Int J Clin Exp Med 2015;8(7):11208-11213
www.ijcem.com /ISSN:1940-5901/IJCEM0010037

Original Article

Description of intraoral pressures on sub-palatal space in young adult patients with normal occlusion

Ramón Fuentes[1], Wilfried Engelke[2], Tania Flores[1], Pablo Navarro[3], Eduardo Borie[1,4], Aldo Curiqueo[5,6], Carlos Salamanca[5]

[1]*Research Centre in Dental Sciences (CICO), Dental School, Universidad de La Frontera, Temuco, Chile;* [2]*Department of Oral and Maxillofacial Surgery, University of Gottingen, Germany;* [3]*Dental School, Universidad de La Frontera, Temuco, Chile;* [4]*Department of Dental Materials and Prosthodontics, Ribeirão Preto Dental School, University of São Paulo, Ribeirão Preto, SP, Brazil;* [5]*MSc Student, Universidad de La Frontera, Temuco, Chile;* [6]*Universidad Adventista, Chillán, Chile*

Received May 8, 2015; Accepted June 24, 2015; Epub July 15, 2015; Published July 30, 2015

Abstract: Under normal conditions, the oral cavity presents a perfect system of equilibrium between teeth, soft tissues and tongue. The equilibrium of soft tissues forms a closed capsular matrix, generating differences with the atmospheric environment. This difference is known as intraoral pressure. Negative intraoral pressure is fundamental to the stabilization of the soft palate and tongue, reducing neuromuscular activity for the permeability of the respiratory tract. Thus, the aim of this study was to describe the variations of intraoral pressure of the sub-palatal space (SPS) under different physiological conditions and biofunctional phases. A case series was conducted with 20 individuals aged between 18 and 25. The intraoral pressures were measured through a system of cannulae connected to a digital pressure meter in the SPS during seven biofunctional phases. Descriptive statistics were used based on the mean and standard deviation. The data recorded pressure variations under physiological conditions, reaching 65 mbar as the intraoral peak in forced inspiration. In the swallowing phase, peaks reached -91.9 mbar. No pressure variations were recorded in terms of atmospheric changes with the mouth open and semi-open. The data obtained during the swallowing and forced inspiration phases indicated forced lingual activity. In the swallowing phase, the adequate position of the tongue creates negative intraoral pressure, which represents a fundamental mechanism for the physical stabilization of the soft palate. This information could contribute to subsequent research into the treatment of primary roncopathies.

Keywords: Intraoral pressure, biofunctional compartment, sub-palatal space, biofunctional model

Introduction

The oral cavity presents a perfect equilibrium between the teeth, soft oral tissues (lips and cheeks) and tongue [1-3]. Accordingly, the position of the tongue has significant repercussions on the etiology, diagnosis and treatment of malocclusions and myofunctional alterations as well as on the diagnosis and treatment of primary snoring, among other things [4].

In the stomatognathic system, the position of the teeth and the shape of the dental arch are subject to constant pressure by the perioral muscles externally and by the tongue internally [5]. The muscle equilibrium was first described by Tomes [6] and then by Ruan et al. [7], who reported that the teeth are in a state of equilibrium between the external forces of the lips and cheeks and the internal forces of the tongue. The equilibrium created by the oral soft tissues forms a closed capsular matrix composed of functional spaces or intraoral biofunctional compartments, which generate differences in pressure with the atmospheric environment. This difference is known as intraoral pressure [3, 8]. The model that underlies this theory of equilibrium is based on the assumption that active neuromuscular forces are responsible, among other components, for the equilibrium of the position of the teeth and vice versa [9].

Wein et al. [10] analyzed the tongue position using ultrasound and observed a congruent

Figure 1. Scheme showing the area in which was measured the atmospheric pressure.

shape of the back of the tongue with a closed mouth-tongue contact at the end of the oral swallowing phase. Engelke and Hoch [11] examined the movements of the soft palate and tongue during swallowing by means of electromagnetic articulography, describing that after the velopharyngeal action of swallowing there is a position of direct contact of the tongue with the hard palate in relation to a position of the antero-inferior uvula. Some observations of the orofacial functions using polysensography [12] revealed a position of direct contact of the tongue with the hard palate, which enables the formation of a velolingual seal after swallowing, contributing to the stabilization of the tongue in the oral cavity.

