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Characteristics of vibrotactile perception by bone-conducted stimuli presented to the facial parts

Ko Uemura[1 ‡], Sho Otsuka[1, 2, 3], and Seiji Nakagawa[1, 2, 3*]
([1]Dept. of Medical Eng., Graduate School of Sci. & Eng., Chiba Univ.; [2]Ctr. for Frontier Medical Eng., Chiba Univ.; [3]Med-Tech Link Ctr., Chiba Univ. Hospital)

1. Introduction

Bone-conducted (BC) stimuli are generally presented to the mastoid process of the temporal bone or condyle process of the mandible[1)]. Recently, however, methods for presenting to the face, such as the nasal and zygomatic bones, have also been considered, and their application to audio devices such as smart glasses have also been explored[2,3)]. The face has a very complicated structure, consisting of many irregularly shaped bones, muscles, fat, and cavity structure. Therefore, it is highly likely that BC-sounds characteristics also change with changes in the presentation parts of the vibrator, but most of these mechanisms remain unclear.

We've studied perceptual and propagation characteristics on the face[2)]. As a result, it was confirmed that differences in presentation parts on the face don't affect hearing sensitivity but may cause changes in the amplitude of each BC component directly acting on the outer, middle, and inner ear, respectively.

On the other hand, with BC presentation to the face, ticklish vibrotactile sensation is sometimes felt when the stimulus intensity is high. The face is generally more sensitive to somatosensory cues[4)], and may be more prone to vibrotactile perception than conventional parts for BC stimulation. Therefore, it is important to suppress this to promote its application in BC devices. In the current study, we estimated the vibrotactile thresholds by BC stimuli on facial parts and compared the characteristics of vibrotactile perception among facial parts.

2. Methods

2.1 Participants

4 men and 3 women (21 to 24 years) with normal hearing participated. The participants were seated in an anechoic room and instructed not to make any large facial movements such as opening the mouth wide, raising the corners of the mouth, or clenching the teeth. BC stimuli were presented to the mastoid process (temporal bone), condyle process (mandible), nasal bone, infraorbital region (maxillary bone), zygomatic bone, jaw angle (mandible), and chin (mandible) using a vibrator (Radioear, B-81) (**Fig. 1**).

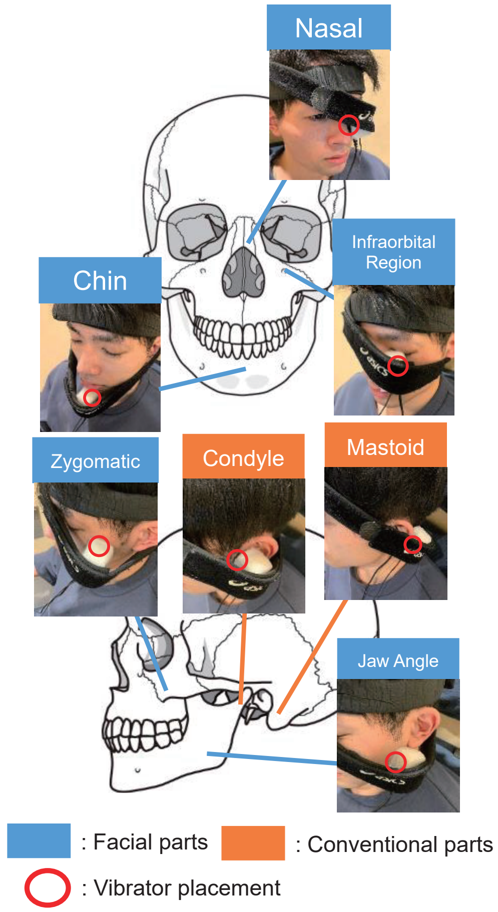

Fig. 1 Presentation of BC stimuli in the experiment.

2.2 Stimuli

BC stimuli were 250, 500, 750, and 1000 Hz tone bursts, and were presented using an audiometer (Resonance, R17A). The air-conducted masking sound (masker) were narrow band noise with the stimulus frequency as the center frequency, and were presented to both ears by insert earphones (Etymotic Research, ER-3A).

