Electromyographic evaluation of the upper lip according to the breathing mode: a longitudinal study

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Abstract: The present study aimed at analyzing and comparing longitudinally the EMG (electromyographic activity) of the superior orbicularis oris muscle according to the breathing mode. The sample, 38 adolescents with Angle Class II Division 1 malocclusion with predominantly nose (PNB) or mouth (PMB) breathing, was evaluated at two different periods, with a two-year interval between them. For that purpose, a 16-channel electromyography machine was employed, which was properly calibrated in a PC equipped with an analogue-digital converter, with utilization of surface, passive and bipolar electrodes. The RMS data (root mean square) were collected at rest and in 12 movements and normalized according to time and amplitude, by the peak value of EMG, in order to allow comparisons between subjects and between periods. Comparison of the muscle function of PNB and PMB subjects at period 1 (P1), period 2 (P2) and the variation between periods (Δ) did not reveal statistically significant differences between groups ($p < 0.05$). However, longitudinal evaluation of the muscle function in PNB and PMB subjects demonstrated different evolutions in the percentage of required EMG for accomplishment of the movements investigated. It was possible to conclude that there are differences in the percentage of electric activity of the upper lip with the growth of the subjects according to the breathing mode.

Descriptors: Electromyography; Malocclusion, Angle Class II; Mouth breathing; Lip.

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Introduction

Since 1907, it has been believed that the unbalanced muscular pressure observed in mouth breathers would trigger the facial and skeletal alterations found in these subjects.[1] Since then, several other authors have been attempting to establish relationships between mouth breathing and muscle function.[2,3,4]

The literature often mentions that the muscles and lips are responsible for the dental and skeletal alterations observed in mouth breathers.[5,6] Subtelny[6] (1954) explained that, as the lips were kept open, the posterior portion of the tongue was moved downwards and forwards, and the mandible was also inferiorly positioned. Therefore, the lips and associated muscles would not perform their function properly, leading to gradual protrusion of the anterior teeth and to the establishment of an Angle Class II Division 1 malocclusion.

Ricketts[7] (1968) believed that proclination of the maxillary incisors and narrowing of the maxillary dental arch yielded by mouth breathing would lead to a reduced pressure of the short upper lip and a poor muscle tonicity. In the opinion of Linder-Aronson[8] (1974), the need to keep the lips open to breathe in mouth breathers would lead to a change in the tension of the orbicularis oris muscle. However, regardless of the cause-effect relationship suggested, all aforementioned authors unanimously established relationships between the muscle activity and the breathing mode.

If a functional modification does affect the orofacial muscles,[6,7,8] then there is a great interest in evaluating the superior orbicularis oris muscle, which represents the upper lip.

This work proposes to analyze and compare the EMG of the superior orbicularis oris muscle in subjects with Angle Class II Division 1 malocclusion with predominantly nose or mouth breathing, at two different periods, with a two-year interval between them.

Material and Methods

The present qualitative and longitudinal study was conducted on a random sample, with 38 subjects, being 24 PNB and 14 PMB. At P1, the subjects were 11 years to 14 years and 11 months old, and, at P2, 13 years and 4 months to 16 years and 6 months old.

All individuals were white Brazilian adolescents, of both sexes, presenting Angle Class II Division 1 malocclusion. The subjects were divided into two groups: predominantly nose breathing (PNB) and predominantly mouth breathing (PMB). Subjects were classified using a multidisciplinary approach, exactly as performed by Vianna-Lara, Caria[4] (2006).

Individuals with early tooth loss and/or extensive caries, as well as those submitted to any type of orthodontic treatment, and/or presenting any deleterious habit besides mouth breathing, were excluded from the study, since these factors might interfere with the outcomes.

Electromyographic examinations were performed in a proper isolated room, with a 16-channel electromyography machine with amplification gain of 1,000 times, high-pass filter of 20 Hz and low-pass filter of 500 Hz (EMG System of Brazil, São José dos Campos, SP, Brazil), properly calibrated in an Intel-based PC equipped with an analogue-digital converter (12 bits of resolution, 32 channels for PC).

The passive bipolar surface electrodes were fastened on the external region of the upper lip and the grounding wire on the wrist. The distance between the electrode centers was 15 mm, so that they were equidistant to the midsagittal plane and 2 mm above the upper margin of the vermillion of the upper lip.[4]

For the purpose of standardization, all situations, including the rest position with the lips relaxed, were considered as movements. Therefore, the “movements” were:

0. Rest with the lips relaxed
1. Blowing
2. Free sucking
3. Reciprocal compression of the lips
4. Opening of the commissures
5. Lip protrusion
6. /b/ phoneme
7. /m/ phoneme
8. /f/ phoneme
9. /v/ phoneme

10. Chewing (of a ½" orthodontic elastic band) at the right side
11. Chewing (of a ½" orthodontic elastic band) at the left side
12. Swallowing of saliva

The electromyographic records – RMS (root mean square) of the electric potentials achieved – were processed with specific software (AqDados, version 5.05, Lynx Electronic Technology, São Paulo, SP, Brazil).

