodes were placed over the anterior portion of the right and left temporal muscles and over the belly of the right and left masseter muscles near their insertion at the angle of the mandible. If necessary a few hairs were removed from the temporal region to improve tissue contact. The immediate area of electrode placement was cleansed with a gauze pad saturated with acetone to remove the fats and fatty acids and to produce a slight erythema which lowered the surface resistance.

Surface electrodes consisting of silver disks with a center hole were used. They were attached to the prepared areas by a thin film of celloidin. Bentonite paste was applied through the central opening of the electrode using a syringe with a blunt 18 guage needle. (Fig. 2)

The subjects tested included five cases from the Northwestern University Cleft Lip and Palate Institute who were wearing complete maxillary prostheses over their remaining natural teeth to compensate for the large interocclusal clearance present, and five subjects who were judged to fall within the normal range as to interocclusal clearance and occlusal relationship by three qualified observers other than the author. The interocclusal clearance was recorded as the difference in the nasion-gnathion measurement taken at rest position and at occlusal position. These measurements were taken from radiographic cephalometric tracings. The normal series included rest position and occlusal position. The cleft series included rest position, occlusal position established by the maxillary prosthesis and occlusal position without the maxillary prothesis.

Two experiments were designed to

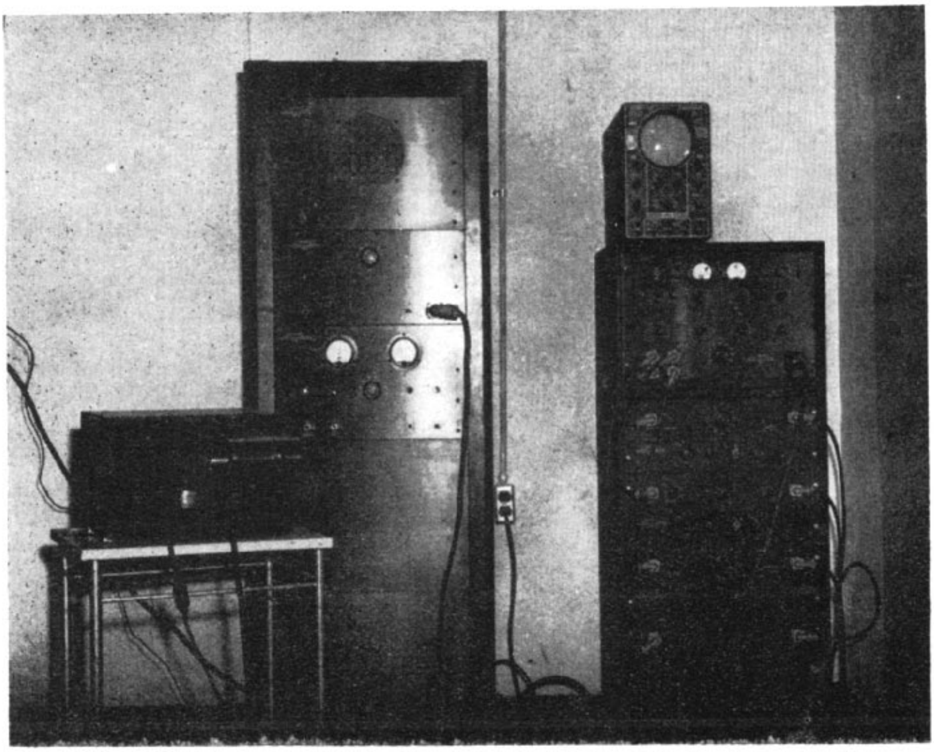


Fig. 1. Equipment used to amplify and record the action potentials.

compare the normal neuromuscular response of the temporal and masseter muscles with that of the cleft palate cases. The first experiment consisted of recording the action potential when the temporal and masseter muscles were called to carry the mandible from rest position to occlusal contact. This experiment was designed to test the assumption that the mandibular elevators are not mechanically or physiologically adapted to carry the mandible through an excessive interocclusal clearance. (Boos 1940)

Electromyographic tracings were made when the patient closed from rest to light occlusal contact. Each experiment on the cleft palate series was repeated with and without the prosthesis.

