PROCEEDINGS of the
23rd International Congress on Acoustics

9 to 13 September 2019 in Aachen, Germany

Applications of psychoacoustics in dental drill noise evaluation

Tomomi YAMADA[1]; Sonoko KUWANO[2]; Mikako HAYASHI[3]

[1, 2, 3]Osaka University, Japan

ABSTRACT

The sound produced by dental drills such as a dental air turbine handpiece can markedly influence the sound environment in a dental clinic. Indeed, many patients report that the sound of a dental drill elicits unpleasant feeling. Comfortable sound environment for patients is pursued in a field of medical care as well as in daily life. The sounds emitted by dental drills at dental clinics have high frequency components up to 20,000 Hz with high sound pressure level. In this study, the effect of sound level or frequency components in high-frequency region on the subjective impression of dental noise was systematically investigated in order to find clues to create comfortable environment in dental clinics. In addition, we also performed the psychological evaluations for the effect of masker on the sounds emitted by dental drills and the results suggested that mixing frequency components may improve the subjective impression of the dental drill noise.

Keywords: Dental drill, Sound quality, Psychoacoustics

1. INTRODUCTION

The sound emitted by a dental drill has a powerful influence on the sound environment in a dental clinic. According to a questionnaire survey regarding comfortable dental environment for patients, approximately half of the respondents reported having experience of unpleasant feelings on hearing the sound of a dental drill (1). Moreover, the fear induced by the sound of a dental drill had a strong influence on dental anxiety level (1). A comfortable sound environment at dental clinics is likely to encourage patients to visit for dental evaluations and treatment, and may facilitate the maintenance of dental health, and accordingly, quality of life.Several kinds of dental apparatuses are used for cutting teeth and removing dental materials in a dental clinic, including dental high-speed air turbines and dental electrical motors (2). The sound emitted by a dental high-speed air turbine is the representative sound of dental treatment and would have a powerful influence in comparison to other devices on the sound environment in a dental clinic. Therefore, in this paper, we considered the sound emitted by dental high-speed air turbines as dental drill noise.

Various psychological measurements have been used to examine the relationship between physical values and subjective judgment in noise research and sound quality engineering for improving the sound environment. In our previous study (3), we assessed the physical values associated with the subjective impressions of 24 original sounds emitted by 12 kinds of dental drills under idling and drilling conditions. We found that the impressions of the sounds of dental drills changed substantially between the idling and active drilling conditions, and that the impressions of the sounds of dental drills consisted of two factors classified as “metallic and unpleasant” and “powerful.” Among the examined physical metrics, L_{Aeq} values were positively correlated with the “powerful impression” factor; the calculated sharpness was related to the adjective scale values for the “metallic impression” factor; and both L_{Aeq} and sharpness predicted the “unpleasant impression” of the sound of dental drills. We performed multiple regression analyses of the scale of “unpleasant adjectives” and, L_{Aeq} and sharpness, and compared the results of the multiple regression analyses with that of *Comfort Index (CI),* which is composed of L_{Aeq} and sharpness (4). In that comparison, the correlations of *CI* with “unpleasant adjectives” were almost same as that of the multiple regression analyses (3).

[1] yamada@dent.osaka-u.ac.jp
[2] kuwano@see.eng.osaka-u.ac.jp

In order to identify cues to improve the sound quality of dental drills for patients, it is necessary to examine the effect of the physical properties of the sounds of dental drills on their impressions. Generally, the main target for improving noise from various sources, particularly machines, is the reduction in sound pressure levels related to loudness (5). In this study, we prepared 13 sound stimuli under active drilling condition processed to have different sound levels or calculated sharpness value of the sounds emitted by a dental drill using sound software and conducted psychoacoustic experiment.

2. MATERIALS AND METHOD

2.1 Sound Stimuli for Psychological Experiment

Thirteen sound stimuli for psychological experiment were prepared as shown in Table 1. The sound of a dental air turbine handpieces was recorded during drilling of an artificial tooth at Osaka University Dental Hospital in a quiet environment. The sounds emitted by the dental drills were recorded using a sound level meter (LA-5560; Ono sokki) and a Digital recorder (DR7100; Ono sokki). We edited the duration of the dental drill noise recording to approximately 5 s using sound software (Auditon 2.0; Adobe) and named it Stimulus No.1. The average spectrum of Sound Stimulus No.1 is shown in Figure 1. Stimuli No.2 and No.3 were made from No.1 attenuated by 5 dB and 10 dB. Stimulus No.4 was made by attenuation of the frequency components over 9 kHz of No.1and Stimuli No. 5 and No. 6 were attenuated by 5 dB and 10 dB. Stimuli No.7, 10 and13 were made by mix-pasting noise A, B and pink noise, and Stimulus No.1in the original sound level , and adjusted the sound level using the sound software. Noise A was a dental vacuum noise and it had broad band frequency components up to 20 kHz, especially high level from 500 Hz to 10 kHz as shown in Figure 1. Noise B had only frequency components below 3.5 kHz of Noise A. The analyses, processing and calculating sharpness were conducted using sound quality software (7698, 5265; Brüel and Kjær).