The intraoral biofunctional compartments, formed during habitual functions, have been described in the literature [13, 14]. There are two functional “suction” spaces: one around the dental arches externally (the occlusal space of Fränkel) and the other below the palatal vault (sub-palatal space). In 1991, Fröhlich et al. [15] described the formation of negative pressure at the palatal vault, which until then had not been considered in the study of intraoral forces [1]. Engelke [16] studied these biofunctional compartments as part of an integral biofunctional model, indicating the formation of two different intraoral compartments that can generate intraoral negative pressure in the resting position [13].

Strong negative pressure was reported experimentally by Fränkel [17], while some moderate negative pressure was also subsequently described in other studies [18]. Lindner and Hellsing [19] recorded the formation of negative intraoral pressure in children due to thumb sucking as well as when breastfeeding, and they concluded that, from the correlation between the atmospheric depression and the positive forces of the soft tissues, the perioral muscles and the tongue are particularly active during thumb sucking. Other authors have reported that the negative pressures of the sub-palatal space (SPS) occur normally during swallowing [20]. Some studies where a funnel membrane was used in an oral shield to gauge the pressure have reported the formation of negative intraoral pressure during and after swallowing [4]. Additionally, Engelke et al. [16] showed that there is a spontaneous formation of negative intraoral pressure during and after the swallowing phases that seem to be common during sleep.

Some studies [4] have proposed a closed resting oral position with a tongue position suited to generating negative intraoral pressure, which could be a fundamental mechanism of physical stabilization of the soft palate and tongue and could also reduce the amount of neuromuscular activity needed to maintain the permeability of the respiratory tract.

Thus, the aim of this study was to describe the variations of intraoral pressure of the SPS under different physiological conditions and biofunctional phases.

Materials and methods

A descriptive, cross-sectional case series was conducted. The sample was comprised of Dentistry students of the Universidad de la Frontera (Temuco, Chile) who fulfilled the selection criteria. 20 individuals were selected, aged between 18 and 25 years, determined according to previous studies [21].

Inclusion criteria

Men and women, with all mandibular and maxillary teeth, class I molar and canine.

Exclusion criteria

Patients with presence of oral lesions or pathologies in the mucosa, orthodontic braces, obstruction in the upper airway (according to medical history), oral respirators and with atypical swallowing or tongue thrusting.

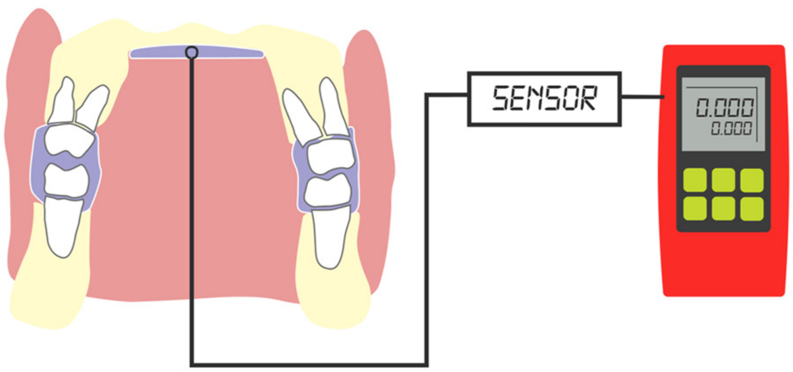

Figure 2. Scheme exhibiting the position in which the catheter connected to sensor was placed.

Materials

A portable digital pressure meter (GMH 3156, Greisinger Electronic, Germany) connected to two GMSD 350 MR piezoresistant relative pressure sensors (Greisinger Electronic GmbH, Regenstauf, Germany) with a measurement range of 500 mbar (rel.) (100 to-400 mbar) and a resolution of 0.1 mbar relative pressure. Each sensor was connected independently to a flexible PVC tube (4 mm internal diameter) [3, 13, 21].

