Facial Morphology and Activity of Temporal and Lip Muscles during Swallowing and Chewing

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Several recent investigations have shown a correlation between the activity of the masticatory muscles and facial and bite morphology. The investigations were electromyographic and performed on children[1,2,7] as well as on adults.[9] Studies of the bite force in adults[10] have given results corresponding to those in the electromyographic investigations. Strong activity of the masticatory muscles in postural position of the mandible and during chewing, biting and swallowing is found in individuals with a small face height, parallelism between the jaw bases (anterior inclination of the mandible), and a small gonial angle. The shape of the face in persons with strong muscle activity has been characterized as rectangular in profile.[7] In children the correlation found between facial morphology and EMG-activity during chewing and biting has been shown to be closer than with the activity during swallowing.[7] In adults, on the other hand, the activity of the masticatory muscles during swallowing has been demonstrated to be clearly correlated with facial morphology.[9]

The degree of activity of the masticatory muscles during different natural functions thus appears clearly to vary with facial form. The correlation may be interpreted as suggesting either that muscular activity contributes to shape the facial skeleton or that the degree of muscular activity (strength) varies with the genetically-determined shape of the face. In the above-mentioned electromyographic investigations and studies of bite force it was not possible to decide which of the above alternatives was correct, but the demonstration of the correlation per se is important in the discussion of the significance of the function for growth.[8]

The role played by the orofacial musculature in the shaping of the dentition has long attracted the interest of orthodontists. Since 1946 when Rix[11] described so-called "atypical" swallowing, an abnormal type of swallowing has been regarded in orthodontic textbooks as a contributory cause of malocclusion. Though the pressure from, among other things, the lips has been regarded as being capable of causing malocclusion, only a few quantitative electromyographic investigations are available on the relation between the activity of the labial muscles during natural functions and the bite and facial morphology. Möller[9] found several interesting correlations between facial and bite morphology and the activity of the upper and lower lips during chewing and swallowing in adults. In children[7] the amplitudes of the electromyographic recordings from the upper lip, particularly during chewing, but also during swallowing, have been found to be correlated with facial morphology, but the activity in the lower lip was not studied in that investigation. However, the activity of the lower lip may also be related to the bite morphology like, for example, the relation between the upper and lower incisors and the inclination of the incisors.

The present investigation was undertaken to find out whether, in children, any correlations exist between the muscular activity of the lower lip during natural functions and, respectively, the bite and facial morphology. The investigation was also extended to in-

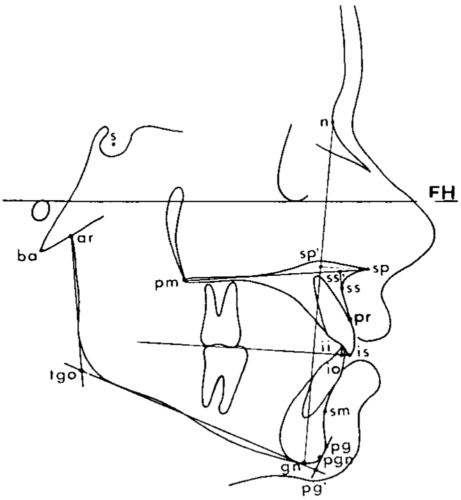

Fig. 1 Reference points for roentgen-cephalometric analysis.

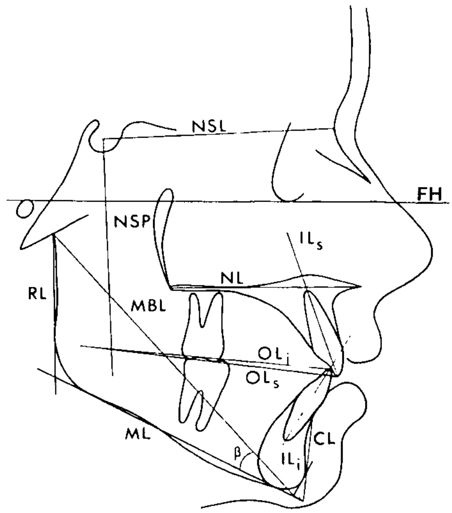

Fig. 2 Reference lines for roentgen-cephalometric analysis.

clude an endeavour to check the validity of correlations demonstrated earlier between the muscular activity of the upper lip and, respectively, the temporal muscle and facial morphology.

