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Masseter Muscle Position Relative to Skeletal Open Bite and Skeletal Closed Bite

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MASSETER MUSCLE POSITION RELATIVE TO SKELETAL OPEN BITE AND SKELETAL CLOSED BITE

by

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A Thesis in Partial Fulfillment

of the Requirements for the Degree

Master of Science in the Field of Orthodontics

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I certify that I have read this thesis and recommend that it be accepted as fulfilling this part of the requirements for the degree of Master of Science in the field of Orthodontics.

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CHAPTER I

INTRODUCTION

Facial balance is a very important factor to the orthodontist, because of the relationship between dental occlusion and facial appearance. Extensive research dealing with the stomatognathic system and its direct relationship to facial appearance has been reported in the literature.

With the advent of roentgenographic cephalometry, Broadbent (1931), the dentofacial complex has been subject to extensive evaluation and re-evaluation. Careful study of the relationship of many structures of this system has shown the importance of the standard cephalometric technique at both the research and clinical levels. These studies have been beneficial in the establishment of norms and have pointed out the extreme variation in facial types in both horizontal and vertical proportions.

Among the most difficult patients to treat satisfactorily are those presenting open bite and closed bite characteristics viz., extremely high and low mandibular plane angles. Although advances in diagnosis and treatment procedures have been made, skeletal open bite and closed bite still present perplexing problems.

A thorough evaluation of the stomatognathic system and its influence on facial form must include all of the dynamic facets which make up the system. Orthodontists are aware of the delicate balance between the neuromuscular and dentoskeletal systems and the contributing influence of the genetic and environmental factors. With the close interaction of these factors, a malfunction of any one may upset the normal balance of the entire system.

Considerable research has been completed to test the hypothesis that form and structure of bone are partially influenced by soft tissue. Studies by Washburn (1947), Horowitz and Shapiro (1955), and Avis (1961), give evidence, although questionable according to research by Boyd, Castelli and Huelke (1967), to support this hypothesis. Sassouni (1962, 1964) has proposed that a relationship exists between facial proportions and anatomic variations in muscular components. Eschler (1961) and Van Zile (personal correspondence, 1968) report clinical findings, which are subjective, that support this hypothesis. With the aid of a modified roentgenographic cephalometric procedure, Petersen (1966) found a difference in the position of the anterior border of the masseter muscle when comparing Class I and Class II subjects (Angle Classification). Comparison, of the masseter muscle position, between subjects exhibiting extreme differences in skeletal patterns would be a more meaningful evaluation.

The purpose of this investigation is to determine if there is a difference in spacial relationship of the masseter muscle (superficial portion) between extreme skeletal open bite and skeletal closed bite facial patterns. This investigation is limited to a study of the masseter muscle in the vertical and anterior-posterior dimensions of space.

CHAPTER II

LITERATURE REVIEW

It has been proposed that the form of certain parts of the skeleton is dependent, to some degree, on the developmental and functional relationship of the neuromuscular system.

Developmental Considerations

According to Arey (1948) bone is formed embryologically later than muscle, and the temporomandibular and facial musculature is well defined by the time ossification of facial and cranial bones begins. Scott (1954) observed that developing muscles at first are "independent" of the skeletal elements to which they later gain attachment. Observations by Dahan (1965) were in agreement with this. Stewart (1951) stated that pathological conditions such as clubfoot may be due to developing muscles having abnormal attachment to the skeleton, thus have a deforming action. Bechtol (1950) proposed a different concept when he stated that clubfoot is a result of (1) muscle imbalance due to unequal maturation of opposing muscle groups, and (2) retained fetal position as a result of insufficient total muscle volume. Clinical and microscopic reports by Middleton (1934) linked prenatal lesions of striated muscle with various congenital deformities. He felt the findings were the result of either (1) embryonic interruption of muscle fiber differentiation or (2) fatty degeneration of muscles during intrauterine life.

Moss (1962) used the term "functional matrix" to include all of the soft tissue related functionally to a given skeletal part. He proposed the theory that the initiation of bone form is due to inherent genetic potential, but further morphological differentiation and maintenance is due to the influence of the "functional matrix."

Scott (1954, 1957) gave evidence to support the hypothesis of a developmental and functional relationship between soft tissue and bone. He stated that the degree of development of the muscular and dental elements could modify the form of the skull through certain structural changes such as sagittal crests, size of mandibular ramus and pterygoid plates, etc. These bony changes would, therefore, modify the development of the skeletal buttress system of the face. Scott did not propose that the development of muscles determined the total form of bony elements, but rather modified them. Moss's "functional matrix" theory is supported by Scott's following statement:

> Quite independently of muscle function and development, the growth of the cartilage of the cranial base, mandibular condyle, and nasal septum play an important part in contributing to the development and form of the skull.

Scott further contended that growth of muscle is regulated by nerve reflexes developing in conjunction with the dentition, and in this way specialized muscle actions found in different animals are related to their specialized dentition and skeletal structure.

Functional Considerations

Other investigations attempting to show a correlation between function and form of the stomatognathic system have been undertaken in various ways. Friel (1926) published results showing a correlation between maximum biting force and sitting height, measured by a gnathodynomometer inserted between the first permanent molars. The results gave an indication of a correlation between form and function. In correlating maximum biting force with the steepness of the mandibular plane angle, White (1967) found indications of a negative correlation.

In the literature there have been many electromyographic studies reported correlating bony form and electrical activity of certain masticatory muscles. Some investigators have found a difference in muscular activity when comparing subjects presenting different skeletal patterns (Moyers 1949, Perry 1955, Liebman 1966). Carlsoo (1952) attempted to divide the mandibular elevators into their component parts and to investigate the interrelationship of these components during different mandibular movements. The muscular activity of these different muscle parts, as recorded electromyographically, was correlated with their mechanical action, as determined by comprehensive anatomical analysis. He concluded that certain distinguishing innervation patterns occur during different movements and show close agreement between activity of muscle components and their mechanical qualifications. He also indicated that "the distribution of the muscular activity among portions with synergistic action, however, is not in direct relation to their relative mechanical potentialities." This indicated that the distribution of muscular activity could not be deduced from a knowledge of mechanical qualifications alone.

Carlsoo felt that the innervation pattern seemed to be intimately related to the "bite type." Moller (1966) found a difference in muscular activity when comparing cases of different cranial base form. In cases with a smaller cranial base angle there was stronger activity of the masseter muscle, also with the anterior and posterior portions of the temporal muscle, during swallowing. Masseter muscle action during swallowing was also directly correlated to facial prognathism. He found a small gonial angle and prognathic jaw associated with strong activity of the masseter muscle during maximum biting.

As might be expected, there is not complete agreement on the correlation between soft tissue and skeletal elements. Research reported by Lancet (1927), Winders (1958), Ahlgren (1966) and others found negligible difference in muscular activity between subjects with normal and those with abnormal occlusion.

Surgical intervention has been another tool used to investigate the functional relationship between muscle and bone. Various investigators have removed muscles of mastication, or their bony attachments, and investigated the effects on related skeletal parts. Studies by Washburn (1947), Horowitz and Shapiro (1955) and Avis (1961) indicated that bony changes did take place on experimental rats when the alterations were performed.

Boyd, Castelli and Huelke (1967) removed the temporalis muscle from its origin without disrupting its blood supply and after 80 days found no demonstrable change in the coronoid process of the mandible. This opened the question of the importance of the blood supply to the bony part which in former studies had been destroyed.

Nanda et al (1967) reported that masseter muscle repositioning in dogs resulted in bony changes of portions of the mandible.

Van Zile (1963) in his surgical approach to reducing mandibular prognathism, reattached the masseter muscle farther forward on the mandible and detached that portion of the medial pterygoid muscle which inserted on the posterior border of the ramus. He felt this muscle alteration was the reason for the satisfactory and consistent results, without evidence of relapse, in his surgical procedures (personal correspondence 1968).

It was believed by Eschler (1961) that mandibular retraction was caused by defective development of muscles having protractive components of force. This clinical manifestation (retrognathia) is grossly apparent in cases exhibiting Pierre-Robin syndrome. In these individuals the mandible is located in such a retruded position that air and food passages are severely impaired. Upon the supposition that the protracting (oblique) component of the masseter muscle was hypoplastic or incompletely formed, Eschler repositioned the remaining (vertical) portion. His method of operation involved detaching the insertion of the deep portion of the masseter muscle and transplanting it from the horizontal body to the vertical ramus. In this manner he obtained a more protracting action, with the muscle thus relieving the "choking" effect of the severely retruded mandible. In Eschler's words,

> Children who have been fed by means of a permanent tube for months are enabled to feed normally three weeks after this operation without any further treatment.

An interesting observation is the fact that during the surgical procedure, he removed the stylomandibular ligament which appeared to be hypertrophic.

Anatomical Considerations

The masseter muscle is composed of two portions, a large superficial and a smaller deep portion (Sicher 1965). The superficial part arises from the anterior two-thirds of the lower border of the zygomatic bone and may extend forward to include the zygomatic process of the maxilla. Its fibers pass downward and backward to insert onto the angle and lower half of the lateral surface of the ramus and as far forward as the lower second molar. The deep portion, divided into two parts by some anatomists (Davis and Davies 1962, Last 1963), can be separated only in the posterior part. It takes its origin from the entire length of the deep surface of the zygomatic arch and the posterior one-third of the lower border. The fibers of the deep part lie vertically, the anterior fibers fusing with the superficial portion. Immediately in front of the temporomandibular joint capsule, the posterior portion is seen as a triangular area, not being covered by the superficial part. Insertion of the deep masseter is to the upper part of the ramus as well as to the coronoid process, according to some authors.

