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Tongue position after deglutition in subjects with habitual open-mouth posture under different functional conditions

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Structured Abstract

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Objective – To test the null hypothesis of no significant differences in (1) the duration of the post-deglutory, cranial tongue rest position (CTP) between different functional orofacial conditions and (2) the presence or absence of an oral screen (OS) in subjects with a habitual open-mouth posture.

Subjects – Twenty-nine subjects (aged 6–16; mean: 9.69 years; 13/16 girls/boys) were selected according to the inclusion criterion of a habitual, daytime open-mouth posture.

Methods – Deglutition was screened at baseline during resting respiration using orofacial polysensography and simultaneous assessment of tongue-to-palate position and nasal airstream, during five functional intervals of 8 min each: F1 without instruction (RR); F2 the *same*, but including an oral screen (RROS); F3 with OS and the instruction to maintain a tongue-to-palate contact (IROS); F4 with OS and the instruction to perform tongue repositioning manoeuvres at the time of spontaneous swallowing (TRMOS); and F5 corresponds to F3 omitting OS (IR). Duration and frequency of deglutition were analysed descriptively as well as by ANOVA and subsequent multiple comparisons, and the CTP was evaluated with chi-square tests and paired comparisons at a significance level of 5%.

Results – Of 542 identified swallowing acts, 75% were accompanied by a post-deglutory CTP. Mean duration of CTP increased for functional conditions RR/1.01s > RROS/2.56s > IR/3.21s > IROS/6.53s > TRMOS/6.58s. The null hypothesis (1) was rejected in comparison of resting respiration (F1, F2) with IROS and TRMOS, whereas the use of an oral screen alone did not significantly prolong the duration of CTP.

Key words: open-mouth posture; Polysensography; tongue–palate contact

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Introduction

Orofacial muscular balance depends on the opposing forces of the lips, cheeks and tongue at rest and during deglutition (1). The pronounced effects that persisting deglutation interference, such as the visceral swallowing pattern, can have on this balance and, in turn, on craniofacial development highlight its fragility (1, 2). The importance of distinguishing between short-term forces of 1 s duration or less, which comprise forces generated during chewing and speaking for example, on the one hand, and long-term forces caused by individual mimic and tongue muscle tone or various orofacial habits such as tongue thrust or lip biting, on the other, has already been established (1–3). Whereas those belonging to the first category do not seem to have a structural influence on the development of the dentofacial complex, those belonging to the latter do indeed (1). Ideal functional orofacial conditions are characterized by a resting position with a tongue–palate contact with lightly sealed lips and with the teeth almost in contact, thereby providing a basis for normal facial and dental development (3). In the context of therapeutically created normal orofacial soft tissue development as the basis for the normal development of the dento-alveolar complex, the characteristics of the orofacial resting posture as well as the individual's ability to maintain it are of particular importance. Apart from the use of functional appliances, e.g. oral screens (4–6), recent approaches deriving from the treatment of snoring during sleep have addressed the question of the correction of tongue posture by training prolongation of cranial tongue posture (7, 8).

Study aims

This study aimed to consider the efficiency of training instructions and the use of a customary oral screen in a group of children with habitual open-mouth posture. In doing so, account was taken into the fact that mouth breathing coincides with a caudal tongue position, and, to answer the key question of the adaptability of tongue activity patterns, i.e. in the sense of prolonged tongue–palate contact following deglutition as a therapeutic approach to treating orofacial tongue dyskinesis and to create a basis for normal dentofacial development.

In particular, we tested the null hypotheses of no significant differences in duration of the post-deglutory cranial tongue resting position

1. between the different functional orofacial conditions and
2. in relation to the presence or absence of an oral screen.

Subjects

Twenty-nine subjects (aged 6–16; mean: 9.69 years; 13/16 girls/boys) attending two orthodontic centres in Santa Fé, Argentina, were consecutively selected within a 6-month time span and assessed according to the inclusion criterion of having a habitual daytime open-mouth posture, but not having other major diseases. Eligibility of subjects to participate in the study as well as correctness of the anamnesia documentation and conducting of the experiments was controlled by an orthodontist. The exclusion criteria were a lack of compliance, having had serious diseases and the inability to voluntary position the tongue at the palate in a position at the papilla incisiva in the open-mouth condition. The study had the approval of the local Human Ethics Commission (Ref. #4905, University Medical Center, Göttingen, Germany), and the patients or their guardians gave informed consent for participation in this study.