Material and Methods

The clinical material consisted of 50 girls aged 9-13 (mean 11 years) with a clinically normal occlusion. The material and the electromyographic and analytical methods have been described earlier.[6]

The activity in the anterior and posterior portions of the temporal muscle was recorded bilaterally, and that of the upper and lower lips symmetrically relative to the midline. The recordings were made during swallowing of water and saliva and during chewing and swallowing of apples and peanuts.

Analysis of the electromyograms included measurement of: a) maximal mean voltage amplitude during swallowing, b) maximal mean voltage amplitude during the closing phase of the chewing cycle and in the lips during the opening phase of the chewing cycle, and c) the number of chewing cycles during an act of chewing (one act of chewing = trituration of apples and peanuts, respectively, until swallowed).

The facial morphology was judged from profile roentgenograms taken with the mandible in intercuspal position. The roentgenographic and analytical methods used have been described earlier.[4] The reference points and lines used are given in Figures 1 and 2.

The cephalometric analysis comprising the variables given in Table I was supplemented by measurements, made on dental casts (Fig. 3), of the width of the upper dental arch between the central fossae (var. 42) of the first permanent molars, and the length of the dental arch from a line joining the above mentioned fossae and the edge of the central incisors (var. 43). In the lower jaw, measurements were made of the width between the mesiobuccal cusps of the first molars (var. 44) and the length of the dental arch to the central incisors (var. 45).[5] The number of erupted permanent teeth (var. 46) and the number of deciduous teeth (var. 47) as well as the total number of teeth (var. 48) were counted on the casts.

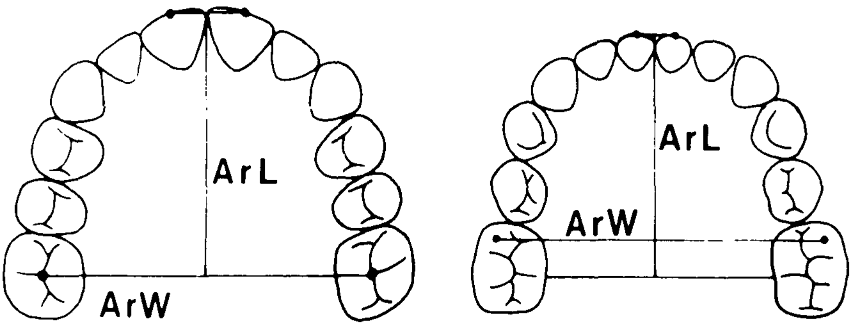

Fig. 3 Measuring points for determination of width and length of dental arches.

Results

The EMG-values found for the temporal muscle on either side, as well as the double recordings of lip-activity, which have been described earlier,[6] were pooled and correlated with the morphological variables. The rank-correlation according to Spearman was used.[12] The critical value for the correlation coefficient was 0.28 for $0.01 < P < 0.05$, 0.37 for $0.001 < P < 0.01$ and 0.47 for $P < 0.001$.

TABLE I

Linear dimensions and angles used in the profile roentgencephalometric analysis

Linear	*Angles*
1. n-s	20. n-s-ar
2. n-ar	21. n-s-ba
3. n-ba	22. s-n-pr
4. s-ar	23. s-n-ss
5. s-ba	24. s-n-sm
6. ss-pm	25. s-n-pg
7. ss'-pm	26. ss-n-pr
8. sp-pm	27. ss-n-sm
9. pm-NSL	28. ss-n-pg
10. pm-NSP	29. s-ar-tgo
11. ar-ss	30. NSL/NL
12. n-gn	31. NSL/ML
13. n-sp'	32. NL/ML
14. sp'-gn	33. NL/OL_s
15. tgo-pg'	34. IL_s/NL
16. ar-tgo	35. IL_i/ML
17. ar-pgn	36. IL_s/IL_i
18. is-io	37. OL_i/ML
19. ii-io	38. ML/CL
	39. ML/RL
	40. beta
	41. NSL/MBL

The amplitude of the recording from the lower lip during the act of swallowing was not correlated with any of the roentgencephalometric variables, but negatively with the width and length of the upper dental arch (Table II).

