Patterns of electromyographic activity in subjects with different skeletal facial types

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The relationship between form and function of the stomatognathic system has been studied by several researchers. There is, however, much controversy regarding the patterns of elevator electromyographic (EMG) activity in relation to craniofacial characteristics.[1] Differences in criteria for sample classification (skeletal or occlusal), may have contributed to this fact, since occlusion may vary independently of skeletal morphology.[2,3]

Several cephalometric measurements have been proposed for skeletal classification of subjects.[4-8] The sagittal difference between the maxillary and mandibular apical bases has been generally measured through the ANB angle.[4,9] However, a marked part of the variation of the ANB angle is caused by variations in the maxillary position (indicated by the SNA angle) and also by rotation of the jaw (indicated by SN-GoGn angle.)[10-14]

Freeman[12] proposed a simple method for adjusting ANB angle measurement in relation to SNA angle reading. Other authors[11,13-14] have proposed a method for compensating ANB angle measurement in relation to SN-GoGn angle reading. Therefore, in this study, Steiner ANB angle reading corrected both for maxillary position and rotation of the jaw was used as a criterion of skeletal classification. The aim was to record and compare electromyographic elevator activity at different functional requirements of the stomatognathic system, in a young adult sample with different craniofacial characteristics, classified according to this corrected ANB angle.

Material and methods

The study was carried out on 33 young adult subjects, 18 male and 18 female, ranging in age from 16 to 30 years (mean, 22.9 years). The sub-

Abstract

Integrated electromyographic activity of masseter and anterior temporal muscles was recorded using bipolar surface electrodes in 33 young adults. Subjects were skeletally classified according to ANB angle reading corrected both for maxillary position and rotation of the jaw.

Postural activity for both muscles was higher in Class III subjects than in Class I and Class II, whereas in Class I and II subjects activity was similar. During swallowing, masseter muscle activity in Class III subjects was higher than Classes I and II, whereas anterior temporal muscle activity was not different between Classes III and I. During maximal voluntary clenching, activity was not different among classes. High correlations between electromyographic activity and corrected ANB angle as well as with overjet were observed.

Skeletal classification used in the present study may have clinical relevance regarding treatment and prognosis, as well as in the assessment of the relationship between muscular activity and craniofacial characteristics.

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Key Words

Skeletal facial type • Cephalometry • Electromyography • Tonic activity • Swallowing activity

