Original Article

# Effects of Habit-Breaking Appliances on Tongue Movements during Deglutition in Children with Tongue Thrust Swallowing using Ultrasonography – A Pilot Study


## Abstract

**Objective:** The aim of this study is to evaluate and compare the duration and range of tongue movements in tongue thrust swallow patterns with and without habit-breaking appliances using computer-aided M-mode ultrasound images. Also to record the corresponding position of the tongue associated with normal and tongue thrust swallowing pattern using B-mode ultrasound images. **Methodology:** Ten patients with mature swallow pattern, ten subjects with anterior tongue thrust (ATT) and ten patients with lateral tongue thrust (LTT) swallowing habit were analyzed for the duration and range of tongue movement using two-dimensional ultrasound M-mode images before and after insertion of three habit-breaking appliances (anterior tongue crib [ATC], double oral screen [DOS] and DeLuke oral trainer [DOT]). Further, B-mode images were examined for the tongue positions in different swallow patterns with and without appliances. **Results:** Duration and range of tongue movement for the entire swallowing phase did not show a statistically significant difference for mature, ATT and LTT. Statistical significant difference existed in the duration between ATC and DOS with DOT for ATT patient ($P \leq 0.05$). Furthermore, a significant difference existed in the range of tongue movement between DOS and DOT in LTT patients ($P \leq 0.05$). **Conclusion:** Remarkable changes in the tongue position were observed postinsertion of DOT in both anterior and LTT swallow patterns where the tongue tip and anterior tongue dorsum shifted upward toward the anterior palate resembling that of a mature swallow pattern.


**Keywords:** *Swallowing, tongue habits, ultrasonography*


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## Introduction

In mature somatic swallowing, the tip of the tongue rests on the palatal part of the anterior dentoalveolar area, and there is neither a tongue thrust nor a constant forward posture. Tongue thrust swallowing or preserved visceral swallowing comprising forward tongue posture and tongue thrusting during swallowing supposedly plays a significant role in the etiology of orofacial deformities.[1]

Clinical visualization of the tongue in function is restricted because of the presence of various anatomic structures surrounding the tongue. The traditional method of identifying the swallowing pattern through the forced opening of the mouth is rather an obsolete method. Numerous methods such as radiocinematography, electropalatography, electromagnetic articulography, magnetic resonance, and two-dimensional ultrasonography tested in the past decade to investigate tongue function during swallowing are stated complicated and unreliable.[2]

Ultrasound technique popularized by Peng *et al*. 2000 utilized M-mode and B-mode images for digital evaluation of tongue movement in function. Along with the cushion scanning technique, differentiation between mature and anterior tongue thrusting swallowing pattern was made possible as the technique provides a constant and defined scan of the tongue movement during swallowing.[3] However, the application of this method for other types of tongue thrusting habits is seldom documented, much less with the habit breaking appliances.

Thus, the present study was aimed at comparing the duration and range of movement of the tongue in various swallowing patterns before and after



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insertion of three habit-breaking appliances using M-mode ultrasound images and recording the corresponding positions of the tongue associated with normal, anterior and lateral tongue thrust (LTT) swallowing with and without appliances using B-mode ultrasound images.

## Methodology

A nonrandomized pre- and postclinical trial was designed. The study was carried out in the Department of Pediatric Dentistry for 6 months. The research proposal was submitted to and approved by the Institutional Ethical Committee and Review Board and written consent was obtained from the parents of all the participants. A convenience sample consisting of 30 patients with age ranging from 11 to 16 years were assessed in the study. Group 1 consisted of 10 patients with mature swallowing pattern (7 females, 3 males), Group 2: 10 patients with anterior tongue thrust (ATT) swallowing pattern (4 females, 6 males), and Group 3: 10 patients with LTT swallowing pattern (5 females, 5 males) were included in this study.

### Sample selection

Patients were selected clinically by the primary investigator using the forced opening of the lips during swallowing. Inclusion criteria for ATT were tongue press between maxillary and mandibular anterior teeth in anterior open bite, increased overjet and hyperactive mentalis, and orbicularis oris muscle. For LTT, subjects with posterior open bite were included in the study. Borderline, inconstant patients and patient who had previously undergone treatment for habit correction or orthodontic treatment were excluded from the study.