As for the upper lip, the amplitude during swallowing of apples and peanuts was negatively correlated with the cranial base length (var. 1 and 2) and with the size of the gonial angle (var. 39), but positively with the maxillary prognathism (var. 23). The amplitude during swallowing of peanuts was also negatively correlated with the vertical jaw relation (var. 32) and with the length of the upper dental arch (var. 43). The amplitude of the upper lip during swallowing of saliva was negatively correlated with the vertical jaw relation (var. 32) and positively with the curvature of the mandible (var. 40, angle beta).

The amplitude of the recording from the temporal muscle during swallowing was negatively correlated with the upper face height (var. 13) and with the inclination of the maxilla and mandible (var. 30, 31, 41), but positively with their prognathism (var. 22, 23, 27). A positive correlation was found between the amplitude of the recording from the temporal muscle and the proclination of the lower incisors (var. 35) as well as with the mandibular alveolar prognathism (var. 38).

TABLE II

Significant rank-correlation coefficients between maximal mean voltage amplitude during swallowing and morphologic variables (n = 50)

	Ant. temporal m.				*Post. temporal m.*				*Upper lip*				*Lower lip*			
Variable	Water	Saliva	Apple	Peanuts	Water	Saliva	Apple	Peanuts	Water	Saliva	Apple	Peanuts	Water	Saliva	Apple	Peanuts
1. n-s											—.35	—.30				
2. n-ar											—.30	—.28				
3. n-ba			—.28													
13. n-sp		—.32		—.34		—.33	—.42	—.36								
20. n-s-ar	—.29															
22. s-n-pr			.35				.41									
23. s-n-ss			.35				.39				.30	.29				
27. s-n-sm			.29													
30. NSL/NL		—.32			—.35	—.43										
31. NSL/ML					—.35	—.29										
32. NL/ML										—.33		—.33				
35. IL_i/ML			.30				.37									
36. IL_s/IL_i							—.29									
38. ML/CL			.30		.29		44									
39. ML/RL											—.31	—.29				
40. beta										.35						
41. NSL/MBL					—.34											
42. ArWM,uj														—.29		
43. ArLM,uj												—.28	—.31			

The amplitude of the recording from the lips during the opening as well as the closing phase of the chewing cycle was negatively correlated with dimensions of the cranial base (var. 1 and 2) [Table III]. The amplitude of the activity of the upper lip during the opening phase was also positively correlated with the mandibular prognathism (var. 24), and the amplitude of the activity of the lower lip was negatively correlated with the length of the maxilla (var. 8) and lower dental arch (var. 45) as well as with the overbite (var. 19).

The amplitude of the recording from the temporal muscle was negatively correlated with the anterior and posterior upper face height (var. 9 and 13) and with the total face height (var. 12). The amplitude of the recording from the anterior portion of the temporal muscle was also negatively correlated with the width of the upper and lower dental arches (var. 42 and 44). The amplitude of the recording from the posterior temporal muscle was negatively correlated with the overbite (var. 19) and with the length of the posterior cranial base (var. 5) and positively with the number of deciduous teeth (var. 47).

The number of chewing cycles was negatively correlated with, among other things, dimensions of the cranial base (var. 2 and 3), the depth of the face (var. 11 and 17), and the number of permanent teeth (var. 46) as well as the total number of teeth (var. 48). A negative correlation was found also with age (var. 49), but a positive correlation with the number of deciduous teeth (var. 47).

