the Journal of CONTEMPORARY DENTAL PRACTICE at www.thejcdp.com
Volume 7 Number 3 July 1, 2006

Evaluation of Swallowing Patterns of the Tongue Using Real-time B-mode Sonography

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Abstract

The aim of the present study was to evaluate the swallowing patterns of the tongue using B-mode sonography. A total of 65 patients aged between eight and 35 years were enrolled in the study including 25 controls. The swallowing patterns of the 40 patients were divided into groups of ten normal, 12 inconsistent, and 18 abnormal. Eight patients with a swallowing abnormality had Angle Class I occlusions, two had Class II, and the remaining ten patients had Class III. The majority of abnormal or inconsistent swallowing patterns were found in cases of mandibular prognathism. Quantitative data was not analyzed in this study. The results of this study show that B-mode sonography, being a non-invasive procedure permitting direct visualization of the movements of the tongue in both coronal and sagittal planes, can be used with certainty for diagnosing swallowing abnormalities.

Keywords: Ultrasonic diagnosis, swallowing patterns, B-mode sonography, tongue, tongue habits, deglutition disorders, open bite

Citation: Ardakani FE. Evaluation of Swallowing Patterns of the Tongue Using Real-time B-mode Sonography. J Contemp Dent Pract 2006 July;(7)3:067-074.

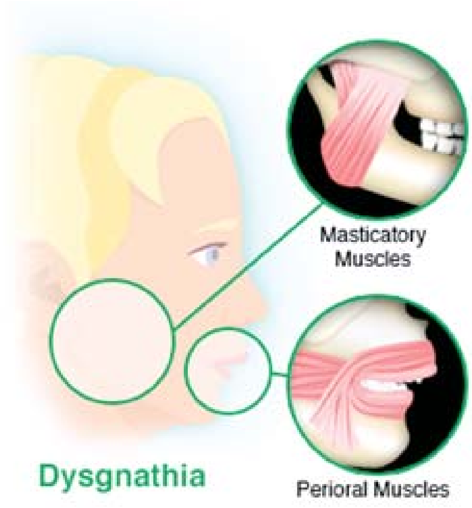
Introduction

Disturbances in the dynamic balance between functional tongue movements and the masticatory and perioral muscles have a primary influence on tooth and jaw positions.[1] Both the thrust and size of the tongue and its dysfunction have been discussed as essential etiological factors in the morphogenesis of dysgnathia.[2] Suspected dysphagia of organic origin has to be distinguished from habitual uncoordination of the oral phase of swallowing. The swallowing sequence is composed of reflex and voluntary components[3], but there is a marked variation in the normal individual pattern. Abnormal orofacial movements may also be a secondary development in the process of adaptation to changed bite relationships.[4] To date, there has been no means of differentiating between primary and secondary disturbances in normal oral motor functions and non-physiological swallowing patterns.

A precondition for diagnosing dysfunctional movement patterns within the oral cavity is the objective visualization of tongue movements and their systematic interpretation. B-mode sonography was first used by Shawker et al.[5-7] to show the tongue in speech assessment and neurological diagnosis.

Previous ultrasonographic studies on tongue functions were limited by the possibility of artifacts caused by movement of the submental area during function. Consequently, tongue movements were misinterpreted.[8] Many studies have proven tongue thrusting plays a significant role in the etiology of some orofacial deformities. To learn more about the relationship between tongue function and the form of orofacial structures, it is important to recognize patients with abnormal swallowing patterns. Distinctly different movements can be positively differentiated with the method used.[9]

Diseases of the oral cavity, floor of the mouth, and nervous system can be accompanied by disturbances in tongue movement during swallowing.[10] The possibility of using ultrasonography to analyze tongue function in the orthodontic setting was investigated in a pilot study involving ten dental students and ten adult, former patients with cleft lip, jaw, and palate.[11]



The aim of the present study was to evaluate the applicability of dynamic B-mode sonography for visualization of the tongue in order to differentiate normal from abnormal swallowing.

