Measurement of air-conducted and bone-conducted dental drilling sounds

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ABSTRACT
Patients in dental clinics perceive the bone-conducted sound via the teeth in addition to the air-conducted sound from the ear during the drilling of their teeth. In order to reduce the discomfort during treatment, it is necessary to find the characteristics of both the air-conducted and the bone-conducted dental drilling sounds. It was found in our former studies that rich high-frequency components up to 20 kHz are included in the air-conducted dental drilling sound. However the characteristic of the bone-conducted dental drilling sound is not well known. In this study, the air-conducted and the bone-conducted dental drilling sounds up to high frequency range were simultaneously measured by microphones placed near the participants and on the participants' foreheads during drilling dental materials covered on their teeth. Further, the bone-conducted sound was measured during the drilling of the artificial teeth on the measurement model using the twelve kinds of dental drills. As the result, high frequency components up to 20 kHz in the bone-conducted dental drilling sound were observed.

Keywords: bone-conducted sound, dental drill, noise
I-INCE Classification of Subjects Number(s): 51.463.2 Perceived noisiness, annoyance

1. INTRODUCTION
The sound often gives discomfort to many patients in drilling teeth due to dental treatment (1). The comfortable sound environment at a dental office should be given to patients. In order to find clues to improve the sound quality of dental drills for patients, we investigated the impression of the sound quality of dental drills. It was suggested in our former studies that the air-conducted sound in drilling teeth have rich high frequency components up to 20 kHz and it is found that the physical metrics such as the combinations of L_{Aeq} and sharpness, which is named Comfort Index (*CI*) by Kuwano *at.el*, had a significant effect on the subjective unpleasant impression based on the psychological experiment (2). These reports are limited to air conducted dental sounds.

In addition to the air-conducted sound through the ears, the bone-conducted sound is also perceived via the teeth of patients when drilling their teeth for the treatment. Countermeasures for bone conducted sound are required besides those for air-conducted sound in order to reduce the discomfort of the patient during treatment. Therefore, it is necessary to find the characteristics of bone conducted sounds. In this study, the air-conducted and the bone-conducted sounds were simultaneously measured in drilling dental materials covered on the participant's own teeth. Further, the air-conducted and the bone-conducted sounds were also simultaneously measured during the drilling of the artificial teeth on the measurement model.

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2. Method

2.1 Experiment 1

Three participants joined in this measurement experiment. This experiment was conducted in the dental hospital attached Osaka University. The condenser microphone was placed at a position of 30 cm from the head. The electret condenser microphone (ECM) was modified for recording the bone conducted sound. Its sound inlet was covered in order to block air-conducted sound and the microphone was placed on the participant's forehead (Figure 1). Artificial temporary teeth were made from dental materials and they were used to cover the natural teeth of participants. The measurement was conducted while a dentist was repeatedly drilling the artificial teeth. Both the air-conducted sound and the bone-conducted sound were recorded simultaneously using a multi-channel data station (DS2000, Ono Sokki) and they were analyzed by the acoustic analysis software. This study was approved by the Ethics Committee of Osaka University Graduate School of Dentistry.

Figure 1–Measurement system with headband type microphones.

2.2 Experiment 2

To carry out the measurements repeatedly at the same conditions, we have developed an artificial tooth cut measurement model shown in Figure 2. The artificial teeth have the hardness of the two-layer structure of dentin and enamel. A microphone was attached to the inner surface of the Model in order to record solid borne sound as bone-conducted sound via teeth. Another microphone was located near the Model to record air-conducted sound. Twelve kinds of dental drills shown in Figure 2 were prepared. The bone-conducted sound and air-conducted sound were measured in drilling the artificial teeth at constant pressure. Both of sounds were recorded simultaneously using a multi-channel data station (DS2000, Ono Sokki) and they were analyzed by the acoustic analysis software in order to find the characteristics.