The deep part is inseparably fused with the most superficial fibers of the temporalis muscle and is given a separate name "zygomatico-mandibular" by some men. Sicher (1965) stated that in individuals presenting a very strong muscle mass, the area of insertion is widened and may show a bundle of fibers extending anteriorly along the lower border of the mandible. The posterior fibers may end behind the posterior border of the ramus, joining the medial pterygoid in a tendinous raphe.

The superficial masseter is formed by alternate tendon and muscle bundles (Sicher), giving the effect of shorter but larger contractile elements. This arrangement is considered a bipinate formation of muscle fibers and would enlarge the functional cross section of the muscle, making it a very powerful muscle. Muscle fibers arranged in long parallel fibers in the long axis are believed to be "fast movers" whereas the multipinate muscles are considered "power" muscles. The action of the masseter muscle is therefore that of a powerful elevator of the mandible, and because of its location is capable of exerting pressure on the molar teeth. According to Carlsoo (1952) and Schumacher (1961), 25 - 30 percent of the force produced by the muscle during closure may be exerted to protrude the mandible. Carlsoo (1952) and Sicher (1965) assumed that the deep portion of the muscle acts as a retractor of the mandible.

Work by Eschler (1961, 1962) and others point out the variability that may be seen when assessing muscle position in extreme skeletal patterns. He suggested that one reason for mandibular prognathism may be due to the abnormal insertion of the superficial (oblique) portion of the masseter. In these cases the insertion is placed higher on the vertical ramus than is normal, thus giving a marked protracting component of action.

Van Zile (correspondence 1968) made this same observation in over 85 prognathic cases which he reduced by ostectomy of the vertical rami. Frischfield (1927) projected the same idea when he indicated the muscle to be narrow and inserted higher on the ramus in "mesiobite" (prognathic) cases as compared to "deep bite" cases. He indicated the muscle is wider, runs more vertically and inserts farther forward in deep bite cases.

Petersen (1966) indicated that he found a more anteriorly inclined muscle in Class II (Angle) subjects when compared to Class I subjects.

Sassouni (1962) has hypothesized an archial concept of facial types with a corresponding archial design of facial musculature. He purported the facial musculature be divided into an anterior and posterior vertical chain, the anterior being composed of the mimetic muscles, orbicularis oris, supramental and suprahyoid muscles. The incisor teeth correspond to this chain of muscles. The posterior chain of muscles, being the stronger group, include the masseter, medial pterygoid and temporalis with the molar teeth corresponding to this chain. It was hypothesized that the posterior chain of muscles exerts a different directional force in skeletal open bite than it does in skeletal closed bite. In open bite the muscles of mastication exert an oblique force, relative to the molars, creating a mesial component of force having the effect of squeezing the denture forward between the highly divergent palate and mandible. It was felt that in skeletal closed bite individuals, the posterior chain of muscles had a more vertical relationship relative to the molars and more horizontally placed palate and mandible.

Skeletal Considerations

The literature has been reviewed regarding the two skeletal entities, open bite and closed bite. Only those characteristics which separate skeletal open bite from skeletal closed bite and upon which various investigators are in agreement will be reported here.

Facial Planes

Investigations by Bjork (1947), Bushra (1948), Johnson (1950), Lindegard (1953), Sassouni (1962, 1964), Hapak (1964), and Subtelny and Sakuda (1964) showed either (1) divergent facial planes seen in skeletal open bite or (2) horizontal facial planes in skeletal closed bite.

Gonial Angle

A large gonial angle was seen in skeletal open bite and the opposite seen in skeletal closed bite. This has been shown by Bushra (1948), Johnson (1950), Jensen and Palling (1954), Sassouni (1964) and Subtelny and Sakuda (1964).

Anterior Facial Height

Small lower anterior facial height and small total anterior facial height was seen in closed bite while the opposite of these was present in open bite. These findings have been found by Bjork (1947), Johnson (1950), Hapak (1964), Sassouni (1962, 1964) and Subtelny and Sakuda (1964).

Ramus Length

Studies by Johnson (1950), Bolton (1956), Sassouni (1964) indicated a short mandibular ramus in open bite and a long ramus in closed bite. Evidence and agreement on this measurement is not as well established as the other findings mentioned above.

Studies have been reported showing an association between tooth morphology and skeletal type, as well as degree of incisor overbite to distinguish between skeletal open bite and closed bite.

This review has been limited to skeletal factors and therefore does not include dental entities.

CHAPTER III

METHODS AND MATERIALS

Sample

Eighty individuals were studied in this investigation, all being prospective orthodontic patients. Both sexes, with subjects ranging in age from 10 to 17 years with various ethnic backgrounds, were represented in the group. Seventy-two of the individuals were from the Orthodontic Clinic at Loma Linda University and eight were from the private practice of Dr. Roland Walters.

Preliminary Sample Grouping

The first 46 patients which presented themselves to the Orthodontic Clinic for treatment in the summer of 1967 were used as a sample from which criterium was established to separate subjects into two opposed groups, viz., skeletal open bite and skeletal closed bite. Tracings were made from the cephalograms with subsequent computation of the mean and standard deviation of the mandibular plane angle (sella-nasion to gonion-gnathion).

Using the values obtained, the 46 subjects were divided into three groups based on plus one or minus one standard deviation. The mean value for this group was 34° with a standard deviation of 5°. Additional subjects exhibiting mandibular plane angles of less than 29° or greater than 39°, based on this one skeletal measurement, were selected in an attempt to enlarge the sample size of the two extreme groups. Thirty-four additional subjects were selected in this manner.

Final Sample Grouping

The statistical quantity known as the "first principle component" was employed to combine the five most highly correlated measurements, characteristic of skeletal type (Table I, page 27) into one value that would best represent the five.

The first principle component values, computed for each of the eighty subjects (Table II, page 28) were then divided into three groups according to the boundries of plus one and minus one standard deviation from the mean. This resulted in a "homogenous" skeletal open bite group having a total of 14 individuals, a "homogenous" skeletal closed bite group comprised of 12 individuals and a third group consisting of 54 subjects which will be called the "normal bite" group.

Cephalometric Procedure

Standard cephalometric procedure (Graber 1958) was used to obtain roentgenographic cephalograms. Cephalograms were taken with the aid of a modified Broadbent-Bolton cephalometer with a focal to film distance of 60 inches.

Tracings of each cephlogram were made on frosted acetate tracing film with a No. 2 lead pencil. Standardization of tooth size was accomplished by the use of a plastic template (Steiner design). Accepted tracing technique was used whereby all bilateral appearing structures were bisected, giving an average of the two. Linear and angular measurements were recorded with the aid of a cephalometric protractor (Baum design). Measurements were recorded to the nearest millimeter and degree.

Measurements Used

The following is a detailed description of the measurements used to assess skeletal types and to relate the masseter muscle to skeletal elements.

Skeletal Measurements (Figure 1)

1. Mandibular plane angle - the angle formed by the mandibular plane and sella-nasion plane.
2. Frankfort-mandibular plane angle - the angle formed by the mandibular plane and Frankfort plane.
3. Palatal plane angle - the angle formed by the mandibular plane and palatal plane.
4. Occlusal plane angle - the angle formed by the mandibular plane and the occlusal plane.
5. Gonial angle - the angle formed by the mandibular plane and the ramal plane.
6. Ramus height - the length of the ramal plane as taken from the center of condyle to gonion.
7. Mandibular body length - the length of the mandibular plane as taken from gonion to gnathion.
8. Upper anterior facial height - the length of a line from nasion to anterior nasal spine.
9. Lower anterior facial height - the length of a line from anterior nasal spine to menton.

