Development of X-ray TV M-mode and reconstructed ultrasound M-mode methods for investigating tongue movement during swallowing in humans

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Abstract: There were two purposes of this study. The first purpose was to introduce the “X-ray TV M-mode waveform” which is reconstructed from sequential X-ray TV images and the “reconstructed ultrasound M-mode waveform” which is delivered from ultrasound B-mode images. The second purpose was to evaluate the usefulness of these two types of waveforms in the investigation of tongue movement during swallowing. The instrument system employed in this study consisted of ultrasound and X-ray TV synchronized by a time marker. After the X-ray images and ultrasound B-mode images were recorded on an optical disk, X-ray TV M-mode waveform and ultrasound M-mode waveform were reconstructed using an MC 68030/OS-9 computer. No significant differences in quality of images were observed between the X-ray TV M-mode waveform and the reconstructed ultrasound M-mode waveform. Therefore, both waveforms of the X-ray TV M-mode and the reconstructed ultrasound M-mode are equally useful in measuring tongue movement. (J. Oral Sci. 41, 1-4, 1999)

Key words: X-ray TV; ultrasound; M-mode; reconstruction; tongue movement.

Introduction

Recently, X-ray TV and ultrasound systems have been used clinically to investigate various oral functions. For example, there have been several studies in which such systems were used to measure tongue movement during swallowing in humans (1-9).

To date, quantitative and qualitative analysis of tongue movement have mainly been performed using ultrasound B-mode images (1-5,9), although sequential X-ray images have also been used for such analysis (10-12). Whereas both methods are commonly used, for functional diagnosis waveforms reconstructed from ultrasound and X-ray images are thought to be more useful than the original images.

The purposes for conducting the current study were as follows. First, to introduce the “X-ray TV M-mode waveform” which is reconstructed from sequential X-ray TV images and the “reconstructed ultrasound M-mode waveform” which is delivered from ultrasound B-mode images. The second purpose of the current study was to evaluate the usefulness of these two types of waveform for investigating tongue movement during swallowing.

Materials and Methods

Subjects

Seven healthy male volunteers ranging in age from 23 to 27 (mean age: 24.6) participated in the study. All subjects had normal occlusion and none had any temporomandibular disorders.

Observation methods

The observation system consisted of ultrasound and X-ray TV systems, synchronized by a time marker. Tongue movement was observed by taking ultrasound images at 30 frames per second as previously described (6). BaSO4 contrast medium on a tongue blade was used as a marker (about 8 mm wide), which was applied on the middle of the tongue from its tip to its posterior portion. The marker was attached to the midline of a plastic, 0.6 mm-thick temporary plate (Erkoder; Erkodent Inc.) set between the left upper second premolar and the right upper second premolar to retain the marker on the midline of the temporary plate.

The tongue movement was observed from the lateral side by using the X-ray TV camera. The central X-ray beam was oriented parallel to the head-holder system used to fix the ultrasound probe, X-ray TV camera and subject’s head via a head rest and an ear rod. The ultrasound probe was placed about 1 cm posterior to the menton. X-ray TV images taken from the lateral side were used to confirm that the ultrasound probe was positioned on the extension line against the marker on the palate. Individual observations of saliva swallowing were performed after the subject swallowed 5 ml of water. Just as the subject was instructed to swallow, the time marker was switched on for the observation. Each subject was instructed to repeat the
swallowing movement six times during the experiment.

Reconstruction of the X-ray TV M-mode and ultrasound M-mode waveforms

After the X-ray TV and ultrasound B-mode images had been recorded on the optical disk, X-ray TV M-mode and ultrasound M-mode waveforms were reconstructed by using an [MC68030]/OS-9 computer. Mid-tongue movement was reproduced by means of the ultrasound M-mode waveforms reconstructed from the B-mode images. Next, M-mode waveforms were reconstructed from the X-ray TV images to observe the tongue movement from the point of the ultrasound probe to the marker on the temporary plate.

