2P5-6

Examination of characteristics of vibrotactile perception by bone-conducted stimuli presented to the human face

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1. Introduction

In bone conduction, stimuli are generally presented to the mastoid process of the temporal bone and the condyloid process of the mandible. [1-2] However, methods to present stimuli to the face such as the nasal bone and zygomatic bone have also been investigated, and their application to audio devices such as smart glasses is being considered recently.[3-4] The face is one of the most complicated structures in the human body, consisting of many irregularly shaped bones, muscles, fat, and cavities. Therefore, it is highly likely that the bone conduction mechanism varies with changes in the position of the transducer, but much of this remains unexplored.

In previous papers, we conducted a threshold measurement and a monosyllabic intelligibility test, when bone-conducted sounds were presented to various parts of the face[5]. The results showed that the cheek bone and mandibular angle had similar intelligibility to conventional areas. In particular , the cheek bone had intelligibility close to that of air-conducted sound.

On the other hand, when the stimulation intensity is increased in face-presentation bone conduction, a feeling of vibration may be felt. The face is generally more sensitive to somatosensory stimuli[6] and is thought to be more prone to vibrotactile perception than conventional areas. In this study, we estimated the threshold of vibrotactile perception induced by bone-conduction stimulation in the face using masking, and compared the characteristics of vibratory sensation between the different presentation sites.

2. Methods

2.1 Subjects

Seven normal-hearing subjects (4 males and 6 females, 21-24 years old) participated. The subjects were seated in an anechoic chamber and instructed not to make large facial movements such as opening the mouth wide, raising the corners of the mouth, or clenching the teeth. The bone-conducting transducer (Radioear, B-81) was used to present stimulus sounds at seven sites; mastoid, condyle, nasal, infraorbital region, zygomatic, jaw angle, chin (**Fig. 1**).

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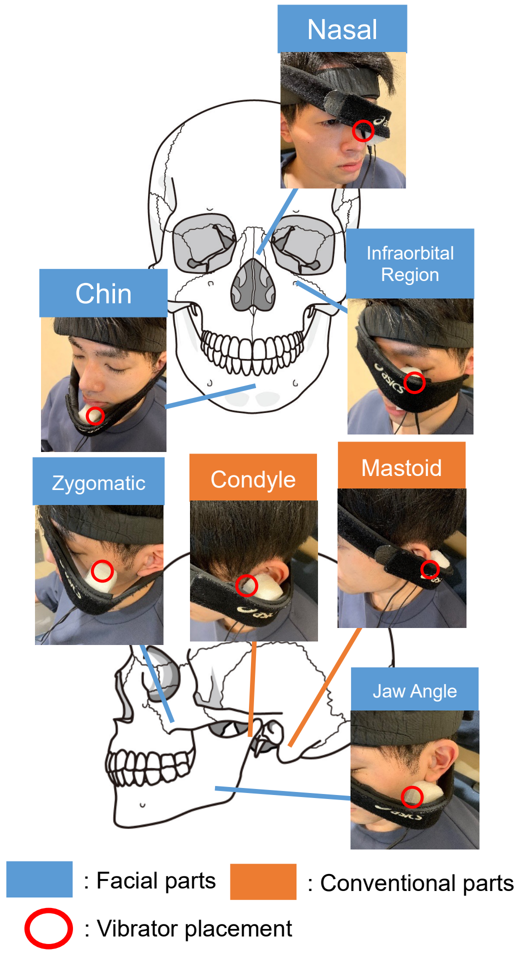

Fig. 1 Presentation of bone-conduction stimuli in the experiment.

2.2 Stimuli

250, 500, 750, and 1000-Hz tone bursts were presented by bone conduction using an audiometer (Resonance, R17A). Air-conduction masking tones (maskers) were narrow band noises with center frequencies same as the stimulus frequencies, and were presented to both ears by insert earphones (Etymotic Research, ER-3A).

2.3 Procedure

(1) Bone-conduction stimulus was presented. The presentation level was set to the level at which both bone conduction sound and vibration are sufficiently perceived.

