Function of tongue during mastication using ultrasonographic technique

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ABSTRACT

Tongue movement during mastication is unquestionably important, but its physiologic mechanism remains to be elucidated. We have studied on the tongue position and movement by means of ultrasonography. Ultrasonographic technique has the advantages of being noninvasive, rapid, easily repeated and relatively inexpensive. The tongue image was obtained using a 7MHz mechanical convex transducer. The transducer, which was small and light, permitted the capture of images on videotape without manual placement scanner. Focal depth used was 10cm. Healthy volunteers were seated with their heads straight and the FH plane parallel with the floor. The ultrasonographic transducer was fixed by custom made resin transducer holder and flexible tape below the medial chin with gentle contact on the skin. Real time B mode ultrasonographic observation of the tongue was carried out in the medial saggital plane of the mandible as 11 flame/sec. Thereafter, karsol was established on the line linked between right and left molars and the vertical motion of tongue was recorded as M mode. The picture was recorded on the videotape recorder and simultaneously obtained by line scan recorder. Using vertical motion of the tongue in M mode, mastication were divided into two types : catching and crashing between the tongue and hard palate and slicing and grinding between the upper and lower teeth. Furthermore mastication between the teeth had two phases, sorting and bolus formation. Efficient masticatory function was corresponded with the food texture and the change of food texture in mastication progress.

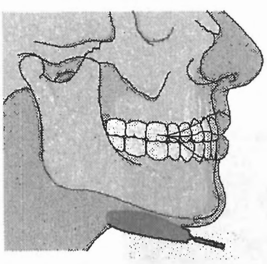
INTRODUCTION

The masticatory system is unquestionably important for life support. The masticatory system can be regarded as one functional unit within the context of other overlapping functions comprising the head and neck and, indeed, the entire body. Its principal components include the dentition, periodontal supporting structures, Temporomandibular joint, masticatory muscles associated with the soft tissues such as lips, cheeks and tongue(Mohl, 1988). During mastication, The tongue functions to replace and collect foods between teeth, makes an alternate, side to side churning movement and forces to masticate by pressure between the tongue and the plate(Abd-El-Malek, 1955, Arai, 1992). However, very few reports have appeared in the literature concerning the movement of the tongue during mastication. Some studies were carried out on tongue movement, using X-ray cinematography, electromyographic, magnetic drive or fluorography(Christrup, 1964). However these studies had radioactive and non-physiological problems. Ultrasonography was introduced for studies in swallowing, sucking and pronunciation(Fuhrmann, 1993, Stone, 1986). Meanwhile, it has the advantage of being noninvasive, rapid, easily repeatable and relatively inexpensive. The purpose of the present investigation was to observe the tongue functions during mastication using serial ultrasonic images.

MATERIALS AND METHODS

Real-time ultrasonic image of the tongue was obtained using a 7MHz mechanical convex scanning transducer (MICRO PROBES PVF-738F, TOSHIBA) and ultrasonic (SONOLAYER SSA-250A). Focal depth used was 10cm. The ultrasonic transducer was fixed below the chin to make gentle contact with the skin. Real-time B-mode ultrasonic observation of the tongue was carried out in the median saggital plane of the mandible (Fig 1).

Thereafter, vertical motion of the dorsal surface was recorded as the M-mode on a line connecting the mandibular first molars. The picture in Fig. 2 was recorded VTR and simultaneously obtained by Line Scan Recorder.



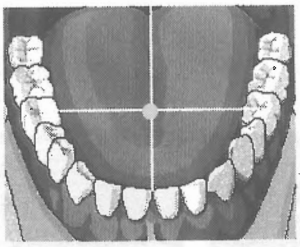


Fig 1. Fixation of ultrasonographic transducer and measurement point of tongue

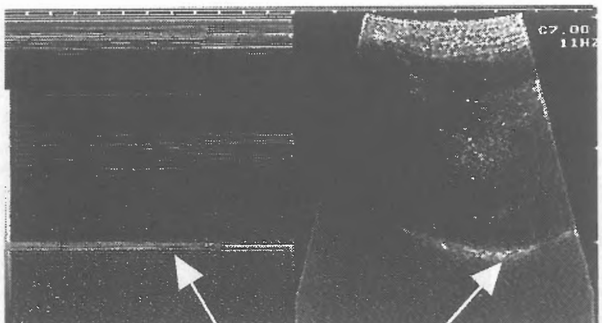


Fig 2. B- and M-modes at resting position

Twenty healthy male volunteers participated in the first study. All subjects had complete natural dentition that included at least the second molars. None showed any signs or symptoms of problems in the stomatographic system. Informed consent was obtained from each volunteer after a brief explanation of the study. The subjects were seated with the head straight and parallel between F-H plane and the floor.