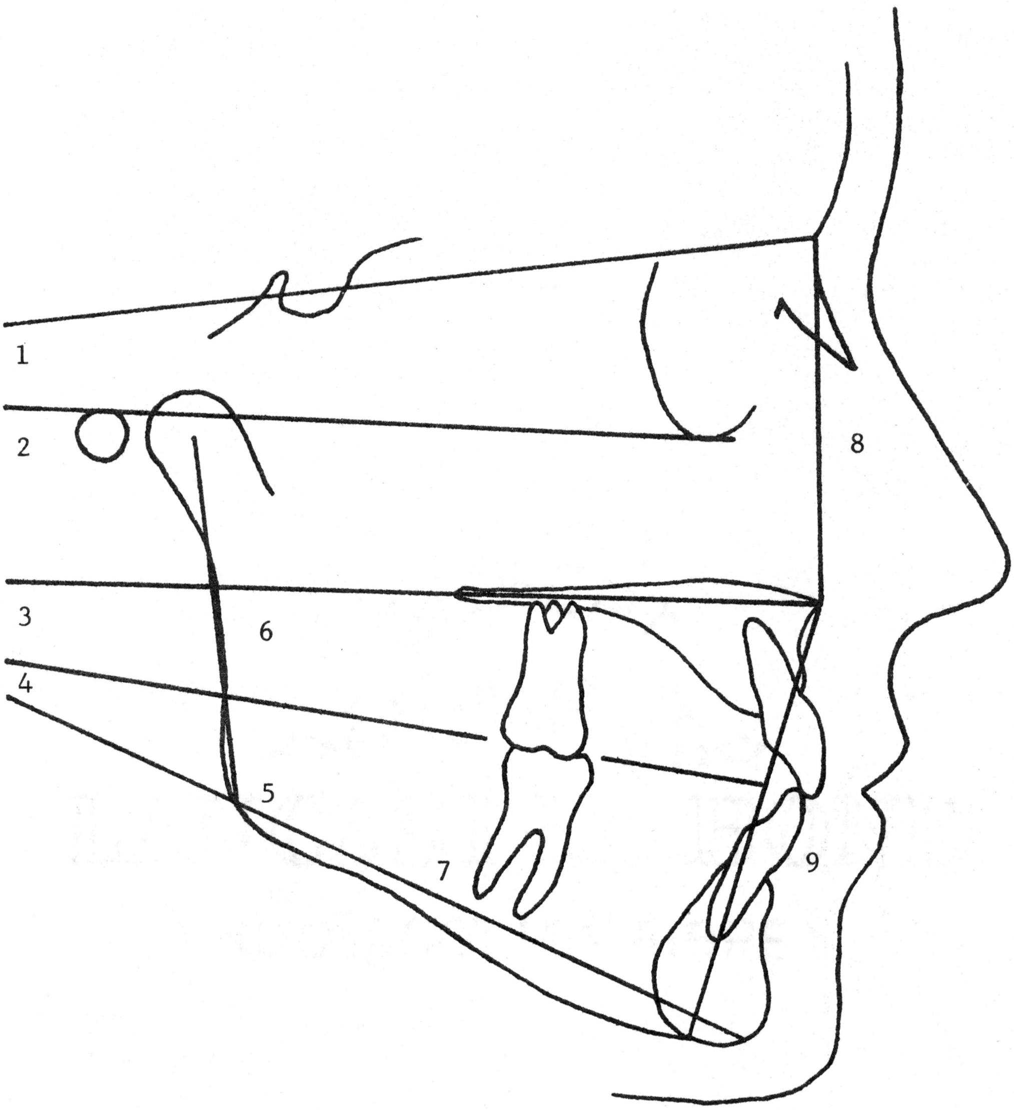

FIGURE 1

SKELETAL MEASUREMENTS TAKEN FROM CEPHALOGRAM

1. Sella-nasion to mandibular plane angle
2. Frankfort to mandibular plane angle
3. Palatal to mandibular plane angle
4. Occlusal to mandibular plane angle
5. Gonial angle
6. Ramus height
7. Body length
8. Upper anterior facial height
9. Lower anterior facial height

(Angular measurements in degrees; linear measurements in millimeters)

Measurements Relating Masseter Muscle to Skeletal Elements (Figure 2)

1. Mandibular plane to muscle border angle - the angle formed by the mandibular plane and anterior muscle border.
2. Ramal plane to muscle border angle - the angle formed by the inferior projection of the ramal plane and anterior muscle border to the point of intersection.
3. Gonion to muscle border - the distance from gonion to anterior muscle border, measured along mandibular plane.
4. Condyle to muscle border - the distance from center of condyle to the anterior muscle border, measured perpendicular to ramal plane.
5. Gonion to muscle border - the distance from gonion to the anterior muscle border, measured perpendicular to the ramal plane.
6. Mandibular first molar to muscle border - measurement taken on occlusal plane from the anterior muscle border to a perpendicular projected from occlusal plane to mesial contact point.

Computed Measurements (Figure 3)

1. Lower facial ratio - the ratio of lower anterior facial height to total facial height.
2. The ratio of the distance from gonion to anterior muscle border (measured on mandibular plane) to total mandibular body length.
3. Sella-nasion to muscle border angle - the angle formed by

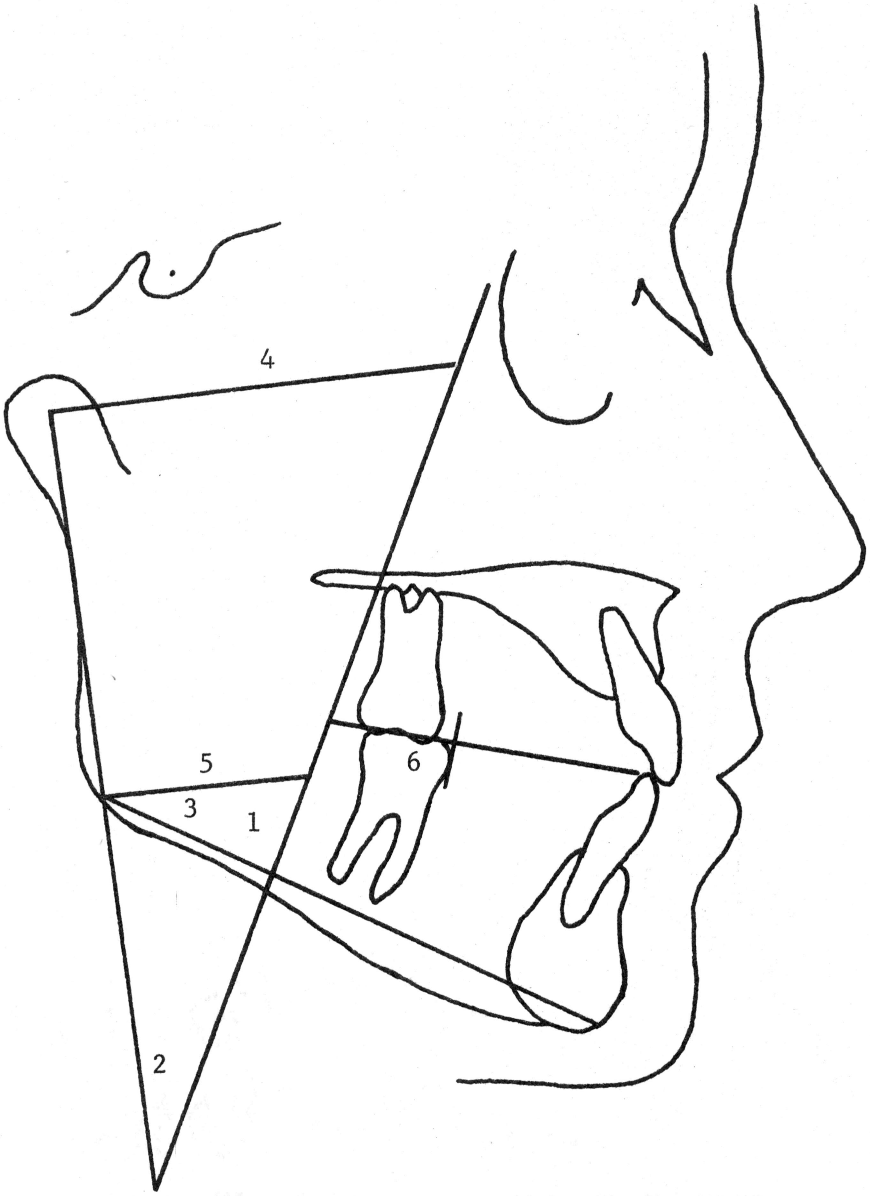

FIGURE 2

MEASUREMENTS RELATING MUSCLE TO SKELETAL ELEMENTS, TAKEN FROM CEPHALOGRAM

1. Mandibular plane to muscle border angle
2. Ramal plane to muscle border angle
3. Gonion to muscle border (at mandibular plane)
4. Condyle to muscle border (measured perpendicular to ramal plane)
5. Gonion to muscle border (measured perpendicular to ramal plane)
6. Mandibular first molar to muscle border. (One measurement used to relate muscle position to dental elements.)

(Angular measurements in degrees; linear measurements in millimeters)

