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Correlation between morphology and function of the upper lip: a longitudinal evaluation

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SUMMARY In order to evaluate the relationship between the morphology of the upper lip and muscle activity in a sample of 38 subjects (17 males and 21 females) with Angle Class II division 1 malocclusions, cephalometric and electromyographic analyses were conducted. The sample was subdivided into either predominantly nose or mouth breathers. The individuals were evaluated at two different periods, with a 2 year interval. At the first observation, the subjects were 11 years to 14 years 11 months of age and at the second observation, 13 years 4 months to 16 years 6 months of age. Height and thickness of the upper lip were measured on lateral cephalograms with the aid of a digital pachymeter. For each individual, electromyographic records were obtained of the orbicularis oris superior muscle at rest and in a series of 12 movements. The electromyographic data were normalized as a function of amplitude, for achievement of the percentage value of each movement. Pearson and Spearman correlation tests were applied.

The results showed some correlation between morphology and muscle function (at a confidence level of 95 per cent). However, as the values of the correlation coefficient (*r*) were too low to establish associations between variables, it was concluded that the dimensions of the upper lip are not correlated with muscle activity.

Introduction

For more than a century, attempts have been made to correlate breathing mode, craniofacial morphology (Montgomery *et al.*, 1979; Diamond, 1980; Harvold *et al.*, 1981; Weber *et al.*, 1981; Hartgerink and Vig, 1989; Vig, 1998), malocclusion, and muscle function (Linder-Aronson and Backström, 1960; Harvold *et al.*, 1981). It has been shown that the function of the orofacial muscles may be impaired in mouth breathers, with a short and hypotonic upper lip (Angle, 1907; Ricketts, 1968; McNamara, 1981; Graber and Vanarsdall, 2000). However, a causal relationship determining whether craniofacial alteration is influenced by muscle function or muscle function by craniofacial alteration is difficult to establish (Kluemper *et al.*, 1995; Vig, 1998). Despite this, the proponents, while advocating their point of view, do not always provide rationales on the order of the events. Gwynne-Evans (1957) believed that muscle alteration was the main causal factor leading to mouth breathing, while others have stated that the lack of a lip seal would alter the muscle function and consequently result in craniofacial alterations (Subtelny, 1954; Paul and Nanda, 1973; Linder-Aronson, 1974). Similarly, Valera *et al.* (2003) observed that functional alterations occur before dentoskeletal changes in children with enlarged palatal and pharyngeal tonsils.

In general, despite the difficulty in establishing a cause–effect relationship (Solow *et al.*, 1984; Kluemper *et al.*, 1995), correlations may be analysed, and specific statistical tests may be applied for that purpose. These correlation tests evaluate both the relationship between variables and the force of such relationships (Graber and Vanarsdall, 2000).

Investigation of the presence or absence of correlations between morphology and muscle function might greatly contribute to understanding the relationship of a certain structure in a specific group of individuals. Clearer knowledge on the relationships between the orofacial structures will allow correct diagnosis and treatment of these subjects.

Currently, few studies have been published on the correlations between function of the orbicularis oris superior muscle and morphology of the upper lip in predominantly nose or mouth breathers.

Investigations of orbicularis oris muscle function are conducted using electromyography, which quantifies the muscle bioelectrical impulses (De Luca, 1997). Concerning the difficulties of electromyographic analysis, application of the concepts suggested by Basmajian (1980), De Luca (1997), and Soderberg and Knutson (2000) might allow reduction of interferences and a more precise and reliable analysis of the electromyographic data. With normalization of electromyographic data as a function of amplitude, it is possible to determine the percentage of muscle activity required to accomplish certain muscle movements (Soderberg and Cook, 1984; Mirka, 1991; De Luca, 1997; Soderberg and Knutson, 2000). This procedure aims at transforming the gross root mean square (RMS) values to percentage values of activity (Soderberg and Cook, 1984; Mirka, 1991; Turker, 1993; Soderberg and Knutson, 2000).

