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Lip and tongue pressure in orthodontic patients

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SUMMARY The contribution of the force of the lips, cheeks, and tongue is of particular interest in planning treatment. Thus, the aim of this study was to determine if there are differences in lip and tongue pressure as a function of gender, age, Angle classification, characteristics of occlusion, and oral habits.

This cross-sectional study comprised 107 subjects (63 females and 44 males), between 7 and 45 years of age (median 15.2 years), seeking orthodontic treatment. The patients were characterized by the variables gender, age, Angle classification, the characteristics of the occlusion, and oral habits. Lip and tongue pressure were measured with a Myometer 160 and the obtained values were statistically analysed (Kruskal–Wallis and Mann–Whitney U-tests) to highlight possible significant differences between the groups.

There was a difference in lip pressure between males and females, between the Angle Classes, and between patients with various associated oral habits. Lip pressure was not significantly correlated with age or with occlusal characteristics. There was no evidence for a relationship between tongue pressure and any of the five considered variables. The findings of present study showed statistically significant differences in lip pressure between different orthodontic patients. There was a difference ($P = 0.004$) in lip pressure between Class I and Class II division 1 subjects. A higher lip pressure exists in males. Lip pressure in subjects with an open lip relationship was lower ($P = 0.026$) when compared with those with tongue interposition or with no particular habits. Lip pressure was also lower in subjects with lip interposition compared with those with tongue interposition.

Introduction

Bone is one of the hardest tissues of the body, although also very responsive to changes in environmental balance. The musculature plays a major role in this field (Jung *et al.*, 2003). It is generally also assumed that alveolar bone responds to external influences.

Most dental professionals accept the theory of Tomes (1873), who asserted that opposing forces or pressure from the lips and cheeks on one side and the tongue on the other, determine the position of the teeth (Posen, 1976; Mitchell and Williamson, 1978). The contribution of the forces of the lips, cheeks, and tongue are of particular interest to orthodontists in correct treatment planning. The technical skills and protocol that the orthodontist uses to assess these forces may determine the ultimate success of orthodontic treatment (Winders, 1962).

Nevertheless, the literature on this topic contains many contradictions. The aims of the present study were to evaluate whether there are statistically significant differences between lip pressure and tongue pressure, and to determine whether those differences are influenced by gender, age, Angle classification, characteristics of occlusion, and oral habits.

Subjects and methods

The peak lip and tongue pressure of 107 subjects (63 females and 44 males) between 7 and 45 years of age (median 15.2 years) was measured during maximum voluntary contraction. At the initial orthodontic consultation, an informed consent was obtained from the patients. They were classified into groups based on gender, age, Angle classification (occlusion of the first molars or the expected occlusion of the first molars in the case of primary teeth), the characteristics of the occlusion, and oral habits (Table 1).

Maximum lip and tongue pressure was measured with a Myometer 160 (MFT-Products, Matzendorf, Switzerland; Figure 1). This type of myometer, manufactured specifically for measurement of pressure or tension of the intra- and perioral muscles in the field of orthodontics, used in the study of Horn *et al.* (1995). The Myometer 160 contains a probe, which consists of two plates that are screwed together on one side. On the other side (probe tip), the two plates can be pushed towards each other. The applied force is measured by an electronic device installed between the plates and shown on a bar graph.

Lip pressure was measured by placing the thumb and forefinger on one side of the probe behind the electronic device to avoid interference with the measurements. The patient was told to occlude maximally, which inhibited biting on the probe. Two investigators (EDB and HL) were trained and calibrated in the use of the Myometer. The probe was held against the most prominent maxillary central incisor. The patient enclosed the probe tip with the lips and pressed the two plates towards each other as close as

Table 1 Division of the patients into groups.