Firstly, we recorded each tongue position at rest and after swallowing the masticated peanut as B-mode. We measured the distance from the submental skin to the surface of the tongue on the line that linked right and left first molars in the saggital plane. The second measurements of the distance were carried out in volunteers at rest and the measurement error were calculated at rest. To confirm the tongue movement, the volunteers tapped ad-lib with their own teeth in an empty mouth and then masticated peanuts. We digitized a trace for 5 sec into 300 points during tapping and peanut mastication, and statistically analyzed the average, standard deviation and coefficient of variation by the Wilcoxon signed-ranked test.

Six of the 20 males were chosen for the next study. Test foods were rices steamed in eight degrees. The hardness and adhesiveness of each steamed rice were measured using texturometer. They were instructed to masticate freely, resting between the different test foods. Tongue movement was simultaneously recorded with a vertical motion trace of the mandibular kinesiograph. We visually inspected detailed data of tongue movement during mastication of each steamed rice, and measured the number and time of masticated. We digitized the trace for 1 sec from the beginning of mastication into 300 points, and statistically analyzed the coefficient of variation.

RESULTS

Figure 3 showed the pictures of tongue at rest and after mastication. The tongue was a convex shape at rest. Each image indicated a close resemblance of shape and showed similar positions. The tongue position was fairly constant within the individuals, regardless of the first and the second measurements (Fig 4). The measurement error, expressed as a percentage of the mean between both measurements, was 1.45%. High reproducibility was indicated. The both images of the measurement of points at rest position and peanut mastication after swallowing position indicated a close resemblance of shape and showed similar positions (Fig 3). The tongue position was fairly constant within the individuals, regardless of the rest before or after the masticatory movements (Fig 4).