Methods and Materials

Real-time B-mode sonography was performed with a Sonoline SI 200 (Siemens, Germany) which has a rotary mechanical sector scanner with a sound frequency of 5 MHz, a 100° sector, and a frame rate of 30 fps; the axial resolution of 0.6 mm and the lateral resolution of 1.5 mm.[8] The transducer was positioned in the midline beneath the chin (Figure 1). All the examinations were performed by two operators.

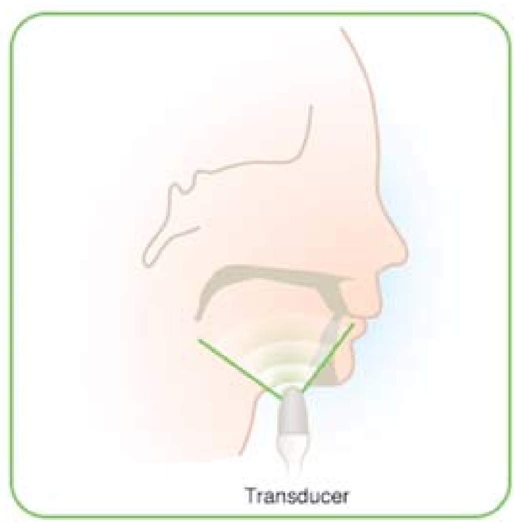


Figure 1. Diagram showing the submental position of the transducer and setting of the 100° sector during ultrasound scanning of the tongue in the sagittal plane.

A standard television signal was computed from the sonic data by a digital scan transducer inside the sonographic unit. A video timer recording to 0.01 second added a coordinated time code, and the ultrasound sequences were then videotaped at 25 fps (Panasonic, Tokyo, Japan). The post-processing mode of the sonographic unit was used for the subsequent tracing and superimposition of surface of the dorsum of the tongue.

The study was based on a series of 20 children (10 female and 10 male) aged between eight and 16 years and 20 adults (7 female and 13 male) aged between 17 and 35 years who on clinical examination had been found to have dysfunctional tongue movement, such as tongue thrust or speech disorder, together with a skeletal or dental abnormality, such as open bite, mandibular prognathism, or maxillary protrusion. The control group consisted of 25 adults (12 female and 13 male) aged between 20 and 29 years with an Angle Class I occlusion with normal tongue function.

The ultrasound examination was started by asking the subjects to place the tongue in the rest position on the floor of the mouth with the tip of the tongue contacting the lingual tooth surfaces or the gingiva of the lower anterior teeth; this was defined as the first reference position. They were then asked to place the tip of the tongue in contact with the incisive papilla and the anterior one third of the tongue to the palate; this was defined as the second reference position. Swallowing was performed with 2 ml of water, comparable with normal salivary volumes, applied from a syringe. At least three swallowing sequences were recorded for each subject, and the sequence with the clearest image quality evaluated for the four successive stages of swallowing by two investigators was used.

At the outset, the tongue lies in its normal rest position in the oral cavity. In the first stage, the water collection stage (Figure 2), the water flows into the anterior part of the floor of mouth and the tip of the tongue is retracted slightly. The second stage, the water elevation stage (Figure 3), starts with the tongue tip moving vertically upwards to contact the incisive papilla, while the mid-dorsum is lowered.

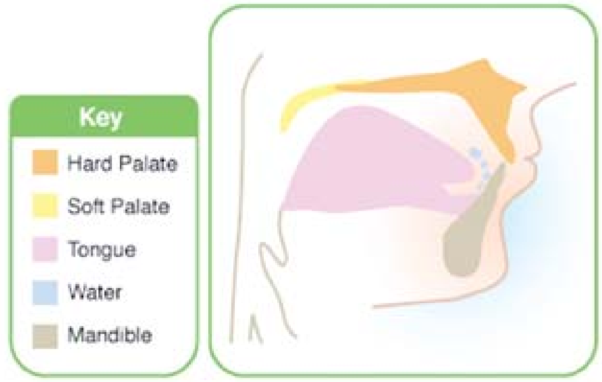


Figure 2. Water collection stage: initial retraction of the tongue tip; collection of water on the anterior floor of the mouth.