Methods

Polysensography

Orofacial polysensography (SensOral III, v1.2, with software OPSG-Lab 3.0; Sensomedical, Göttingen, Germany) using intra-oral sensors on individual palate splints was used to measure the simultaneous optical distance between tongue and palate, optometric assessment of the degree of mouth opening and the nasal airstream measured at the nostrils by two thermosensors (dimensions $1 \times 2 \times 3$ mm), separately for each side (Fig. 1). All assessments were carried out by one assessor (SK). Measurements were taken in an upright position and in an air-conditioned room with an ambient temperature of 22°C. To allow the subjects to acclimatize to the palate splint, the plate was incorporated 5 min before starting the assessment. Intra-oral sensors were located at the raphe palatina level with the first premolars. Increasing tongue–palate distance produced a decrease in reflected light intensity. To assess the cranial tongue posture to the greatest degree of accuracy, an eight-point scale has been used to define the vertical tongue position during the calibration of the system. A measuring range of the upper eighth of the full scale was designated as tongue–palate

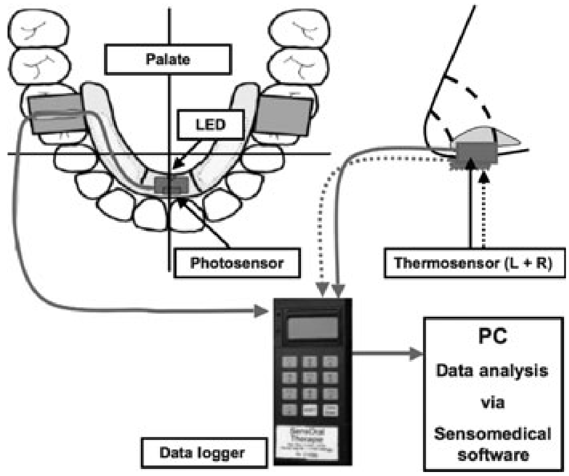

Fig. 1. The experimental set-up.

contact, whereas the lower 7/8th of the scale indicated a caudal tongue position.

System calibration

To unambiguously assign the light signals to be assessed to different degrees of mouth opening and tongue positions, a system calibration was performed prior to each assessment, including maximum mouth opening, closure and intercuspidation while tongue–palate contact was maintained.

Functional conditions

The trial assessments were made during five functional intervals of 8 min each: F1, respiration at rest (RR); F2, respiration at rest with an oral screen (RROS; oral screen (OS): Akkuphon; Unna; Germany), F3, with OS and the instruction to maintain tongue-to-palate contact (IROS); F4, with OS and the instruction to perform tongue repositioning manoeuvres (8) (collection of saliva with subsequent swallowing) during spontaneous swallowing (TRMOS); F5, corresponds to F3, but without OS (IR). The order of the functional intervals was identical for all subjects, and a description of the intervals is summarized in Table 1. Acts of swallowing were identified by an interruption of nasal airflow combined with a vertically oriented tongue activity. Acts of swallowing were categorized as those with early and those with later cranial tongue movement (during nasal airflow interruption). Duration and frequency of deglutition based on nasal airflow interruption (NAI) and cranial tongue position after swallowing were assessed separately for the five conditions.

Table 1. **Description of the five functional trial assessment intervals**

Code	Functional condition	Duration (min)	Oral screen (OS)
RR	Respiration at rest without instruction	8	No
RROS	Respiration at rest without instruction	8	Yes
IROS	Instruction to maintain a tongue-to-palate contact throughout the measurement interval	8	Yes
IR	Instruction to maintain tongue-to-palate contact throughout the measurement period	8	No
TRMOS	Tongue repositioning manoeuvre: collection of saliva and swallow	8	Yes

Data analysis

The data used for the identification of single acts of swallowing were judged by two criteria: 1) nasal airflow interruption (NAI) followed by expiration (9, 10) and 2) the occurrence of cranially oriented tongue movement (11). The NAI has a minimum value of 200 ms and a maximum value of 1000 ms and should be located on the exhalation curve of the respiration amplitude (9, 12, 13). Fig. 2 illustrates the identification of single swallowing acts.