The second experiment consisted of

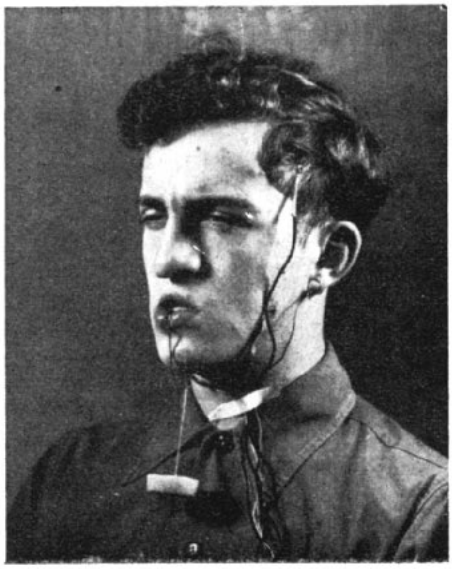


Fig. 2. Cleft subject showing electrode placement and position of weight hanger.

suspending weights (1.0, 2.0, 3.0 Kgs.) from the lower six anterior teeth by a bent suspension hook so that the weight fell under the chin. This was to enable the recording of action potentials produced during the isometric contraction of the temporal and masseter muscles at rest position. (Carlsoo 1952)

The recordings were made at paper speeds of 2.5 cm./sec. and at 10.0 cm.-/sec. The slower speeds were utilized in visual and amplitude determinations. The 10 cm./sec. speed was used in analyzing the frequency responses.

Preliminary records revealed a nonlinearity to the amplitude response of the crystograph through the working range of the experiment. This necessitated having each channel calibrated against known amplitudes of the Offner Electronic Corporation to accurately determine the response of each channel throughout its working range.

At the beginning and end of each recording all four channels were again calibrated against a known imput of 100 microvolts.

The amplitudes obtained were small and extremely variable throughout a single recording spindle. This made direct measurement difficult and injected a major source of error. With measurement technics accurate to plus or minus .5 millimeters and an amplitude range of one to five milimeters there could be as much as 50 percent error in measurement. All amplitude studies were, therefore, completed using a gravimetric technic.

Representative areas of each recording spindle were obtained by finding the center of each spindle and taking .5 millimeters on each side. (Fig. 3) This area was then enlarged five times with a photo enlarger and projected onto 28 gauge casting wax. (Fig. 4) The outline was cut out in the wax with a sharp pointed stylus. The wax was then weighed on a torsion balance.

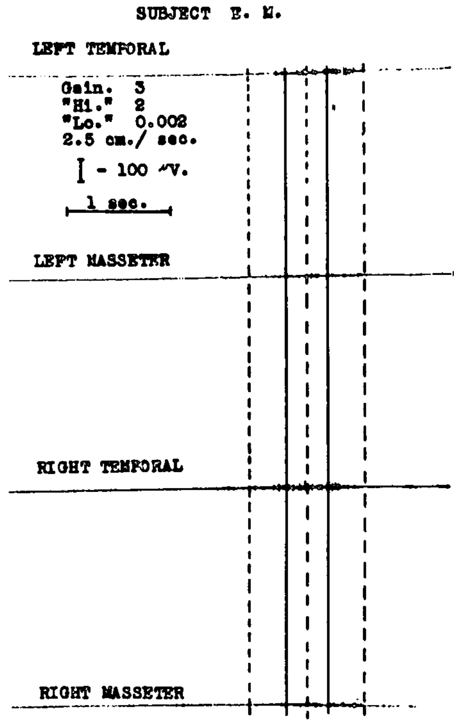


Fig. 3. Myogram showing method used in locating area for amplitude studies. The two extreme dotted lines indicate the limits of the recording spindles. The middle dotted line indicates the center of the spindles. The solid lines indicate the area used for the amplitude study; they are one-half centimeter on either side of the center line.

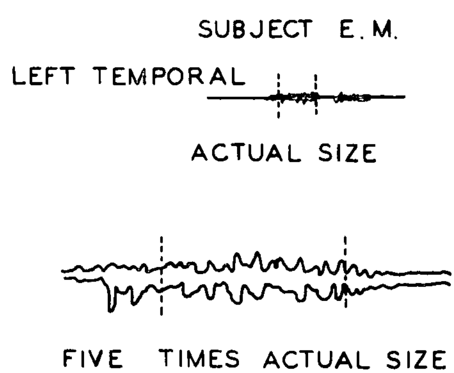


Fig. 4. Illustrations of the magnification used in obtaining 28 gauge wax cutouts for use in the gravimetric technique employed in the amplitude determinations.