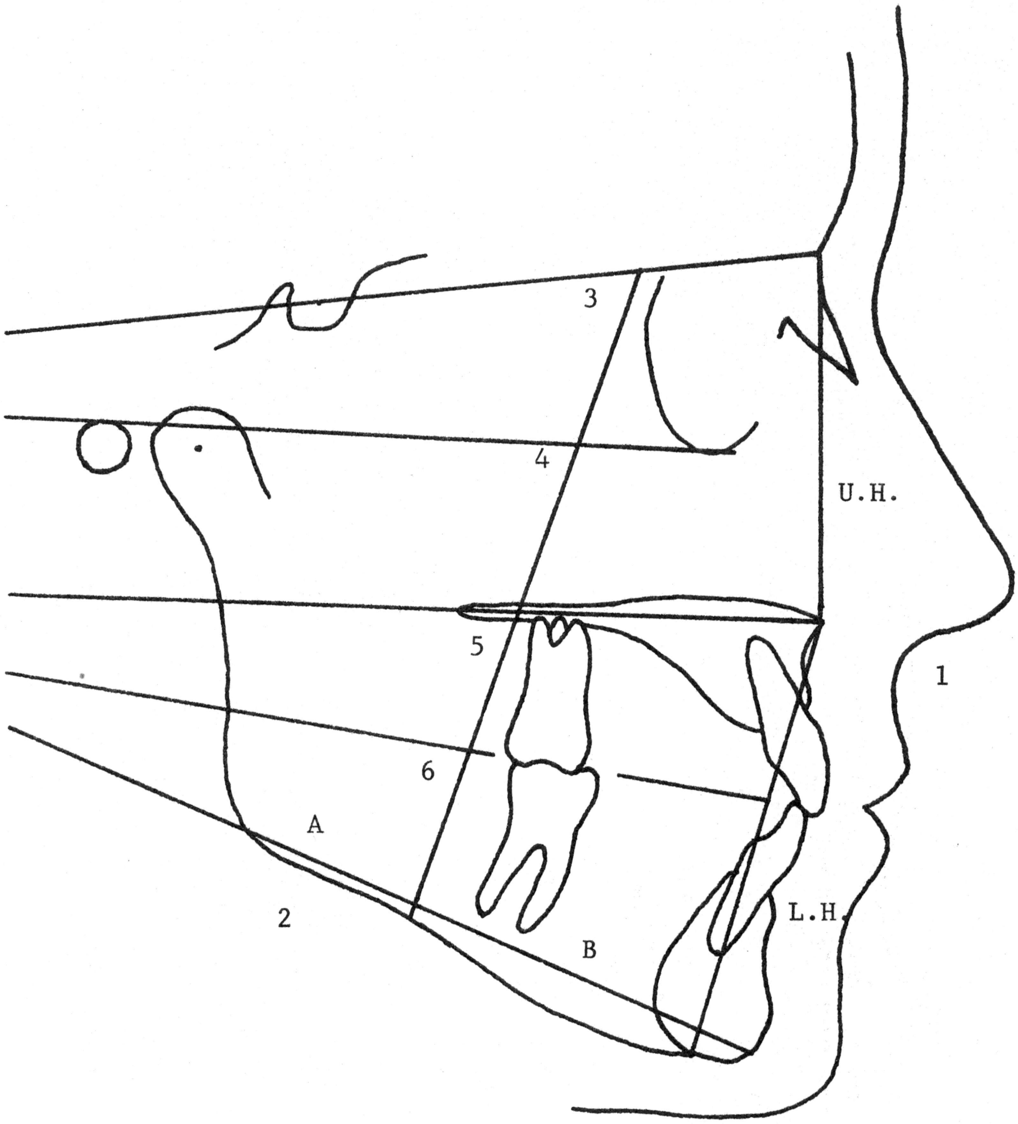

FIGURE 3

COMPUTED MEASUREMENTS

1. Lower facial ratio - the ratio of the lower anterior facial height (L.H.) to total facial height (L.H. + U.H.)
2. The ratio of the distance from gonion to muscle border (A) to total mandibular body length (B).
3. The angle formed by the SN plane and projected muscle border.
4. The angle formed by the Frankfort plane and muscle border.
5. The angle formed by the palatal plane and muscle border.
6. The angle formed by the occlusal plane and muscle border.

the SN plane and projected anterior muscle border.

4. Frankfort to muscle border angle - the angle formed by Frankfort horizontal and the projected anterior muscle border.

5. Palate to muscle border angle - the angle formed by the palatal plane and the anterior muscle border.

6. Occlusal plane to muscle border angle - the angle formed by the occlusal plane and anterior muscle border.

Masseter Muscle Locating Procedure

A line representing the anterior border of the masseter muscle (superficial portion) was used to represent the long axis of this muscle.

The technique used to assess the muscle border location was that of the lateral cephalogram. The location of the muscle border was detected by palpation due to the turgescence of the muscle upon clenching of the teeth. An .020 inch round stainless steel wire, approximately two inches in length, was then positioned directly superficial to the muscle border just prior to exposure of the lateral cephalogram. Once the muscle border was approximated, the wire was held lightly between the fingertips and the apparent muscle border. The small stiff wire afforded a rigid object with which to compare the "flexing" muscle border. The wire was manipulated until it was felt to be directly superficial to the apparent muscle border; then was fastened to the cheek with masking tape. This procedure was performed on both right and left sides, affording an average of the bilateral structures to be used upon bisection of the radiopaque lines presented on the cephalogram.

Variability in Muscle Position Due to Locating Procedure

To determine the reliability of the procedure, it was felt that the consistent placement of a wire in the same position on a number of occasions would be meaningful. Having accomplished this does not necessarily mean the "true" muscle border has been located (this appears to be an impossibility in a living subject), but it is a good indication of such position.

To minimize radiation exposure of the subjects, a method was employed whereby measurements were taken directly from the face (Figure 4) of the individuals. Reference lines, selected arbitrarily, were drawn on the side of the face with a red pencil. Angular and linear measurements were made relating the wire to these lines.

Fourteen individuals were employed for this procedure. It was preferred to have a random sampling for this investigation, but this becomes an impossibility when prospective orthodontic patients are used. The receptionist at the Loma Linda University Orthodontic Clinic was asked to make appointments with individuals of her choosing. This was done for two reasons: (1) to eliminate the possibility of the investigator's being selective in choosing more brawny subjects whose muscles would, therefore, be more easily palpable; (2) her knowledge of the residence and availability of most of the patients would allow her to choose individuals who would be willing to sit for a period of time.

The subjects were divided into two groups. The first group, comprising nine individuals, was used to measure the posterior inferior

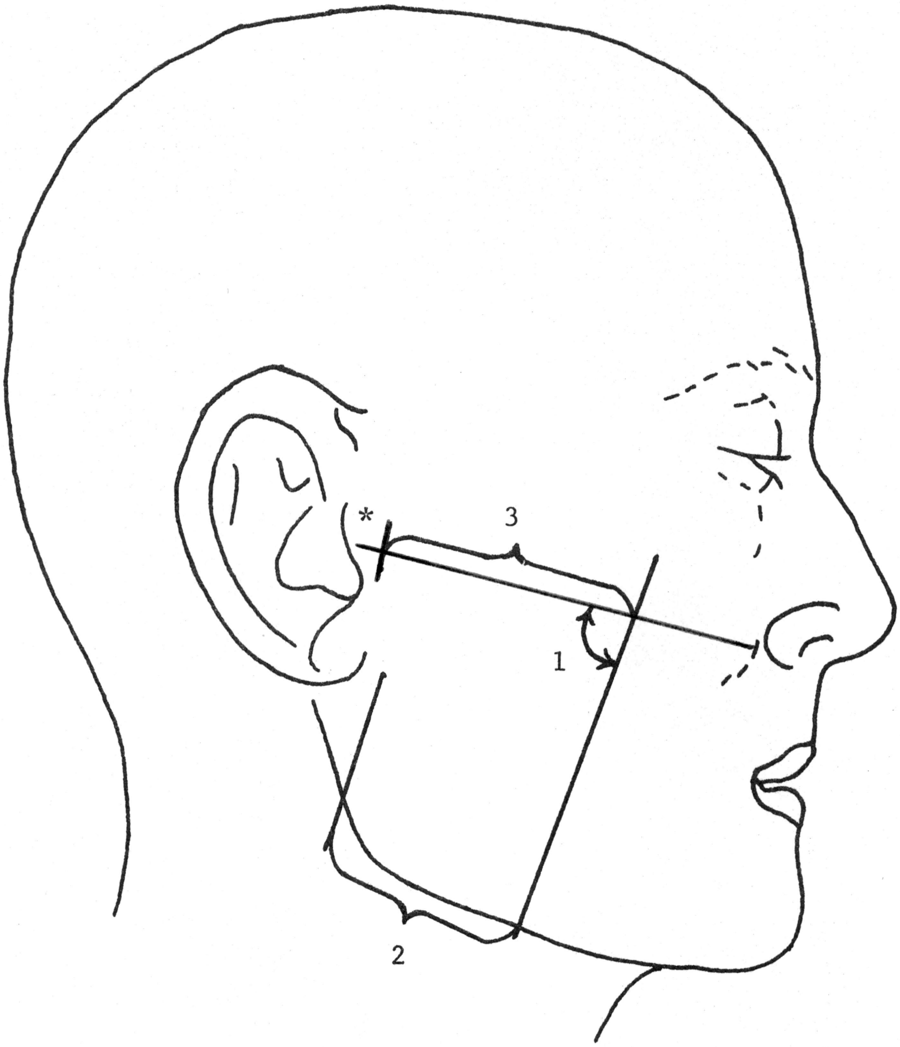

FIGURE 4

ILLUSTRATION OF METHOD USED TO ESTIMATE MUSCLE VARIABILITY DUE TO LOCATING TECHNIQUE

* Red lines drawn on face as arbitrary reference lines

1. Angular measurement in degrees
2. Width of muscle in millimeters
3. Antero-posterior placement in millimeters

angle the wire formed with a reference line drawn from the tragus of the ear to the ala of the nose. This measurement was recorded to the nearest degree with the aid of a small protractor. An attempt to measure the width of the muscle was made by placing a second wire superficially to the posterior border of the muscle at the area of insertion.

Angular measurement and muscle width was recorded five times for each subject. Data on the first group of nine patients was recorded on two different sessions--five subjects were used the first day and four a few days later. Each patient was measured once and then a new cycle was started with the original patient. This procedure allowed approximately 15 minutes between recordings on a given patient. Upon completion of five recordings for each subject, the investigator was then blindfolded and the procedure repeated six times. The investigator manipulated the wire to the desired position, at which time an assistant taped both ends of the wire to the cheek and recorded the measurements.

The second group, comprising five individuals, was studied at a later date. Linear measurements only were made on these individuals. This group of patients had a second arbitrary line drawn just in front of the ear (Figure 4, page 22) and perpendicular to the original line. Linear measurements were then recorded, measured from the line in front of the ear to the wire representing the anterior muscle border. The investigator measured all five patients once, then returned to the first subject recorded to begin another cycle. This procedure was followed until ten recordings were made for each subject. The blindfold study was not performed on this group.

Statistical Procedure

Correlations

A correlation coefficient matrix for all variables, both measured and calculated, was established, and from this matrix the following information was extracted:

a. The five most highly correlated skeletal measurements were combined by means of the first principle component for final grouping.

b. Those correlation coefficients relating masseter muscle to skeletal elements having significant levels of 5 percent or less were tabulated and analyzed.

In addition, partial correlation coefficients were computed relating the masseter muscle border to sella-nasion, mandibular and ramal planes.

First Principle Component

The five variables associated with skeletal type used for this analysis were sella-nasion to mandibular plane angle, Frankfort to mandibular plane angle, palate to mandibular plane angle, occlusal to mandibular plane angle and gonial angle. After computing this value for each of the 80 subjects, they were divided into a mean group. A group with values greater than plus one standard deviation, and a group comprising those values less than minus one standard deviation.

Means, Standard Deviations and Ranges

The mean, standard deviation and range for all measurements were computed for each of the three groups. Tests of significance for the differences between mean values of the two extreme groups were computed for the measurements relating the muscle border to skeletal elements.