### Study method

During the preliminary appointment, subjects, along with their parents, were explained about the procedure and time required for the ultrasound diagnostics. Patients with mature swallowing patterns were evaluated at only one session of ultrasonography. However, patients with anterior and LTT swallow patterns were evaluated at four different sessions. The first evaluation was before the placement of the appliance. Later, three intraoral appliances, namely anterior tongue crib (ATC), double oral screen (DOS), and DeLuke oral trainer (DOT) were fabricated for each patient with anterior and LTT habit and subsequent evaluations were postplacement of these appliances.

### Ultrasound diagnostics

An ultrasonographic technique by means of computer-aided B-mode + M-mode (Philips HD11XE) was used to investigate tongue movements during swallowing. Ultrasound diagnostics were performed by an experienced radiologist. A stable head support provided by a customized head position stabilizer was designed, especially for the study purpose. The apparatus was fixed onto a chair such that Frankfort Horizontal plane was parallel to the floor. An adjustable holder was fixed onto the same apparatus for ultrasound transducer, which permitted reproducible images. The cushion-scanning technique similar to Peng *et al*., 2000[3] was adopted for the study. The ultrasound transducer was coated with aqueous contact transmission gel and placed midway between the posterior border of the symphysis and anterior margin of the hyoid bone in the mid-sagittal plane, perpendicular to FH plane. The scan line (SL) was placed through the middle of the B-mode sector image and tracing, i.e., M-mode sweeping of images was performed at 35 mm/s [Figure 1].

Swallowing was reproduced after asking the patient to have a sip of water with a straw, wait for 10 s and then swallow without water. After repeating these cycles for eight times, the most consistent image was selected by the radiologist for interpretation. Ultrasound M mode images were acquired and reconstructed for each of the swallowing patterns, i.e., mature swallow (MS), ATT and LTT. In total, ten mature swallowing images and twenty tongue thrust swallowing images were obtained. Following the fabrication of three intraoral appliances, ATC, DOS and DOT, images were obtained while wearing the appliance at three different occasions. One image per appliance for each patient, a total of sixty images were registered. The acquired data from the ultrasound system were transferred to a personal computer for interpretation.

Descriptive statistics were calculated for all the measurements used in this study. Intergroup comparison for duration and range of tongue movement was carried out using ANOVA and *post hoc* test. Values of $P < 0.05$ were considered statistically significant. All statistical calculations were done using computer program SPSS 17 (Statistical Package for the Social Science; SPSS Inc., Chicago, IL, USA).

## Results

In this study, M-mode images were obtained to calculate and compare duration and range of movement of the entire

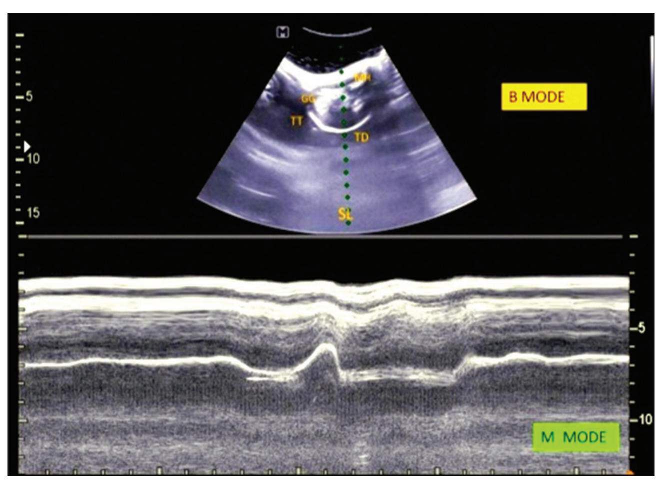


**Figure 1: B mode and M mode image of swallowing. Note the scan line position adjusted in the middle of the tongue dorsum. TT: Tongue tip; TD: Tongue dorsum; GG: Genioglossus; MH: Mylohyoid**