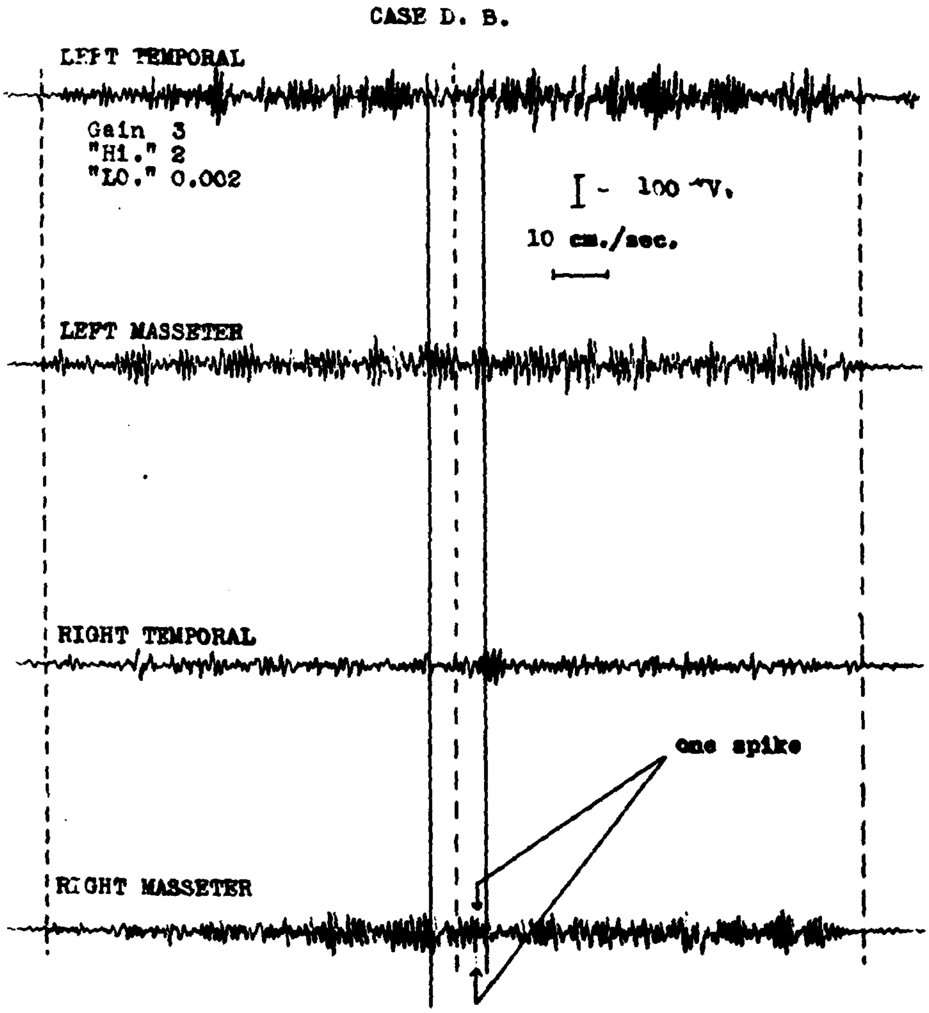


Fig. 5. Myogram showing method used in locating area for frequency studies. The two extreme dotted lines indicate the limits of the recording spindles. The middle dotted lines indicates the center of the spindles. The solid lines are one-half centimeter either side of the center line and indicate the area used in the frequency study.

The net weight was obtained by subtracting the zero or resting recording from each of the subsequent recordings on each channel. The calibration recordings were treated in a like manner and the resultant net weights were plotted graphically by the method described above.

The limits of this method were established by running a series of 10 tracings of the same calibration recording and establishing a range of 463.7 to 474.3 milligrams, a mean of 468.5 and a standard deviation of 2.9 milligrams.

Frequency determinations were made by counting the spikes in a .10 sec. section taken from the center of the registration spindle on the 10 cm./sec. tracings. (Fig. 5)

Discussion

The limits of reliability of equipment and technics of the type used in this study have been established (Moyers, 1949, 1950; Pruzansky, 1952; Geltzer, 1953). They preclude the use of this equipment in the determination of any discrete or subtle changes in wave form, frequency or amplitude. An attempt has been made to analyze the data collected in accord with the above concept.

The term pattern has been advanced by electromyographers as descriptive of the recorded action potential and is composed of the following components: wave form, sequence, duration, frequency and amplitude. The crystographic penwriter type of recorder is not adapted to a study of wave form. The experiment design did not include a provision for the study of duration. The sequence of response was variable and so slight as not to be measurable with the recording equipment used. The frequency and amplitude components are, however, isolable and measurable with this equipment. The term pattern will, therefore, for the purpose of this study be limited to the components of frequency and amplitude.