Additionally, an intravenous semi-flexible polyethylene catheter (20 G × 1.00, BD Cateter Insyte[TM], Becton Dickinson Ind. Cir. Ltda., Brazil), sterile, 15 cm long, was connected to the pressure sensor. The measurement of the atmospheric pressure was done intraorally in the sub-palatal space between the palatal vault and the surface of the tongue (**Figure 1**). To measure the SPS, the catheter was positioned intraorally until reaching the central zone (middle line) of the palatal vault, 3 cm from the alveolar ridge to the third transverse palatine ridge so as to reduce interference with the back of the tongue (**Figure 2**). In order to stabilize the catheter, the patient was asked to hold it, supporting it on the distal face of the central incisor [21].

Measurement of intraoral pressure

All the measurements were taken by a single previously trained operator. Each patient was seated vertically in an armchair with a natural head position [22]. The sensors were located in front of him at the height of the oral cavity. After explaining the procedure and fitting the device into the mouth, the subject was asked to follow the instructions indicated by the operator. The measurements were taken in 7 phases, in addition to a calibration phase, as is detailed next:

Phase A: Calibration

This phase was meant to be a control of the pressure during a total period of 15 minutes in order to assess the effects of the intraoral device for measuring the SPS. The subjects were instructed to keep the devices pressed softly with their lips, to swallow and breathe normally during the period so as to maintain their natural biofunctionality.

Phase B: These were the measurements of functional pressure, as following phases:

B1: Rhythmic inspiration every 4 seconds mouth open.

B2: Rhythmic inspiration every 4 seconds mouth semi-open.

B3: Swallowing every 10 seconds.

B4: Forced snoring every 10 seconds mouth closed.

B5: Maximum forced inspiration every 10 seconds.

B6: Letter “m” sounds for 3 seconds every 10 seconds.

B7: Apnea for 30 seconds at 10 seconds measurement.

Results

Of all the individuals, it was observed that the sample revealed similar patterns in the measurements of intraoral pressure in the SPS, as it was summarized in the **Table 1**.

In Phase B1, with the mouth open, the pressure was constant between 0 and -0.1 mbar, producing a negative plateau, which was not considerable in relation to the atmospheric pressure.

Table 1. Mean, maximum and minimum relative pressure during different conditions in phase B

Phase B	Condition	Relative pressure mean ± SD	Minimum relative pressure	Maximum relative pressure
1	Rhythmic inspiration every 4 seconds mouth open	0.0017 ± 0.1291	0	0.1
2	Rhythmic inspiration every 4 seconds mouth semi-open	2.3067 ± 2.7018	-2.9	11.8
3	Swallowing every 10 seconds	-10.050 ± -11.1486	-91.9	-1.4
4	Forced snoring every 10 seconds mouth closed	5.1867 ± 3.6906	-1.9	28.6
5	Maximum forced inspiration every 10 seconds	16.7417 ± 9.8426	-3.1	59.8
6	Letter “m” sounds for 3 seconds every 10 seconds	1.4083 ± 2.0594	-7.1	34.7
7	Apnea for 30 seconds at 10 seconds measurement	2.3217 ± 5.3188	-3.4	29.2

In Phase B2, with the mouth semi-open, peaks of increased positive pressure were observed up to 11.8 mbar, which occurred approximately every 4 seconds, coinciding with the inspiration stages.

In Phase B3, swallowing, pressure peaks reached -91.9 mbar of negative pressure, registering the highest points every 10 seconds, when these declined gradually until reaching -1.4 mbar, forming a plateau of negative pressure.

In Phase B4, forced snoring, peaks of increased pressure were identified up to 28.6 mbar of positive pressure, which occurred every 10 seconds, coinciding with the stages where the snoring was forced, which dropped to -1.9 mbar.

In Phase B5, peaks of increased positive pressure reached 59.8 mbar, which occurred every 10 seconds, coinciding with the maximum inspiration stages, similar to Phase B3 every 10 seconds, this condition being the second in increased pressure values.

In Phase B6, peaks of increased positive pressure up to 34.7 mbar of positive pressure were identified, which occurred every 10 seconds, coinciding with the stages where the snoring was forced, which decreased slowly to -0.5 mbar.

In Phase B7, peaks of increased positive pressure up to 29.2 mbar were observed at 10 seconds, coinciding with the moment at which the maximum inspiration prior to apnea was reached. During the apnea, the pressure fluctuated between 3.6 mbar and -3.2 mbar, forming a plateau of negative pressure during most of the apnea, and once this had finished, at 40 seconds, the pressure returned to positive, fluctuating between 0.4 and 6.8 mbar until 60 seconds.