Statistical analysis

The post-deglutitional cranial tongue resting position (CTP) was the principle parameter analysed. CTP was measured in terms of duration and frequency, the presence or absence of an oral screen and the functional condition (F1–F5), using descriptive statistics as well as ANOVA and subsequent multiple comparisons, with an a-level of 5% using the method of Tukey. These analyses were carried out with SPSS software (Chicago, IL, USA). Chi-square tests were used for tongue rest position (TRP) and functional conditions F1 to F5 (RR, RROS, IROS,

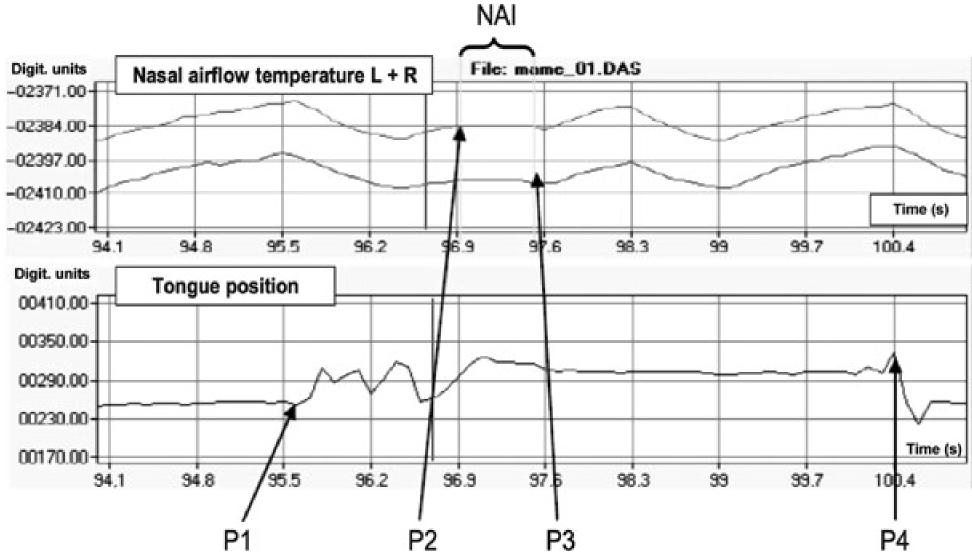

Fig. 2. Identification of single swallowing acts. Reading point P1 is the start of tongue activity prior to swallowing, P2 is the beginning and P3 the end of the NAI. P4 indicates the end of the cranial post-deglutory tongue position, with a subsequent relapse to a caudal position. Accordingly, interval P2–P3 indicates the tongue position during deglutition, and P3–P4 characterizes the post-deglutory tongue rest position.

TRMOS, IR). If global significance was established, paired comparisons between all functional conditions were performed. Comparing each pair of functional conditions, a power analysis was carried out for the total acts of swallowing with either early or late tongue–palate contact, for each functional condition. All *p* values were adjusted for multiple testing using the method of Holm (14) and are subsequently referred to as adjusted *p* values. These analyses were carried out using the statistical software R (v2.9.2, http://www.r-project.org).

Results

Identification of swallowing acts during functional conditions F1-F5

We identified a total of 542 single swallowing acts, of which 21% (n = 114) were identified under condition F1 (RR), 20.1% (n = 109) under condition F2 (RROS), 23.6 % (n = 128) under condition F3 (IROS), 21.9 % (n = 119) under condition F4 (TRMOS) and 13.3 % (n = 72) under condition F5 (IR).

Post-deglutory tongue resting position

Post-deglutory tongue dynamics can be divided into the two major forms:

1. Post-deglutory *cranial* tongue resting position (CTP): prior to and during NAI, the tongue adopts a maximally cranial position and maintains this for several seconds, which is graphically represented by a plateau in Fig. 2. The tongue resting position is defined as being a post-deglutory tongue resting position if it lasts at least 0.1 s longer than the NAI.
2. Post-deglutory *caudal* tongue resting position: the tongue resting position does not exceed the NAI or is even shorter (of up to only 100 ms), and the tongue relapses into a caudal posture (Fig. 2).