Pooled Estimate of Variance

Estimation of the variability of muscle border position for a given individual due to the muscle locating procedure was obtained by using the pooled estimate of variance. Fourteen subjects were used to provide the data for this estimation.

CHAPTER IV

RESULTS

Comparison of the Two Groups

The correlation coefficients were computed between all skeletal measurements and tabulated in Table I. The measurement of upper facial height and mandibular length were not correlated highly with other measurements.

The first principle component was calculated for all 80 subjects and was tabulated in Table II. These values ranged from a high of 4.35 to a low of -6.5, having a standard deviation of 2.09.

The values for the mean, standard deviation and range for skeletal open bite, normal bite and closed bite are shown in Tables III and IV. Table III shows the results of all skeletal measurements employed. Table IV gives the results relating the masseter muscle to the skeletal elements.

Analysis of the data representing the extreme groups indicated a difference, although small, when comparing the angles formed by the palatal, Frankfort and sella-nasion planes with the masseter muscle border. The angle formed by the muscle border and the occlusal plane showed no statistical difference between the groups. The angles formed by the palate and Frankfort planes with the muscle border showed a small (5^{o}) difference that was statistically significant between the two groups. The sella-nasion to muscle border angle had an 8^{o} difference which was statistically significant.

TABLE I

SIMPLE CORRELATION COEFFICIENTS
OF SKELETAL MEASUREMENTS

	S-N Mand. Pl. Angle	Frankfort Mand. Pl. Angle	Palatal Mand. Pl. Angle	Occlusal Mand. Pl. Angle	Gonial Angle	Lower Facial Height	Lower Facial Ratio	Ramus Height	Upper Facial Height	Mand. Body Length
S-N Mand. Pl. Angle										
Frankfort Mand. Pl. Angle	.94									
Palatal Mand. Pl. Angle	.90	.92								
Occlusal Mand. Pl. Angle	.83	.84	.88							
Gonial Angle	.78	.80	.80	.75						
Lower Facial Height	.69	.69	.75	.72	.47					
Lower Facial Ratio	.46	.56	.67	.59	.43	.76				
Ramus Height	-.55	-.56	-.48	-.38	-.52					
Upper Facial Height	.32					.32	-.36			
Mand. Body Length					-.36			.36		

TABLE II

FIRST PRINCIPLE COMPONENT VALUES DIVIDED INTO THREE GROUPS
BASED ON ONE STANDARD DEVIATION

Skeletal Open Bite		Normal Bite				Skeletal Closed Bite	
Case #	Component #	Case #	Component #	Case #	Component #	Case #	Component #
47	4.35	6	2.06	14	-.30	1	-2.16
54	3.86	50	2.04	8	-.32	63	-2.32
52	3.71	24	1.99	10	-.48	77	-2.35
59	3.66	29	1.87	9	-.60	17	-2.37
48	3.55	49	1.66	61	-.66	2	-2.41
51	3.11	19	1.61	26	-.68	65	-2.51
68	3.07	30	1.55	34	-.76	66	-2.53
56	2.80	12	1.48	16	-.84	27	-2.64
55	2.68	42	1.48	25	-.94	71	-2.76
28	2.68	37	1.43	41	-1.01	78	-3.65
57	2.48	58	1.42	11	-1.06	74	-4.28
5	2.26	64	1.21	75	-1.15	79	-6.52
53	2.23	35	1.10	32	-1.24		
15	2.22	7	1.09	20	-1.26		
		43	.89	62	-1.35		
		13	.81	46	-1.36		
		3	.80	60	-1.42		
		22	.54	39	-1.43		
		31	.34	67	-1.44		
		4	.34	18	-1.44		
		45	.33	76	-1.50		
		23	.13	44	-1.53		
		33	.12	69	-1.58		
		38	.11	70	-1.79		
		21	-.16	73	-1.79		
		36	-.18	80	-1.98		
		40	-.29	72	-1.99		

Standard Deviation = 2.09

TABLE III

MEANS, STANDARD DEVIATIONS AND RANGES OF THE SKELETAL MEASUREMENTS USED

		SN Mand. Plane	F.H. Mand. Plane	Palatal Mand. Plane	Occlusal Mand. Plane	Gonial Angle	Upper Anterior Facial Height	Lower Anterior Facial Height	Ramal Height	Mand. Body Length	Lower Facial Ht. to Total Facial Ht.
		deg.	deg.	deg.	deg.	deg.	mm	mm	mm	mm	Ratio
Skeletal Open Bite	Mean	46.5	33.9	36.6	25.5	130.2	54.0	73.4	46.3	72.6	.57
	S.D.	3.7	3.7	4.0	2.9	3.8	2.6	6.7	4.8	5.4	.02
	Range	13.0	12.0	13.0	9.0	14.0	9.0	26.0	15.0	20.0	.07
Normal Bite	Mean	33.8	23.7	26.9	18.7	122.1	51.5	65.9	49.2	73.5	.56
	S.D.	4.9	4.3	4.5	2.9	4.8	3.4	4.7	4.5	4.8	.02
	Range	21.0	17.0	15.0	13.0	19.0	16.0	17.0	20.0	25.0	.09
Skeletal Closed Bite	Mean	24.1	14.9	17.4	11.9	113.5	51.5	60.3	53.3	75.9	.54
	S.D.	3.8	4.5	4.4	3.7	4.0	3.5	5.8	5.1	3.7	.03
	Range	15.0	17.0	14.0	14.0	15.0	11.0	19.0	16.0	13.0	.11

TABLE IV

MEANS, STANDARD DEVIATIONS AND RANGES OF MEASUREMENTS
RELATING MASSETER MUSCLE TO SKELETAL ELEMENTS

Muscle Border to:		SN Plane	F.H. Plane	Palatal Plane	Occlusal Plane	Mand. Plane	Ramal Plane	Gonion*	Condyle**	Gonion**	Lower First Molar	Gonion to Mand. Length
		deg.	deg.	deg.	deg.	deg.	deg.	mm	mm	mm	mm	Ratio
Skeletal Open Bite	Mean	48.7	61.3	58.6	69.8	84.7	34.8	40.0	80.4	48.1	-2.2	.54
	S.D.	6.6	5.3	5.3	6.7	5.4	6.5	5.5	8.0	4.6	4.2	.05
	Range	22.0	18.0	19.0	26.0	18.0	20.0	23.0	25.0	20.0	13.0	.16
Normal Bite	Mean	54.1	64.2	61.0	69.1	92.0	34.1	39.2	80.8	47.0	-2.4	.53
	S.D.	5.9	5.3	6.0	5.9	6.6	6.5	5.9	9.0	5.6	4.8	.06
	Range	31.0	25.0	30.0	30.0	33.0	30.0	25.0	35.0	26.0	29.0	.29
Skeletal Closed Bite	Mean	57.0	66.3	63.8	69.3	98.7	32.2	40.4	80.9	46.8	- .5	.53
	S.D.	5.2	4.4	4.8	3.9	4.8	3.8	5.2	7.7	6.0	4.5	.06
	Range	15.0	13.0	14.0	11.0	15.0	14.0	18.0	28.0	23.0	16.0	.29

Key: * = Measured on Mandibular Plane
** = Measured Perpendicular to Ramal Plane

When the distance from gonion to the muscle border (measured on mandibular plane) and the ratio of this distance to total mandibular body length was compared, there was no difference found between the groups.

The distance between the ramal plane and muscle border, measured perpendicular to the ramal plane from the center of the condyle and from gonion, indicated no difference between the open bite and closed bite groups.

The angle formed by the ramal plane and masseter border revealed only a slight difference between the two groups, although not enough to be statistically significant.

When the angle formed by the mandibular plane and masseter border was compared, there was a significant difference between the skeletal open bite and closed bite groups. The open bite group had a mean and standard deviation of 84.7 and 5.4^{o} respectively, while the closed bite group had a mean of 98.7^{o} and a standard deviation of 4.8^{o}

The distance between the lower first molar and the muscle border revealed no significant difference between the two groups.

After it was established that there was a small difference between the two groups in masseter muscle position with the exception of the masseter border relative to the mandibular plane, which showed considerable difference, the same measurements were subjected to correlation procedures. In Table V the simple correlation coefficients are presented for analysis.

TABLE V

SIMPLE CORRELATION COEFFICIENTS RELATING MASSETER MUSCLE TO SKELETAL ELEMENTS

Muscle Border to:		S-N Plane	F.H. Plane	Palatal Plane	Occlusal Plane	Mand. Plane	Ramal Plane	Gonion+	Condyle++	Gonion++	Lower First Molar	Gonion to Mand. Length
		deg.	deg.	deg.	deg.	deg.	deg.	mm	mm	mm	mm	Ratio
Sella-Nasion Mand. Pl.	deg.	-.49	-.32	-.27*		-.65						
Frankfort Mand. Pl.	deg.	-.34	-.34			-.72			-.27*		-.23*	
Palatal Mand. Pl.	deg.	-.36	-.28*	-.36		-.67						
Occlusal Mand. Pl.	deg.	-.33	-.24*	-.28*		-.62					-.26*	
Gonial Angle	deg.	-.30	-.23*	-.22*		-.59	.34	-.30			-.27*	
Upper Anterior Facial Height	mm											
Lower Anterior Facial Height	mm	-.24*		-.23*		-.54					-.27*	
Ramal Height	mm	.29	.27*			.34			.25*			
Mandibular Body Length	mm						-.33	.56		.50		
Lower Anterior Facial Height to Total Ant. Facial Height	Ratio			-.33		-.41						

Key: + = Measured on Mandibular Plane
++ = Measured Perpendicular to Ramal Plane
* = Significant at the 5% level, all other correlations are significant at the 1% level

Blank spaces = no correlation

The angle formed by SN-masseter border showed a negative correlation significant at the 1 percent level with the SN, Frankfort, palatal and occlusal to mandibular plane angles as well as ramal height and gonial angle. This angle also showed a negative correlation significant (at the 5 percent level) with lower anterior facial height. There was no correlation between SN-muscle border angle and the ratio of lower facial to total facial height.