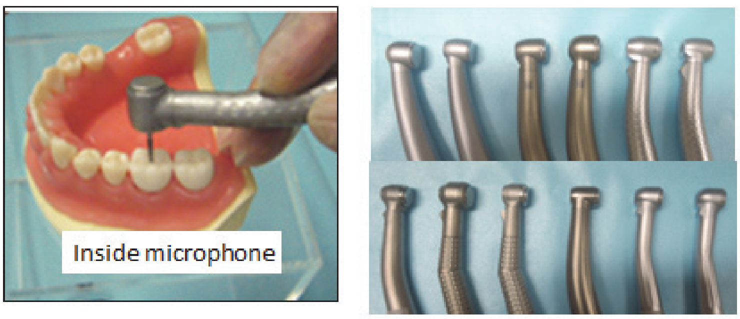


Figure 2 – Measurement Model with artificial teeth and twelve drills prepared in this experiment.

3. RESULT AND DISCUSSION

The sound while the participant was chewing a cracker was recorded using the recording system for Experiment 1 as a preliminary experiment. Figure 3 shows the results measured from the start to the end of the chewing a cracker. The sound level of the background noise in the room was 32 dB. It was found that the bone-conducted sound could be measured clearly until the end of chewing without being affected by the background noise. It was confirmed that the system can work in human.

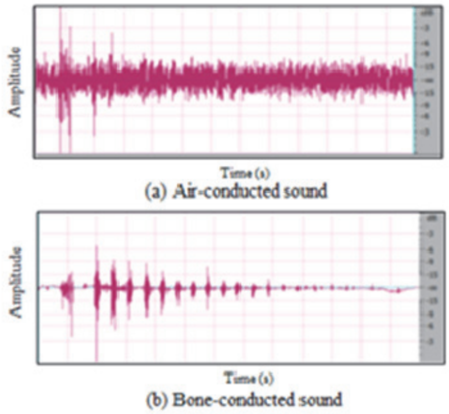
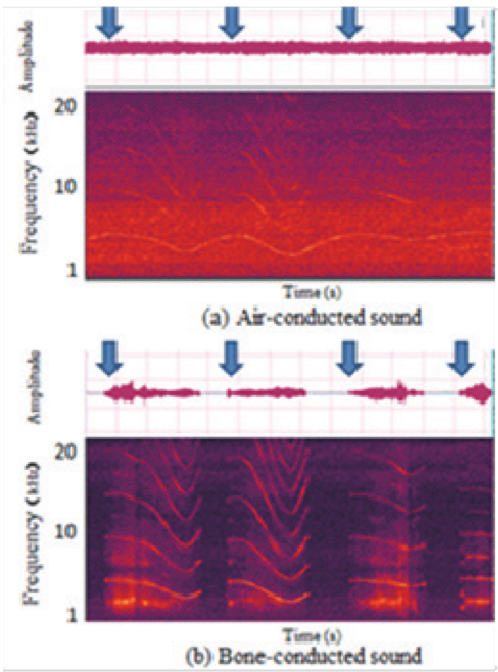


Figure 3 – Amplitude-time graphs of the air-conducted and bone-conducted mastication sounds.



Arrows indicate start of drilling.

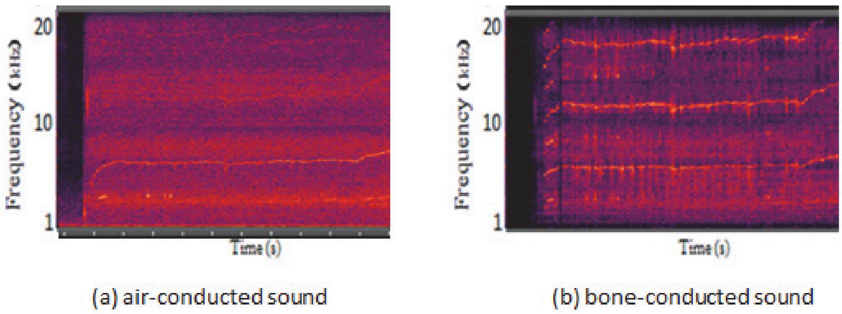
The magnitude of the brightness of the spectrums indicates the intensity of both sounds.

Figure 4 – Amplitude-time graphs and spectrograms of acquired drilling dental sounds simultaneously.