Discussion

The investigation included a large number of tests of the correlation coefficients. The calculation according to Eklund and Seeger[3] showed that many of the significances found for the correlation coefficients might have been false. In the interpretation of the results attention should, therefore, primarily be given to groups of correlation coefficients suggesting a correlation between several similar electromyographic and morphologic variables and to agreements with earlier results.

The amplitude of the recordings from the temporal muscle during swallowing showed a notably clearer correlation with facial morphology than what has been found in earlier investigations in children.[7] The results, which are in line with earlier findings, show that the activity of the temporal muscle during swallowing is considerable if the upper face height is small, if the anterior cranial base and the jaw bases are parallel, and in the presence of marked prognathism. The rectangular shape of the face described in the introduction, which has generally been found to be characteristic of marked muscular activity, is thus also characterized by considerable activity of the temporal muscle during swallowing.

Analysis of the variables of the dentoalveolar morphology of the face showed clear correlations with the inclination of the lower incisors and mandibular alveolar prognathism. Individuals with marked proclination of the lower incisors and pronounced mandibular alveolar prognathism showed considerable muscular activity of the temporal muscle during swallowing.

The correlation demonstrated between the activity of the temporal muscle during swallowing and facial morphology of the children examined is in agreement with Möller's[9] findings in adults. He, too, found a negative correlation between the curvature of the cranial base and the activity of the temporal muscle and, in addition, clear positive correlations between the activity of the masseter muscle and facial

TABLE III

Significant rank-correlation coefficients between maximal mean voltage amplitude during chewing and number of chewing cycles and morphologic variables ($n = 50$)

Variable	*Ant. temp. m.*		*Post. temp. m.*		*Upper lip*[1]		*Lower lip*[1]		*Upper lip*[2]		*Lower lip*[2]		*Number of chewing cycles*	
	Apple	Peanuts	Apple	Peanuts	Apple	Peanuts	Apple	Peanuts	Apple	Peanuts	Apple	Peanuts	Apple	Peanuts
1. n-s					—.40	—.37	—.28	—.35	—.37		—.31	—.35		
2. n-ar						—.32							—.31	
3. s-ar													—.30	
5. s-ba				—.32										
8. sp-pm											—.28	—.29		
9. pm-NSL	—.38		—.33											
11. ar-ss													—.31	—.36
12. n-gn		—.33		—.37										
13. n-sp	—.43	—.44	—.44	—.43									—.34	
16. ar-tgo													—.34	
17. ar-pgn													—.32	
19. ii-io			—.35	—.32							—.33			
24. s-n-sm									.29					
42. ArWM,uj	—.28	—.38												
44. ArWM,lj		—.30												
45. ArLM,lj												—.29		
46. Number of perm. teeth													—.44	—.35
47. Number of deciduous teeth			.28										.39	
48. Total number of teeth													—.37	—.40
49. Age													—.31	

1) during closing phase of the chewing cycle
2) during opening phase of the chewing cycle

prognathism, but negative ones with the inclination of the face.

The activity of the temporal muscle during swallowing of peanuts was only weakly correlated with facial morphology compared with the activity during swallowing of other media. This may perhaps be explained by the peanuts being relatively difficult to swallow and requiring extra muscular activity in certain children. The amplitude of the EMG-recording during swallowing of peanuts also showed the smallest number of significant correlations with the amplitude of the recordings from the other muscles during swallowing.[6]

The amplitude of the EMG of the upper lip was, like the activity in the temporal muscle, related to the maxillary prognathism as well as to the shape of the mandible and the vertical jaw relation. The activity in the upper lip during swallowing, therefore, fitted in well with the general correlation between facial shape and muscular activity. The activity in the lower lip during swallowing, on the other hand, appeared less dependent on facial morphology since no significant correlations were found with the variables of facial morphology. The activity in the lower lip was related only to the size of the upper dental arch. The activity in the lower lip during swallowing was independent of facial morphology and of the activity in the temporal muscle in contrast with that of the upper lip. Yet a relatively close positive correlation was found between the activity in the upper and lower lips.