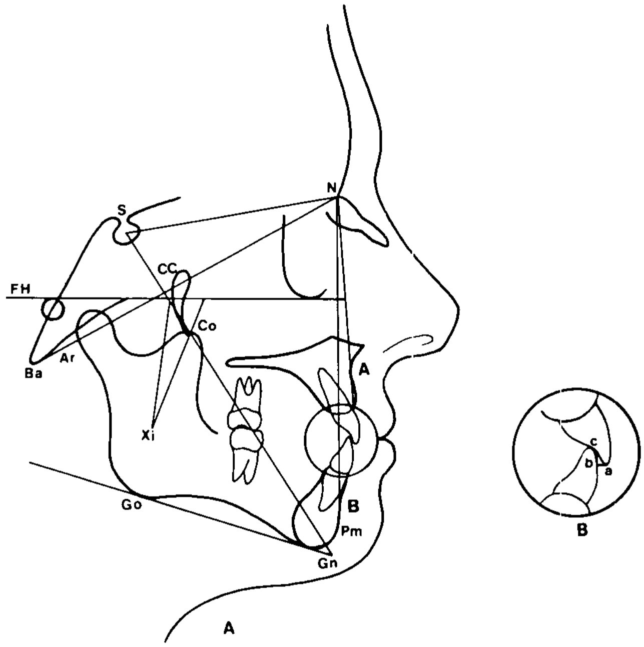

Figure 1

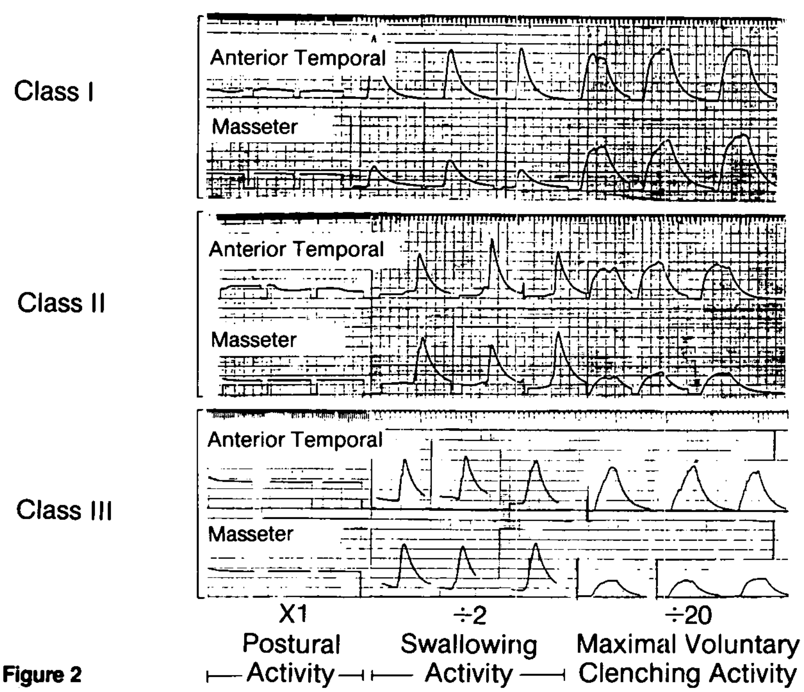

Figure 2

Figure 1
Angular and linear dimensions used in the present study.

Figure 2
Representative integrated EMG activity record.

jects presented natural dentition with at least 24 teeth and posterior molar support and had not received orthodontic treatment. Lateral skull radiographs (with mandible in the intercuspal position), dental casts and wax bites, were taken for each subject.

A sheet of transparent acetate was placed over the radiograph, the anatomical structures were outlined and the points and lines of reference selected for cephalometric analysis were located. Angular and linear measurements (Figure 1A), were carried out using a protractor and a millimeter rule, approximating to the 0.5 degree or millimeter respectively. In order to minimize methodological error, two outlines and measurements were made on each roentgenogram by the same examiner with a 5-day interval. The mean value of both measurements was used. In the present study the following angular and linear dimensions were measured: SNA angle; ANB angle; GoGn-SN angle; Facial Y axis length (S to Gn distance); Mandibular ramus position angle (between FH and CC-Xi lines); Posterior coronoid angle (between FH and Xi-Co lines). Overjet and overbite were measured on dental casts mounted in an articulator (fixator), using the wax bite in the intercuspal position (Figure 1B). Measurements were performed with a compass of dry points and a millimeter rule. A measurement procedure similar to one described previously for cephalometric analysis was used.

The procedure for skeletal classification of the subjects was as follows (Table 1): ANB angle was measured according to Steiner,[4] and the value was adjusted according to Freeman[12] subtracting or adding one degree to the ANB angle value for every two degrees that the SNA angle reading exceeded or was under 81.5°, respectively. This ANB angle, adjusted according to Freeman, was modified according to SN-GoGn angle reading.[13,14] This procedure consisted of subtracting or adding 25% of the difference by which the SN-GoGn angle reading exceeded or was under 32°, respectively. Thus, original ANB angle,[4] adjusted according to maxillary position and rotation of the jaw was used to classify the subjects into three groups. When the value of the corrected ANB angle varied between 0° and 4°, subjects were included in skeletal Class I. Subjects with values higher than 4°, were classified as skeletal Class II, whereas subjects with negative values were considered as skeletal Class III.