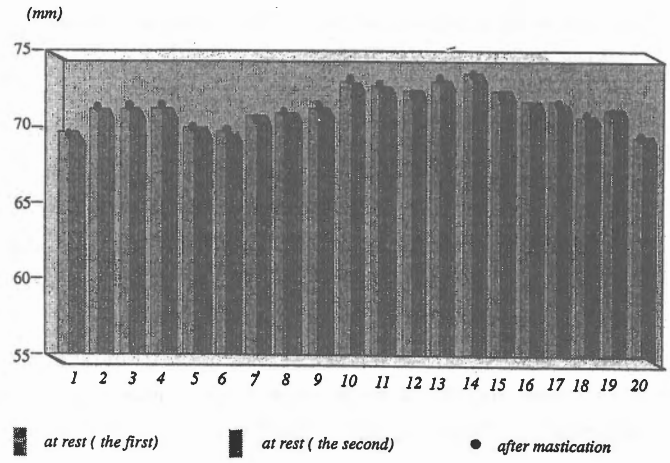


Fig 4. The measurement of tongue position

Fig 3. The picture of tongue position

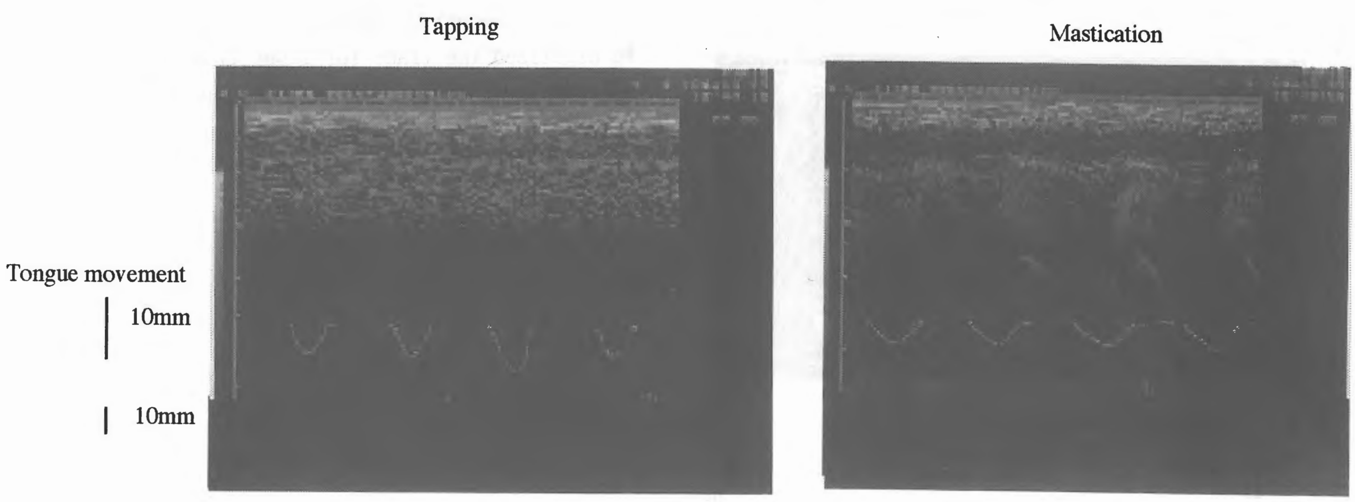


Fig 5. Tongue movements during tapping and peanuts mastication

Figure 5 showed that the motion of tongue movements was stable despite tapping, although there was considerable vertical variation during peanut mastication. Figure 6 showed the average, SD and CV for the total distance of the tongue movement during 5 sec. All parameters were different for tapping and mastication. The CV values for the Wilcoxon signed ranked test were statistically significant well below the 1% level.

The results of measurement of texture were shown in Figure 7. The texture were different each steamed rice, and the hardness and the adhesiveness were decrease from no. 1 to no. 8. Figure 8 illustrated the vertical motion of the tongue movement from no. 1 to no. 8, the number and distance of vertical tongue motion decreased with visual inspection. The decrease of the average and SD of the number and time of mandibular motion were shown Figure 9. The result of the CV value digitized the trace for 1 sec were statistically significant well below the 5% level between from no. 1 to no. 4 and from no. 5 to no. 8 (Fig 10).