The validity of any conclusion drawn from such data is dependent upon its agreement with established anatomical and physiological concepts. To illustrate, the presence of an action potential spike or spindle indicates only that the muscle fibers in the area of the electrode are contracting. It does not of itself indicate the muscle action occurring, the direction in which it occurs or the force of that contraction. To ignore this concept can only lead to speculation and fallacious conclusions.

A breakdown of the normal amplitude response of the temporal and masseter muscles (Table I) reveals that a greater action potential is elicited

TABLE I

Closure Data — Normal Series

Subject:	*Diff.*	*Uv.Temp.*	*Uv.Mass.*	*Uv.Total (mean)*
H. G.	2.0	7.3	0.8	4.0
H. P.	2.5	7.3	2.8	3.9
M. D.	1.5	8.0	5.3	6.8
E. M.	2.0	4.5	0.8	2.6
E. Z.	1.5	5.0	0.5	2.8
TOTAL:	9.5	32.1	10.2	20.1
MEAN:	1.9	6.4	2.0	4.0

LEGEND

DIFF. — Interocclusal Clearance
Uv. TEMP. — Mean Action Potential of Right and left Temporal
Uv. MASS. — Mean Action Potential of Right and Left Masseter
Uv. TOTAL — Mean Action Potential of Right and Left Temporals and Masseters.

Table I presents the breakdown of the mean action potentials of normal subjects elicited from the temporal and masseter muscles in simple closure from rest to occlusion. Column two is the mean temporal response, column three is the mean masseter response and column four is the mean total response for each subject. The mean total response of 6.4 micro-volts for the temporal muscles is considered here to be significantly greater than the 2.0 mean total response for the masseter muscles.

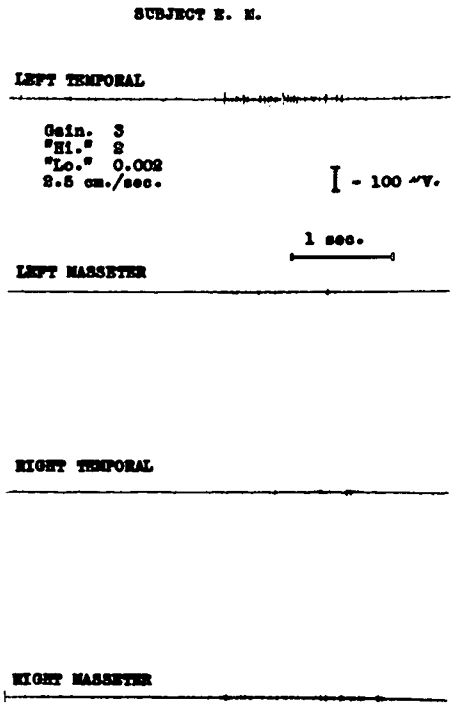


Fig. 6. Representative myogram of normal subject closing from rest to occlusion at 2.5 cm./sec.

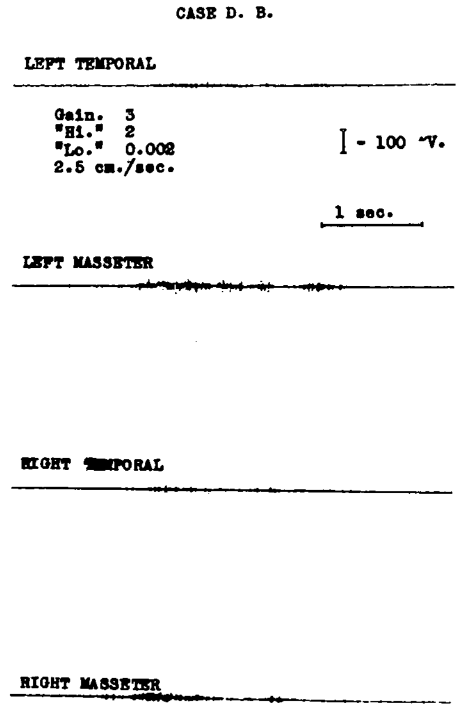


Fig. 7. Representative myogram of cleft palate subject closing from rest to occlusion with maxillary prosthesis at 2.5 cm./sec.