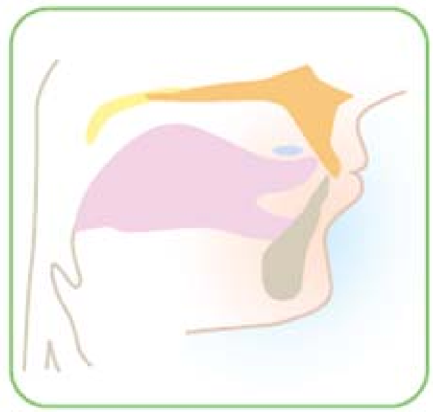


Figure 3. Water elevation stage: upward scooping towards the incisive papilla; lowering of the middle section of the dorsum of the tongue.

The anterior part of the tongue assumes a typical scoop shape and then at the end of this stage is in contact with the palate surface. The third stage, the water transport stage (Figure 4), starts with complete apposition of the tongue surface to the anterior palate and a simultaneous peristaltic wave in the mid-tongue. This small- or large- amplitude peristaltic movement transports the water to the pharynx. In the fourth, late transport stage (Figure 5), the dorsum of the tongue is lowered further, the tongue musculature contracts, and the remaining water flows through the oropharyngeal isthmus. The return to the starting position is designated the final, rest stage. During this phase, the tip of the tongue moves back to the floor of the mouth, the dorsum either remains in contact with the palate or returns to its normal position with simultaneous increasing muscle relaxation.

The tongue movements during the water collection and elevation stages (Figures 2 and 3) were examined for the extent of forward or upward movement by superimposing the position of the dorsum of the tongue during each of the four stages on its position at rest. The line tracing the tongue dorsum at the outset was kept in the same position on the monitor, while the video recorder gradually played back the successive swallowing phases in single-frame mode (Figures 6 a-e). Accurate superimposition depended on ensuring the same transducer position throughout the swallowing sequence.

In addition the extent of tongue movement was assessed by comparing its upward movement towards the incisive papilla in relation to the maxillary and mandibular reference positions. Swallowing sequences showing an initial upward scooping of the tongue towards the incisive papilla were designated normal. Those in which either ventral movement of the tongue was initially predominant, upward movement of the anterior part of the tongue was missing or delayed, protrusion was detectable in comparison with the reference positions, or the elevation stage was absent were classified as swallowing

Figure 4. Water transport stage: complete apposition of the tongue to the anterior with a simultaneous peristaltic wave in the mid tongue.

Figure 5. Late water transport stage: the dorsum of the tongue is lowered, the tongue musculature contracts, and the remaining water flows through the isthmus.

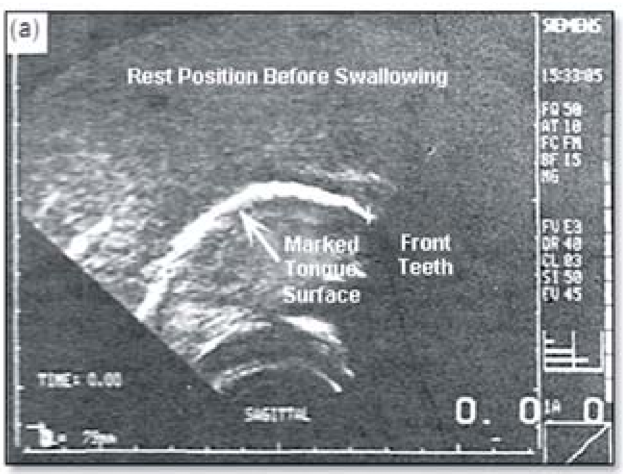


Figure 6a. Video-based analysis of swallowing with sagittal sonograph. The transducer was kept in the same submental position throughout the swallowing sequence. (a) Ultrasound image of the habitual rest position after application of 2 ml water before swallowing; the dorsum of the tongue was traced manually in the postprossing mode on the monitor.