Method error was determined by random selection of four individuals in the sample for the repetition of examinations performed to confirm the results[9] and by the box plot evaluation to see if there were extreme outliers that could influence the value of the mean for each treatment.[10]

Thereafter, the data obtained were tabulated and normalized in relation to the amplitude by the peak electromyographic value.[11,12] Since the electromyographic signal presents a large variability, its absolute value provides little information for comparisons among individuals and at different periods.[13] This can be addressed by transforming the absolute value into a relative value, on the basis of a reference electromyographic datum taken as 100% of the muscle activity.[13,14,15] This involves selecting the movement presenting the higher RMS (lip protrusion) and using it as the maximum reference of the muscle. By dividing each RMS of the other movements by this maximum value, a percentage of activity of each movement in relation to the maximum activity is obtained.

For the statistical analysis, homogeneity of variance was evaluated by the Levene test and the normality test applied was the Kolmogorov-Smirnov test.

For comparison of the differences between the means of the two groups (PNB and PMB) at each period (P1 and P2), Student's t test for independent samples (normal distribution) and the non-parametric Mann-Whitney U test (not normal distribution) were used.

Comparison of the mean values between periods 1 and 2 of the variables investigated for groups PNB and PMB was performed by Student's t test for dependent samples (normal distribution) and the non-parametric Wilcoxon test for dependent samples (not normal distribution).

Results

Tables 1 and 2 display the comparisons of the means between the PNB and PMB groups at each period. At both periods, no movement presented statistically significant differences ($p < 0.05$) when the means of each movement were compared between the breathing modes.

Tables 3 and 4 present the comparisons of the means between the two periods (longitudinal view) for the PNB and PMB groups. When comparing the means of the movements between periods for the PNB group, the movements of swallowing, /b/, /m/ and /f/ phonemes presented statistically significant difference ($p < 0.05$). With regard to the PMB group, only the movement of free sucking presented a statistically significant difference ($p < 0.05$).

Table 1 - Student's t test for independent samples, for comparison of the means between the breathing modes.

Movement	Period	PNB Mean	PMB Mean	T	p value
/v/ phoneme	1	0.78	0.60	0.96	0.3453
Rest with the lips relaxed	2	0.17	0.25	−1.86	0.0712
Reciprocal compression of the lips	2	0.97	1.07	−0.64	0.5232
Opening of the commissures	2	0.41	0.42	−0.03	0.9751
/b/ phoneme	2	0.46	0.50	−0.71	0.4811
/m/ phoneme	2	0.59	0.70	−1.07	0.2936
/v/ phoneme	2	0.58	0.62	−0.38	0.7041
Chewing at the right side	2	0.31	0.35	−0.70	0.4877
Chewing at the left side	2	0.31	0.37	−0.90	0.3724

Table 2 - Non-parametric Mann-Whitney U test, for comparison of the means between breathing modes.

Movement	Group	Period	Mean Rank	Sum of Ranks	Z	p value
Rest with the lips relaxed	PNB	1	19.67	472.00	−0.12	0.9037
	PMB	1	19.21	269.00		
Blowing	PNB	1	19.17	460.00	−0.24	0.8087
	PMB	1	20.07	281.00		
	PNB	2	19.71	473.00	−0.15	0.8797
	PMB	2	19.14	268.00		
Free sucking	PNB	1	18.38	441.00	−0.82	0.4139
	PMB	1	21.43	300.00		
	PNB	2	18.75	450.00	−0.54	0.5860
	PMB	2	20.79	291.00		
Reciprocal compression of the lips	PNB	1	20.50	492.00	−0.73	0.4677
	PMB	1	17.79	249.00		
Opening of the commissures	PNB	1	20.13	483.00	−0.45	0.6499
	PMB	1	18.43	258.00		
/b/ phoneme	PNB	1	21.17	508.00	−1.21	0.2261
	PMB	1	16.64	233.00		
/m/ phoneme	PNB	1	19.75	474.00	−0.18	0.8559
	PMB	1	19.07	267.00		
/f/ phoneme	PNB	1	21.21	509.00	−1.24	0.2147
	PMB	1	16.57	232.00		
	PNB	2	19.71	473.00	−0.15	0.8797
	PMB	2	19.14	268.00		
Chewing at the right side	PNB	1	20.08	482.00	−0.42	0.6718
	PMB	1	18.50	259.00		
Chewing at the left side	PNB	1	18.88	453.00	−0.45	0.6499
	PMB	1	20.57	288.00		
Swallowing	PNB	1	19.38	465.00	−0.09	0.9277
	PMB	1	19.71	276.00		
	PNB	2	17.13	411.00	−1.72	0.0845
	PMB	2	23.57	330.00		

Discussion

Comparison of the percentage of muscle activity of the superior orbicularis oris muscle required for each movement at P1 and P2 between PNB and PMB did not reveal statistically significant differences. For example, if approximately 70% of the muscle capacity were required for accomplishment of blowing by the PNB subjects at P1, a similar mean (76%), with non-statistically significant difference, would be required for accomplishment of the same movement by PMB subjects at the same period. The same is true at rest and for all the other movements evaluated.