Of the 542 identified acts of swallowing, 25 % were accompanied by a post-deglutory caudal tongue posture (vs. 75% post-deglutory cranial tongue posture, CTP).

Table 2 shows the frequencies of post-deglutory cranial (CTP) or caudal tongue rest position. In resting

Table 2. **Frequencies and proportions of post-deglutory cranial (CTP) or caudal tongue rest position**

Functional condition	CTP	n	Proportion (%)
RR	No	75	65.79
RR	Yes	39	34.21
RROS	No	19	17.43
RROS	Yes	90	82.57
IROS	No	15	11.72
IROS	Yes	113	88.28
IR	No	28	38.89
IR	Yes	44	61.11
TRMOS	No	6	5.04
TRMOS	Yes	113	94.96

Table 3. **Significance of differences between functional conditions and results of power analysis in terms of *frequencies* of cranial post-deglutory tongue rest after deglutition (CTP)**

Comparison	Adjusted *p* value	Power (%)	N = 200 (%)	N = 300 (%)	N = 400 (%)	N = 500 (%)	N = 800 (%)
RR vs. RROS	**0.000000**	100.00					
RR vs. IROS	**0.000000**	100.00					
RR vs. IR	**0.002872**	96.00					
RR vs. TRMOS	**0.000000**	100.00					
RROS vs. IROS	0.287133	19.70	29.40	41.00	51.00	61.00	81.00
RROS vs. IR	**0.009173**	90.70					
RROS vs. TRMOS	**0.016379**	83.00					
IROS vs. IR	**0.000098**	99.00					
IROS vs. TRMOS	0.197239	50.00	71.00	86.00	94.00		
IR vs. TRMOS	**0.000000**	95.80					

Bold values are significant. The significance level is 0.05. N refers to numbers of early/late tongue–palate contacts in the single conditions.

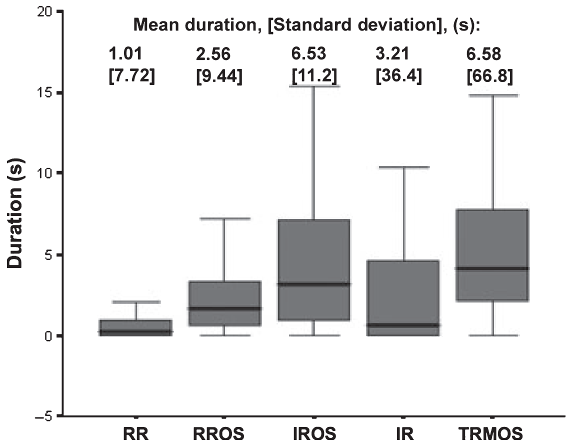

Fig. 3. Box plot and additional mean duration values for the post-deglutory cranial tongue rest position (CTP).

Table 4. **Significance of differences between functional conditions in terms of duration of post-deglutory tongue rest position**

Comparison	*p* value
RR vs. RROS	0.999
RR vs. IROS	**0.0019**
RR vs. IR	0.7182
RR vs. TRMOS	**0.0153**
RROS vs. IROS	**0.0002**
RROS vs. IR	0.6518
RROS vs. TRMOS	**0.0026**
IROS vs. IR	0.1504
IROS vs. TRMOS	0.9842
IR vs. TRMOS	0.3785

Bold values are significant.

respiration (RR), the CTP occurred least frequently (n = 39) and the caudal tongue rest posture was seen most often (n = 75), whereas the highest numbers of CTP were observed for conditions IROS and TRMOS (both n = 113). Incorporation of the OS results significantly more often in a cranial tongue resting position (Table 3).

Coherence between post-deglutory tongue resting position and functional condition

There was a significant global effect of the functional condition on the post-deglutory tongue resting position ($p < 0.001$, Fig. 3). Therefore, their duration was subjected to multiple comparisons, and the results are shown in Table 4. Highly significant differences in the duration of the post-deglutory cranial tongue resting position were observed between conditions IROS and TRMOS compared to resting respiration with or without OS (RROS and RR), but not compared to IR. Condition IR was also not significantly different from resting respiration (condition RR, Table 4).