Group	Number of patients (total number of patients: 107)
Gender	107
Female	63
Male	44
Age	107
<18 year	89
>18 year	18
Angle classification*	107
Class I	49
Class II/1 (+Class II/1-subdivision)	41
Class II/2 (+Class II/2-subdivision)	6
Class III (+Class III-subdivision)	11
Patients with characteristics of the occlusion**	78 (physiological occlusion: 29)
Anterior open bite	15
Posterior open bite (uni- or bilateral)	10
Deep bite	18
Anterior crossbite	9
Posterior crossbite (uni- or bilateral)	12
Patients with habits**,***	61 (no habits: 46)
Tongue interposition during swallowing****	30
Lip interposition (partial and full)	14
Habitual open lip relationship	21

*Occlusion of the first molars: mesial step of the second primary molars (one patient) was classified as Class I, distal step (four patients) as Class II/1.
**One subject can display a variety of characteristics or habits.
***Thumb and lip sucking, lip and nail biting, tongue thrusting, mentalis habit, bruxism, and clenching were also diagnosed but the number of patients with these habits was too small to be relevant.
****Infantile swallowing and tongue interposition as a consequence of missing teeth.

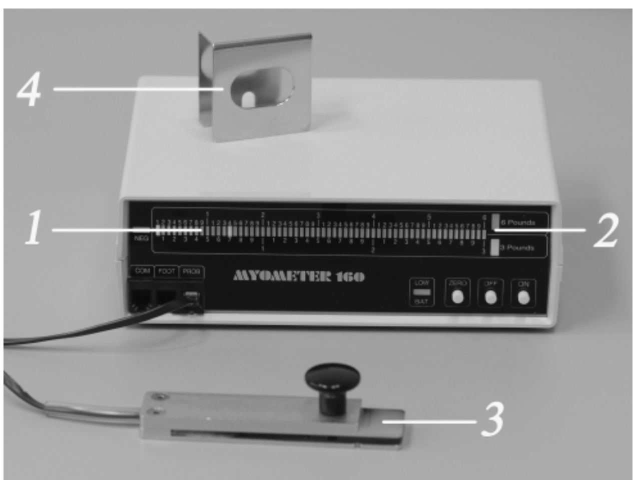

Figure 1 Myometer 160 (1) bar graph showing the current and peak values, (2) scale (0–3 pounds or 0–6 pounds), (3) probe, and (4) tongue plate.

possible. This procedure was repeated three times and the average of the obtained values was used.

The tongue plate was then screwed on the probe. The patient placed the lips around the opening of the plate and protruded the tongue as hard as possible against the probe tip. This procedure was also repeated three times and the average value was obtained.

Statistical analysis

All analyses were performed using the SAS software, Windows version 9.2 (SAS Institute Inc., Cary, North Carolina, USA). Kruskal–Wallis and Mann–Whitney U-tests were used to compare maximum lip and tongue pressure between the four Angle Classes and between males and females. Spearman's correlation coefficients were calculated in order to determine possible relationships between age and pressure.

The relationship between pressure and the characteristics of the occlusion was verified through a regression model (using five dummy variables, value 1 if the subject had the specific characteristic and value 0 if not; note a subject can have multiple characteristics). A similar approach was used for the classification of habits (using three dummy variables). Gender, age, Angle Classes, characteristics of occlusion, and oral habits were combined in a multivariable regression model (main effects). Tongue pressure was log-transformed in the regression models to obtain a symmetric distribution of the residuals. The results from the regression models on lip pressure were obtained after exclusion by the author of a subject with a very high maximum lip pressure (7.50 N), which had a high influence on the conclusions derived from the models.

A regression model with tongue pressure log-transformed was used to verify if the relationship between lip and tongue pressure differed between males and females.

All reported *P*-values were two-sided tests and considered statistically significant if less than 0.05. Bonferroni and Tukey–Kramer corrections for multiple testing were performed.

Results

The average lip pressure was 2.95 N (SD 0.108) and the average tongue pressure was 1.66 N (SD 0.06).

Lip pressure

There was evidence for a difference in lip pressure between the four Angle Classes (Kruskal–Wallis test, $P = 0.0009$). After correction for multiple testing, the only difference was between the Class I and Class II division 1 subjects; maximum lip pressure was lower in the Class II division 1 subjects (Figure 2).