The Frankfort plane-masseter border angle had the same correlations that the SN-masseter angle presented, with the exception of the correlation with lower anterior facial height. The level of significance was not as good, however, at a 5 percent level (rather than 1 percent). This angle showed a correlation with SN-masseter angle significant at the 1 percent level.

The palate-masseter border angle was always negatively correlated when a statistical relationship existed. This angle had a correlation with the palatal-mandibular plane angle and the ratio of lower face to total facial height, significant at the 1 percent level. There was also a correlation shown with SN and occlusal to mandibular plane angles as well as with gonial angle and lower facial height.

The measurement taken from gonion to the masseter border, measured on mandibular plane, had no correlation with the other measurements with the exception of the gonial angle which was negative and a positive correlation with mandibular body length, both significant at the 1 percent level.

The angle formed by the ramal plane and masseter border showed a positive correlation with gonial angle and a negative correlation with mandibular body length, both significant at the 1 percent level.

The only correlations associated with the distance from the condyle to the muscle border were significant at the 5 percent level, being positive with ramal height and negative with Frankfort-mandibular plane angle.

The measurement taken from gonion to the masseter border, measured perpendicular to ramal plane, showed only one correlation, a positive one, with the mandibular body length significant at the 1 percent level.

There were correlations between mandibular body length and both measurements taken from gonion to the muscle border, as well as with the angle formed by the ramal plane and muscle border. These three correlations were significant at the 1 percent level.

Negative correlations significant at the 1 percent level were found between mandibular plane-muscle border angle and all of the skeletal measurements except upper facial height, mandibular body length and ramal height. There was a positive correlation with ramal height and no correlation, with the first two exceptions.

There were negative correlations significant at the 5 percent level between the lower first molar-muscle border distance and the Frankfort-mandibular plane angle, occlusal-mandibular plane angle, gonial angle and lower facial height.

The measurements of upper facial height, the ratio of gonion-muscle border to total body length and the angle formed by the occlusal plane to muscle border showed no correlations with any of the skeletal measurements used.

Partial correlation coefficients were computed relating the masseter muscle border to the sella-nasion, mandibular and ramal planes with the results tabulated in Table VI.

When the SN-mandibular plane angle was held constant, there was no correlation between the ramal-SN plane angle and the mandibular plane-muscle border angle. When the ramal-SN plane angle was used as the constant variable there was a negative correlation between the SN-mandibular plane angle and the muscle-mandibular plane angle, as well as the gonial angle and muscle-mandibular plane angle. There was a negative correlation between gonial angle and SN-muscle border angle also when the ramal-SN angle was held fixed.

When the gonial angle was used as the constant variable, there was a negative correlation between ramal-SN plane angle and both the SN-muscle border angle and the mandibular plane-muscle border angle.

These correlation coefficients were all significant at the 5 percent level or less.

The utilization of significance tests for the difference between mean values enabled the investigator to determine which values were statistically significant. The results of these tests are tabulated in Table VII. Four measurements--all angular--were significant when comparing the two groups. The palatal plane to muscle border angle, as well as the Frankfort to muscle border angle were significant at the 5 percent level of significance. The angle formed by the muscle border and sella-

TABLE VI

PARTIAL CORRELATION COEFFICIENT MATRIX

Variable No.	(constant) 1	2	3	4
	D	A	C	-.63
	A	D	C	
	D	B	C	-.63
	B	D	C	-.38
	D	B	E	-.35
	B	D	E	-.43

Level of Significance = 5% or less

Key:

Variable #4 gives partial correlation coefficient between Variable #2 and #3, holding Variable #1 constant.

A = Sella-Nasion - Mandibular Plane Angle

B = Gonial Angle

C = Mandibular Plane - Masseter Border Angle

D = Ramal - SN Plane Angle

E = Sella-Nasion - Masseter Border Angle

TABLE VII

TESTS OF SIGNIFICANCE FOR THE DIFFERENCE BETWEEN MEANS OF THE SKELETAL OPEN BITE AND CLOSED BITE GROUPS

	t Value	Level of Significance
Ramal Plane - Masseter Border Angle	1.22	--
**Condyle - Muscle Border Distance	.15	--
**Gonion - Muscle Border Distance	.61	--
*Gonion - Muscle Border Distance	.19	--
Lower First Molar - Masseter Border	.99	--
Ratio of Gonion - Masseter Border to Total Mandibular Length	.72	--
Occlusal Plane to Masseter Border Angle	.21	--
Palatal Plane - Masseter Border Angle	2.59	5%
Frankfort Plane - Masseter Border Angle	2.61	5%
Sella-Nasion - Masseter Border Angle	3.58	1%
Mandibular Plane to Masseter Border Angle	6.95	1%

Key: * = Measured on Mandibular Plane
** = Measured Perpendicular to Ramal Plane

nasion plane plus the angle formed by the muscle border and mandibular plane were statistically significant at the 1 percent level, the latter having "t" value approximately double that for the sella-nasion to masseter border angle.

Variability in Muscle Position Due to Locating Procedure

The pooled estimate of variance was the statistical procedure used to estimate the variability in muscle position due to the locating procedures for a given individual. The results of this procedure are seen in Tables VIII and IX and X.

The angular variability of the masseter muscle border relative to an arbitrary line (Figure 4, page 22) was determined both with and without a blindfold. Without the blindfold, the investigator found the pooled variance in locating the muscle was 4.4^{o} with a 2^{o} pooled standard deviation; the pooled variance with the investigator blindfolded was 13^{o}, with a 3.6^{o} pooled deviation. Table IX gives the results of the variability of the muscle width due to locating procedures. When the investigator used the blindfold the pooled variance was 18 mm and it was 15 mm when he was not blindfolded.

The variability in muscle border position measure linearly in an anterior-posterior direction due to the locating error was 3.5 mm (Table X), having a pooled standard deviation of 1.8 mm.

TABLE VIII

ANGULAR VARIABILITY IN MUSCLE BORDER POSITION
DUE TO LOCATING PROCEDURE

Measurements recorded in degrees

	VISION			BLINDFOLDED		
Case #	$\overline{X}$	S	S^2	$\overline{X}$	S	S^2
1	88.5	1.80	3.31	84.3	1.74	3.03
2	86.8	2.02	4.20	79.6	4.34	18.95
3	85.6	1.96	3.85	80.6	2.58	6.70
4	88.0	1.32	1.75	83.9	4.06	16.5
5	83.4	2.40	5.77	81.2	4.48	20.13
6	84.6	.89	.80	78.9	4.03	16.2
7	87.0	2.54	6.50	84.2	5.0	25.0
8	87.7	2.88	8.30	84.2	1.33	1.77
9	85.5	2.30	5.31	82.7	2.5	6.25
	$Sp^2 = 4.42$ $Sp = 2.10$			$Sp^2 = 12.73$ $Sp = 3.56$		

$\overline{X}$ = Mean

S = Standard Deviation

S^2 = Variance

Sp = Pooled Standard Deviation

Sp^2 = Pooled Variance

TABLE IX

VARIABILITY OF MUSCLE WIDTH
DUE TO LOCATING PROCEDURE

Measurements recorded in millimeters

Case #	VISION			BLINDFOLDED		
	$\overline{X}$	S	S^2	$\overline{X}$	S	S^2
1	36.4	1.13	1.29	35.	3.31	13.6
2	29.5	1.94	3.76	29.8	3.97	15.18
3	32.9	3.11	9.70	31.9	2.99	8.95
4	33.5	2.08	4.32	33.0	5.51	30.50
5	33.9	3.26	10.70	38.0	4.01	16.20
6	35.3	4.15	17.35	40.4	4.87	23.80
7	35.4	4.09	16.8	43.7	5.0	25.00
8	32.1	4.82	23.4	34.2	4.34	18.90
9	34.9	4.67	21.9	40.5	2.73	7.46
	$Sp^2 = 15.11$ $Sp = 3.89$			$Sp^2 = 17.87$ $Sp = 4.20$		

$\overline{X}$ = Mean

S = Standard Deviation

S^2 = Variance

Sp = Pooled Standard Deviation

Sp^2 = Pooled Variance

TABLE X

LINEAR VARIABILITY IN MUSCLE BORDER POSITION
(ANTERO-POSTERIORLY) DUE TO
LOCATING PROCEDURE

Measurements recorded in millimeters

	VISION ONLY		
	$\overline{X}$	S	S^2
10	54.8	1.76	3.10
11	54.8	2.13	4.54
12	51.0	1.70	2.89
13	50.4	1.79	3.20
14	55.8	1.68	2.82
$Sp^2 = 3.51$ $Sp = 1.87$			

$\overline{X}$ = Mean

S = Standard Deviation

S^2 = Variance

Sp = Pooled Standard Deviation

Sp^2 = Pooled Variance

CHAPTER V

DISCUSSION

Comparison of the Two Groups

The results revealed a difference in masseter muscle position when comparing the two extreme groups. The significant differences observed seemed to be more apparent in the lower half of the face, viz., the mandible.