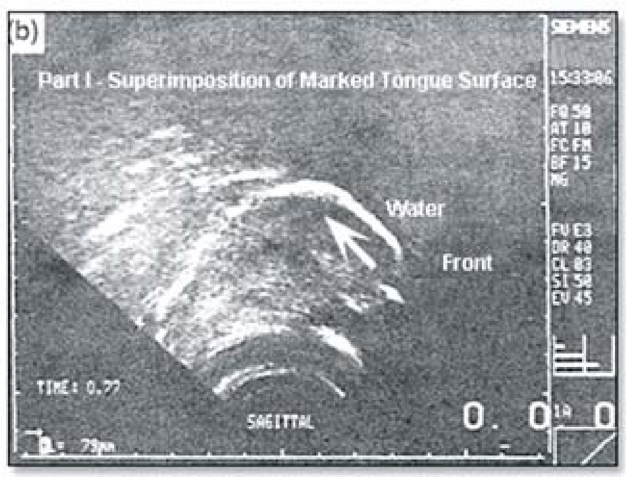


Figure 6b. Water collection stage: the outline of the tongue at rest is shown by the dotted line; retraction of the tongue tip (arrow), water collection visible on anterior mouth floor and on anterior part of the tongue, initiation of tongue protrusion.

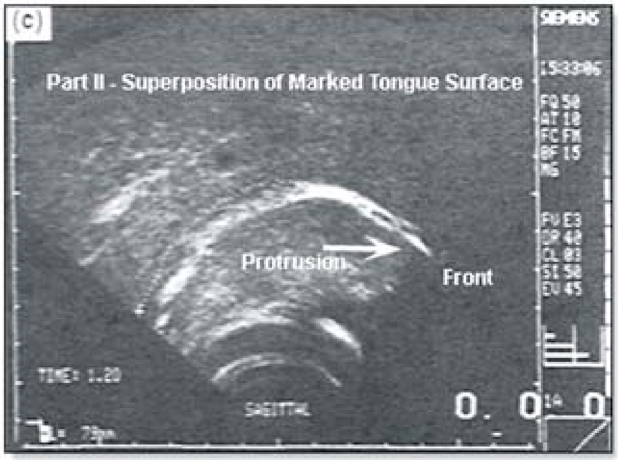


Figure 6c. Water elevation stage: the outline of the tongue at rest is shown by the dotted line; tongue protrusion (arrow), sagittal movement pattern.

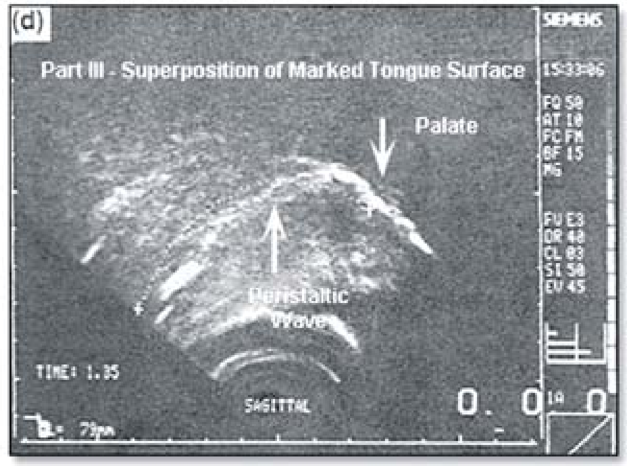


Figure 6d. Water transport stage: the outline of the tongue at rest is shown by the dotted line; peristaltic wave in the mid-tongue (upward arrow): the tongue tip is in contact with the anterior palate (downward arrow).