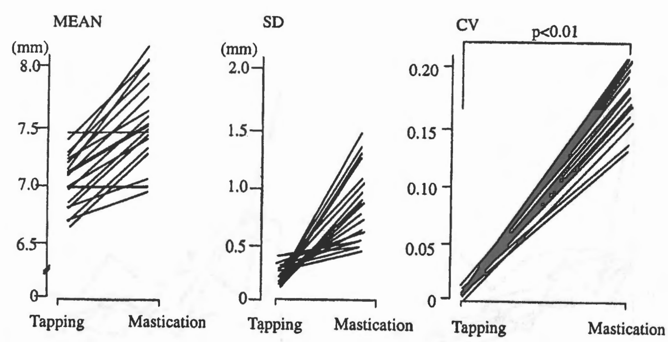


Fig 6. Results of tongue movement for 5 sec during tapping and mastication

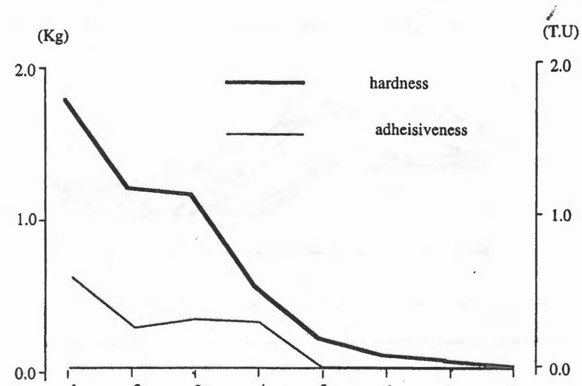


Fig 7. The hardness and adheisiveness of the test steamed rice

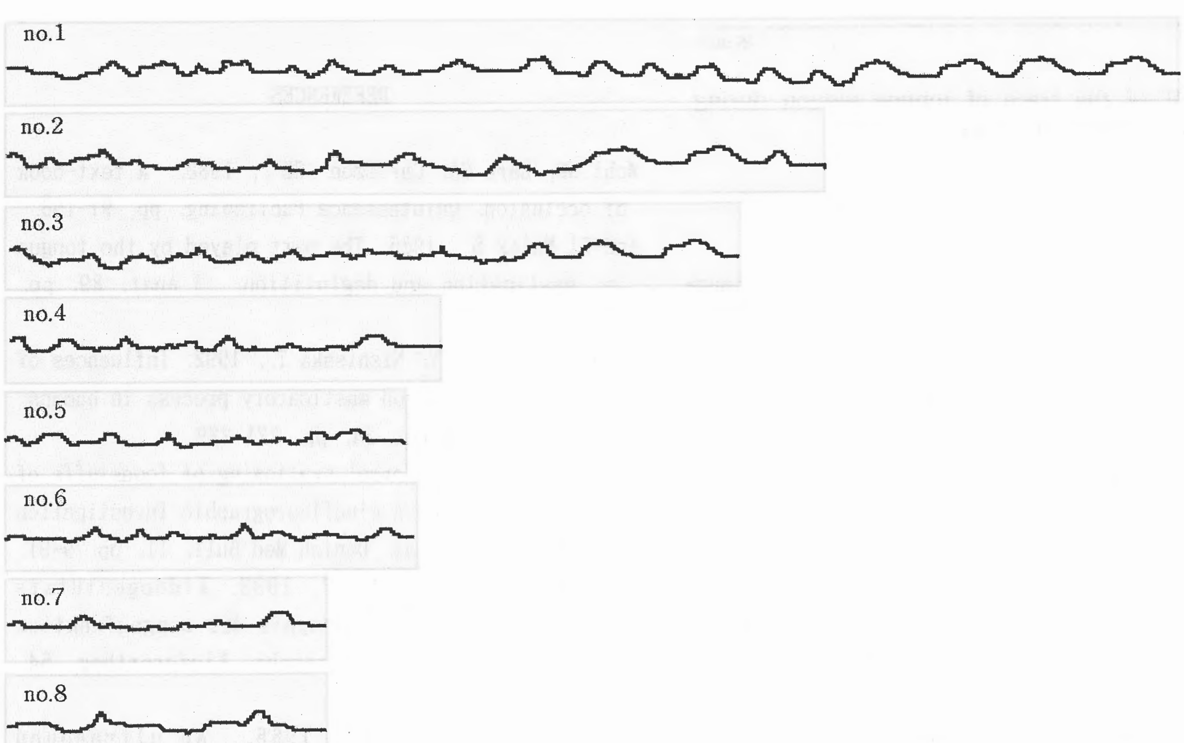


Fig 8. Trace of the tongue motion during mastication of steamed rice

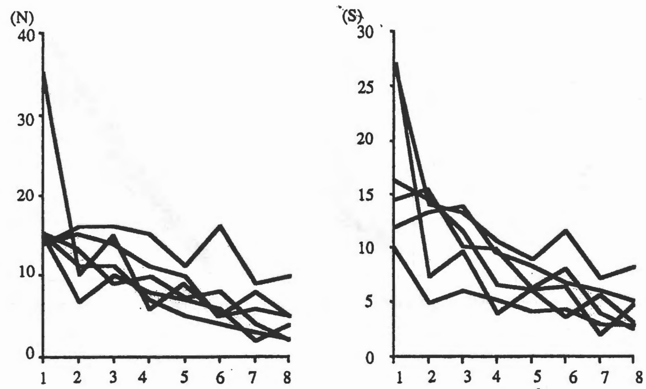
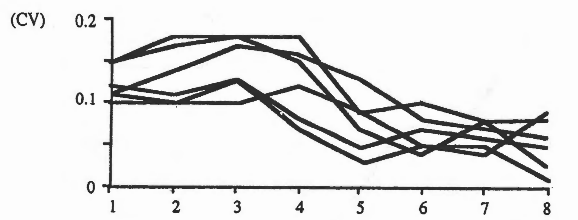


Fig 9. The number and times of mandibular motion during mastication of steamed rice



steamed rice	2	3	4	5	6	7	8
1	–	–	–	*	*	*	*
2		–	–	*	*	*	*
3			–	*	*	*	*
4				*	*	*	*
5					–	–	–
6						–	–
7							

*<0.05

Fig 10. CV of the trace of tongue motion during mastication of steamed rice

DISCUSSION

The tongue surface in an ultrasonography M-mode image was continuously recorded without fixed contrivance of the transducer using the operators finger and holder, because the transducer was small and light. The tongue position during resting was stable within individuals in this study. That is to say, the measurements could be best executed in the tongue resting position with ultrasonography. The reproducibility of the tongue resting position was very high. This tongue resting position was acceptable as a reference position of the functional movement. In addition, the tongue resting positions after swallowing were within the limits of mean ± 1SD. This also indicated that the ultrasonographic transducer did not shift throughout the experiment.

Comparison of traces during tapping and peanut mastication led us to conclude that the recorded M-mode images represented vertical motion of the tongue.

In this study, test steamed rice were divided into 2 groups. The steamed rices observed on 2 phases were from no. 1 to no. 4 and on 1 phase only were from no. 5 to no. 8 with visual inspection. That is to say, mastication pattern was different. We concluded that the group of from no. 1 to no. 4 was to help mastication between the teeth. And another one was to forced by pressure between the tongue and the palate. We interpreted 2 phase as the sorting out phase (SO-phase) and the bolus formation phase (BF -phase). In SO-phase, the trace was not regularly, whereas it was very regularly in BF-phase with visual inspection. Tongue movement in SO-phase showed the picking over particles of food, which was positioned between antagonist teeth. Then, we observed that the tongue made particles of crushed food into a bolus in BF-phase. It was concluded that coordinated movements of tongue and mandible produced the rhythmic pattern in progress to masticate. Efficient masticatory function was corresponded with the food texture and the change of food texture in mastication progress.

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