2.3 Procedure

(1) BC stimuli were presented. The presentation level was set so that both BC-stimuli hearing and vibrotactile were sufficiently perceived. (2) The masker sound and the BC stimuli were presented simultaneously. The presentation level of the masker

‡k_uemura1112@chiba-u.jp, *s-nakagawa@chiba-u.jp

[dB a.u.] at which the BC sounds were not heard at the presentation level set in (1) was estimated by an ascending method. (3) Initial levels of both the BC stimuli and masker were set at 30 dB below the levels estimated in (2). Levels of the masker and BC stimuli were increased simultaneously with 5-dB steps, and the vibrotactile thresholds were measured by the ascending method. It was confirmed that participants did not hear any BC sound during the measurement.

3. Results

Fig. 2 shows the vibrotactile thresholds at each stimulated part (The thresholds of the mastoid process, condyle process, and nasal at 1000 Hz were averaged for four participants). Regardless of the stimulated parts, the vibrotactile thresholds were estimated at 50-55 dB at 250 Hz. Then the vibrotactile thresholds increased at 250-750 Hz, and leveled off at 62-64 dB at 750-1000 Hz. The vibrotactile thresholds of the nasal, zygomatic, and jaw angle were slightly lower than those of the mastoid process (the conventional part), regardless of frequency. On the other hand, the vibrotactile thresholds of the infraorbital region and chin were 3-7 dB higher than those of the mastoid process and other facial parts, especially at 250-500 Hz.

A two-way analysis of variance (ANOVA) revealed that the main effect of the frequency was significant ($p < .05$), however, that of the stimulated parts was not. Interaction was not significant.

4. Discussions

The characteristics of vibrotactile perception were similar for both the facial and conventional parts. The vibrotactile thresholds of each presentation part were 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 presentation parts, it is necessary to consider the vibrotactile perception when the stimulus intensity exceeds 50 dB.

The nasal, zygomatic and jaw angle showed slightly lower thresholds, especially in the low frequency range (250-500 Hz). In these three parts, it is necessary to consider the suppression of vibrotactile, especially in the facial parts. On the other hand, the vibrotactile thresholds of the infraorbital region and chin were higher than those of other facial parts at low frequency region. It is thought that there is little concern about the occurrence of vibrotactile sensation.

In our previous study[2)], the hearing thresholds of the jaw angle at 250-500 Hz was slightly decreased by 7-16 dB compared to the other facial parts (**Fig. 3**). The jaw angle also had relatively lower vibrotactile thresholds among facial parts, so the sensitivities of jaw angle to both hearing and vibrotactile in the low frequency range are slightly higher than that of other facial parts especially. In terms of the infraorbital region and chin, vibrotactile thresholds were increased compared to the nasal and zygomatic, especially at 500 Hz. The infraorbital region and chin show the same hearing sensitivity as other facial parts such as the nasal and zygomatic, while the vibrotactile sensitivity is decreased. Therefore, it is expected that the infraorbital region and chin can be used for BC devices while minimizing the occurrence of vibrotactile.

Acknowledgment

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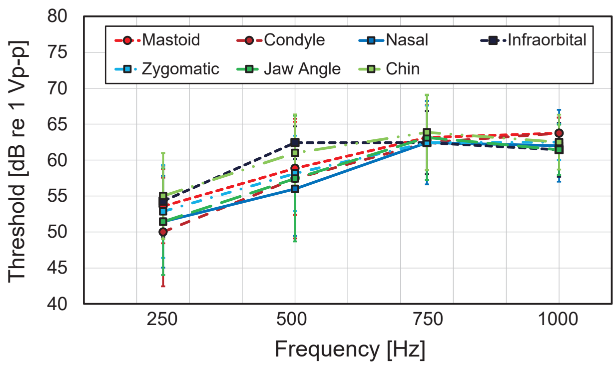

Fig. 2 Vibrotactile thresholds for each part.

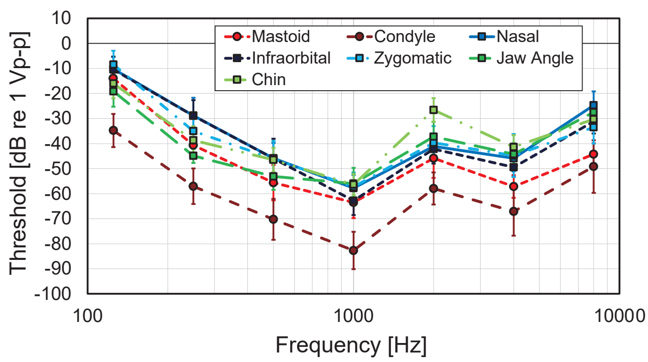

Fig. 3 Hearing thresholds for each part[2)].