The results of drilling sound for a participant in Experiment 1 are shown in Figure 4. The arrows in Figure 4 indicate the starting point of drilling the dental material on his (or her) tooth. The recorded air-conducted sound included various noises such as water spray for cooling and compressor for operating the dental drill in addition to the drilling sound. Therefore, it was difficult when drilling had started only by the amplitude graph of air-conducted sound. On the other hand, the change of amplitude levels of bone-conducted sound showed whether the sound in drilling or not.

A characteristic frequency component at 5 kHz could be observed continuously in both drilling and idling conditions as shown in Figure 4 (a). The drill was operating while it did not contact with the teeth. There is no signal in the non-drilling time in the bone conduction sound. It was found that the frequency components around 5 kHz were generated when the drill is operated independently of the drilling. Multiple frequency components were observed up to 20 kHz in both of the air and bone-conducted sounds when drilling. Any frequency components in the bone-conducted sound were clearly observed in wide frequency region.

The results of Experiment 2 are shown in Figure 5. A prominent frequency component at 6 kHz was clearly observed in both of the air-conducted and the bone-conducted sounds. Characteristic frequency components at 12 kHz and 18 kHz were also observed in both of the air-conducted sound and bone-conducted sound. Multiple characteristic components including the basic frequency between 5 kHz and 8 kHz up to 20 kHz were observed in the drilling sound of all drills used.



The magnitude of the brightness of a spectrum indicates the intensity of both sounds.

Figure 5 – Spectrograms of simultaneously-acquired drilling dental sounds

In our former study, it was reported that there were multiple prominent frequency components up to 20 kHz including the component that at approximately 6 kHz in air-conducted dental drilling sounds. Similar results were obtained in the measurement of both of the air-conducted and bone-conducted sounds in this study.

The measurement model made in Experiment 2 seems to be useful to investigate the air-conducted and bone-conducted sounds. The similar result was obtained to the measurement in humans though the model was simple structure and it was not considering bone organization structure model. Further investigation using this model is in the process.

Clinically, a dentist drills the teeth while adjusting in the speed of the drill. As in Experiment 1, when the rotational speed changed, every frequency component was varied. When drilling teeth at a constant pressure in the Model experiment, the same fundamental frequency component was observed as shown in Figure 5. These results suggested that the fundamental frequency and its harmonics might vary depending on the rotation speed of the drill.

The same frequency spectra up to 20 kHz shown in Figure 4 and Figure 5 in drilling condition were observed in both air-conducted and bone-conducted sounds. On the other hand, there was a difference in the intensity of the characteristic components between the air-conducted and the bone-conducted sounds. In the air-conducted sound, the intensity of the fundamental frequency can be seen more strongly than those of other frequency components in high frequency region. In bone-conducted sound, the peaks of characteristic frequency components were as clear as the fundamental frequency. It was found that the intensity of the vibration in high frequency region was almost equivalent to that of the fundamental frequency.

It is possible that these high frequency components of dental drilling sounds are perceived as unpleasant feeling. In our study young people can hear pure tone in high frequency region up to 16 kHz (3). The relations between amplitude of bone-conducted sound via teeth and the perception of patients are not well known. Further the study is being investigated the perception of the bone-conducted sound.

4. SUMMARY

In this study, the air-conducted and the bone-conducted dental drilling sounds up to high frequency range were simultaneously measured during the drilling of the artificial teeth. The following results were found.

The measurement model made in this study seems to be useful to investigate the air-conducted and bone-conducted sounds. Both air-conducted and bone-conducted sounds of dental drilling sounds had the same rich frequency spectra up to 20 kHz in drilling condition. The fundamental frequency and its harmonics might vary depending on the rotation speed of the drill. In the bone-conducted sound, the intensity of these characteristic components in high frequency region was observed as the same as that of basic frequency.

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REFERENCES

1. Yamada T, Kuwano S, Ebisu S., A questionnaire survey on the effect of the sound of dental drills on the feeling of patients in dental clinics, Acoust. Sci. Tech., 27(5):305-308, 2006.
2. Yamada T, Kuwano S, Ebisu S., Effect of the sound level and frequency characteristics on the impression of the sound of dental air turbine, Proc. INTER-NOISE08, 2008.
3. Yamada T, Kuwano S, Ebisu S., Does teenagers' hearing ability affect the unpleasant feeling of the sound of a dental drill, Proc. INTER-NOISE12, 2012.