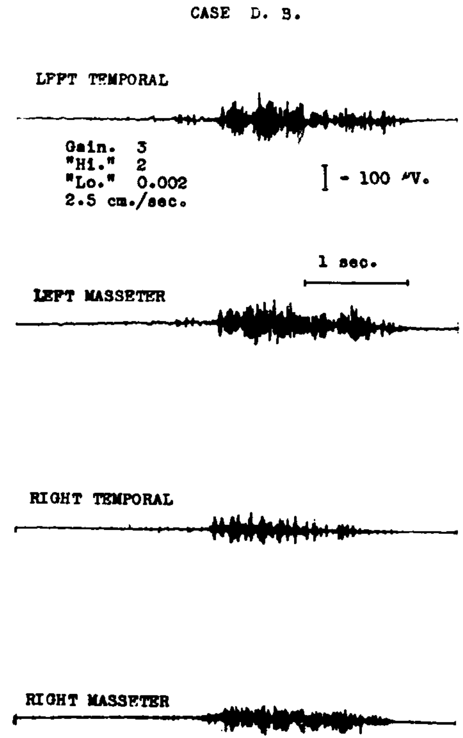


Fig. 8. Myogram of cleft palate subject closing from rest to occlusion without maxillary prothesis at 2.5 cm./sec.

from the temporal muscles (6.3 microvolts) than from the masseter muscles (2.0 microvolts) in the closing movement. The normal group had a mean interocclusal clearance of 1.9 millimeters with a mean amplitude response of 4 microvolts. The small action potential would indicate that very little energy is necessary to carry the mandible to normal occlusal relation with the maxilla. (Fig. 6)

A similar breakdown of the cleft amplitude response of the temporal and masseter muscles shows (Table II, Fig. 7-8) the greater temporal response in both series, i.e., with and without maxillary prosthesis. In the series without maxillary prosthesis, however, there is an apparent greater proportional participation on the part of the masseter muscles. The first series, with prosthesis, had a mean interocclusal clearance of 6.6 millimeters with a mean amplitude response of 9.0 microvolts. The second series, without prosthesis, had a mean interocclusal clearance of 16.6 millimeters with a mean amplitude response of 63.7. Grossly this would indicate a geometric relationship between the response and the interocclusal clearance, i.e., with an increase in interocclusal clearance there is a geometric increase

TABLE II

CLOSURE DATA — CLEFT SERIES

Subject:	*Diff.*	*Uv.T.*	*Uv.M.*	*Uv.Mean.*	*Diff.²*	*Uv.T.²*	*Uv.M.²*	*Uv.Mean²*
D. B.	2.0	6.3	0.0	3.1	10.0	101.8	54.8	78.2
W. S.	8.0	6.0	1.0	3.5	25.0	129.5	33.0	76.2
R. F.	3.0	10.3	2.8	6.5	9.0	75.3	7.3	41.3
J. B.	13.0	10.8	4.5	7.6	25.0	67.5	64.0	65.8
D. S.	7.0	17.8	13.3	15.5	14.0	67.8	46.5	57.1
TOTAL:	33.0	51.2	21.6	36.2	83.0	441.9	205.6	318.6
MEAN:	6.6	10.2	4.4	7.3	16.6	88.4	41.6	63.7

LEGEND:

DIFF. — Interocclusal Clearance with Prothesis
Uv.T. — Mean Action Potential of Right and Left Temporals with Prothesis
Uv.M. — Mean Action Potential of Right and Left Masseters with Prothesis
DIFF.² — Interocclusal Clearance without Prothesis
Uv.T.² — Mean Action Potential of Right and Left Temporals without Prothesis
Uv.M.² — Mean Action Potential of Right and Left Masseters without Prothesis
Uv.MEAN² — Mean Action Potential of Right and Left Temporals and Masseters without Prothesis

Table II presents a breakdown of the mean action potentials of cleft subjects elicited from the temporal and masseter muscles in closure from rest to occlusion while wearing a maxillary prosthesis and without the maxillary prothesis. Column two is the mean temporal response, column three is the mean masseter response and column four is the mean total response for each subject while wearing the prosthesis. This series is comparable to the normal series in both magnitude and in proportionality between temporal and masseter response.

Column six is the mean temporal response, column seven is the mean masseter response and column eight is the mean total response for each subject without maxillary prothesis. This series is greatly different from either the normal series or the cleft series with prosthesis in both magnitude and proportionality between the temporal and masseter components. This increase is interpreted to indicate the greater muscular action necessary to close through the greater distance.

in the amplitude response. To adequately test this hypothesis it would be necessary to design an experiment to test each subject at millimeter intervals through the full range of their interocclusal clearance. This was not within the scope of this study. There is adequate evidence, however, to support the hypothesis that as the interocclusal clearance approaches normal limits the amplitude response approaches the normal range.