Morphology of the upper lip has been investigated in both the vertical and anteroposterior directions by measurement of the height and thickness of the upper lip, respectively. These measurements are commonly obtained from lateral cephalograms (Graber and Vanarsdall, 2000), on which standardized measurements are adopted to allow comparisons between studies (Proffit and Fields, 2000).

As the possible effects of mouth breathing may dramatically affect facial aesthetics, the aims of this study were to determine whether the activity of the orbicularis oris superior muscle has any relationship with the dimensions of the upper lip in predominantly nose or mouth breathers.

With regard to the morphofunctional and longitudinal investigation of the orbicularis oris superior muscle in individuals with Angle Class II division 1 malocclusions with predominantly nose or mouth breathing, this study aimed to verify whether there is any correlation between the percentage of electromyographic activity and morphology of the upper lip (thickness and height of the upper lip), at two different periods, with a 2 year interval.

Subjects and methods

Sample selection

The present qualitative and longitudinal study was conducted on a random sample of 38 Brazilian adolescents, 17 males and 21 females, presenting with a Class II division 1 malocclusion according to the classification of Angle (1899). The subjects were divided into two groups according to whether they were predominantly nose or mouth breathers; there were 24 predominantly nose breathers (PNB), 10 males and 14 females, and 14 predominantly mouth breathers (PMB), seven males and seven females.

Classification of breathing mode was conducted using a multidisciplinary approach, including evaluation of lip seal by clinical observation; completion of a questionnaire by the parents, an ear, nose, and throat examination and speech therapy evaluation (Wieler, 2002).

At the first observation (T1), the subjects were 11 years to 14 years 11 months of age and at the second observation (T2), 13 years 4 months to 16 years 6 months of age.

Individuals with early tooth loss, extensive caries, and/or malocclusions with a high discrepancy, as well as those who had undergone any orthodontic treatment and/or presenting any deleterious habit, besides mouth breathing, were excluded from the study, as such factors might influence the outcomes. Seventy-eight children, who were part of the databank of the Master of Science course in Dentistry, Area of Concentration in Orthodontics, of Pontificial Catholic University of Paraná, were originally investigated; 40 individuals were excluded from the study.

Morphological analysis of the upper lip

Morphological analysis of the upper lip was conducted by evaluation of lateral cephalograms, on which the linear measurements considered were the height and thickness of the upper lip.

The radiographs were obtained at the Radiology Center of the Dental Clinic of PUCPR, following the guidelines of Broadbent (1931). In order to achieve standardized lateral cephalograms, the subjects were asked to keep their teeth in maximum intercuspation and with lips in habitual occlusion.

The radiographs were taken with a Orthophos-Plus/CD (Siemens, Sirona, Bensheim, Germany). The tracings of the lateral cephalograms were performed twice by the same operator (ARA), with a 3 month interval (Figure 1), and linear measurements of the height and thickness of the lips using an electronic pachymeter (Mitutoyo Corporation, Tokyo, Japan) with an accuracy of 0.01 mm. The linear measurements were tabulated and statistically analysed.

Electromyographic analysis of the orbicularis oris superior muscle

Electromyographic examinations were undertaken in a room isolated and protected from interference. Investigation