Results

Observations of tongue movement during swallowing

Movement of the mid-tongue blade was divided into three stages. Stage 1 began at the onset of tongue movement and lasted until the tongue made contact with the palate. Stage 2 was from the point when the tongue and palate made contact (end of stage 1) to when the tongue and palate separated. Stage 3 was from tongue-palate separation (end of stage 2) to the end of tongue movement. During stage 1, the mid-tongue blade moved forward as the bolus (saliva) moved backward. During stage 2, there was a long period of tongue-palate contact. The return of the tongue to rest was third stage (Figs 1-4).

Comparison between ordinary ultrasound M-mode waveforms and ultrasound M-mode waveforms reconstructed from B-mode

There were no qualitative differences between the ordinary ultrasound M-mode waveforms (Fig. 1) and the ultrasound M-mode waves reconstructed from the B-mode waveforms (Fig. 2). Moreover, there were no obvious differences in the waveform type and the quality of images (contrast, brightness, etc.) between the ordinary ultrasound M-mode waves and the reconstructed M-mode waveforms.

Comparison between X-ray TV images and the X-ray TV M-mode waveforms

There were no differences in the anatomical positions between the X-ray TV images (Fig. 3) and the X-ray TV M-mode waveforms (Fig. 4).

Comparison between waveforms of the X-ray TV M-mode and reconstructed ultrasound M-mode

There were no qualitative differences between the X-ray TV M-mode and the reconstructed ultrasound M-mode waveforms.

Discussion

Observations of tongue movement have been very important for dentists and otorhinolaryngologists in the investigation of tongue functions during speech, swallowing and mastication (2-5,7,9-11). There have been many studies on methods for quantitative analysis of tongue movement using strain-gauge pressure transducers and palatograms. However, in these cases the tongue movements could not be observed when the tongue was not in contact with the measurement equipment. Studies using numerous sequential X-ray TV images have provided images which make it possible to observe movements of the entire tongue. However, excessive radiation exposure is a
potential risk with such methods. Ultrasound images have also been used, however they are only tomographic in nature, and the entire tongue can not be observed.

Therapeutic ultrasonography has been used for many years in medicine because it has few harmful effects on patients (7). Authors have examined the usefulness of the ultrasound M-mode waveform analysis for investigating tongue movement. Results obtained using ultrasound with X-ray TV images were similar to those obtained a strain-gauge pressure transducer. No significant differences in the results were obtained when the two methods were compared, regardless of the demographic characteristics of the subjects or the duration of observation and the number of repetitions. Moreover, there were no significant differences in the degree of variance between the two methods (8).

For analysis of tongue movement, X-ray systems have been mainly used, although the application of ultrasound systems for such analysis has progressed markedly in the past several years. Examinations of patients with dysfunction have usually been performed using a barium contrast medium, with observation being made by X-ray TV, ultrasound and, oral or tongue pressure measurement methods. However, in analyzing tongue movement using waveforms reconstructed from ultrasound and X-ray images, the waveform is quantitatively more useful than the original images for functional diagnosis.

Based on the results of the present study, we conclude that the X-ray TV M-mode waveforms accurately reproduced anatomical and other points (positions of the mandible, teeth, marker on the plate and ultrasound probe) and that the reproducibility was similar to that obtained using the X-ray images. In particular, there were no apparent negative influences on the teeth or bones with the X-ray TV M-mode method regardless of whether we used the contrast medium. Moreover, there were no qualitative differences between the X-ray TV M-mode and the reconstructed ultrasound M-mode waveforms. We conclude that the method of analysis should be selected according to the level of oral function. Since tongue functions are complex and variable, the examiner must select the appropriate waveforms for observing tongue movement simultaneously.

In summary, it was confirmed that waveforms of the X-ray TV M-mode and the reconstructed ultrasound M-mode waveforms were useful for observing tongue movement. These two types of waveforms could be useful for investigating physiological function during swallowing, speaking and mastication.

References
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