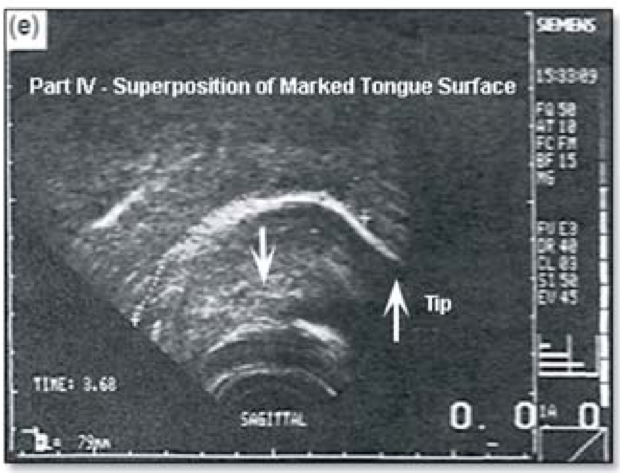


Figure 6e. Rest stage: the outline of the tongue at rest is shown by the dotted line; the dorsum is in contact with the palate after swallowing; the tip of the tongue (arrow) has returned to the floor of the mouth.

abnormalities. Irregular upward and forward movements in the initial swallowing phases were rated as an inconsistent swallowing pattern. If both investigators differed in their assessment, the swallowing pattern was also classified as inconsistent.

The swallowing patterns of the 40 patients were divided into groups of 10 normal, 12 inconsistent, and 18 abnormal. Eight patients with a swallowing abnormality had Angle Class I occlusions, two had Class II, and the remaining ten patients had Class III. The majority of abnormal or inconsistent swallowing patterns were found in cases of mandibular prognathism.

Abnormal swallowing was confirmed sonographically in eight of 17 patients with an anterior open bite. In five patients with an anterior open bite the initial upward and forward movements during swallowing alternated so no predominant swallowing pattern could be evaluated. They were rated as an inconsistent swallowing pattern. As four of these patients were undergoing speech therapy and had been repeatedly reminded of the significance of the tongue in articulation, it is likely the voluntary influence on the swallowing must have been higher.

In 15 subjects in the control group the swallowing pattern was classified as normal. The other ten cases in the control group were considered inconsistent because there was no predominantly upward pattern of movement.

Discussion

Sagittal sonography of the tongue makes it possible to evaluate the tongue at rest and during swallowing. The relationship of the tongue to the anterior part of the mandible and the shape of the anterior palate in relation to the position and the shape of the dorsum of the tongue can be demonstrated in this process, thus, providing an indirect indication of the size of the oral cavity.[5-7] Ultrasound visualization of the tongue tip at rest depends on the degree of skeletal abnormality, the submental contact area, and the quantity of intra-oral saliva. Bone, teeth, or a substantial air cushion between the tongue and the transducer have the effect of reflecting the majority of sound waves owing to the excessive impedance differential between these structures. The tongue can be focused more easily in cases of mandibular prognathism compared with retrognathism where the submental contact area is smaller. The ultrasound shadow of the hyoid bone masks the deepseated posterior parts of the tongue base. This high echogenic area with posterior acoustic shadowing improves dorsal orientation in the image but restricts analysis of the retrolingual region.[5-7]

The exact extent of interdental tongue protrusion cannot be analyzed with certainty on sagittal sector images as the sound waves are absorbed by the alveolar bone. Video-based superimposition of the course followed by the dorsum of the tongue improves the evaluation of the individual components of swallowing. However, the forward and upward movements of the tongue can be analyzed only approximately, as there are no constant identifiable reference points on its surface. Stone and Shawker[12] showed the direction of tongue movements on ultrasound depends on the positioning of the tongue and the water bolus (in their case 20 ml) in its initial position. They fixed a 5 mm stainless steel sphere to the tongue using dental impression materials. However, these materials could also have influenced the swallowing pattern.