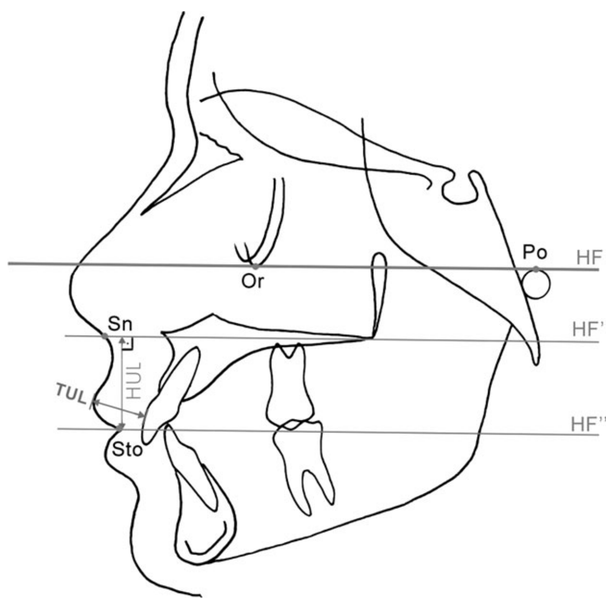

Figure 1 Cephalometric tracing of the linear measurements used to determine the height (HUL) and thickness (TUL) of the upper lip. Po, porion; Or, the lowest point on the inferior margin of the orbit; Sn, subnasal; Sto, stomion; HF, Frankfort plane; HF′, plane parallel to the Frankfort plane through Sn; HF″, plane parallel to the Frankfort plane through Sto.

was performed with a 16-channel electromyographic system (EMG System do Brasil, São Paulo, Brazil) with an amplification gain of 1000 times, a high-pass filter of 20 Hz and a low-pass filter of 500 Hz, correctly calibrated in an Intel based PC equipped with analogue–digital converter (12 bit resolution, 32 channels for PC).

Before the electromyography tests, the subjects underwent asepsis of the skin with 96 per cent alcohol to remove the excess oil on the skin at the area of interest and enhance the fixation of electrodes, reception, and transmission of electric potentials.

The passive bipolar surface electrodes employed at the two examinations were of the same brand and presented the same specifications, such as material composition and diameter, which are fundamental for comparison of the data (De Luca, 1997).

The electrodes were fixed on the external region of the upper lip, corresponding to the medial area of the orbicularis oris superior muscle. The distance between the electrodes 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 (Vianna-Lara and Caria, 2006). A reference electrode was also applied on the wrist of the adolescents.

The examinations were performed with the subjects seated and with the Frankfort plane parallel to the floor.

The selection of movements registered represented the daily activities of individuals, such as speech, chewing, and swallowing. The protocol selected was strictly followed. For the purpose of standardization, all situations, including the rest position with the lips relaxed, were referred to as movement to facilitate their description. Therefore, the 'movements' were as follows: 0, at 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 half inch orthodontic elastic) at the right side; 11, chewing (of a half inch orthodontic elastic) at the left side; and 12, swallowing of saliva.

Three repetitions were performed for each movement with a time interval of 10 seconds, except for the rest position, which was constant, and for the chewing movements, which were free. Standardization of the moments of initiation of movements was achieved by utilization of a visual signal.

The electromyographic data obtained were processed using the AqDados software program (version 5.05, Lynx Tecnologia Eletrônica Ltda. São Paulo, Brazil). The RMS of the electric potentials of each movement were achieved using the following criteria: each repetition of movement was selected within a time interval of a second, so that only the active part of the movement was recorded, with no interference from the rest periods between repetitions. The first repetition was discarded and the mean of the other two repetitions was calculated, yielding the RMS of this movement. For the rest position, the same range with a 1 second interval was selected to allow normalization as a function of time.

Method error was determined by random selection of four individuals from the sample for repetition of the examinations performed and confirmation of results (Ferrario *et al.*, 2000). Visual identification of extreme outliers in the boxplot was also undertaken (Zar, 1999).

Thereafter, the data obtained were tabulated and normalized in relation to amplitude. This procedure is indicated for comparisons between individuals and between moments for the same individual. If data are normalized as a function of amplitude, this interindividual variability may be reduced, allowing comparisons of the percentage of activity required for different activities. This is important because electromyographic data present a high variability, which might lead to inconclusive outcomes if this procedure is not adopted (De Luca, 1997).

The method for normalization as a function of amplitude applied in this study was conducted using the peak electromyographic value (Yang and Winter, 1984). It comprises selection of the movement presenting the higher RMS and utilization of this movement as the maximum reference of the muscle, that is 100 per cent of activity. Division of each other RMS of each movement by this maximum value provides the percentage of activity of each movement in relation to the maximum activity.