The comparison of the mean values which relate the masseter muscle to skeletal elements (Table IV, page 30) showed there were four angular measurements that demonstrated a statistically significant difference between the two groups. The angles formed by the palatal and Frankfort planes with the muscle border showed only a slight difference being 5^{o} at the 5 percent level of significance. There was an 8^{o} difference, significant at the 1 percent level, of the angle formed by the projected muscle border with sella-nasion plane. Peterson (1966) also found an 8^{o} difference (muscle relative to sella-nasion plane) when comparing Class I and Class II subjects. The most meaningful difference shown between the two groups was the difference in the size of the angle formed by the masseter muscle with the mandibular plane. This angle, having a difference of 14^{o} significant at the 1 percent level, showed that the skeletal open bite group had a more acute angle than the closed bite group.

These findings would raise the question: is the difference in muscular position due to a difference in muscular attachment sites per se or due to a difference in orientation of the attachment sites relative to one another? The linear measurements used to orient the muscle in the anterior-posterior direction would indicate the latter situation to be true. The measurement taken from condyle to muscle border and the two measurements taken from gonion to muscle border are the same in both groups. These measurements would indicate constant origin and insertion areas regardless of skeletal type. This idea is also supported by the ratio of gonion-muscle border to total mandibular body length. Petersen (1966) found the same indication when comparing Class I adults and early permanent dentition subjects with Class II early permanent dentition cases. He also found no difference when comparing the muscle border position relative to the mandibular first molar. This investigator also found no difference between the extreme groups when relating the muscle border to the mandibular first molar. These findings would indicate that the inclination of the muscle relative to the facial planes may be determined primarily by the anterior-posterior relationship of the mandible to the upper half of the face and the size of the gonial angle. This concept would also be supported by the constant angular relationship found between the muscle border and the occlusal and ramal planes. These findings would indicate that growth is a contributing factor in the orientation of the masseter muscle.

The findings in this investigation agree with and support the accepted theories of facial growth. The influence of growth correlated with the findings of this study can best be demonstrated by Shudy's (1965) report of the rotation of the mandible resulting from growth. He feels that if condylar growth is less than combined nasal, maxillary and alveolar growth, the mandible would rotate downward and backward around the most distal molar in occlusal contact. If condylar growth is greater in quantity than combined nasal, maxillary and alveolar growth, the result would be an upward and forward rotation.

Anterior-posterior growth dysplasia, as described by Wylie (1947), as well as the movement of the glenoid fossa downward and backward at the dictation of the posterior cranial base, Sassouni (Lecture at Loma Linda University 1967), could produce a similar effect as mandibular rotation, which would influence the spacial orientation of the origin and insertion sites of the masseter muscle.

The differences in quantity of growth may result in either a skeletal open bite or a skeletal closed bite, depending on the location and severity of the discrepancy. The anterior-posterior displacement of the mandible as it influences the position of the masseter muscle relative to the upper face is shown in Figure 5. This schematic drawing is a composite of the two groups based on mean values. It was observed that though the rotation of the mandible could change the relationship of the masseter muscle, it would take a tremendous rotation to account for the differences seen between the two groups, particularly the mandibular plane-muscle border angle. The gonial angle seems to play an important part in this situation. The size of the gonial angle appears to be an important factor in the skeletal proportion of the face and apparently accounts for a substantial part of the difference seen in the size of the angle formed by the mandibular plane and muscle border, as

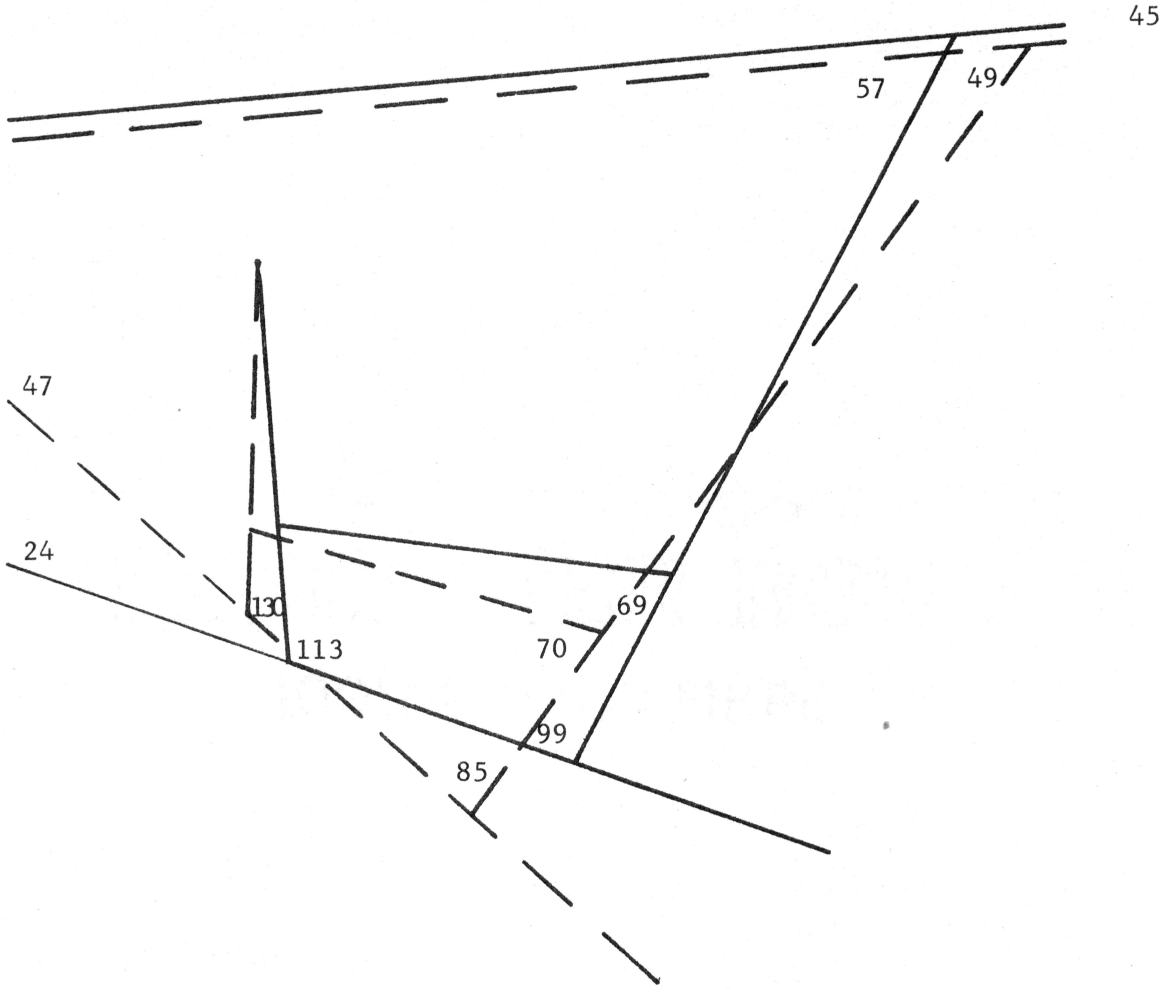

FIGURE 5

COMPOSITE SCHEMATIC DIAGRAM SHOWING ANTERIOR BORDER OF MASSETER MUSCLE RELATIVE TO SELLA-NASION, OCCLUSAL AND MANDIBULAR PLANE IN SKELETAL OPEN BITE AND CLOSED BITE TYPE

Point of Registration is center of condyle with anterior cranial base (S-N) superimposed.

Drawing based on mean values representative of the two groups.

Solid line = Skeletal closed bite
Dashed line = Skeletal open bite

well as the size of the angles formed by the muscle border and Frankfort, palatal and S-N planes.

Various studies have been done to assess genetic influence in facial patterns. Sassouni (1964) presented evidence of a close similarity between parents and offspring in the shape, size and proportion of various facial bones as did Kraus, Wise and Frei (1964) in studying twins and triplets. These findings would indicate that perhaps genetic influence on skeletal elements could, in turn, be a determining factor in muscular orientation in a given individual. Studies by Sarnas (1959) tends to support the theory of muscle elements having a genetic influence. He found a much greater intrafamily resemblance when the mandible was at rest position than when it was fully closed.

It is possible that the degree of neuromuscular development with influence of the environmental factors may impart more influence upon the delicate balance of the stomatognathic system than does muscular position. A case report by Proffit, Gamble and Christiansen (1968), in which a generalized muscular weakness was believed to be a contributing factor in severe anterior open bite, would support this idea. Jensen and Palling (1954) found a smaller gonial angle associated with very muscular individuals than was seen in subjects presenting less apparent muscular elements. This could indicate the influence of muscular development on the form of the gonial angle.

Having established a difference in orientation of the masseter muscle and having knowledge of the differences seen in muscle activity between different skeletal types, (as recorded electromyographically, Moyers 1949, Perry 1955, and Liebman 1966), the following question is raised: does muscle orientation have any effect on muscle activity or are the differences in activity due to muscular development? Carlsoo (1952) concluded that muscular activity could not be deduced from a knowledge of mechanical qualifications alone. Scott (1954) stated that the size of the mandibular ramus is directly correlated with the degree of use of the masticatory muscles. These investigations as well as those of Jensen and Palling (1954), could indicate muscular development being associated with muscular activity but do not rule out the possibility of muscular orientation being an important factor. If it were possible for muscular orientation to make a difference in muscle activity, then it would be conceivable that this could effect the shape or position of skeletal elements.