Discussion

Intraoral pressures have been studied mainly to determine how these can influence the function of dynamic physiological changes [24]. Nevertheless, information about the production and coordination of absolute intraoral pressures and the respective resulting pressure gradients seems very limited in the literature [25].

Hiss et al. [24] reported in their study that there are no significant differences in the intraoral pressure of the air between individuals of different ages or genders. Consequently, this study worked with a limited age range.

The data in this work show that in the phase where the lips were open (Phase B1) there was no considerable difference in atmospheric pressure, indicating that the formation of closing the compartments does not occur spontaneously, similar to what was reported by Engelke et al. [26].

With the mouth in the semi-open condition (Phase B2), the tongue is postural, and involuntary swallowing and breathing occur [26]. Likewise, an increase in pressure is produced in the SPS which may indicate an increase in the activity of the soft palate and tongue [16].

Additionally, suction and swallowing are a complex activity between the neuromusculature and functional units of hard tissues, which together form valves and functional compartments [26]. Accordingly, in the swallowing phase (Phase B3), the SPS presents a negative peak pressure of -91.9 mbar, which may indicate that the position of the tongue when is located against the soft palate produces a closing and a sealing of the compartment [16]. The strong negative pressure obtained is similar to that described experimentally by some studies [17, 27]. Engelke et al. [27], studying the influence of pressures on the intraoral compartments during swallowing, reported similar values to those found here, the mean of which was -89 mbar in the region of the SPS. The generation of this negative pressure in the SPS compartment is a crucial parameter to determine suction and swallowing and thus to define its time, coordination and quality [27].

The same authors [27] conclude that during suction the SPS expands from a resting position to a suction phase, reaching its maximum expansion at the end of the suction. In the swallowing phase, when the back of the tongue is located against the soft palate, this generates negative intraoral pressure, which represents a fundamental mechanism for the physical stabilization of the soft palate and tongue. In turn, this can reduce the amount of neuromuscular activity needed to maintain the permeability of the respiratory tract, which would allow, by means of a tongue repositioning maneuver described by Engelke [26], the stabilization of the soft palate to generate negative pressure, which may contribute to later studies into the treatment of primary roncopathies.

Finally, the data recorded during the phases of swallowing and forced inspiration indicated forced lingual activity. With respect to the open and semi-open phases of the mouth, there were no considerable variations with respect to the atmospheric pressure, indicating that the closing of the compartment is not spontaneous, similar to what has been described in other studies [26].

Conclusion

Pressure variations were recorded in physiological conditions, reaching 65 mbar as a peak of intraoral pressure under forced inspiration and a peak of -91.9 mbar during the swallowing phase. The physiological understanding of the biofunctional compartments is needed in order to understand the normal functions and be able to serve as a guide in the establishment of new therapies for patients with orofacial dysfunctions.

Acknowledgements

The authors want to acknowledge to the DIUFRO project (DI12-0051) of Universidad de La Frontera, Chile, for the financial support.

Disclosure of conflict of interest

None.

Address correspondence to: Ramón Fuentes Fernández, Dental School, Universidad de La Frontera. Av. Francisco Salazar 01145, Temuco 4811230, Chile. Tel: 56-45-2734153; Fax: 56-45-2325777; E-mail: ramon.fuentes@ufrontera.cl