The sum of the values of lip protrusion of all subjects yielded the highest mean among all movements. Therefore, this movement served as the reference, representing 100 per cent of muscle activity for the orbicularis oris superior muscle. The values of the data, normalized as a function of time and amplitude, were statistically examined.

The Kolmogorov–Smirnov normality test was conducted for all variables investigated for both breathing modes. Pearson correlation test was used for the variables normally distributed and the Spearman correlation test for those not normally distributed. After determining the presence of correlation, qualitative evaluation as to the intensity of correlation was measured (Callegari-Jacques, 2003).

Results

Descriptive statistics of the variables analysed are shown in Table 1 and the correlation tests for the PNB group at T1 and T2 in Table 2. The correlation between the thickness of the upper lip and movements 2, 8, and 9 and between the height of the upper lip and movements 4, 10, and 11 displayed regular intensity, since the R values ranged from 0.3 to 0.6. At T2, there was a correlation, of regular intensity, only between the thickness of the upper lip and movement 2.

The correlation tests for the PMB group are shown in Table 3. There was a lack of correlation between the movements and cephalometric variables at T1. The presence

Table 1 Descriptive statistics of the variables analysed at the first (T1) and second (T2) examinations in predominantly nose breathers (PNB) and predominantly mouth breathers (PMB).

M	Group	*n*	Mean		Median		Confidence interval (95%) Lower bound		Confidence interval (95%) Upper bound		Minimum		Maximum		Standard deviation		Variation coefficient (%)	
			T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2	T1	T2
0	PNB	24	0.45	0.17	0.21	0.14	0.14	0.13	0.76	0.21	0.04	0.04	3.60	0.43	0.74	0.11	163.32	62.51
	PMB	14	0.35	0.25	0.16	0.23	0.11	0.16	0.60	0.33	0.04	0.07	1.43	0.54	0.42	0.15	119.77	60.68
1	PNB	24	0.70	0.55	0.41	0.46	0.32	0.43	1.08	0.67	0.08	0.21	4.45	1.46	0.90	0.29	127.56	52.51
	PMB	14	0.76	0.55	0.41	0.50	0.16	0.35	1.35	0.76	0.16	0.21	4.14	1.46	1.03	0.36	136.22	64.16
2	PNB	24	0.91	0.58	0.64	0.48	0.36	0.42	1.45	0.74	0.18	0.24	6.66	2.08	1.29	0.38	141.61	65.93
	PMB	14	1.31	0.68	0.74	0.48	0.39	0.37	2.23	0.99	0.10	0.15	5.86	2.19	1.59	0.53	121.55	78.50
3	PNB	24	1.52	0.97	0.94	0.90	0.85	0.75	2.20	1.19	0.23	0.23	6.21	2.89	1.60	0.52	104.85	53.93
	PMB	14	1.16	1.07	0.93	1.08	0.45	0.86	1.86	1.29	0.27	0.53	5.24	2.01	1.22	0.37	105.50	34.48
4	PNB	24	0.76	0.41	0.34	0.37	0.17	0.32	1.34	0.51	0.06	0.07	6.73	0.98	1.39	0.23	182.55	54.89
	PMB	14	0.61	0.42	0.25	0.43	0.17	0.33	1.04	0.51	0.08	0.15	2.80	0.74	0.75	0.16	123.91	37.88
6	PNB	24	1.65	0.46	0.67	0.43	−0.15	0.38	3.44	0.53	0.08	0.23	21.45	0.80	4.26	0.18	258.98	38.64
	PMB	14	0.57	0.50	0.53	0.50	0.41	0.37	0.74	0.63	0.16	0.18	0.95	0.91	0.28	0.23	48.90	45.36
7	PNB	24	0.87	0.59	0.67	0.55	0.60	0.49	1.14	0.69	0.07	0.26	3.10	1.18	0.64	0.24	74.31	40.33
	PMB	14	0.75	0.70	0.75	0.61	0.52	0.48	0.99	0.93	0.08	0.19	1.45	1.61	0.41	0.39	54.19	55.66
8	PNB	24	0.92	0.53	0.64	0.50	0.46	0.41	1.38	0.65	0.10	0.21	5.54	1.23	1.09	0.29	118.14	53.79
	PMB	14	0.54	0.53	0.39	0.41	0.34	0.33	0.74	0.73	0.08	0.19	1.04	1.52	0.34	0.35	63.41	65.15
9	PNB	24	0.78	0.58	0.65	0.51	0.51	0.45	1.05	0.71	0.09	0.16	2.57	1.30	0.65	0.31	82.70	54.20
	PMB	14	0.60	0.62	0.53	0.53	0.37	0.42	0.83	0.81	0.08	0.20	1.33	1.43	0.39	0.34	65.62	54.37
10	PNB	24	0.47	0.31	0.35	0.28	0.32	0.23	0.62	0.38	0.07	0.08	1.26	0.88	0.36	0.18	77.42	59.22
	PMB	14	0.44	0.35	0.31	0.34	0.24	0.28	0.64	0.42	0.04	0.16	1.04	0.61	0.34	0.12	78.45	35.52
11	PNB	24	0.55	0.31	0.31	0.27	0.34	0.24	0.76	0.39	0.06	0.10	2.23	0.71	0.50	0.18	90.80	55.77
	PMB	14	0.70	0.37	0.40	0.34	0.26	0.26	1.14	0.47	0.05	0.13	3.02	0.73	0.76	0.18	109.22	48.58
12	PNB	24	0.44	0.21	0.26	0.17	0.25	0.16	0.63	0.26	0.05	0.04	1.90	0.47	0.45	0.11	102.75	54.34
	PMB	14	0.48	0.27	0.23	0.25	0.12	0.20	0.85	0.35	0.06	0.11	2.51	0.63	0.64	0.13	132.00	48.32

