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Tongue resting pressure of the tongue anchorage pad in different body positions: a pilot study

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SUMMARY We designed a modified transpalatal arch (tongue anchorage pad, TAP) to help control the vertical dimension. This study aimed to evaluate its efficiency by measuring the tongue resting pressure at different anteroposterior positions of the TAP in the upright and supine positions and to investigate the effect of changes in body position. Our study recruited 17 volunteers with individual normal occlusion (4 males, 13 females, age 22–33 years). An individualised TAP was designed for each subject. With a miniature sensor (FSS1500NS) installed in the device, we measured the pressure at the level of the distal second premolar (PM2), the first molar (M1) and the second molar (M2) in both the upright and supine positions. Nonparametric analysis was applied with the level of significance set at 0·05. In the upright position, tongue pressures obtained at PM2, M1 and M2 were 183·94, 130·81 and 113·07 Pa, respectively, with the maximum value detected at PM2 ($P = 0{\cdot}001$). While in the supine position, pressures of 187·03, 156·87 and 201·69 Pa were detected at the same sites, with significantly higher values for M1 ($P = 0{\cdot}002$) and M2 ($P = 0{\cdot}004$). Tongue resting pressure decreases from the anterior aspect to the posterior aspect in the upright position. In the supine position, the pressure is consistent across the midline with pressure enhancement at M1 and M2. As many questions remain about this appliance and appropriate intruding force, further clinical and basic studies are required prior to its clinical implementation.

KEYWORDS: **tongue, pressure, rest, molar, vertical dimension, supine position**

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Introduction

As Proffit (1) put, light sustained pressures from lips, cheeks and tongue at rest are important determinants of tooth position. However, few orthodontic appliances utilise tongue function, the most popular being the transpalatal arch (TPA) and the bionator. Several functions have been ascribed to the TPA, one of which is to transmit tongue pressure to molars and restrain their extrusion to control the vertical dimension. However, this effect is controversial (2–4). Nanda *et al.* (5) improved the design by adding an acrylic button to the middle of the TPA, which exhibited favourable results in their sample, but little research has been conducted since that initial study. Therefore, we designed a modified TPA, tongue anchorage pad (TAP) and evaluated its efficiency.

Considering the interindividual variation of the tongue pressure in swallowing (6, 7), which may result in different forces acting on the TPA, an individualised distance between the appliance and palatal mucosa corresponding to tongue strength needs to be adopted to improve the effects. The TAP analysed in our study was designed according to this principle. In addition, most studies measuring tongue pressure in swallowing suggested that the magnitude was significantly larger in the anterior part compared with that in the median or posterior part (7–9). While Chiba *et al.* (10) held a completely contrary view in their study examining tongue pressure on loop of TPA

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at various anteroposterior positions during deglutition. Furthermore, tongue exhibits a posterior movement in supine position which also have an influence on the tongue pressure (11). Considering these functional characteristics, we would expect that pressure should be variable on the TAP in sagittal direction and increase at the posterior aspect in supine position. It has been generally acknowledged that a continuous, light force is more effective than an intermittent, heavy force in terms of teeth movement (1). Therefore, the purpose of our research was twofold: (i) to detect tongue resting pressure in various anteroposterior positions of the TAP in both the upright and the supine positions, which simulate body positions in daytime and night-time, respectively, and (ii) to clarify the effects of changes in body position on tongue resting pressure.

Materials and methods

Subjects

Seventeen healthy volunteers (4 males, 13 females; age 22–33 years; mean age 26·12 ± 2·40 years) were recruited. The inclusion criteria were as follows: individual normal occlusion, normal mastication and swallowing, complete dentition with the exception of the third molar, no history of orthodontic treatment and no temporomandibular disorders. The study was approved by the Institutional Review Board of the Medical School of Peking University, and informed consent was obtained from all subjects.

Maxillary cast and record of tongue position

Maxillary casts of all subjects were prepared (Fig. 1a). Next, a defined amount of silicone impression material (Betasil*) was placed on the hard palate to obtain an impression of the tongue during swallowing, of which the thickness was correlated with tongue strength. That is, one with higher pressure shows a thin pattern and vice versa. We called this the 'impression of tongue position during swallowing' (Fig. 1a). Its high repeatability was proven in our preliminary study with the intraclass correlation coefficient (ICC) being 0·983. Next, a cast of the tongue position was constructed using a dental stone (Fig. 1b); this cast occluded with the corresponding maxillary cast and was used in the next step.