This study is in agreement with that of Vianna-Lara, Caria[4] (2006), who also did not observe a relationship between the EMG of the superior orbicularis oris muscle and the breathing mode in 48 individuals when a period was considered separately from the other.

When conducting a more detailed analysis of the rest position, it should be remembered that PMB in-

Table 3 - Student's t test for dependent samples, for comparison of the means between P1 and P2 according to the breathing mode.

Group	Movement	Mean	SD	DF	T	p value
PNB	/v/ phoneme (P1)	0.78	0.66	23.00	1.50	0.1460
	(Δ)	0.20				
	/v/ phoneme (P2)	0.58				
	Chewing at the right side (P1)	0.47	0.41	23.00	1.92	0.0671
	(Δ)	0.16				
	Chewing at the right side (P2)	0.31				
	Swallowing (P1)	0.44	0.46	23.00	2.44	0.0227*
	(Δ)	0.23				
	Swallowing (P2)	0.21				
PMB	/b/ phoneme (P1)	0.57	0.24	13.00	1.10	0.2913
	(Δ)	0.07				
	/b/ phoneme (P2)	0.50				
	/m/ phoneme (P1)	0.75	0.31	13.00	0.61	0.5538
	(Δ)	0.05				
	/m/ phoneme (P2)	0.70				
	/f/ phoneme (P1)	0.54	0.31	13.00	0.12	0.9047
	(Δ)	0.01				
	/f/ phoneme (P2)	0.53				
	/v/ phoneme (P1)	0.60	0.29	13.00	−0.26	0.7975
	(Δ)	−0.02				
	/v/ phoneme (P2)	0.62				
	Chewing at the right side (P1)	0.44	0.33	13.00	1.06	0.3089
	(Δ)	0.09				
	Chewing at the right side (P2)	0.35				

*p < 0.05.

Table 4 - Non-parametric Wilcoxon test, for comparison of the means between P1 and P2 according to the breathing mode [continued on next page].

Movement	Group	Ranks	Mean Rank	Z	p value
Rest with the lips relaxed	PNB	Negative 15	14.00	−1.71	0.0865
		Positive 9	10.00		
		Ties 0	-		
	PMB	Negative 7	7.57	−0.03	0.9750
		Positive 7	7.43		
		Ties 0	-		
Blowing	PNB	Negative 9	17.00	−0.09	0.9317
		Positive 15	9.80		
		Ties 0	-		
	PMB	Negative 4	11.75	−0.35	0.7299
		Positive 10	5.80		
		Ties 0	-		

*p < 0.05, **p < 0.01.

Table 4 [continued] - Non-parametric Wilcoxon test, for comparison of the means between P1 and P2 according to the breathing mode.

Movement	Group	Ranks	Mean Rank	Z	p value
Free sucking	PNB	Negative 15	13.40	−1.46	0.1451
		Positive 9	11.00		
		Ties 0	-		
	PMB	Negative 10	8.70	−2.17	0.0303*
		Positive 4	4.50		
		Ties 0	-		
Reciprocal compression of the lips	PNB	Negative 14	13.43	−1.09	0.2776
		Positive 10	11.20		
		Ties 0	-		
	PMB	Negative 5	6.60	−1.22	0.2209
		Positive 9	8.00		
		Ties 0	-		
Opening of the commissures	PNB	Negative 13	13.46	−0.71	0.4751
		Positive 11	11.36		
		Ties 0	-		
	PMB	Negative 5	12.00	−0.47	0.6378
		Positive 9	5.00		
		Ties 0	-		
/b/ phoneme	PNB	Negative 18	13.72	−2.77	0.0056**
		Positive 6	8.83		
		Ties 0	-		
/m/ phoneme	PNB	Negative 18	13.06	−2.43	0.0152*
		Positive 6	10.83		
		Ties 0	-		
/f/ phoneme	PNB	Negative 18	12.39	−2.09	0.0370*
		Positive 6	12.83		
		Ties 0	-		
Chewing at the left side	PNB	Negative 14	14.86	−1.66	0.0975
		Positive 10	9.20		
		Ties 0	-		
	PMB	Negative 9	8.78	−1.66	0.0962
		Positive 5	5.20		
		Ties 0	-		
Swallowing	PMB	Negative 8	7.75	−0.60	0.5509
		Positive 6	7.17		
		Ties 0			