Discussion

Discussion of the method

The major advantage of the measuring system used here is that it combines the simultaneous assessment of all parameters that are of relevance during deglutition, i.e. tongue motion and nasal airflow assessment, without exposure to X-rays or stress caused by laborious measuring procedures, such as magnet resonance tomography. Instead, the process of deglutition can be easily identified by a cranially oriented movement of the tongue and the characteristic interruption of nasal airflow, even in mouth-breathing subjects, as parallel nasal and oral airflow is also common in mouth-breathing subjects, and a total reliance on mouth breathing only can be regarded as being very rare, even in those subjects (15). It has been suggested that of the various methods of assessing nasal airflow, those utilizing either pressure or thermosensors are the most relevant and are comparable in terms of validity or informative value (16–18). The identification of a plateau phase in the respiration curve has also been previously recommended as a tool for identifying NAIs (9).

The subjects were monitored throughout the assessment. In two patients, the thermosensors slipped, requiring these assessments to be repeated. No further technical malfunctions occurred.

The assessment of the tongue–palate distance by intra-oral optic light reflection, including the measurement of the intensity of the LED-generated light reflected by the dorsum of the tongue, has the advantage when compared to ultrasound-based approaches (19, 20) of not being affected by air cushions that often hinder the assessment of the palate–tongue contact (21). The method is a refinement of the technique introduced by Chuang and Wang (22). However, despite this advantage, its disadvantage is that it cannot be used for metric tongue–palate measurements. However, for the purpose of this study, a determination or differentiation between caudal and cranial tongue position is sufficient, as it can be assumed, on the basis of available literature, that the key to normal dento-alveolar development is the maintenance of a cranial tongue position, including tongue–palate contact. Cranially orientated tongue motions, as characteristic during deglutition, can be easily and accurately detected. It should be noted that there were no cases of slipping or loosening of the sensors from the acrylic plate.

Discussion of the results

The focus of previous research has been the description of the complexity of the biomechanical sequence that characterizes swallowing (11) together with an analysis of simultaneously collected data from different intra-oral sites of subjects with normal orofacial function (23), which suggested a highly coordinated order and duration of tongue contacts with each part of the palate. The present study tried to fill the gap in information about tongue posture and function in subjects with a habitual open-mouth posture during the act of swallowing. Tongue motion associated with the act of swallowing can also be further differentiated into tongue posture before swallowing, during interruption of nasal airflow, which is an essential characteristic of swallowing, and the post-deglutory tongue resting position. The latter is of particular importance, as a cranial tongue position at rest is considered to be a crucial element for the normal development of the dentofacial complex (1, 3).

The null hypothesis (1) of no significant differences in the *duration* of the post-deglutory cranial tongue resting position between the different functional orofacial conditions was rejected for the comparison of resting respiration with instructed swallowing (IROS) and also with the tongue reposition manoeuvre.

The descriptive results seem to indicate an increased mean duration with the use of the oral screen for approximately 1.5 s in the resting posture to approximately 3.3 s in the swallowing mode. However, the impact of the oral screen did not prove to be statistically significant. Consequently, the second null hypothesis was rejected only for oral screen wearing when the tongue reposition manoeuvre (TRMOS) was effected or the instructed respiration (IROS) in comparison with resting respiration (RR), but not when juxtaposing comparable conditions (i.e. swallowing or resting conditions with or without an oral screen) (Table 4).

Habitual open-mouth posture does not necessarily coincide with habitual mouth breathing, implicating that the latter – in contrast to habitual open-mouth posture – requires airway temperature or pressure recordings for a secure diagnosis (24). However, the research presented here aimed at assessing tongue posture during deglutition in subjects with open-mouth posture in general and did not specifically focus on mouth breathers only.