Tongue anchorage pad

A clasp for the first molar was created from 0·8-mm stainless steel wire. The clasps were only used for convenience in the experiment and would be replaced by bands in clinical practice. The palatal plate was created using the following method: First, an amount of self-curing resin was spread over the palatal surface of the maxillary cast; then, the cast of the tongue position was occluded with the maxillary cast to shape the resin before it polymerised. Thus, the distance from the mucosa to TAP was identical to that of the impression of the tongue position. Next, the plate was trimmed to an appropriate and individualised size. Its width was two-thirds the molar-to-molar distance. The anterior edge was at the level of the mesial aspect of the second premolar, and the posterior edge was 4 mm distal to the second molar (Fig. 1c).

Sensor and monitor

The sensor used in this study was an FSS1500NS model (†Honeywell) (Fig. 2a). A waterproof plastic sheath (Fig. 2b) was also applied to protect the sensor from saliva. The calibrator, monitor, (Fig. 2c) and analysis software were designed and produced by FuXinWei Electronic Technology Co. Ltd‡ .

All sensors should be calibrated before measurements were performed. Wax was used to embed the sensor in the plate successively at the level of the distal second premolar (PM2), the first molar (M1) and the second molar (M2) along the median line. The cables of the sensor were passed behind the last molar and via the oral vestibule to exit the oral cavity. Data were collected at intervals of 0·1 s.

Pressure measurement

Before measuring, all subjects wore the TAP for 10 min to adapt to the appliance and minimise the influence of oral temperature. The subjects were then instructed to sit upright with the Frankfort plane par-

*Betasil, Müller-Omicron GmbH Co. KG, Köln, Germany

†Honeywell, Morristown, New Jersey, USA

‡FuXinWei Electronic Technology Co. Ltd., Xiamen, China

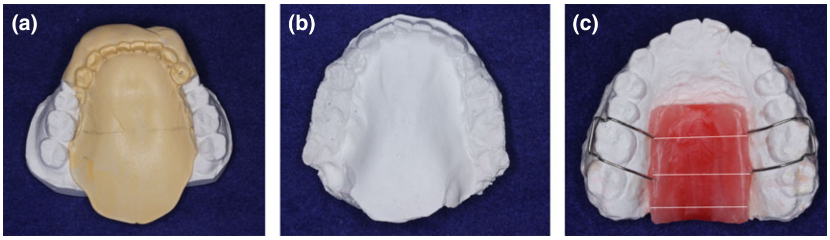

Fig. 1. (a) Maxillary cast and impression of tongue position during swallowing. (b) Cast of tongue position. (c) Tongue anchorage pad (TAP). Its width is two-thirds the molar-to-molar distance. The anterior edge is at the level of the mesial aspect of the second premolar, and the posterior edge is 4 mm distal to the second molar. The three white lines indicate measuring points at the level of the distal second premolar (PM2), the first molar (M1) and the second molar (M2).

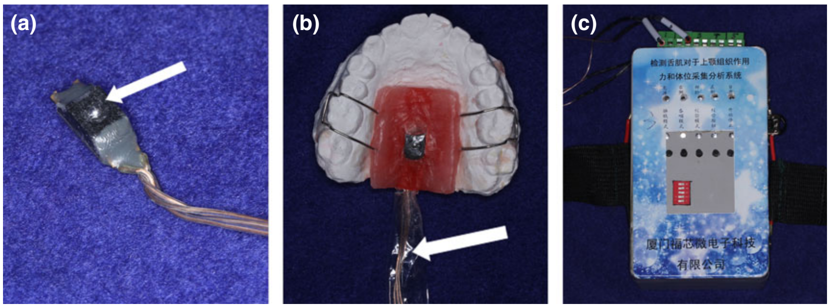

Fig. 2. (a) Sensor. The white arrow indicates the receptor sensing pressure. (b) The TAP was installed with a sensor at M1. The white arrow indicates the waterproof plastic sheath. (c) Monitor.

allel to the ground, occlude in the intercuspal occlusion and breathe naturally with the tongue relaxed. After the measurements stabilised, the tongue resting pressure was recorded for 2 min. During this process, swallowing was permitted, but as it significantly increased the pressure, data recorded during swallowing could be easily defined and were ultimately removed from the final results. Next, the procedure was repeated in the supine position. After at least 1 week, all measurements were repeated to test the intrasubject reliability of the experiment, and the ICC was calculated.