swallowing phase for mature, anterior and LTT swallowing. The duration of the entire swallowing phase in MS, ATT, and LTT ranged from 1.4–4.04 s (mean, 2.66 ± 0.86), 1.81–4.29 s (mean, 3.03 ± 0.71) to 1.19–4.74 s (mean, 2.79 ± 1.23), respectively. The mean range of movement of entire swallowing for MS, ATT and LTT was 21.76 ± 7.94 mm, 20.48 ± 3.05 mm, and 16.63 ± 6.03 mm, respectively. Comparison of the duration and range of movement in different types of swallowing as depicted in Tables 1 and 2 revealed no significant difference in the overall duration and range of movement among these groups. The mean duration of ATT after placement of ATC, DOS, and DOT was 2.31 s, 2.36 s, and 3.55 s, respectively whereas in LTT it was 3.007, 2.899, and 2.693 s, respectively [Tables 3 and 4]. Statistical significant difference existed in the duration between ATC and DOS with DOT for ATT patients. The mean range of movement of ATT swallowing cycle after insertion of ATC, DOS, and DOT was 17.89 mm, 18.18 mm, and 19.16 mm, respectively, whereas for LTT swallow, it was 15.50 mm, 14.80 mm, and 21.86 mm, respectively, [Tables 5 and 6]. Higher individual variability existed in the range of tongue movement in anterior and LTT swallowing with appliances. Among the three appliances, a significant difference existed in the range of movement between DOS and DOT in LTT patients.

## Discussion

The tongue is relatively large and located in the forward suckling position in neonates. With the eruption of the incisors, the tongue position starts to retract. By 2–4 years, functionally balanced or mature somatic swallowing prevails. Persistence of visceral swallowing beyond 4 years is considered dysfunctional or abnormal.[4] The effect of tongue thrust swallowing on dentofacial deformities is long debated. However, the researchers have confirmed that tongue thrust and resting tongue posture may have substantial contributing effects causing dentofacial deformities.[5] Thus, it becomes important to consider tongue dysfunctions to reduce the possibilities of developing malocclusion, the severity of prevailing malocclusion and when long term stability after treatment is desirable.

Several researchers studying tongue dynamics using ultrasound technique faced difficulties to obtain correct registration as the head was not stabilized in most of the studies, and it was difficult to position handheld ultrasound

**Table 1: Comparison of duration (seconds) in normal swallowing, anterior tongue thrust and lateral tongue thrust**

| Groups (I) | Mean±SD | Intergroup comparison | Mean difference (I-J) | Significance |
|---|---|---|---|---|
| Normal swallowing | 2.66±0.86 | Anterior tongue thrust | −0.370 | 0.669 |
| | | Lateral tongue thrust | −0.137 | 0.946 |
| Anterior tongue thrust | 3.03±0.71 | Normal swallowing | 0.370 | 0.669 |
| | | Lateral tongue thrust | 0.233 | 0.851 |
| Lateral tongue thrust | 2.79±1.23 | | | |

*P*≤0.05. SD: Standard deviation

**Table 2: Comparison of range of movement (millimeter) in normal swallowing, anterior tongue thrust, and lateral tongue thrust**

| Groups (I) | Mean±SD | Intergroup comparison | Mean difference (I-J) | Significance |
|---|---|---|---|---|
| Normal swallowing | 21.76±7.94 | Anterior tongue thrust | 1.2800000 | 0.883 |
| | | Lateral tongue thrust | 5.1270000 | 0.157 |
| Anterior tongue thrust | 20.48±3.05 | Normal swallowing | −1.2800000 | 0.883 |
| | | Lateral tongue thrust | 3.8470000 | 0.341 |
| Lateral tongue thrust | 16.63±6.03 | | | |

P≤0.05. SD: Standard deviation

**Table 3: Comparison of duration (seconds) in anterior tongue thrust swallowing with three habit-breaking appliances**

| Groups (I) | Groups (J) | Mean difference (I-J) | Significance |
|---|---|---|---|
| Anterior tongue thrust without appliance | ATC | 0.7132000 | 0.297 |
| | DOS | 0.6695000 | 0.351 |
| | DeLukes oral trainer | −0.5226000 | 0.564 |
| ATC | Anterior tongue thrust without appliance | −0.7132000 | 0.297 |
| | DOS | −0.0437000 | 1.000 |
| | DeLukes oral trainer | −1.2358000* | 0.019 |
| DOS | Anterior tongue thrust without appliance | −0.6695000 | 0.351 |
| | ATC | 0.0437000 | 1.000 |
| | DeLukes oral trainer | −1.1921000* | 0.025 |

