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THE PALATOTRACER:

A NEWLY DEVELOPED DEVICE TO MEASURE THE PALATAL SHAPE

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We have been conducting a study to determine the vocal tract dynamics during speech production. For this study, information on the vocal tract shape is essential. Although X-rays have been utilized to visualize the vocal tract, the unfavorable biological side effects have prevented us from getting enough data to extract the essential dimensions for articulatory dynamics.

We substituted an ultrasonic system for X-rays to monitor the articulatory dynamics without any biological hazard.[1] By using the ultrasonic system, the tongue can be visualized nicely. However, since the ultrasonic beam is radiated from beneath the chin, the palatal shape cannot be visualized. Since we are interested in the vocal tract shape, we must know the shape of the palate as well. Theoretically, it is impossible to visualize the palatal shape using the present ultrasonic system, because the ultrasonic pulse train is reflected at the surface of the tongue and does not reach the oral surface of the palate.

We have developed a special device to extract the inner contour of the palate, which constitutes the roof of the vocal tract, without using X-rays or ultrasound.

DEVICE

The device (palatotracer) consists of a rod with a sliding pivot as schematically shown in figure 1. The pivot is held in place with the subject's incisors. The pivot enables the rod to slide in and out and rotate around the pivot, resulting in a free two dimensional movement. This means that the inner end of the rod can trace the inner surface of the palate at the mid sagittal line. When the inner end of the rod traces the oral surface of the palate, the outer end of the rod moves on a trajectory which must correspond to the shape of the palate. Light emitting diodes (LED) are attached to the end of the outer rod, so that the PSD system[2] outputs the coordinate values of the LED to the computer. A computer converts the coordinate values into a two dimensional figure of the palatal shape and displays it on a CRT. To extract the precise shape of the palate, the constant contact between the tip of the inner rod and the oral surface of the palate is required. In order to detect the contact, an electric current is applied to the rod and the impedance between the lever and the body is monitored.

METHOD

A cylinder with a known diameter, a palatal cast and the palate of a normal male subject were measured. There are two different ways to get to the LED trajectory: continuous tracing and spot-tracing. For this preliminary test, spot-tracing was employed. The tip of the lever touched several points on the palatal surface. The PSD system output several sets of the coordinates which corresponded to the measured points on the palatal surface. The computer converted the coordinate values into the shape of the palate. By the spot-tracing, the palatal shape observed on the CRT was drawn with the dotted line.

RESULTS

The results are shown in Figures 2-4.

DISCUSSION

In order to observe the articulatory movement, the ultrasonic system has been devised for safety and convenience[3]. However, this system has a shortcoming in that the palatal shape cannot be visualized. To monitor the tongue shape, the ultrasonic pulse train is emitted from a probe beneath the chin. Since the radiated pulse train is mostly reflected at the border between the tongue surface and the air space in the oral cavity, the ultrasonic pulse cannot reach the palatal surface. On the other hand, from a phonetic point of view, determining the palatal shape is a major research task, because the palate is an important component of the vocal tract. However, it has been difficult to extract the palatal shape without using an X-ray system.

We have developed a device which enables us to extract the palatal shape without using X-rays. The output of the device can be superimposed on the ultrasonic image of the tongue. Thus, we can know the vocal tract shape without any biohazard.

The system consists of a lever with LEDs and a PSD system. The reason we employ the LED and PSD is that the output of the system can be easily transferred to a computer. Once the data is transferred to the computer, it is ready to be superimposed on the ultrasonic image on the CRT.

As described above in the METHOD part of this paper, there are two ways of tracing the palatal surface. It is obvious that in order to get an accurate contour , the tip of the inner lever should firmly and constantly touch the palatal surface. To confirm the firm contact of the tip of the lever and the palate, the detection of the palatal shape was performed point by point (spot-trace). We are trying to make a contact sensing system using a minimal electric current as in the electropalatogram[4]. When it is completed, continuous tracing can will

be possible. Compared to spot-tracing, the continuous tracing should be much more convenient and time-saving. Using the present system, it took about 4 minutes to cover the whole area of the palate with 15 measurement points.

Figure 5 indicates the basis of the calculation. Figure 5-(A) indicates the method of using the coordinate values of the pivot which is fixed by the subject's incisors and the coordinate values of the LED on the outer lever. On the other hand, figure 5-(B) indicates the other way of the calculating the palatal shape. The idea is that the triangle determined by the contact point at the palate, and the two LEDs on the outer lever is always constant, so that the coordinates of the LEDs on the outer lever should represent the contact point at the palate. Geometrically, these two methods of calculation are essentially the same. For technical convenience, we employed the latter method of calculation.