Statistics

All data were analysed using the IBM SPSS version 19.0 software[§]. Normality was assessed with the Kolmogorov–Smirnov test and a histogram. As the data were not of a normal distribution, we used nonparametric statistical analysis. The *Friedman test* was performed to compare the pressures at PM2, M1 and M2 ($P < 0{\cdot}05$ was considered to indicate statistical significance), and if significant differences were found, post hoc analysis using the *Wilcoxon signed-rank test* with Bonferroni correction was applied. Next, the *Wilcoxon signed-rank test* was applied to analyse the influence of body position change at a significance level of 0·05.

[§]IBM SPSS version 19.0 software, IBM, Beijing, China

Results

The ICC of the two measurements was 0·753–0·956, which indicates good reliability. The mean of the two measurements was calculated.

In the upright position, the pressure decreased in an anterior-to-posterior direction, with the means being 183·94, 130·81 and 113·07 Pa at PM2, M1 and M2 ($P = 0{\cdot}001$) (Table 1, Fig. 3). Multiple comparisons were performed using the Bonferroni correction (as three groups were compared, $P = 0{\cdot}05/3 = 0{\cdot}017$ was finally used). The average pressure detected at PM2 was greater than that at M1 ($P = 0{\cdot}002$) and M2 ($P = 0{\cdot}004$), while the latter two sites showed no significant difference ($P = 0{\cdot}062$) (Table 2).

In the supine position, the pressures were consistent among the three sites ($P = 0{\cdot}12$), with means of 187·03, 156·87 and 201·69 Pa, respectively (Table 3, Fig. 3).

As described in Table 4, when the subjects laid down, the pressures at M1 and M2 increased significantly while that at PM2 remained constant.

Table 1. Tongue resting pressure in the upright position (Pa)

	Median	Range	Mean	s.d.	*P*
PM2	147·6	79·48–416·06	183·94	108·75	0·001**
M1	109·82	71·28–308·50	130·81	64·07	
M2	89·39	54·21–269·10	113·07	65·87	

**Significance less than 0·01.

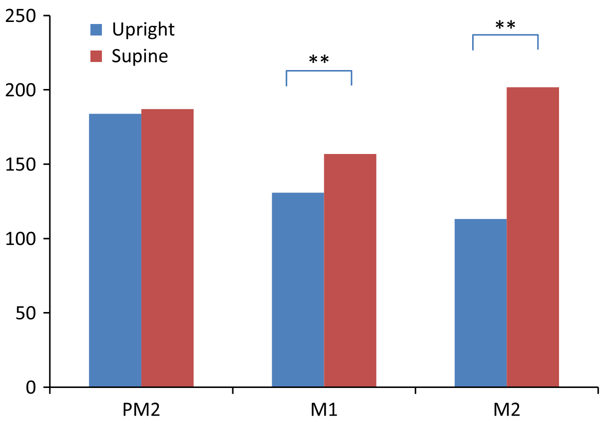

Fig. 3. Tongue resting pressure at different anteroposterior positions (Pa) (***P* < 0·01).

Table 2. Multiple comparison among different anteroposterior positions in upright position

	PM2 vs. M1	PM2 vs. M2	M1 vs. M2
P	0·002*	0·004*	0·062

*Significance less than 0·017.