(2) The presentation level of the masker that is

perceived as not hearing the bone conduction sound at the presentation level set in (1) is estimated by the ascending method.
(3) The threshold of vibrotactile perception was measured by the ascending method using the initial value of 30-dB smaller than the presentation level of both the bone conduction stimulus and the masker. The threshold of vibration perception by the bone conduction stimulus was calculated by simultaneously increase of the presentation level of the masker and the bone conduction stimulus with a step width of 5 dB. The subject did not hear any bone-conduction sound during the measurement.

3. Results

The thresholds at each presentation site are shown in Fig. 2 (the thresholds at 1000 Hz for the mastoid process, condylar process, and nasal bone are averages for the four subjects). Regardless of the presentation site, the vibrotactile threshold increased from 250 to 750 Hz and leveled at 62-64 dB (a.u.) from 750 to 1000 Hz. The thresholds at the nasal, zygomatic, and mandibular angles were slightly lower than those at the mastoid process, the conventional site, regardless of frequency. On the other hand, the vibratory thresholds of the suborbital and mussel ridge were 3-7 dB higher than those of the mastoid process and other facial regions, especially at 250-500 Hz. A two-way analysis of variance revealed a significant main effect of frequency ($p < .05$), but no main effect of presentation site or interaction.

4. Discussions

The vibrotactile thresholds were similar for both facial and conventional sites. The nasal bone, zygomatic bone, and mandibular angle showed slightly lower vibrotactile thresholds, especially in the low frequency range (250-500 Hz). These three areas need to be suppressed in the perception of vibrotactile sensation in the facial region. On the other hand, the thresholds of the infraorbital region and the chin were higher than those of the other facial regions at low frequencies. These regions are less susceptible to the generation of vibratory sensation.

The threshold for vibration perception at each presentation site was 50-55 dB at 250 Hz, then increased with frequency up to 750 Hz, and saturated above 750 Hz. Although it depends on the frequency and the presentation site, it is necessary to consider the generation of vibratory sensation when the stimulus intensity exceeds 50 dB.

In a previous study, the auditory threshold at the mandibular angle at 250-500 Hz was slightly lower than that at other facial sites (Fig. 3). The sensitivity of the mandibular angle to both bone-conducted hearing and vibration at low frequencies may be slightly higher than that of other facial regions. The vibration thresholds of the infraorbital region and chin were higher than those of the nasal bone and zygomatic bone, especially at 500 Hz, but the auditory thresholds were not significantly different. The infraorbital and chin showed similar auditory sensitivity, but lower vibratory sensitivity compared to other facial regions, such as the nasal bones and zygomatic bone. It is expected that the infraorbital region and the chin can be used for bone conduction devices while reducing the generation of vibratory sensation.

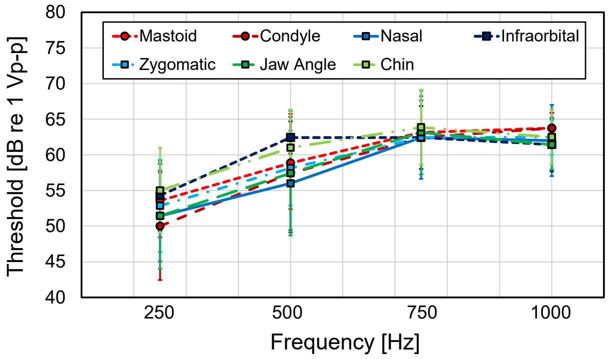

Fig. 2 Vibrotactile thresholds for each part.

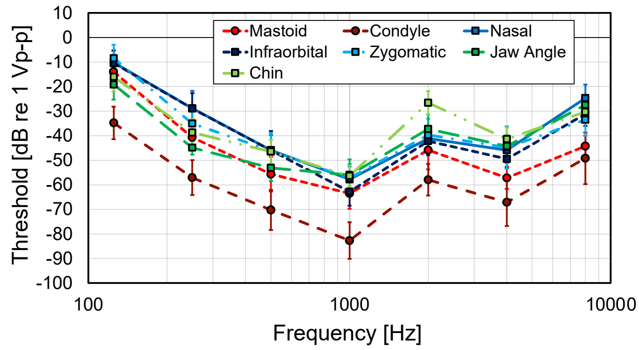

Fig. 3 Hearing thresholds for each part[3].

Acknowledgment

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