Surface electrodes (Grass 5e 5s, Grass Instrument Co., Quincy, Mass.) were used for electromyographic (EMG) recording. The electrodes were fixed on the left masseter muscle 1 cm above and below the motor point, on a line running parallel to the ear border (tragus) across the motor point. In the left anterior temporal muscle one electrode was attached about 1 cm above the zygomatic arch and 1.5 cm behind the orbital border and the other was placed 1.5 cm above the lower electrode. A large surface (about 9 square-cm) ground electrode was attached to the forehead.[15-18] The EMG activity was filtered (80 Hz to 100 KHz), amplified 1000 times, and then amplified again 10 to 50 times, integrated

Table 1
Angular cephalometric measurements used for skeletal classification of the subjects studied.

Subjects	ANB (*) angle	SNA angle	ANB (**) angle	GoGn-SN angle	ANB (***) angle	Skeletal Group (I)
1	4.00	86.50	1.50	31.25	1.69	I
2	4.25	86.25	1.88	30.50	2.25	I
3	2.25	82.50	1.75	33.50	1.38	I
4	1.75	78.25	3.38	29.50	4.00	I
5	4.25	77.25	6.38	44.25	3.31	I
6	3.00	89.25	-0.88	27.00	0.38	I
7	1.75	82.50	1.25	21.00	4.00	I
8	4.25	83.00	3.50	30.75	3.81	I
9	0.00	86.75	-2.63	6.15	3.84	I
10	2.00	82.00	1.75	27.00	3.00	I
11	6.25	80.50	6.75	45.00	3.50	I
12	-0.90	81.00	-0.65	27.00	0.60	I
13	0.50	80.00	1.25	34.00	0.75	I
14	13.75	80.75	14.13	50.75	9.44	II
15	10.75	83.25	9.88	42.50	7.25	II
16	7.75	81.00	8.00	37.00	6.75	II
17	12.00	83.25	11.13	38.50	9.50	II
18	1.50	73.50	5.50	30.75	5.81	II
19	7.00	85.00	5.25	25.50	6.88	II
20	4.00	83.00	3.25	27.50	4.38	II
21	7.75	78.00	9.50	32.50	9.38	II
22	7.00	81.00	7.25	40.00	5.25	II
23	5.00	80.50	5.50	35.50	4.63	II
24	9.50	84.50	8.00	41.50	5.63	II
25	-1.65	83.00	-2.40	25.50	-0.78	III
26	-12.00	83.00	-12.75	29.75	-12.19	III
27	-5.50	88.50	-9.00	31.00	-8.75	III
28	-4.25	79.00	-3.00	40.50	-5.13	III
29	0.75	80.75	1.13	44.25	-1.94	III
30	-2.00	89.75	-6.13	19.00	-2.88	III
31	-6.25	76.00	-3.50	41.75	-5.94	III
32	-1.90	84.60	-3.45	33.75	-3.89	III
33	-2.90	83.50	-3.90	23.00	-1.65	III

ANB angle (*) (according to Steiner)
ANB angle (**) (adjusted according to Freeman)
ANB angle (***) (according to Steiner, adjusted according to Freeman and compensated according to GoGn-SN angle value)
Skeletal Group (I) (classification according to ANB angle (***)

(time constant 1800 ms) and finally registered on a polygraph (Nihon Kohden RJD-4022).

The subjects, sitting upright in a dental chair with the head supported and the Frankfurt plane parallel to the floor, inside a Faraday cage, were submitted to six recordings of EMG activity in the postural mandibular position and during swallowing of saliva and maximal voluntary clenching in intercuspal position (Figure 2).

Each curve of postural activity lasted approximately 20 seconds and was divided into periods of 5 seconds. Values in the ordinate were obtained by manual measuring; the mean amplitude was then calculated for each curve.

During swallowing of saliva, the peak of integrated EMG (IEMG) activity was measured, allowing a resting period of 1 minute between each swallowing. During maximal voluntary clenching, the peak of IEMG activity was also measured. A resting period of 30 seconds between clenching was allowed to avoid muscular fatigue.

Table 2
Group mean of electromyographic activity in the facial skeletal classes studied.