Table 3. Tongue resting pressure in the supine position (Pa)

	Median	Range	Mean	s.d.	*P*
PM2	151·24	84·46–410·62	187·03	98·96	0·12
M1	119·82	84·43–314·58	156·87	72·85	
M2	141·69	76·03–795·13	201·69	171·91	

Table 4. Comparison of pressure in different body positions

	PM2	M1	M2
P	0·687	0·001**	0·001**

**Significance less than 0·01.

Discussion

Individuals with a steep mandibular angle constitute a group of clinically challenging patients in the treatment of malocclusions. They are susceptible to molar extrusion, backward mandibular rotation and eventual aesthetic deterioration during orthodontic treatment. Traditional techniques that help to control vertical dimension include a high-pull headgear or chin cup, bite block, transpalatal arch, etc.; however, their effectiveness has not been demonstrated (2, 4, 12–14). For absolute anchorage, a miniscrew can achieve efficient molar intrusion (15, 16), but possible complications include injury to adjacent teeth, infection, implant failure and fracture (17). A reliable conservative technique is needed for these cases, such as the TAP we designed in our study. Also, a previous study proved the efficiency of a similar appliance (5). However, there are still many unknowns pertaining to this treatment method: Is the pressure on the TAP optimum? Is the pressure distributed through the TAP evenly? Where should the TAP be placed to distribute appropriate force to the upper molars? Our study serves as a preliminary step in addressing these issues.

Kunvara (18) reported that the average person swallows approximately 2400 times per day, but the duration of each is <1 s (7, 8). Therefore, the tongue pressure produced during swallowing is an intermittent heavy force, while the resting pressure is a continuous light force. Proffit (1) stated that the resting pressure from the surrounding musculature determines the dental position. While the tongue pressure during swallowing is currently under investigation, the current study focused on tongue resting pressure with a TAP. And as far as we know, this is the first study investigating tongue resting pressure on such appliance. People assume different body positions during the daytime and night-time, which correspond to different tongue pressures (11, 19). Therefore, to obtain accurate data, it was necessary to take into account the effect of body position.

Defined individual pressure patterns occur during swallowing (20), which can be determined from the ICC of the impression of tongue position. During swallowing, the tongue contacts the palate to propel the bolus to the pharynx. Therefore, the impression of tongue position does not reflect the actual tongue–palate relationship in deglutition, but rather the tongue strength. This explains why it is preferable to fabricate an individualised TAP and why the tongue resting pressure can be detected on TAP.

In the upright position, the tongue pressure decreases from the anterior to the posterior aspect, which is in agreement with previous studies (7–9). In contrast, Chiba (10) reported that the maximum pressure was obtained at M2. However, his study included only four subjects and recorded swallowing pressure. Further studies are needed to investigate the pressure distribution on TAP.

In the supine position, with pressure enhancement at M1 and M2, tongue pressure is consistent across the midline. This is probably attributable to the posterior movement of the tongue due to gravity. Therefore, we postulate that the TAP is more efficient with the patient supine, as during sleep. However, as this is only a simple position simulation and many physiological factors are involved in sleep, future studies involving all-night monitoring are needed to verify our speculation.

Regarding the optimum force for upper molar intrusion, a variety of opinions have been presented. Melsen (21) used 25–50 g for adult patients, while Park (15) suggested 150–200 g per tooth and Umemori (22) recommended an initial force of 500 g. As there is a lack of sufficient evidence on this subject, the data above are for reference only. Regarding the force exerted on the TAP, if one speculates that the dimensions of the TAP are approximately 2·5 × 3·5 $cm^{2,}$ and the pressure is 150 Pa with uniform distribution, then the intruding force is ~13 g, which is considerably less than the 'ideal amount' suggested above. In our study, the distance from the palatal mucosa to the TAP at the middle of the first molar ranged between 4·25 and 12·90 mm (8·81 ± 2·21 mm), which is far greater than the height of a conventional transpalatal arch. Therefore, vertical control through these types of appliance may not be as reliable as previously thought. However, in Nanda's (5) research, the mandibular plane angle was maintained and the increase of lower anterior face height was limited in the treatment group with the use of such appliance, when compared with patients treated with the contemporary Tweed technique in control group. So we put the following questions. Does the optimum force have a wider range than we thought? Or, does the long duration of resting pressure profoundly influence the final result? Perhaps the intermittent swallowing force plays an essential part in the intrusion. Further clinical and basic studies are needed to answer these questions.

Conclusion

In the upright position, the tongue resting pressure decreases in the anterior-to-posterior direction, but in the supine position the pressure is consistent across the midline with pressure enhancement at M1 and M2.

Based on the pressure measurements in our study, the appropriate intruding force, as well as the effectiveness of this appliance, should be validated via further clinical and basic studies.

Acknowledgments

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Conflict of interest

The authors declare no conflict of interest.

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