The dichotomy of the vertical tongue posture has been investigated in many studies, mostly subdividing subjects into those with 'normal' or 'deviating' tongue posture (25–29). However, the data presented here suggest that there is not only one reproducible tongue posture typical for subjects with a habitual open-mouth posture, but instead that there is a tongue posture that does indeed vary depending on functional condition and orofacial posture. The ratio of caudal and cranial post-deglutory tongue rest postures in these subjects was 25/75%, with an immediate commencement of the caudal ones following NAI. The causation of caudal tongue resting postures may be substantiated by their proportions during different conditions, i.e. 56% of caudal post-deglutory tongue resting postures were observed in the resting position and 19% at IR, whereas the rest (25%) were distributed across the conditions that incorporated oral screens, with a remarkably low portion of 2% during TRMOS. This means that 75% of CTP occurred during an oral screen condition. But while there was no significant impact of OS wearing alone on the *duration* of the post-deglutory CTP, the use of the oral screen had a significant impact on the increase in the *frequency* of occurrence of this cranial post-deglutory tongue rest posture (Table 3). Moreover, the further inclusion of additional manoeuvres (tongue reposition manoeuvre or instructed respiration, IROS) had an additional significant positive effect on the increase in these frequencies (Tables 2 and 3).

The results of the power analysis (Table 3) indicate that the frequencies of early or late tongue–palate contacts in the distinctive functional conditions yield a sufficient power for all comparisons of functional conditions, with an exception for comparison RROS/IROS (19.7%) and IROS/TRMOS (50%). The similarity of manoeuvres IROS and TRMOS on the one hand and that of resting respiration with the incorporated oral screen (RROS) in comparison with IROS on the other give explanations for the not significant differences. To show significant differences despite the similarity in these conditions, frequencies of 200 (for comparison IROS/TRMOS) or 500 (for RROS/IROS) acts of deglutition and more would have been necessary (Table 3). However, this study investigated the tongue dynamics during deglutition in a sample of school kids, and as the subjects needed to be focussed, a decision was made to limit the time span of observation to 40 min, equal to a school lesson period. Whereas the similar results between RROS and IROS are more likely to be because of the fact that during 40 min, school kids' attention may show a tendency to fade, the reduced power and non-significant difference between TRMOS and IROS are obviously a result of the similarity of the two manoeuvres.

Our data therefore suggest that the instruction to maintain tongue–palate contact or to perform a tongue reposition manoeuvre both result in a statistically significantly prolonged duration of the favourable cranial deglutory tongue position. However, the single element of the oral screen does not.

The combination of these manoeuvres together with the wearing of an oral screen (TRMOS, IROS) seemed to be the most appropriate functional conditions for achieving the highest frequencies and durations of cranial post-deglutory tongue rest position. The negative pressure typically created during normal swallowing (7) may be enhanced by these manoeuvres. This may provide an explanation for the prolonged tongue–palate contact following deglutition, as the tongue may be adhered cranially by the increased negative pressure.

Based on our data, the instruction to position the tongue at the palate, as a typical component of myofunctional therapy, without the use of additional oral screens appears to be sufficient for training the duration of a favourable CTP. In general, the duration of the cranial tongue resting position seems to be more affected by the functional condition than by the incorporation of the OS.

Future research will consider the temporal co-ordination of pre-deglutory tongue movement and NAI and the combination of polysensographic assessments with intra-oral pressure recordings, to characterize the act of deglutition in greater detail and to correlate the data with morphological features of growing subjects.

Conclusions

There were significant differences in the duration of the post-deglutory cranial tongue rest position between the resting and instructed respiration conditions (IROS, TRMOS). The instruction to position the tongue at the palate during deglutition or to perform tongue reposition manoeuvres was seen to be a valid aid in training tongue–palate contact. The use of oral screens significantly increased the *frequency* of occurrence of cranial post-deglutory tongue rest posture after deglutition. This effect can be significantly enhanced by carrying out distinctive swallowing manoeuvres. However, in terms of *duration* of the favourable cranial tongue rest position, the additional use of an oral screen could be dispensed with: it did not produce significant improvement.

Clinical relevance

On the basis of the results obtained from this study, the instruction to position the tongue at the palate during deglutition or to perform tongue reposition manoeuvres appears to be a valid aid in training the tongue–palate contact. But, while a significant effect of oral screen use was found on the frequencies of post-deglutory cranial tongue postures, in terms of duration of the favourable cranial tongue rest position, the additional use of an oral screen can be dispensed with, because it did not produce a significant improvement.

Conflict of interest

The authors declare that they have no conflict of interest.

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