Conditions	Anterior Temporal Muscle Skeletal Classes I		II		III		Kruskal-Wallis test
	X	SEM	X	SEM	X	SEM	H values
Postural	4.4	0.5	5.4	0.8	12.0	1.2	17.34 **
Swallowing	49.2	12.2	33.5	7.2	86.6	16.7	5.96 *
Maximal clenching	312.0	40.8	256.5	49.6	275.0	48.5	0.73 NS

Conditions	Masseter Muscle Skeletal Classes I		II		III		Kruskal-Wallis test
	X	SEM	X	SEM	X	SEM	H vales
Postural	8.0	0.6	7.1	0.8	13.7	1.3	14.56 **
Swallowing	30.2	3.6	31.3	10.7	56.3	12.7	6.14 *
Maximal clenching	349.6	66.4	232.0	40.8	303.7	40.5	4.11 NS

*$p < 0.05$; **$p < 0.01$; NS = Non-significant

Subsequently, for each subject a mean value based on the six curves in each condition and for each muscle was used.

Comparison of cephalometric, dental casts and IEMG measurements between all classes, as well as the paired comparison between classes, were performed through the Kruskal-Wallis test.

The relationships between IEMG activity and angular or linear dimension were studied by means of a simple linear correlation.

Results

Table 2 presents the group mean of IEMG anterior temporal and masseter muscle activity in each condition studied and for each skeletal class. Significant differences between both muscles and among classes were evident in postural activity and during swallowing of saliva, whereas during maximal voluntary clenching activity was not different.

Table 3 shows the paired comparison of IEMG activity between skeletal classes in the postural position and during swallowing of saliva. Postural activity for both muscles was significantly higher in Class III subjects than in Classes I and II, where activity was similar.

During swallowing of saliva in the anterior temporal muscle, activity in Class III subjects was higher than in Class II. No significant differences were observed between Classes III and I, or between Classes I and II. In the masseter muscle, activity in Class III subjects was higher than in Classes I and II, whereas activity in Classes I and II was similar.

Table 4 presents the group mean of complementary angular and linear measurements performed in the subjects studied (Figure 1). Significant differences between all classes in facial Y axis length, mandibular ramus position angle, posterior coronoid angle, overjet and overbite are evident.

Table 5 shows the paired comparison of complementary angular and linear measurements. Note significant differences between Classes III and I and between Classes III and II, whereas no difference was found between Classes I and II.

Table 6 presents a simple linear correlation between IEMG activity and angular or linear dimensions. High correlations between IEMG activity and ANB angle (***) as well as overjet were observed.

Discussion

The existence of a great anteroposterior discrepancy between subjects of different skeletal facial types is well know. The present sample was no exception to this rule.

ANB angle, a widely used indicator of apical base relationship, compensated according variations in maxillary position and rotation of the jaw, was used for skeletal group classification in the present study. Other factors that could be introduced for improving skeletal classification were not considered in the present study, since a more cumbersome criterion could induce more confusion than benefits.

Differences between ANB angle reading according to Steiner and ANB angle reading in which maxillary position and rotation of the jaw

Table 3
Paired comparison of IEMG activity between facial skeletal classes studied (Kruskal-Wallis test).

Condition		Anterior Temporal	Masseter
Postural activity	I vs. II	H = 1.2 NS	H = 1.1 NS
	I vs. III	H = 14.1 **	H = 10.7 **
	II vs. III	H = 11.3 **	H = 10.8 **
Swallowing activity	I vs. II	H = 0.3 NS	H = 1.5 NS
	I vs. III	H = 3.3 NS	H = 3.8 *
	II vs. III	H = 5.7 *	H = 4.4 *

*$p < 0.05$; **$p < 0.01$; NS = Non-significant

Table 5
Paired comparison of complementary angular and linear measurements in the facial skeletal classes studied.

Variables	I vs. II	I vs. III	II vs. III
Facial Y axis length	NS	*	**
Mandibular ramus position	NS	*	**
Posterior coronoid angle	NS	*	**
Overjet	NS	**	**
Overbite	NS	**	*

*$p < 0.05$; **$p < 0.01$; NS = Non-significant

Table 4
Group mean of complementary angular and linear measurements in the facial skeletal classes studied.