M, movement (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 at the right side; 11, chewing at the left side; and 12, swallowing of saliva). There is omission of the movement 5 (lip protrusion) because the sum of these values of all subjects yielded the highest mean among all movements. Therefore, this movement served as a reference, representing 100% of muscle activity for the orbicularis oris superior muscle.

Table 2 Correlation test between the variables height (HUL) and thickness (TUL) of the upper lip in the group of predominantly nose breathers ($n = 24$) at the first (T1) and second (T2) observation.

Movement	Variable		Correlation coefficient (r)		P	
	T1	T2	T1	T2	T1	T2
At rest with the lips relaxed	HUL	HUL*	0.39	0.52	0.0617	0.0099
	TUL	TUL*	0.32	0.25	0.1262	0.2345
Blowing	HUL	HUL*	0.20	0.01	0.3584	0.9582
	TUL	TUL*	0.32	−0.04	0.1235	0.8559
Free sucking	HUL	HUL*	0.20	−0.01	0.3605	0.9453
	TUL	TUL*	0.45	0.42	0.0289	0.0424
Reciprocal compression of the lips	HUL	HUL	−0.04	0.00	0.8638	0.9942
	TUL	TUL	0.24	−0.01	0.2568	0.9488
Opening of the commissures	HUL	HUL	0.47	0.06	0.0203	0.7689
	TUL	TUL	0.16	0.08	0.4477	0.7149
/b/phoneme	HUL	HUL	0.38	0.24	0.0643	0.2569
	TUL	TUL	0.28	0.01	0.1900	0.9656
/m/phoneme	HUL	HUL	0.21	0.14	0.3339	0.5085
	TUL	TUL	0.35	−0.28	0.0905	0.1806
/f/phoneme	HUL	HUL*	0.17	0.00	0.4294	0.9871
	TUL	TUL*	0.41	0.12	0.0486	0.5821
/v/phoneme	HUL*	HUL	0.03	0.12	0.9011	0.5718
	TUL*	TUL	0.47	−0.06	0.0217	0.7735
Chewing at the right side	HUL	HUL	0.43	0.10	0.0353	0.6372
	TUL	TUL	0.19	−0.18	0.3693	0.3955
Chewing at the left side	HUL	HUL	0.41	0.09	0.0476	0.6759
	TUL	TUL	0.21	−0.06	0.3256	0.7920
Swallowing of saliva	HUL	HUL*	0.35	0.12	0.0914	0.5654
	TUL	TUL*	0.17	0.15	0.4391	0.4906