Analysis of the pattern of frequency response of the temporal and masseter muscles when subjected to an increasing mandibular load of one to three kilograms reveals a slight rise in frequency occurring with the increase in weight. There was a 2.5 spikes/sec. rise in cleft palate subjects and a 1.2 spikes/sec. rise in normal subjects. This increase is not of sufficient magnitude to be statistically significant considering the large individual variations, the size of the sample and the recording equipment used. (Figs. 9, 10, 11 above).

Amplitude response to mandibular loading was plotted on semi-logarithmic graph paper with the ordinate logarithmic and the abscissa arithemetric. A steep rise to the regression lines indicates a greater proportional change

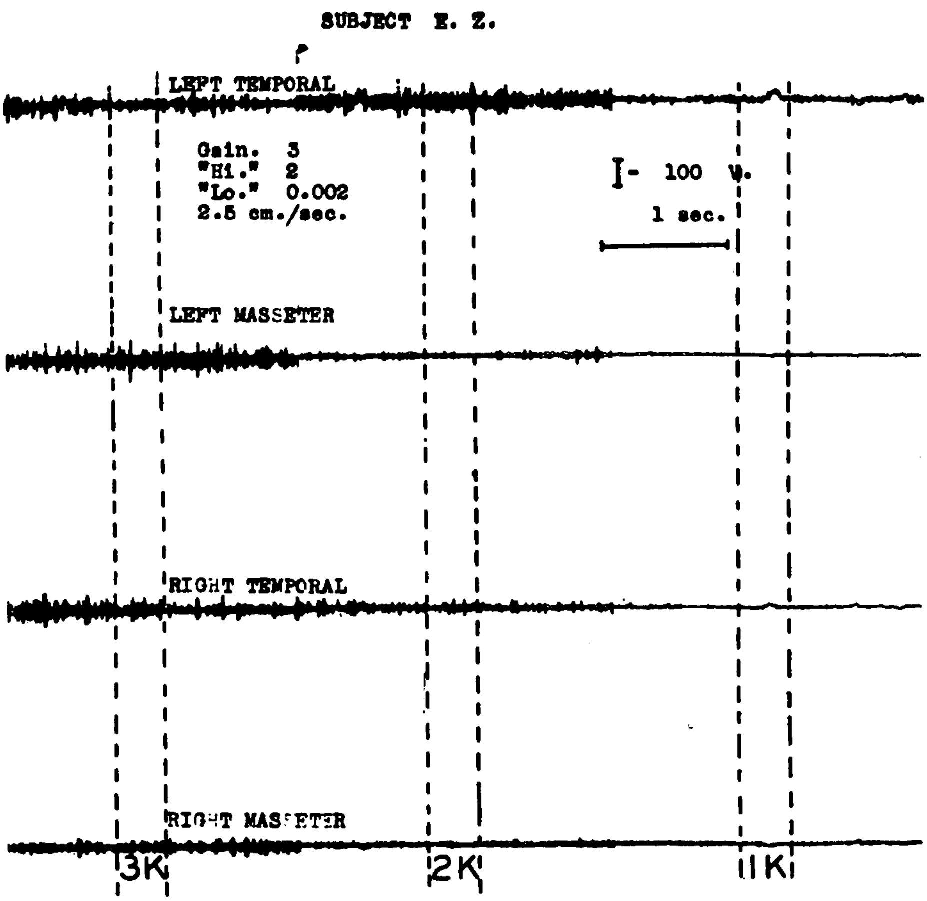


Fig. 9. Composite myogram of normal subject with successive mandibular loading of one, two, and three kilograms.