A significant difference in lip pressure was found between males and females (Mann–Whitney U-test, $P = 0.009$); maximum lip pressure was higher in males than in females.

Although a positive association was observed between lip pressure and age (Spearman $r = 0.19$; Figure 3), the result was not significant ($P = 0.052$).

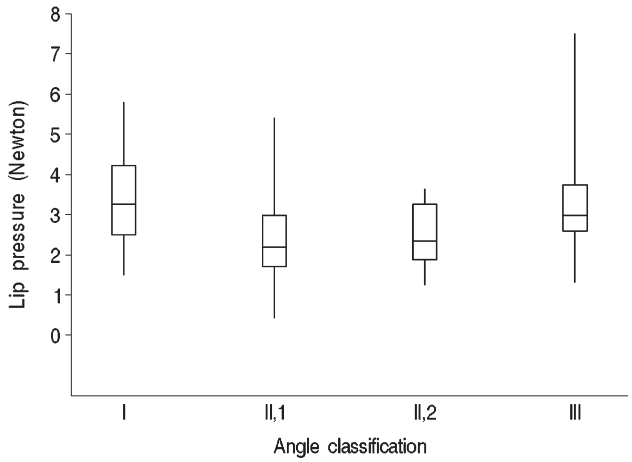

Figure 2 Boxplot of lip pressure (in Newton) versus Angle classification. The whiskers refer to minima and maxima values. The Kruskal–Wallis mean rank sums were 65.55 for Class I, 39.94 for Class II division 1, 41.00 for Class II division 2, and 60.21 for Class III subjects.

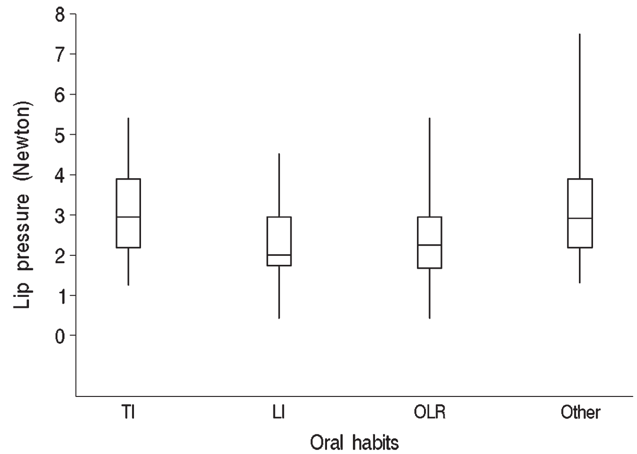

Figure 4 Boxplot of lip pressure (in Newton) versus tongue interposition (TI), lip interposition (LI), open lip relation (OLR), and subjects with no particular habits (Other). Note that a subject with multiple habits appears multiple times. The whiskers refer to minima and maxima values. The Kruskal–Wallis mean rank sums were 73.60 for the tongue interposition group of subjects, 43.43 for the lip interposition group, 49.31 for habitual open lip relation group, and 73.09 for the subjects with no habits.

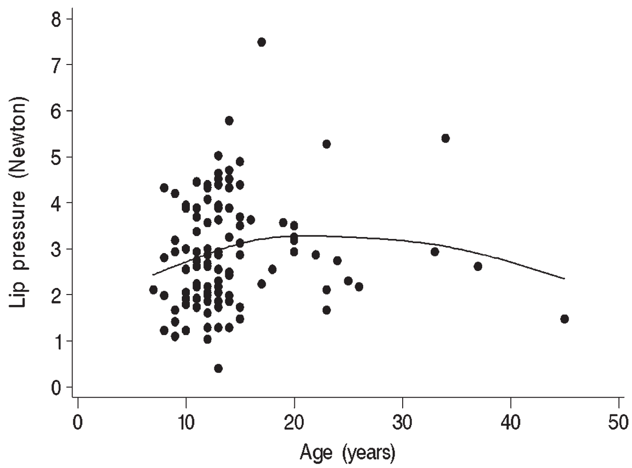

Figure 3 Lip pressure (in Newton) in relation to age.