In order to test the accuracy of the system, a cylinder with a known diameter (55mm) was measured . Judging from Figure 2, the center part of the measured area had a pretty good correspondence, however, the peripheral portion could not be measured accurately, probably because of the thickness of the contact area of the rod.

The palatal cast was measured, and the contour which was traced from the section of the cast, was compared to the result. As far as the area of the hard palate was concerned, a good correspondence between the measurement and the tracing. was obtained.

One of the authors served as the subject. Figure 4 indicates the contour of the subject's palate.

Since this measurement was carried out by using a prototype device, the subject was limited to an adult male because the device was big and heavy. The device should be refined for clinical use.

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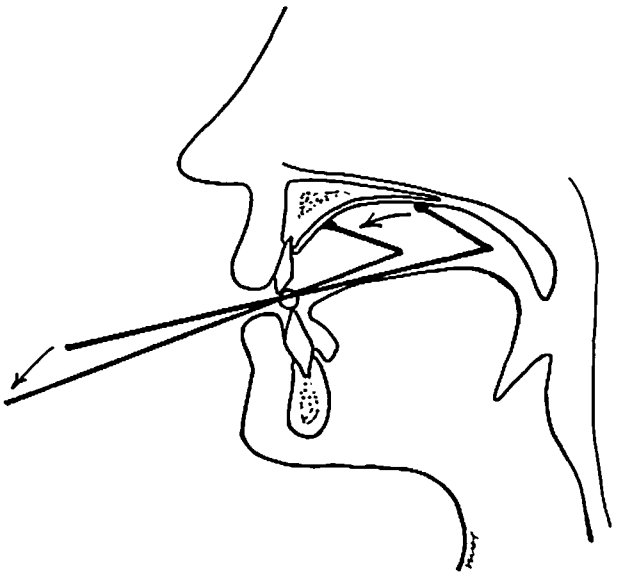

Figure 1 A schema of the device (palatotracer).

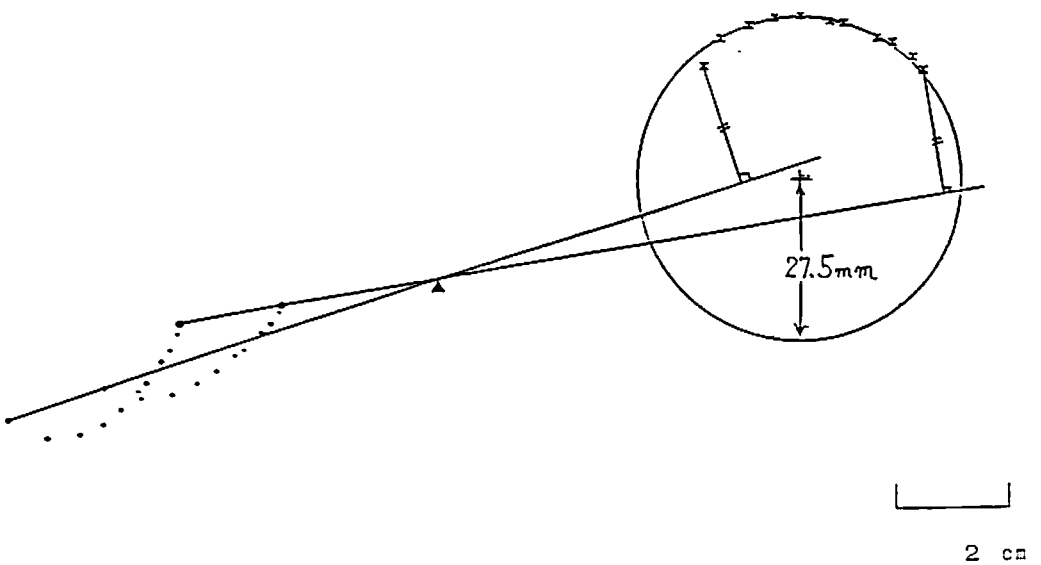

Figure 2 The xs on the circle show the reconstructed shape of the cylinder. The circle indicates the inside of the cylinder with known dimensions.