Table 3 Correlation test between the variables height (HUL) and thickness (TUL) of the upper lip in the group of predominantly mouth breathers ($n = 14$) at the first (TI) and second (T2) observation.

Movement	Variable		Correlation coefficient (r)		P	
	T1	T2	T1	T2	T1	T2
At rest with the lips relaxed	HUL	HUL	0.34	−0.04	0.2354	0.8869
	TUL	TUL	0.02	0.64	0.9584	0.0129
Blowing	HUL	HUL	0.24	−0.08	0.4128	0.7873
	TUL	TUL	0.22	0.19	0.4549	0.5225
Free sucking	HUL	HUL	−0.02	−0.19	0.9345	0.5211
	TUL	TUL	0.20	0.24	0.5028	0.4094
Reciprocal compression of the lips	HUL	HUL	−0.05	0.41	0.8752	0.1405
	TUL	TUL*	0.03	0.09	0.9109	0.7714
Opening of the commissures	HUL	HUL	0.32	0.00	0.2588	1.0000
	TUL	TUL*	0.14	0.16	0.6261	0.5759
/b/phoneme	HUL*	HUL	0.10	−0.06	0.7275	0.8339
	TUL*	TUL*	−0.02	0.11	0.9502	0.7006
/m/phoneme	HUL*	HUL	0.01	−0.02	0.9851	0.9582
	TUL*	TUL*	0.03	0.05	0.9096	0.8568
/f/phoneme	HUL*	HUL	−0.07	−0.15	0.8206	0.6196
	TUL*	TUL	−0.12	0.16	0.6932	0.5733
/v/phoneme	HUL*	HUL	0.14	−0.02	0.6435	0.9523
	TUL*	TUL*	−0.18	0.04	0.5481	0.9037
Chewing at the right side	HUL*	HUL	0.20	0.23	0.4848	0.4212
	TUL*	TUL*	−0.18	0.05	0.5316	0.8703
Chewing at the left side	HUL*	HUL	−0.02	0.10	0.9397	0.7414
	TUL*	TUL*	−0.13	0.09	0.6461	0.7557
Swallowing of saliva	HUL	HUL	0.26	0.08	0.3653	0.7816
	TUL	TUL*	0.11	0.16	0.7140	0.5883

P value < 0.05 indicates the presence of correlation. r value indicates the intensity of the correlation. When $0.3 < r < 0.6$, there is a regular intensity of association, and $r > 0.6$, a strong intensity of association. A Spearman correlation test applied: except for those marked with an asterisk (Pearson).

of a correlation with PMB at T2 was found only between the thickness of the upper lip and movement 0, which was strong. However, the correlation coefficient was low.

Discussion

Mouth breathing almost always indicates a combination between nose and mouth breathing (Timms and Trenouth, 1988; Schievano *et al.*, 1999). A lack of a lip seal is not a reliable indicator of mouth breathing (Harvold *et al.*, 1981). However, this lip posture has been highlighted by several authors as one factor leading to alteration of lip musculature (Subtelny, 1954; Paul and Nanda, 1973; Linder-Aronson, 1974).