No evidence was found for a relationship between lip pressure and the characteristics of occlusion (P = 0.17). However, a statistically significant relationship was observed between lip pressure and oral habits (P = 0.006). More specifically, maximum lip pressure was lower in subjects with an open lip relationship compared with those with a tongue interposition during swallowing (P = 0.026) and with subjects with no particular oral habits (P = 0.028). Lip pressure was also lower in subjects with partial and full lip interposition during rest compared with those with tongue interposition (P = 0.04; Figure 4). The statistical significance of the latter relationship was negated after correction for multiple testing.

Multivariate analysis was carried out to verify whether the conclusion with respect to Angle classification still held true when correction was made for gender, age, and oral habits. The difference between the four Angle Classes remained statistically significant (P = 0.0002). After correction for multiple testing, the difference was still significant between the Class I (mean score: 65.55 N) and Class II division 1 (mean score: 39.94 N) subjects (P = 0.004).

The difference between males and females also remained statistically significant after multivariate analysis (P = 0.016). The mean lip pressure was 14 per cent higher (SE = 0.053) in males than in females. However, there was no evidence of a relationship with age (P = 0.076). With regard to oral habits, a statistically significant relationship with lip pressure was found (P = 0.026). After multivariate analysis and correction for multiple testing, the relationship between an open lip relationship and tongue interposition and between an open lip relationship and no particular habit remained significant. On the other hand, the significant relationship between lip interposition and tongue interposition disappeared (Table 2).

Tongue pressure

There was no statistical evidence for a difference in tongue pressure between the four Angle Classes (Kruskal–Wallis test, P = 0.72) or between males and females (Mann–Whitney U-test, P = 0.063). Moreover, there was no evidence of a relationship between tongue pressure and age (Spearman r = 0.08, P = 0.38), the characteristics of the occlusion (P = 0.80), and oral habits (P = 0.42).

A multivariate regression model (only main effects) for the prediction of tongue pressure confirmed that there was no evidence (P = 0.55) for a relationship with the available information for gender, age, Angle classification, the characteristics of the occlusion, or oral habits.

Table 2 Pairwise comparisons between habits in the univarate regression model and the multivariate regression model.

	Univariable regression model			Multivariable regression model		
	Difference in mean (N)	SE	*P*-value	Difference in mean (N)	SE	*P*-value
Tongue interposition versus other	0.32	0.25	0.21	0.36	0.23	0.11
Lip interposition versus other	−0.44	0.37	0.22	0.11	0.36	0.81
Open lip relationship versus other	−0.63	0.30	0.028	−0.69	0.28	0.01
Tongue interposition versus lip interposition	0.74	0.37	0.041	0.28	0.36	0.45
Tongue interposition versus open lip relationship	0.92	0.42	0.026	1.02	0.39	0.007
Lip interposition versus open lip relationship	0.21	0.55	0.73	0.77	0.53	0.14

The reported *P*-values in the table are not corrected for multiple testing. In the multivariable model, differences of $P < 0.05$ remained significant after correction for multiple testing (SE).

Relationship of tongue and lip pressure

Spearman correlation for the relationship between lip and tongue pressure equalled 0.38 ($P = 0.01$) for males and 0.05 ($P = 0.67$) for females. However, the degree of association was not significant between males and females ($P = 0.26$).

Discussion

It is generally accepted that the forces acting on the dentition are principally produced by the musculature of the tongue, lips, and cheeks. These forces have different roles, such as guiding tooth eruption, influencing occlusal formation, and maintaining dental arch shape and stability (Weinstein *et al.*, 1963; Proffit, 1978; Ruan *et al.*, 2005).