The mean values which showed no significant differences between the two groups could be as important as those which showed a substantial difference because they may reflect constancy regardless of skeletal type. The constant angular relationship found between the muscle border and occlusal plane is of interest. This finding might indicate a constant relationship between the dentition and muscular forces irrespective of mandibular or maxillary shape or position. This constant relationship exists in spite of the significant differences found, in the extreme groups, when the muscle to S-N, Frankfort and palatal plane angles are compared. This finding would be supported by Sicher's (1965) statement when he said: "The superficial portion (masseter muscle) exerts pressure at a right angle to the posteriorly ascending occlusal plane of the molars (curve of spee)." The statement by Brodie (1938) in which he said that when the occlusal plane was tipped as a result of orthodontic treatment, "it tends to return to its original position," would support the idea of the occlusal plane seeking the most stable position within the confines of muscular forces. Reidel's (1960) statement: "the occlusal plane probably cannot be permanently altered except in a negative direction (to SN or F.H.)," would also support this finding.

The findings of this investigation would support the hypothesis that muscular orientation could be a causative factor in skeletal dysplasia. The apparent constancy of muscular attachment sites per se, however, would not support such a hypothesis. This does not imply that muscular attachment sites are not a contributing factor. Sicher (1965) states that if the muscle is very strong, the area of insertion may be slightly widened, by a bundle of fibers extending anteriorly along the lower border of the mandible, rendering the anterior border concave. These additional fibers, if present, were not accounted for in this investigation. This additional bundle was readily palpated on one of the 80 subjects investigated. It must be remembered that the line representing the masseter musculature is only a reflection of the long axis of the right and left muscles (superficial portion). A considerable number of the subjects investigated revealed a divergence of the two muscles. Bisection of the two radiopaque lines gave an average position of the musculature irrespective of whether they be parallel or not. This investigation did not attempt to locate the deep portion of the muscle and therefore does not in any way evaluate its influence on overall muscle position.

These findings provide stimulus for further research, such as longitudinal studies, approached in a similar manner. The correlation of functional activity, expressed in terms of electromyographic and biting force procedures, with skeletal type and muscular position would be meaningful. The orientation of the occlusal plane relative to muscular forces would be significant. The gonial angle is of considerable interest and needs further investigation. To determine the behavior of this angle with respect to growth, genetics, muscular forces, etc., would be meaningful.

Methods and Materials

It was desirable to obtain homogeneous groups for an investigation such as this. It was believed that the use of several measurements characteristic of skeletal type, rather than only one, would allow for variation of bony parts in a given individual and would give a more valid picture of the true skeletal type. The statistical quantity known as the "first principle component," which is the normalized linear combination of variables having the maximum variance, was employed for this purpose. This quantity would best distinguish facial patterns according to the maximum variation of the five most highly correlated measurements exemplifying facial patterns.

A line representing the anterior border of the muscle was used to represent the long axis of the muscle. This procedure is based on the assumption that the muscle is rectangular in shape (Sicher 1965) with the anterior border representing the long axis of the rectangle.

This investigation is concerned primarily with the larger superficial portion of the muscle and is assuming that the general position of the muscle as a whole can be based on this assumption. Since the soft tissue elements being studied are not normally apparent on a cephalogram, modifications were necessitated in order to visualize the position of the muscle. This modification was accomplished by taping wires to the cheeks, directly superficial to the muscle borders, prior to exposure of the cephalogram.

Other procedures considered for muscle locating were those of electromyography and tomography. After consultation with men proficient in the technique, electromyography was not attempted for this procedure. Tomographic procedures were used on two subjects, but muscle visualization could not be attained.

The variability of the position of the masseter muscle, due to the locating technique, is probably the greatest source of error in a study such as this. This variability was estimated by the statistic "pooled variance." This procedure "pools" the variances obtained from repeated measurements on a number of subjects. The value obtained is used as an estimate of the error inherent in locating the muscle border on a given patient.

From the results obtained in this procedure, it is evident that locating the muscle border on one individual is subject to an error of 4.5° angularly and 3.5 mm linearly. The standard error becomes substantially reduced, however, by an inverse factor equal to the square root of the sample size when a number of subjects are investigated. For instance, an angular variance of 5^{o} for a given patient is reduced to $\sqrt{\frac{5}{25}} = 1^{o}$ for the mean of a sample of 25 subjects.

The variability of the masseter border width was so large that this measurement was not used for the investigation. The large variance obtained on this measurement was attributed to the difficulty in palpating the posterior border of the muscle at the insertion area. Based on these results no attempt was made to determine muscle width in the investigation.

It was observed that using full vision was considerably more consistent than locating the muscle border blindfolded, although the latter was not extremely inconsistent.

The sources of error inherent in any cephalometric study would apply to this investigation. The error due to locating and tracing landmarks has been minimized as much as possible by the selection of several measurements indicative of the same structure instead of using only one measurement. Selection of homogeneous groups would also reduce the effect of tracing and recording error due to the large values separating the groups.

It is realized that errors due to instrumentation of tracing and recording as well as variables inherent in roentgenographic procedures, such as exposure time and development procedures, are present.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The purpose of this investigation was to determine if a difference in spacial relationship of the masseter muscle (superficial portion) exists between the facial patterns of skeletal open bite and closed bite. Five measurements indicative of skeletal type were employed for the purpose of dividing the sample of 80 subjects into three groups. The statistic of one standard deviation was used to divide the sample into groups representative of skeletal open bite, closed bite and "normal."

Visualization of the masseter muscles was accomplished by a modified cephalometric technique in which short, stiff, wires were taped to the cheeks subsequent to palpation of the muscle borders and prior to exposure of the film. The radiopaque images projected by the wires were used to represent the anterior borders of the muscles. These images were bisected rendering a single line which was traced along with various dentoskeletal elements, including those representative of skeletal type. The values obtained from the cephalometric tracings were subjected to statistical procedures, including student "t" tests and correlation analysis to compare muscle position between the two extreme groups.

The conclusions drawn from this investigation were as follows:

1. There was a difference in masseter muscle position between skeletal open bite and closed bite individuals, with the

difference much more apparent at the mandibular level than at the mid-face.

2. The masseter muscle maintains a slightly more horizontal position, relative to the mid-face and anterior cranial base, in skeletal open bite than was seen in closed bite individuals.
3. The masseter muscle had a more vertical inclination, relative to the mandibular body, in skeletal open bite than it did in closed bite individuals.
4. Masseter muscle attachment sites, per se, reveal no apparent difference when comparing skeletal open bite and closed bite individuals.
5. Masseter muscle inclination, relative to occlusal plane, was the same in skeletal open bite and closed bite individuals.
6. The size of the gonial angle appears to be an important factor in accounting for the differences seen in masseter muscle inclination between skeletal open bite and closed bite.

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GLOSSARY

Landmarks - (Modified After Krogman)

1.	Anterior Nasal Spine (ANS)	Tip of the anterior nasal spine seen on the x-ray film from norma lateralis.
2.	Condyle (Co)	The center of condyle determined by inspection.
3.	Gonion (Go)	The point which on the jaw angle is the most inferiorly, posteriorly and outwardly directed.
4.	Gnathion (Gn)	The most inferior point in the contour of the chin.
5.	Menton (Me)	The lowermost point on the symphysial shadow as seen in norma lateralis.
6.	Nasion (Na)	The intersection of the internasal suture with the nasofrontal suture in the midsaggital plane.
7.	Orbitale (Or)	The lowest point on the lower margin of the bony orbit.
8.	Porion (Po)	The midpoint on the upper edge of the external auditory meatus.
9.	Posterior Nasal Spine (PNS)	The tip of the posterior spine of the palatine bone in the hard palate.
10.	Sella Turcica (S)	The midpoint of sella turcica, determined by inspection.

Planes

1.	Frankfort Horizontal Plane	Plane from porion to orbitale.
2.	Mandibular Plane	Plane from gonion to gnathion.
3.	Occlusal Plane	A line drawn between points representing one-half of the incisor overbite and one-half of the cusp height of the last occluding molars.
4.	Palatal Plane	Line from anterior nasal spine to posterior nasal spine.
5.	Ramal Plane (modified)	A plane from center of condyle to gonion.
6.	Sella-Nasion Plane	A plane from center of sella turcica to nasion.

Since there is not complete agreement as to what constitutes a "line" versus a "plane", the term "plane" has been used throughout this study.

LOMA LINDA UNIVERSITY

Graduate School

MASSETER MUSCLE POSITION RELATIVE TO SKELETAL OPEN BITE AND SKELETAL CLOSED BITE

by

Alonzo David Proctor

An Abstract of a Thesis

in Partial Fulfillment of the Requirements

for the Degree of Master of Science

in the Field of Orthodontics

June 1968

Modification of cephalometric roentgenographic procedures provided a means to identify the anterior borders of the right and left masseter muscles and relate them to surrounding dentoskeletal elements. Attachment of short, stiff, wires to the cheeks in a position superficial to the anterior borders of the muscles, subsequent to palpation and prior to exposure of the roentgenographic film, was the procedure used. The bilateral images projected on the film were averaged and traced along with dentoskeletal elements including those associated with skeletal type. This line representing the anterior border of the musculature was used to assess muscle position in the vertical and anterior-posterior dimensions of space.

Five measurements indicative of skeletal type were employed for the purpose of dividing a sample of 80 subjects into three groups. The statistic of one standard deviation from the mean was used to divide the sample into groups representative of skeletal open bite, closed bite and "normal." The values obtained from the cephalometric tracings were subjected to statistical procedures, including student "t" tests and correlation analysis to compare muscle position between the two extreme groups.

Comparison of the skeletal open bite and closed bite groups revealed a more horizontally placed masseter musculature, relative to S-N, Frankfort and palatal planes, in the open bite group. The skeletal open bite group had a more vertically inclined musculature than did the closed bite group when relating it to the mandibular plane. Masseter muscle attachment sites, per se, revealed no apparent difference between the two groups. Masseter muscle inclination, relative to occlusal plane, was the same in skeletal open bite and closed bite individuals.