Besides the lack of a lip seal, the backward positioning adopted by the tongue and consequent imbalance in muscle pressure in these subjects result in alterations in craniofacial growth and development (Angle, 1907; Subtelny, 1954; Linder-Aronson, 1974). Even though several authors highlight the craniofacial consequences of mouth breathing on a number of structures (Subtelny, 1954; Paul and Nanda, 1973; Linder-Aronson, 1974; Harvold *et al.*, 1981; Timms and Trenouth, 1988; Berman and Chan, 1999), as well as indicating that craniofacial alterations do not occur as a result of breathing mode (Ballard, 1957; Kluemper *et al.*, 1995), the focus of the present study is the morphology and function of the upper lip.

Some investigations on subjects have evaluated the upper lip according to breathing mode and observed that in PMB, the vertical dimensions of the upper lip are reduced compared with nose breathers (Angle, 1907; Paul and Nanda, 1973; McNamara, 1981) while others did not observe such morphological alterations (Ballard, 1957; Linder-Aronson and Backström, 1960; Vig *et al.*, 1981).

Other authors have evaluated the upper portion of the orbicularis oris muscle (Linder-Aronson, 1974; Murray *et al.*, 1998; Schievano *et al.*, 1999; Yamaguchi *et al.*, 2000). With regard to the studies on muscle function according to breathing mode, there has been considerable divergence in conclusions: some authors have indicated the presence of functional alteration of the orbicularis oris muscle (Linder-Aronson, 1974), whereas others demonstrated similar muscle activity in groups of nose and mouth breathers (Vianna-Lara and Caria, 2006), regardless of breathing mode.

In general, there are indications that the lips may be altered according to breathing mode (Dutra *et al.*, 2006), and there is great interest in observing the presence of relationships between muscle function and morphology of the upper lip.

The results of the present study corroborate several previous investigations (Ingervall and Janson, 1981; Harradine and Kirschen, 1983; Thüer and Ingervall, 1986; Rasheed and Munshi, 1996). As the correlations found were moderate to strong, there is a certain degree of association between the variables; however, the degree of dependence was regular or low (correlation coefficient $r < 0.6$). This indicates that one variable does not determine the other or that other variables may be required for complete analysis of the variables investigated.

Lack of association between the shape and function of the upper lip was found for both PNB and PMB individuals. In the PNB group, the presence of correlations of regular intensity between some movements (free sucking and speech of /f/ and /v/phonemes) and the height of the upper lip and others (opening of the commissures and chewing on both sides) with the thickness of the upper lip, at T1, does not indicate that these correlations exist, since a correlation of regular intensity is very weak when only two variables are correlated. At T2, the number of correlated variables was reduced to only one in PNB subjects, that is between free sucking movement and the thickness of the upper lip.

The fact that the correlations at T1 were not maintained at T2 also indicates a low degree of association between the variables. Thus, the findings indicate that the shape and function of the upper lip cannot be correlated in PNB individuals.

In the PMB group, there was no correlation between the morphological and functional variables of the upper lip at T1. However, at T2, a strong correlation ($r = 0.64$) was observed between the percentage of electromyographic activity at rest and the thickness of the upper lip. However, this does not indicate a real correlation when only two variables are related (Callegari-Jacques, 2003). It should be highlighted that, if there is interest in establishing the degree of dependence, that is the cause–effect relationship, regression analysis is required. For that purpose, the coefficient of determination (r^2) is calculated. In this situation, where $r = 0.64$, the r^2 value would be 0.41, that is variations in one variable would account for only 41 per cent of variations in another, with 59 per cent remaining for other non-investigated variables. A very strong correlation between two variables, demonstrating a cause–effect relationship, would require a r value above 0.90 (Callegari-Jacques, 2003).

The relationships between shape and function have been investigated. Even though some authors state that structure and function cannot be separated and that one supports the other (Subtelny, 1970; Basmajian, 1980), many investigations did not find any correlation with regard to the orbicularis oris muscle and the dimensions of the upper lip (Ingervall and Janson, 1981; Harradine and Kirschen, 1983; Thüer and Ingervall, 1986; Rasheed and Munshi, 1996), supporting the present findings.