Gender

Evidence was found that a difference exists in lip pressure between males and females. More specifically, a higher lip pressure was measured in males than in females. Similar results were reported by Horn *et al.* (1995), also using a Myometer 160, who concluded that lip pressure in males was higher than in females. Kato *et al.* (1989) and Posen (1972) also demonstrated the same variation between force and gender. The same trend was found by Ruan *et al.* (2005), who measured muscle pressure exerted on the primary normal occlusion and concluded that the primary dentition is in a state of dynamic equilibrium. Ruan *et al.* (2005) showed a significant correlation between muscular forces and gender, specifically at rest, but also during swallowing; forces from the cheeks of males were higher than those of females. Thüer and Ingervall (1986) and Ruan *et al.* (2007), contrary to previously reported results (Ruan *et al.*, 2005), found no difference between genders for lip pressure in patients with malocclusions. A more recent study (Ruan *et al.*, 2007) rejected the previous findings (Ruan *et al.*, 2005) and concluded that, in the case of individuals with various types of malocclusion, there were no significant differences between the forces developed by the two genders at rest, even though the muscle pressure of males appeared somewhat higher than that of females.

Age

The findings of the present study did not demonstrate a relationship between age and lip or tongue pressure. Nevertheless, some authors have found a significant relationship. Mitchell and Williamson (1978) showed that 15-year-old subjects had significantly higher maximum perioral muscle force than 8 year olds. Posen (1972) also reported similar results.

Angle classification

Thüer and Ingervall (1986) recorded, with a dynamometer, the lip pressure of 84 patients at rest and during chewing and swallowing of crisp bread. They considered that a Class II division 2 malocclusion was not provoked by a strong upper lip but that the incisor position was responsible for the low lip pressure in such patients. In contrast, the present study of the maximum lip pressure during maximum voluntary contraction showed that lip pressure was lowest in children with a Class II division 2 malocclusion.

Jung *et al.* (2003) found, with a Y-meter (which measures the vertical closing force of the upper lip), that a significant relationship exists between maxillary incisor angulation and the average and maximum upper lip closing force of male subjects during maximum voluntary, as well as rhythmic activity. Posen (1976) stated that great lip strength, measured with the pommeter (perioral muscle meter) during maximum voluntary contraction, can be an indication of a high lip tonus and thus substantial outer forces are acting on the anterior teeth. That author's findings showed that Class II division 2 subjects had a high lip strength, while bimaxillary protrusion subjects had a low lip strength. The same study showed that the pressure in Class II division 1 subjects was lower than in subjects with a Class I occlusion. Both the pommeter and the myometer measure total lip force and cannot separately differentiate the effects of the upper and lower lip. For example, it is possible to measure normal lip pressure in patients with incompetent lips, i.e. when upper lip hypotonicity (low upper lip pressure) is combined with a mentalis habit (strong lower lip pressure). Therefore, the results of both the study of Posen (1976) and the present research should be interpreted with care. Posen (1976) emphasized that knowledge of the maximum tonic activity of the perioral muscles can be of great benefit and should be utilized in orthodontic diagnosis. However, this does not imply that other sources of information must be neglected for analysis and treatment planning.

For Class III subjects, no significant relationship was found between the forces exerted, by either lip or tongue. Ruan *et al.* (2007) showed that patients with Class III malocclusions generated lower perioral muscle forces at rest and during swallowing. This was particularly marked in the case of the upper lip. This may cause less bone apposition in this area, which aggravates the clinical features of a Class III malocclusion. They postulated that their results reflected muscle hypofunction secondary to the spatial relationship of the jaws in Class III subjects, namely retroposition of the maxilla. This hypofunction may be also related to the concave midface in Class III patients (Ruan *et al.*, 2007).