*P*≤0.05, *Indicates statistical significance. ATC: Anterior tongue crib; DOS: Double oral screen

**Table 4: Comparison of duration (seconds) in lateral tongue thrust swallowing with three habit-breaking appliances**

| Groups (I) | Groups (J) | Mean difference (I-J) | Significance |
|---|---|---|---|
| Lateral tongue thrust without appliance | ATC | −2.2100000 | 0.444 |
| | DOS | −0.1020000 | 1.000 |
| | DeLukes oral trainer | 0.1040000 | 1.000 |
| ATC | Lateral tongue thrust without appliance | 2.2100000 | 0.444 |
| | DOS | 2.1080000 | 0.485 |
| | DeLukes oral trainer | 2.3140000 | 0.404 |
| DOS | Lateral tongue thrust without appliance | 0.1020000 | 1.000 |
| | ATC | −2.1080000 | 0.485 |
| | DeLukes oral trainer | 0.2060000 | 0.999 |

$P \leq 0.05$. ATC: Anterior tongue crib; DOS: Double oral screen

**Table 5: Comparison of range of movement (millimetres) in anterior tongue thrust swallowing with three habit breaking appliances**

| Groups (I) | Groups (J) | Mean difference (I-J) | Significance |
|---|---|---|---|
| Anterior tongue thrust without appliance | ATC | 2.5877000 | 0.662 |
| | DOS | 2.3040000 | 0.737 |
| | Delukes oral trainer | 1.3210000 | 0.936 |
| ATC | Anterior tongue thrust without appliance | −2.5877000 | 0.662 |
| | DOS | −0.2837000 | 0.999 |
| | Delukes oral trainer | −1.2667000 | 0.943 |
| DOS | Anterior tongue thrust without appliance | −2.3040000 | 0.737 |
| | ATC | 0.2837000 | 0.999 |
| | Delukes oral trainer | −0.9830000 | 0.972 |

$P \leq 0.05$. ATC: Anterior tongue crib; DOS: Double oral screen

**Table 6: Comparison of range of movement (millimetres) in lateral tongue thrust swallowing with three habit breaking appliances**

| Groups (I) | Groups (J) | Mean difference (I-J) | Significance |
|---|---|---|---|
| Lateral tongue thrust without appliance | ATC | 1.1340000 | 0.972 |
| | DOS | 1.8360000 | 0.895 |
| | Delukes oral trainer | −5.2230000 | 0.206 |
| ATC | Lateral tongue thrust without appliance | −1.1340000 | 0.972 |
| | DOS | 0.7020000 | 0.993 |
| | Delukes oral trainer | −6.3570000 | 0.088 |
| DOS | Lateral tongue thrust without appliance | −1.8360000 | 0.895 |
| | ATC | −0.7020000 | 0.993 |
| | Delukes oral trainer | −7.0590000* | 0.048* |

$P \leq 0.05$, *Indicates statistical significance. ATC: Anterior tongue crib; DOS: Double oral screen

probe in a constant position.[6] Considering these factors, an apparatus with a head position stabilizer and a transducer holder was constructed for this study. The cushion scanning technique used in the present study provided a constant and defined scan of tongue movement during swallowing and prevented compression of submental muscles during the function.[7,8]

Tongue movement examination was done by the setting M position at the center of tongue in the midsagittal plane as the center was more easily reproducible in people with various tongue sizes[3] and muscle contractions in the anterior and posterior part of tongue can more or less be manifested in the center of the tongue.[9] Thus we attempted to determine whether the stretch forward movement of the tongue can be differentiated from the upward movement of the mature swallowing through a central SL. B-mode images allowed analysis of the midsagittal tongue configuration in slow movement or as still video sequences.[3]

Habitual swallowing of saliva was chosen to evaluate tongue movements during ultrasound analysis. Habitual saliva swallowing precludes any impact on the swallowing movement caused by the taste, volume, consistency, or position of the medium being swallowed.[10] Patients were instructed to sip on 3–5 ml of water to avoid swallowing difficulties with a dry dorsum, waited for 10 s, and swallowed again without water as described by Peng, 2004.[2]

In coherence with the available literature,[2,11,12] in the current study, the mean duration of the entire swallowing phase in mature, ATT and LTT were comparable. Although there was no statistically significant difference, ATT swallow required a longer duration to complete the cycle as compared to the other two groups. The possible explanation for this, as described by Peng *et al*. 2004 was that the tongue stretched out in between the maxillary and mandibular teeth to seal the gap between the teeth in ATT swallowing. Consequently, the stretched tongue needed more time to travel in the anterior and posterior parts of the palate.[2] In LTT swallow, the mean duration required to complete the entire swallowing phase was more or less similar to the MS.