Ingervall and Janson (1981) found that muscle function could not be correlated with facial morphology and electromyographic activity of the orbicularis oris superior muscle. The morphological variables analysed included the height and thickness of the upper lip and inclination of the incisors. The lack of association leads to the conclusion that muscle function cannot alter shape. Thüer and

Ingervall (1986) evaluated the pressure of the lips on the teeth and malocclusion. Correlation between lip height and electromyographic activity of the upper lip at rest, and during chewing and swallowing indicated correlation only during chewing. However, the *r* value was –0.27, thus indicating a weak association (Callegari-Jacques, 2003). Therefore, a correlation could not be established between the height and electromyographic activity of the upper lip.

Harradine and Kirschen (1983) did not find any correlation between the thickness of the upper lip and muscle activity at rest or doing speech, chewing, and swallowing in subjects with or without lip competence. Rasheed and Munshi (1996) reported similar outcomes for correlations between orofacial muscle function and muscle thickness. That study was the first to attempt to establish correlations between lip thickness and muscle activity in a group of individuals with a normal relationship of the anterior teeth but with increased overbite and an anterior open bite. The results showed a lack of correlation between muscle activity and thickness of the upper lip.

No correlations have been found between the orbicularis oris muscle and variables other than lip dimension (Lowe, 1980; Thüer and Ingervall, 1986). Lowe (1980) investigated correlations between the activity of some muscles, including the orbicularis oris, and craniofacial morphology by means of electromyographic and cephalometric analysis of 24 subjects. The masseter and genioglossus muscles shared correlations, indicating an influence from the muscles on the development and/or maintenance of teeth. However, the activity of the orbicularis oris muscle could not be correlated with any of the craniofacial variables investigated (maxillary and mandibular length, overbite, overjet, anterior dental height, posterior dental height, total face height, upper and lower face height, posterior face height, and height of the mandibular ramus).

Thüer and Ingervall (1986) also endeavored to correlate the electromyographic activity of the upper lip at rest, during chewing and swallowing with craniofacial variables such as overjet, length of the maxillary and mandibular dental arches, malocclusion, and dimensions of the lower lip. Since no significant correlations were found, it was not possible to establish associations between these variables and muscle function of the upper lip.

However, some investigators who studied the correlation between the orbicularis oris superior muscle and some craniofacial variables, other than the lip dimensions, found some type of correlation (Subtelny and Sakuda, 1966; Gustafsson and Ahlgren, 1975; Harradine and Kirschen, 1983).

Harradine and Kirschen (1983), in an investigation of the correlation between electromyographic activity of the upper lip and positioning of the incisors, observed the presence of a correlation between these variables at rest in individuals with lip competence. Intermittent activities such as speech, swallowing, and chewing did not present any relationship with tooth positioning. Gustafsson and Ahlgren (1975) observed that electromyographic activity of the upper lip was related to the inclination of the mandibular incisors and that when muscle activity was increased, these teeth also tend to be more proclined.

Some studies suggest a correlation between craniofacial shape and muscle function (Subtelny and Sakuda, 1966; Gustafsson and Ahlgren, 1975; Harradine and Kirschen, 1983) while others indicate an absence of such associations (Ingervall and Janson, 1981; Harradine and Kirschen, 1983; Thüer and Ingervall, 1986; Rasheed and Munshi, 1996). This raises the question as to which are the correlated structures and which factors might be associated with shape and function for observation of such associations.

Even though the role played by the muscles on the development and/or maintenance of teeth (Lowe, 1980) is clearly noticeable and revealed by many clinical indicators, the results of present study did not show a relationship between muscle function and muscle shape.

Conclusions

Based on the results of this research, there were no correlations between shape and function of the upper lip for both groups (PNB and PMB) at either of the two studied periods and the lack of correlation was present over time (longitudinal observation).

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