Characteristics of the occlusion

There was no significant relationship between the measured lip pressure and the previously defined characteristics of the occlusion, such as an open bite, uni- or bilateral crossbite, and deep bite. Stahl *et al.* (2007) also could not prove a relationship. This implies that, for example, an open bite is not always associated with higher tongue pressure. However, according to Stahl *et al.* (2007), development of the dentition is without doubt defined by functional patterns. Those authors affirmed that the final dental balance is a result of a different individual combination of intra- and extraoral forces. This is probably the reason no relationship was found between a definite characteristic of the occlusion and lip or tongue pressure in the present study.

The reason why, until now, a significant relationship between an open bite and abnormal high tongue pressure could not be proven could be that the level of lingual force in patients with a dental open bite malocclusion is similar to that of normal subjects (Christiansen *et al.*, 1979).

Proffit (2007) noted that individuals with an anterior open bite (AOB) placed the tongue between the anterior teeth when they swallowed, while those with a normal incisor relationship usually did not. It is consequently tempting to identify the open bite as the aetiology on this pattern of tongue activity. According to the equilibrium theory, the effect of force produced by the tongue depends on the duration of the specific pressure because only sustained pressure by the tongue against the teeth would have an effect on the anterior dentition. The magnitude of force is thought to be of less importance. Proffit (2007) also reported that tongue thrusting is 10 times more frequent than an open bite so that while the tongue could be an influencing factor, it is not always the reason for an open bite. This could explain why no significant relationship between tongue pressure and an open bite malocclusion was found in the current investigation.

Oral habits

In the present study, the significant effect of oral habits on lip pressure was confirmed by analysis on an 'inflated' dataset where subjects were considered as many times as they had multiple habits (maximum three). This is important in the interpretation of the results.

There is evidence in the literature that an AOB is more common among children with different functional disorders, such as an open mouth posture, pathological tongue posture, visceral swallowing pattern, and articulation disorders, than in those without (Grabowski *et al.*, 2007; Stahl *et al.*, 2007).

The present study could not prove a significant difference in lip or tongue pressure between subjects with or without an AOB. This may be due to the multiple origins of an AOB. This means that it is not correct to say that an AOB is only due to an extreme tongue pressure or minimum lip pressure.

Grabowski *et al.* (2007) found no evidence of a relationship between oral habits and lip or tongue pressure. However, in that study, the percentage of lateral crossbites was significantly higher in the primary or mixed dentition of children with functional disturbances.

It is commonly acknowledged that an oral habit can affect the position of the teeth, the dental arches, and the growth of the alveolar processes. The effect of non-nutritive sucking habits depends on the frequency, intensity, and duration of the habit (Proffit, 2007). It is important that parents should be informed about the consequences of their child developing unphysiological functional patterns, such as an open lip relationship, lip interposition, or tongue thrust.

It is generally accepted that it is a good advice to unlearn abnormal oral habits as early as possible (preferably before the age of 4 years) in order to create an environment in which normal development of the facial skeleton can occur (Bertoldi *et al.*, 2005). Screening for malocclusions and orofacial dysfunctions of children in the primary and early mixed dentition is required (Korbmacher *et al.*, 2004).

Conclusions

In this cross-sectional study, the aim was to determine significant relationships between lip and tongue pressure on the one hand and gender, age, Angle classification, the characteristics of the occlusion, and oral habits on the other. The findings can be summarized as follows:

1. There is a difference in lip pressure between Class I and Class II division 1 subjects. More specifically, lower lip pressure was found in subjects with a Class II division 1 malocclusion than in those with a Class I occlusion.
2. There exists a significant difference in lip pressure between males and females: maximum lip pressure is higher in males than in females.
3. No evidence was found of a relationship between lip pressure and age or between lip pressure and the characteristics of the occlusion.
4. With regard to the relationship between oral habits and lip pressure, it was found that lower lip pressure in subjects with an open lip relationship was lower when compared with subjects with tongue interposition during swallowing, and with those with no particular habits. Lip pressure was also lower in subjects with lip interposition compared with those with tongue interposition.
5. No statistical difference in tongue pressure exists between males and females or between the different Angle Classes. Furthermore, a relationship with age, the characteristics of the occlusion, or oral habits could not be proved.

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