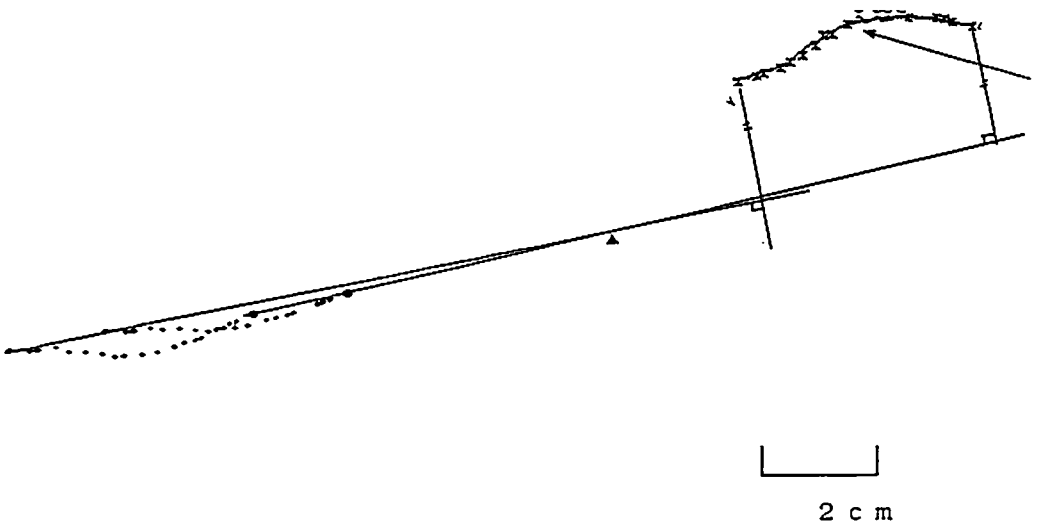

Figure 3 A shape of a plastic cast of the palate (solid line) and the estimated palatal shape.

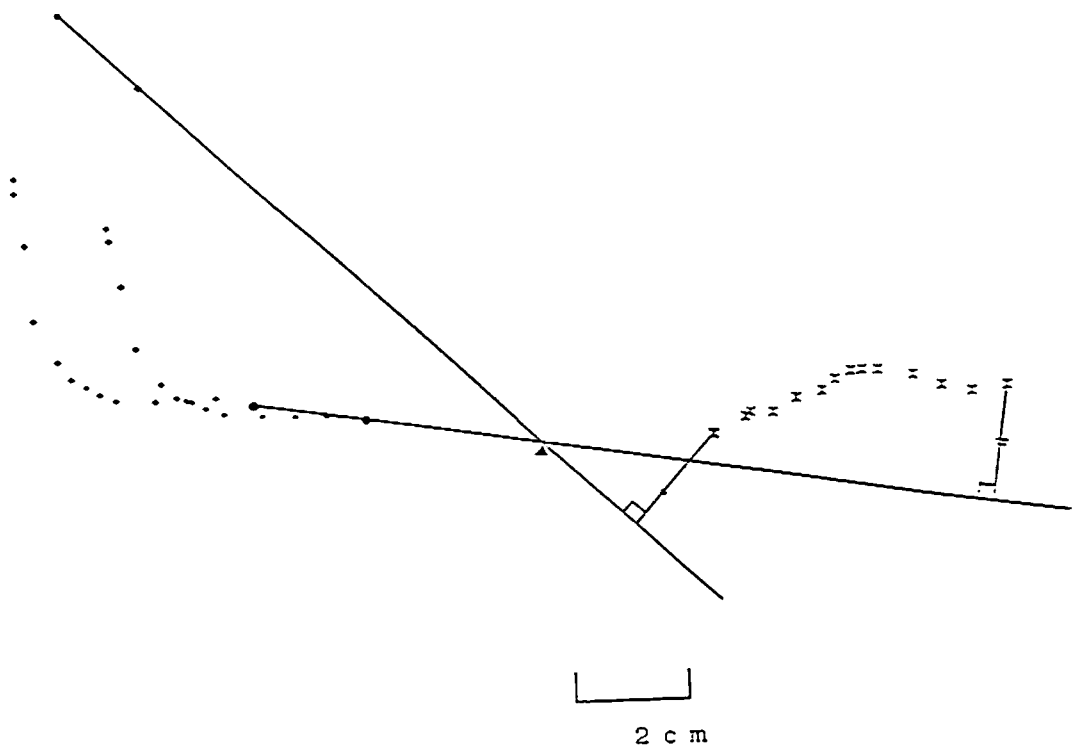

Figure 4 A result of the actual palate measurement.

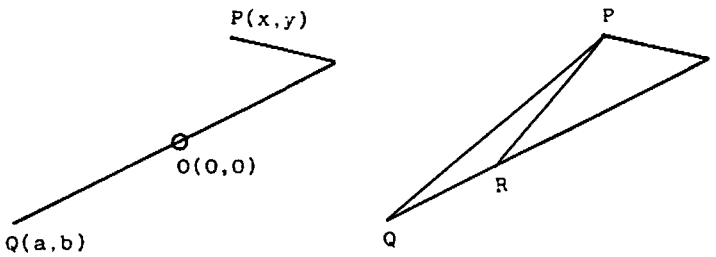

Figure 5 Two different methods of calculation.

References

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