The mean range of tongue movement of the normal and ATT was comparable, as observed by Peng *et al*.[9] However, we observed lower values in most of the subjects with LTT swallow. The reason could be attributed to the very low resting posture of the tongue and its inability of the anterior and middle parts of the tongue dorsum to elevate and touch the anterior parts of the palate in the initial phase of swallowing.[1]

We observed a significant change in the duration of the tongue movement in ATT swallowing subjects postinsertion of the habit breaking appliances. The values were significantly lower in ATC and DOS as compared to DOT. This implied that DOT had little or no effect on altering the duration of the tongue movement in ATT. Similar results were found in a cine-magnetic resonance imaging (MRI) study done by Sayin *et al.* 2006 using tongue cribs in ATT swallowing patients. However, the authors also stated that the deglutitive tongue movements in open bite patients with the tongue cribs differed from those patients with normal overbites.[13]

In LTT swallowing patients, ATC and DOS had little effect on the duration of the tongue movement as compared to DOT. The values observed for DOT, though not statistically significant were lesser in most of the patients. This indicated that DOT had some restrictive effect on the lateral positioning of the tongue, which led to faster completion of the entire phase of swallowing.

Although we did not get any conclusive results in ATT swallowing patients concerning the effect of appliances on the range of tongue movement, the mean values were lowest for the ATC group and highest for DOT group. In contrast, for LTT swallow, range of tongue movement improved after insertion of DOT. The mean values of the range of movement were almost equivalent to that of the normal swallowing pattern.

Analysis of B-mode images helped us gain an insight into the tongue positioning in various patterns of swallowing and also helped us study the effects of habit-breaking appliances on the tongue positioning. Fuhrmann and Diedrich, 1994 and Ardakani 2006 evaluated the ability of video-based dynamic B-mode ultrasound in differentiating normal from abnormal swallowing.[14,15] As per our observation, in patients with ATT swallowing pattern, insertion of the ATC and DOS led the tongue assume more posterior position at the tip, anterior part of the dorsum of the tongue, whereas the middle part of the dorsum of the tongue assumed the more posterior and downward position at the initial phase of swallowing. However, the tongue quickly recovered during the later stages of swallowing. Similar research studying the effects of tongue crib on tongue movement using cine MRI, authors concluded that tongue tip was positioned more posteriorly, and midportion of the tongue dorsum lowered significantly at the oral stage of deglutition postinsertion of anterior tongue crib. They suggested that the midportion of the tongue dorsum lowered as an adaptation to facilitate bolus propulsion and airway protection when tongue crib was in place.[13] In LTT swallowing patients, we did not observe any notable changes following the insertion of ATC and DOT. However, remarkable changes in the positioning of the tongue were observed postinsertion of DOT in both ATT and LTT swallow patterns where the tongue tip and anterior tongue dorsum shifted upward toward the anterior palate resembling that of a MS pattern.

The current study inspects a smaller sample population for the short-term effects of appliances on tongue position and movement. We recommend examination of long-term effects of these appliances on the tongue positioning and corresponding tongue movement on larger sample size. Furthermore, for future research, it is strongly recommended to study differences in each phase of the swallowing cycle of the M-mode images in each swallowing pattern.

## Conclusion

In this study, ultrasound diagnostics using B-mode + M-mode images and cushion scanning technique has proved to be a valuable adjunct for subjective assessment of tongue positioning after placement of various intraoral appliances in patients with anterior and LTT swallow patterns. ATC and DOS reduced the duration of tongue movement in ATT with no effect on LTT swallowing pattern. DOT reduced the duration and improved the range of tongue movement in patients with LTT swallow pattern. On observation of tongue positioning, DOT aided the stretched out tongue to position itself in an upward position toward the anterior part of the palate closer to that of the normal swallowing pattern.

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## Conflicts of interest

There are no conflicts of interest.

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