References

[1] Proffit WR. Equilibrium theory revisited: factors influencing position of the teeth. Angle Orthod 1978; 48: 175-186.
[2] Thüer U and Ingervall B. Pressure from the lips on the teeth and malocclusion. Am J Orthod Dentofacial Orthop 1986; 90: 234-242.
[3] Knösel M, Jung K, Kinzinger G, Bauss O and Engelke W. A controlled evaluation of oral screen effects on intra-oral pressure curve characteristics. Eur J Orthod 2010; 32: 535-541.
[4] Engelke W, Mendoza M and Repetto G. Preliminary radiographic observations of the tonguerepositioning manoeuvre. Eur J Orthod 2006; 28: 618-623.
[5] Perkins RE, Blanton PL and Biggs NL. Electromyographic analysis of the "baccinator mechanism" in human beings. J Dent Res 1977; 56: 783-794.
[6] Tomes C. The bearing of the development of the jaws on irregularities. Dent Cosmos 1873; 15: 292-296.
[7] Ruan WH, Chen MD, Gu ZY, Lu Y, Su JM and Guo Q. Muscular forces exerted on the normal deciduous dentition. Angle Orthod 2005; 75: 785-790.
[8] Moss ML and Salentijn L. The capsular matrix. Am J Orthod 1969; 56: 474-490.
[9] Weinstein S, Haack DC, Morris LY, Snyder BB and Attaway HE. On an equilibrium theory of tooth position. Angle Orthod 1963; 33: 1-26.
[10] Wein B, Alzen G, Tolkdorff T, Bockler R, Klajman S and Hupetr W. Computerized sonographic imaging of tongue motility using pseudo 3-dimensional reconstruction. Ultraschall Med 1988; 9: 95-97.
[11] Engelke W and Hoch G. Simultaneous electromagnetic articulography and video endoscopy. A case contribution to the objective diagnosis of the velopharyngeal sphincter. Fortschr Kieferorthop 1994; 55: 297-303.

[12] Engelke W and Hoch G. Funktionsdiagnostik mit intraoralen Sensoren. Zahnärztll Mitt 1999; 89: 2568-2574.

[13] Engelke W, Engelhardt W, Mendoza-Gärtner M, Deccó O, Barrirero J and Knösel M. Functional treatment of snoring based on the tongue-repositioning manoeuvre. Eur J Orthod 2010; 32: 490-495.

[14] Eckert-Möbius A. Die Bedeutung der Zunge für die Nasen- und Mundatmung. Fortschr Kieferorthop 1953; 14: 229-239.

[15] Fröhlich K, Thüer U and Ingervall B. Pressure from the tongue on the teeth in young adults. Angle Orthod 1991; 61: 17-24.

[16] Engelke W, Repetto G, Mendoza M and Knoesel M. Functional treatment of snoring using oral shields in conjunction with the tongue repositioning manoevre. Int J Odontostomat 2007; 1: 133-139.

[17] Fränkel R. Die Dynamik des interokklusalen Unterdruckes. Dtsch Zahnärztl Z 1967; 22: 282.

[18] Witt E and Kühr HW. Experimental studies on the physiological processes in the wearing of a vestibular plate. SSO Schweiz Monatsschr Zahnheilkd 1969; 79: 650-666.

[19] Lindner A and Hellsing E. Cheek and lip pressure against maxillary dental arch during dummy sucking. Eur J Orthod 1991; 13: 362-366.

[20] Gould MS and Picton DC. Sub-atmospheric pressures and forces recorded from the labiobuccal surfaces of teeth during swallowing in adult males. Br J Orthod 1975; 2: 121-125.

[21] Fuentes R, Engelke W, Fuentes C, Soto N and Cantín M. Determinación de presiones intraorales en compartimientos biofuncionales de pacientes desdentados totales. Int J Odontostomat 2014; 8: 151-157.

[22] Archer SY and Vig PS. Effects of head position on intraoral pressures in Class I and Class II Adults. Am J Orthod 1985; 87: 311-318.

[23] Kieser J, Singh B, Swain M, Ichim I, Waddell JN, Kennedy D, Foster K and Livingstone V. Measuring Intraoral pressure: adaptation of a dental appliance allows measurement during function. Dysphagia 2008; 23: 237-243.

[24] Hiss SG, Treole K and Stuart A. Effect of age, gender, and repeated measures on intraoral air pressure in normal adults. J Voice 2001; 15: 159-164.

[25] Kieser JA, Farland MG, Jack H, Farella M, Wang Y and Rohrie O. The role of oral soft tissues in swallowing function: what can tongue pressure tell us? Aust Dent J 2014; 59: 155-161.

[26] Engelke W, Jung K and Knösel M. Intra-oral Compartment pressures: a biofunctional model and experimental measurements under different conditions of posture. Clin Oral Investig 2011; 15: 165-176.

[27] Engelke W, Glombek J, Psychogios M, Schneider S, Ellenberger D and Santander P. Displacement of oropharyngeal structures during suction-swallowing cycles. Eur Arch Otorhinolaryngol 2014; 271: 1987-1997.