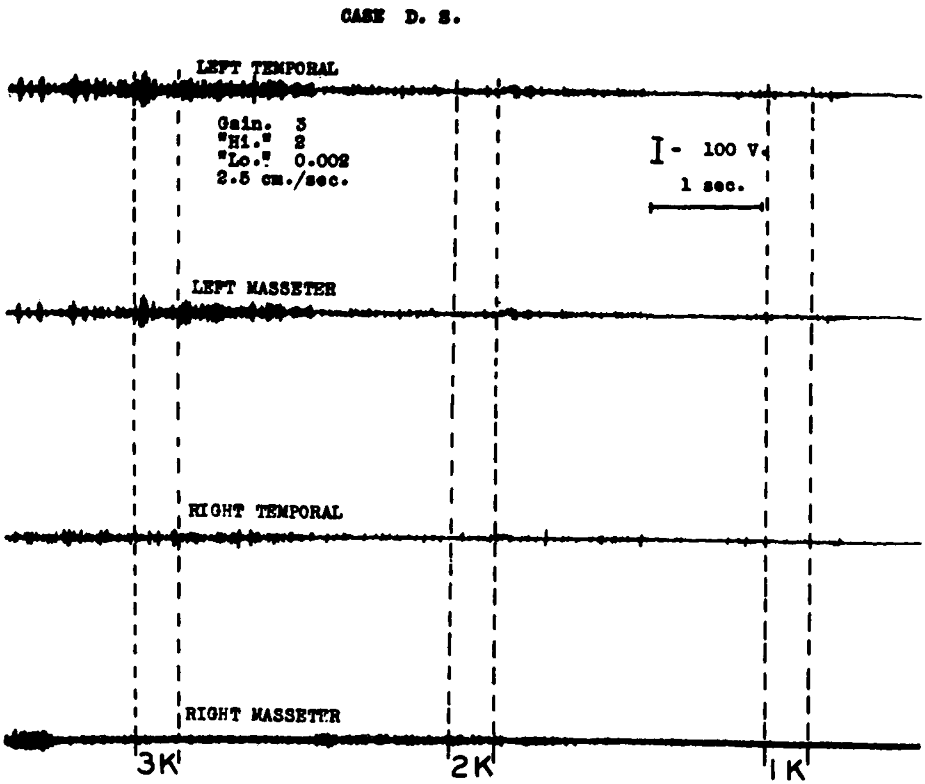


Fig. 10. Composite myogram of cleft palate subject with successive mandibular loading of one, two, and three kilograms.

in amplitude response with an increase in load than was noted in the frequency pattern study. (Fig. 11, below).

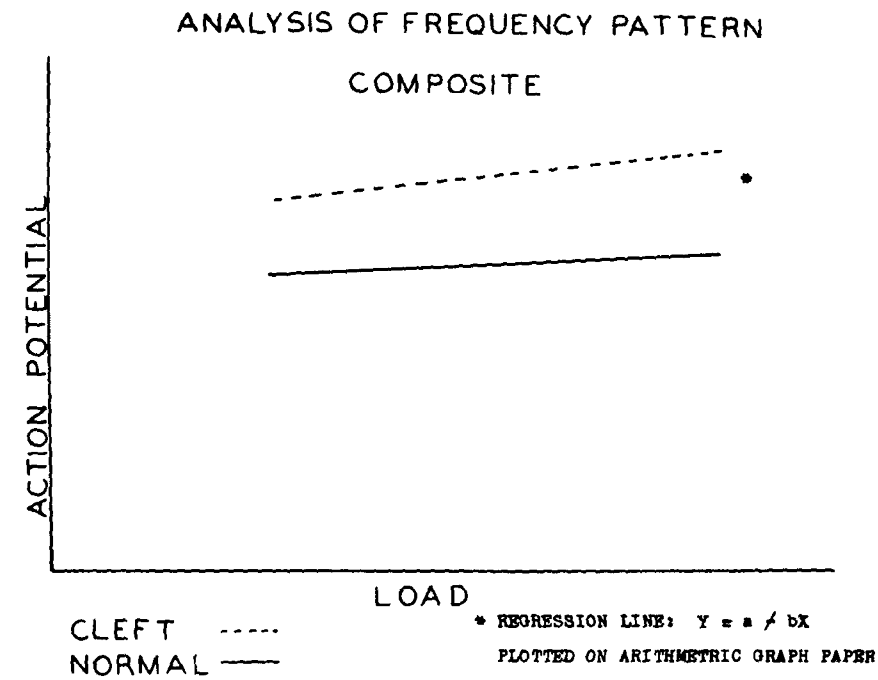
The compatibility of the data to a semi-logarthmic analysis would indicate that the amplitude response of the temporal and masseter muscles bears a logarithmic relationship to the increase in mandibular loading.

The parallelism of the two regression lines and the fact that they fall within one standard error indicates there is no significant difference between the response of the normal group and the cleft palate group. This electromyographic finding is a confirmation of the kinesological concept that the postural muscular complex of the head and neck is essentially normal in this type of cleft palate patient.