An interesting finding was the negative correlation between the activity in the upper lip during swallowing and the dimensions of the cranial base. During chewing such negative correlations were found between the cranial base and the activity of both the upper lip and that of the lower lip. The correlations, which are difficult to explain, were found also in an earlier investigation in children[7] between the activity of the upper lip during chewing and the dimensions of the cranial base. Otherwise the activity of the lip during chewing showed only occasional correlations with few of the morphological variables; the investigation could not verify the relatively few correlations between morphological variables and activity of the lip found in Möller's[9] investigation of adults.

The activity of the temporal muscle during chewing was negatively correlated with the face height, which agrees well with the general correlation between the muscular activity and facial form discussed in the section on activity of the temporal muscle during swallowing. The relation between the activity of the masticatory muscles and facial form is illustrated in Figure 4 which shows the average facial form in five children with, respectively, the greatest and lowest maximal mean voltage amplitude of the recordings from the anterior portion of the temporal muscle during chewing of peanuts. In the girls with a marked activity in the temporal muscle the anterior inclination of the maxilla and mandible was greater, and the face height smaller, than in girls with a low activity.

The negative correlation between the amplitude of the anterior temporal muscle during chewing and the width of the upper dental arch was not demonstrable in the earlier investigation of children,[7] where a negative correlation was found between the duration of the chewing activity and the width of the upper dental arch.

The number of teeth and the number of chewing cycles were included in the analysis mainly to check a negative correlation found earlier in children between the above-mentioned variables.[7] The results agreed with those found earlier and suggested the exist-

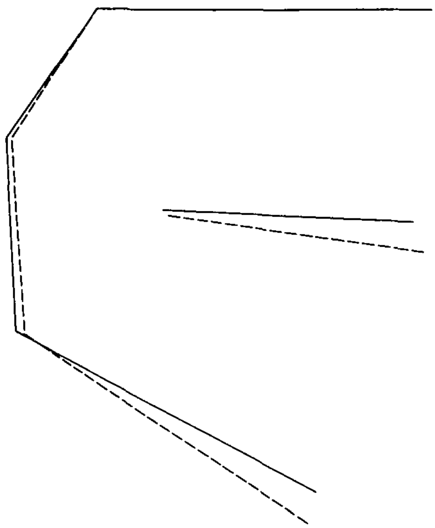

Fig. 4 Facial form in 5 girls with strong (unbroken line) and 5 girls with weak (broken line) activity of temporal muscle during chewing.

ence of an adaptation in such a way that the number of necessary chewing cycles decreased with development of the dentition. This agreed with Ahlgren's[1] observation that in children the chewing activity tends to decrease with increasing age. In the same way one might perhaps interpret the negative correlations between the number of chewing cycles and several linear roentgencephalometric variables since these dimensions increase with age.

Summary

The correlations between facial and bite morphology and the activity in the temporal muscle and in the musculature of the lips during swallowing and chewing were studied in 50 girls, aged 9-13 years.

The activity was recorded electromyographically by determining the maximal mean voltage amplitude and morphologically by analysis of profile roentgenograms and dental casts.

The activity in the lower lip during the swallowing was not correlated with any of the variables of the facial morphology with the exception of the width of the upper dental arch. On the other hand, the activity of the upper lip during swallowing, as in the anterior and posterior portions of the temporal muscle, was correlated with a number of variables used for measuring facial form. The activity was low in girls with a facial shape with anterior inclination of the maxilla and mandible, small face height, and pronounced prognathism.

The activity in the upper lip during chewing varied, as in the lower lip, independently of facial form, while the activity of the temporal muscle during chewing showed the same relation to facial form as during swallowing.

The number of chewing cycles required for trituration of the test media (apples and peanuts) was negatively correlated with the number of teeth and with age. This was interpreted as adaptation in such a way that the number of cycles decreased with development of the dentition.

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