*p < 0.05, **p < 0.01.

dividuals need to keep their lips partially opened to allow breathing, indicating a pattern of lip incompetence. However, if the lips are kept relaxed at rest, the muscle activity obtained tends to be minimal or none, yet the presence or absence of bioelectric activity of the muscles at rest is a controversial aspect.[3] Many studies demonstrated that the muscles tend to present no bioelectric signals when the lips are relaxed at rest regardless of the breathing mode[16] or presence of lip incompetence.[17,18,19] The present results indicate that, despite the same percentage of muscle activity for both breathing modes at rest, since the individuals were asked to keep their lips relaxed, a bioelectric signal of the muscle is detectable, in agreement with the studies of Tomé, Marchiori[20] (1998) and Schievano *et al.*[3] (1999).

However, another aspect of the present sample should be considered. Other investigations[2,20] revealed a mild activity of the superior orbicularis oris muscle at rest in subjects presenting Angle Class II Division 1 malocclusion. The rationale provided for the existence of bioelectrical activity at rest lies in the fact that, even though the rest position requires few or no motor units, this activity is established by the natural elasticity of the muscle, which is altered when the muscles and function are not balanced.[12] Moreover, the muscle function at rest is deemed more important, since the total time period is much longer than during some movements.[21]

With relation to the other movements, the literature has revealed some differences between PNB and PMB individuals; however, in most cases, the data were not normalized as a function of amplitude.

Some studies[16,17,22,23] observed differences between the activities of the superior orbicularis oris muscle when comparing individuals with and without lip competence, by means of electromyographic evaluations.

Even though lip incompetence is not synonymous with mouth breathing, the PMB subjects presented lip incompetence, and the literature suggests that the lack of lip sealing brings about functional alterations,[1,6,8] therefore allowing these comparisons.

Gustafsson, Ahlgren[17] (1975) concluded that the group without lip competence presented much higher activity during lip closure, chewing and swallowing. Harradine, Kirschen[22] (1983) also found activity differences during chewing. These authors suggested that the effects of the activity of the perioral muscles were established by the presence or absence of lip competence. Tosello *et al.*[16,23] (1998, 1999) observed a higher activity during some movements in the group with lip incompetence compared to the group with lip competence.

If only the comparison between mode breathing groups had been considered, the present study would not agree with those previous ones. However, the longitudinal comparison provides a wider view.

With regard to the longitudinal comparison of the present study, which investigated whether the muscle activity was changed after a two-year interval for each breathing mode, the results indicated that there was a modification in the percentage of activity required for accomplishment of some movements.

For the PNB subjects (Table 4), for some movements, the percentage of muscle activity required was different after two years, at a significance level of 95%. These results indicate that the pattern of muscle activity is changed, and accomplishment of the movements evaluated required a smaller percentage of activity of the superior orbicularis oris muscle.

For the PMB subjects (Table 4), only the percentage of muscle activity used for accomplishment of free sucking was changed after two years, requiring a smaller percentage of muscle activity for accomplishment of the same movement over time.

Studies addressing the evolution of muscle activity over time in a sample not submitted to orthodontic treatment were not found. The comparisons observed in the literature evaluate modifications inherent to some type of treatment.[3]

The lack of studies on the evolution of muscle activity over time without any intervention hinders any discussion, yet demonstrates how longitudinal comparisons may provide outcomes that cannot be revealed by transversal studies.[24]

This is confirmed in the present study, considering that no statistically significant differences were observed between the percentages of activity of the superior orbicularis oris muscle between PNB and PMB subjects, regardless of the period (Tables 1 and 2). However, comparison between PNB and PMB individuals between periods 1 and 2 revealed different evolutions in the patterns of muscle activity, indicating that the alterations occurring in PNB individuals were different from those for PMB subjects after two years (Tables 3 and 4).

The PNB subjects had a muscle function improvement, because the percentage of activity required to perform some movements was lower. The PMB subjects did not present the same evolution in muscle performance.

The presence of abnormal patterns of function of the orofacial muscles has been reported for decades in the literature as a factor leading to orthodontic problems.[25,26] Therefore, abnormalities of the lip function during speech and swallowing, as observed in the present report, may affect the dental arch and tooth positioning.[25] Even though there are divergences as to the possible effects of muscles on the occlusion, it is generally agreed that muscular imbalance may be associated to malocclusion.[26,27]

Conclusion

The breathing mode did not influence the pattern of EMG when the evaluation was performed at an isolated moment in time. However, the pattern of muscle activity in PNB and PMB subjects was not constant during growth. The percentages of muscle activity required for accomplishment of some movements for PNB individuals were not the same as for PMB individuals, between P1 and P2, indicating the existence of differences according to the breathing mode.

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