Variables	Skeletal Groups I		II		III		Kruskal-Wallis test
	X	SEM	X	SEM	X	SEM	H values
Facial Y axis length	135.7	2.6	130.0	3.2	146.0	4.2	7.8 *
Mandibular ramus position angle	76.2	0.9	73.7	1.1	80.5	2.1	9.7 **
Posterior coronoid angle	64.5	1.2	61.6	1.0	68.3	1.2	10.3 **
Overjet	2.6	0.5	3.6	0.5	-3.0	1.4	17.9 **
Overbite	3.1	0.3	2.8	0.6	0.6	0.7	12.5 **

*$p < 0.05$; **$p < 0.01$

have been compensated resulted in classification in a different skeletal class for subjects 2, 5, 8, 11, 12, 18, 20 and 29. This fact could be relevant with regard to their treatment and prognosis as well as in the assessment of the relationship between patterns of the elevator activity and craniofacial characteristics.

EMG postural activity for both muscles was higher in Class III subjects than in Classes I and II, whereas activity in subjects in Classes I and II was similar. This postural EMG pattern in Class III could be related to differences in the position and rotation of the jaw found in the complementary angular and linear dimension measured in the present study. Probably, both factors could determine a change in muscular action axis and an increase in the gravitational component, causing a higher stimulation of neuromuscular spindles of jaw elevator muscles and thus reflexively increasing postural EMG activity.

As far as we know, this EMG pattern of higher postural activity in Class III patients has

Table 6
R values of simple linear correlation between IEMG activity and angular or linear measurements in the facial skeletal classes studied.

Condition	ANB (***) angle	Facial Y axis length	Mand. ramus position angle	Posterior coronoid angle	Overjet	Overbite
1	-0.76 **	0.43 *	0.37 *	0.46 **	-0.82 **	-0.51 **
2	-0.55 **	0.24 NS	0.22 NS	0.41 *	-0.59 **	-0.59 **
3	-0.58 **	0.33 NS	0.47 **	0.27 NS	-0.46 **	-0.21 NS
4	-0.44 **	0.30 NS	0.40 *	0.17 NS	-0.49 **	-0.31 NS

1: Temporal postural activity; 2: Masseter postural activity;
3: Temporal swallowing activity; 4: Masseter swallowing activity
*$p < 0.05$; **$p < 0.01$; NS = Non-significant

not been reported and although the clinical implication is still not clear, this fact could be important because jaw muscular posture is a 24-hr function.

EMG activity during swallowing of saliva in the intercuspal position also showed an EMG pattern with higher activity in Class III patients than in Classes I and II for masseter muscle, whereas for anterior temporal muscle, activity between Classes III and I showed no significant difference.

Several factors could be involved in this higher swallowing EMG pattern observed in Class III patients. In addition to change in muscular action axis due to differences in the position and rotation of the jaw, occlusal stabilization of the mandible in the intercuspal position during swallowing of saliva could be important.[17,19] Anterior teeth disclusion, which presents a lower mechanoreceptor threshold, probably determines lower inhibition of the jaw elevator muscles mediated by periodontal mechanoreceptors.

This swallowing EMG pattern in Class III subjects may have clinical relevance, since the process of swallowing is a 24-hr function repeated about 600 to 2400 times each day.[17,18,20,21]

Maximal voluntary clenching activity was not significantly different between skeletal classes. In addition to differences in the position and rotation of the jaw, psychological influences such as fear of pain or tooth fracture may have played some role in the level of recorded muscular activity. Moreover, in accordance with Ahlgren,[22] some people simply clench harder than others in response to the same instruction. Nevertheless, in order to minimize psychological factors we encouraged patients to clench as hard as they could.

The simple linear correlation values found in the present study support the idea of close interrelationships between EMG patterns and craniofacial characteristics of the stomatognathic system. A lesser number of significant correlations for swallowing than for postural activity may arise from the fact that during swallowing other factors predominate, such as periodontal mechanoreceptor stimulation.

The clinical implications of EMG patterns found in skeletal Class III subjects in both functional conditions, postural as well as during swallowing of saliva, are currently being studied.

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