It was not possible to obtain quantitative data because of the considerable variation in the size and position of the tongue with differing oral cavity volumes and occlusion. Since, as shown by Cleall[3], normal intersubject variability is very large, it is difficult to decide if a swallowing pattern is normal or abnormal. Use of the maxillary and mandibular reference positions appeared to provide a yardstick by which it was possible to determine the relationships between the ventral tongue surface and the anterior teeth and the palate. With increasing experience using ultrasound, qualitative differences in tongue position and swallowing patterns should be easier to identify.

Interdental protrusion of the tongue can be visualized using cineradiography. In contrast ultrasound shows a sagittal tomographic section

of the tongue from below, so bone relationships cannot be demonstrated. It is impossible to detect non-occlusion cases where the tongue is interposed between the teeth or to obtain data on individual tooth- tongue contacts. In contrast to radiological methods ultrasound scanning of the swallowing sequence can be repeated as there is no comparable radiation risk. Repetition is essential in those children who display a change in the swallowing sequence at the outset of the examination due to emotional tension.

Using electromagnetic articulography, Schwestkapolly et al.[13] detected a largely upward movement pattern of the tongue in patients with normal occlusion and no lingual dysfunction and a more forward oriented swallowing pattern in patients with anterior open bite. These results are confirmed by the present study.

Peng et al.[14] showed the Cushion Scanning Technique (CST) allows for a better intraindividual reproducibility of the swallowing pattern and for a more standardized and objective ultrasound examination than the hand-held transducer skin coupling scanning technique. Later they[8] showed the computer-aided B-mode plus M-mode ultrasonography in combination with the CST is a valuable tool for study of tongue functions. In our study the video-based ultrasound scanning seems to be a useful screening method.

Chiang et al.[15] found there was no difference in thickness of the tongue or the range of tongue movement in midsagittal plane during articulation of the selected vowels between males and females. Further exploration can be extended in the field of speech research by this valuable tool. Our results showed the importance of ultrasonography in the diagnosis of poor tongue coordination during swallowing.

Cheng et al.[16] found arch length increased with prolonged duration of swallowing. They also showed the computer-aided B+M mode of ultrasonography combined with the CST is a valuable tool for investigating the relationship between tongue movements during swallowing and dentofacial morphology. In our study we used B-mode ultrasonography, which proved useful for the imaging of tongue thrust in children.

Overall, our results confirm the value of ultrasonography in the diagnosis of tongue abnormalities during swallowing. They showed the majority of abnormal or inconsistent swallowing patterns were found in cases of mandibular prognathism. Other researchers have conducted different studies with similar results including Fuhrmann[17] who reported ultrasound scanning in the coronal and sagittal plane is a noninvasive imaging technique free of the biological risks associated with radiation. The dynamic ultrasound technique may be employed for early detection and diagnosis of tongue discoordination and is especially recommended for the objective imaging and identification of tongue thrust in orthodontic patients.

Neuschaefer et al.[10] showed the patients with diseases of the tongue or neuromuscular changes caused by disturbances of the central nervous system have pathological deviations on videosonography. These appeared as local or general reductions in movement, slow speed motions, repetitive swallowing, or unsorted additional movements of the tongue during swallowing.

Peng and Miethke[18] reported use of the cushioning method prevented movement in the ultrasonic probe, and also its use hardly impaired the patients ability to swallow. They, therefore, recommended this cushioning method be routinely applied during ultrasonic examinations of tongue function.

Akgul et al.[19] results were extremely encouraging, and their system can be used in practical speech and swallowing research in the field of otolaryngology. Bohme[20] reported ultrasonic diagnosis of the tongue can be recommended as a simple and cost-saving routine method.

Conclusion

In conclusion video based B-mode ultrasound is not invasive and permits direct visualization of the movements of the tongue in freely selectable coronal and sagittal planes with adequate resolution. Further studies are essential before this technique can be recommended as a suitable method for monitoring the progress of individual orthodontic and functional therapy.

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