An electromyographic study of the neuromuscular response in the temporal and masseter muscles was presented of five subjects with normal interocclusal clearance and of five palate subjects with large interocclusal clearance. The data collected was analyzed for amplitude and frequency: and these findings in the two groups were compared graphically.

The following conclusions were drawn from the observation of the amplitude and frequency response:

1. The temporal muscles are primarily responsible for the closing movement of the mandible under circum-


ANALYSIS OF FREQUENCY PATTERN
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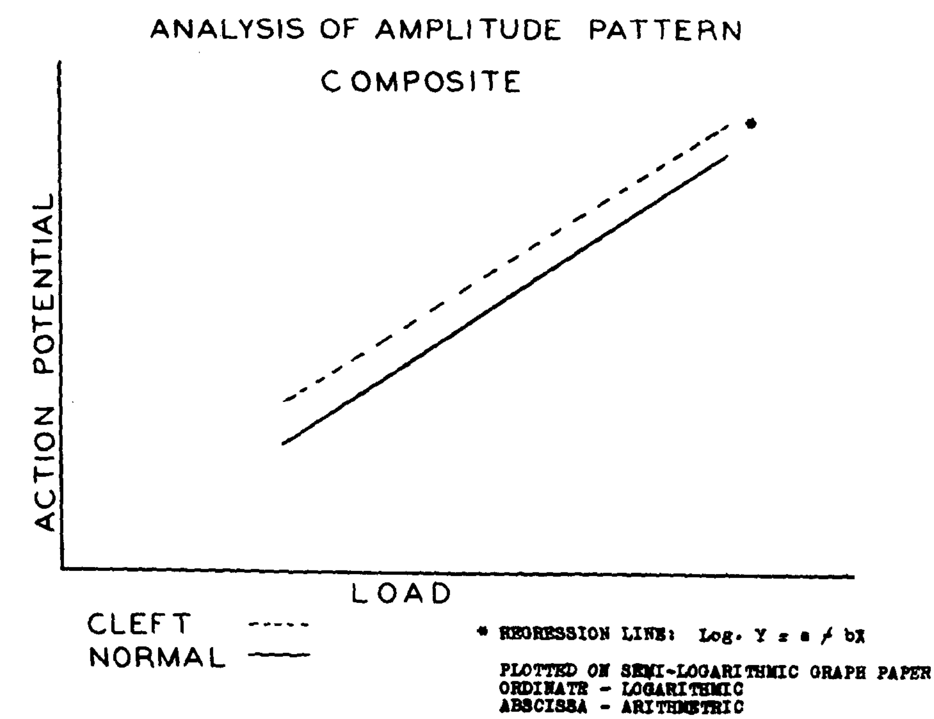
ANALYSIS OF AMPLITUDE PATTERN
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ACTION POTENTIAL
LOAD
CLEFT -----
NORMAL ——
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stances of normal occlusal contact.

2. With an increase in interocclusal clearance there is a marked increase in action potential elicited from the temporal and masseter muscles upon closure to occlusal contact.

3. There is a greater proportional participation on the part of the masseter muscles in mandibular closure to occlusal contact if there is a large interocclusal clearance.

4. Restoration of the natural occlusal level (normal interocclusal clearance) restores the amplitude response of the temporal and masseter muscles to the normal range.

5. Amplitude and not frequency is the important factor to be measured using electromyographic equipment manufactured by Offner Electronics Inc. with a crystographic penwriter and exploring the range of muscle contraction here studied.

6. The similarity of the bioelectric response of the temporal and masseter muscles in both groups of subjects against mandibular loading suggests that the postural function of these muscles in this type of cleft palate subject is within normal limits.

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ACKNOWLEDGEMENTS

The author wishes to thank Dr. John R. Thompson, Dr. Stanley C. Harris, and Dr. Harry Sicher for their direction and counsel. The author also wishes to thank the American College of Dentists, Marquette University and the Northwestern University Cleft Lip and Palate Institute for their material assistance and encouragement in this project.

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Fig. 11, above. Graph showing the increase in frequency trend of action potentials from temporal and masseter muscles when subjected to an increase in weight from one to three kilgrams. The increase is slight and individual variations great which rules out frequency as an index to action potential in this study.

Fig. 11, below. Graph showing the increase in amplitude of the action potential response from temporal and masseter muscles when subjected to an increase in weight from one to three kilograms. The increase is large and the regression lines fall within one standard deviation. This indicates that amplitude is a valid measure of action potential in this study.

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