Table 1 – Sound stimuli used in this experiment

Stimuli No.		L_{Aeq} (dB)	Sharpness (acum)	Fluctuation Strength (vacil)
1	Original	70	4.7	2.7
2	Attenuated of No.1 by 5 dB	65	4.7	2.6
3	Attenuated of No.1 by 10 dB	60	4.7	2.2
4	Attenuated of No.1 over 9 kHz	54	3.0	2.3
5	Attenuated of No. 4 by 5 dB	50	2.9	2.4
6	Attenuated of No. 4 by 10 dB	45	2.8	1.9
7	Mix No.1 and Noise A	63	4.1	1.9
8	Attenuated of No. 7 by 5 dB	58	4.3	1.7
9	Attenuated of No.7 by 10 dB	54	4.0	1.6
10	Mix No.1 and Noise B	65	3.9	2.6
11	Attenuated of No.10 by 5 dB	60	4.0	2.4
12	Attenuated of No. 10 by 10 dB	55	3.7	2.1
13	Mix No.1 and Pink noise	65	4.2	2.6

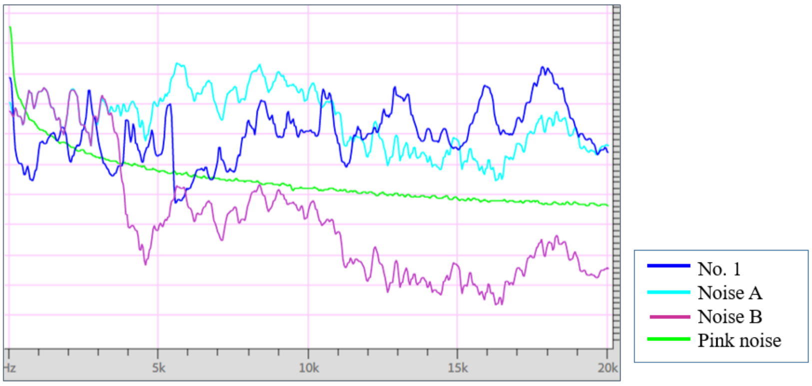

Figure 1 – The average spectra of Stimulus No.1 and the Noise used in the experiment.

2.2 Procedure of Psychological Experiment

We conducted psychological measurements using a semantic differential scale with 15 adjective pairs (see Figure 2) selected on the basis of the pre-experimental results (3). Eleven female and four male participants aged between 24 and 29 years (average, 26.3 years) participated. All of the participants were Japanese and had experienced dental treatment. Participants were seated alone in a room and instructed to judge the impression of the sound stimuli delivered through headphones (SRM-313; STAX). Before exposure to the test stimuli, participants were informed that the test stimuli consisted of the recordings of dental drill sounds. Participants were then asked to judge their impressions of the sound stimuli twice in two separate sessions.

The experiment was approved by the Ethics Committee of the Osaka University Graduate School of Dentistry. All participants provided written informed consent before taking part in the experiments.

2.3 Statistical Analysis

All statistical analyses were performed using SPSS statistical software (SPSS, Inc.), and p values of <0.05 were considered statistically.

3. RESULT and DISCUSSION

3.1 Subjective Impressions of the original sound stimuli

We found a significant correlation between the results from the two psychological evaluation sessions in all participants (Spearman's rank correlation, correlation coefficient $r = 0.73$). This result indicates that the judgments of all participants were reliable. Therefore, we combined the results of the two psychological evaluation trials in the subsequent analyses.

Figure 2 shows the results of subjective impressions to Stimuli No.1-3. As shown in Table 1, the calculated values of these stimuli were the same as 4.7 acum and the L_{Aeq} values were 70, 65 and 60 dB, respectively. There are statistically differences among the scale values of "loud" or "clamorous" for Stimuli No. 1-3. However the "unpleasant- pleasant" impressions hardly improved. Figure 3 shows the relation between the adjective scaled of "soft- loud" and L_{Aeq} of all stimuli. Overall, attenuation of the sound level seemed to improve the impression of "loud" in this experiment. The correlation coefficients between the "soft-loud" adjective scales and L_{Aeq} were 0.94.

Next, we compared the stimuli to examine the effect of the maskers. Figure 4 shows the spectra and the average of the FFT analysis of Stimuli No.2, 7 and 11. We can observe characteristic sound waveforms changing with time around 6 kHz clearly in Stimuli No.2 and 11, however, it is difficult to see the fluctuating waveform in Stimuli No.7. Figure 5 shows the results of the subjective impressions of Stimuli No. 2, 7 and 11. The score of the adjective "loud" of Stimuli No.2 and 7 (65dB and 64 dB, respectively) were evaluated nearly close, however they got different subjective evaluations on the other several adjectives. Stimulus No.11 (60 dB) was evaluated almost the same of the judgement of Stimulus No. 2.

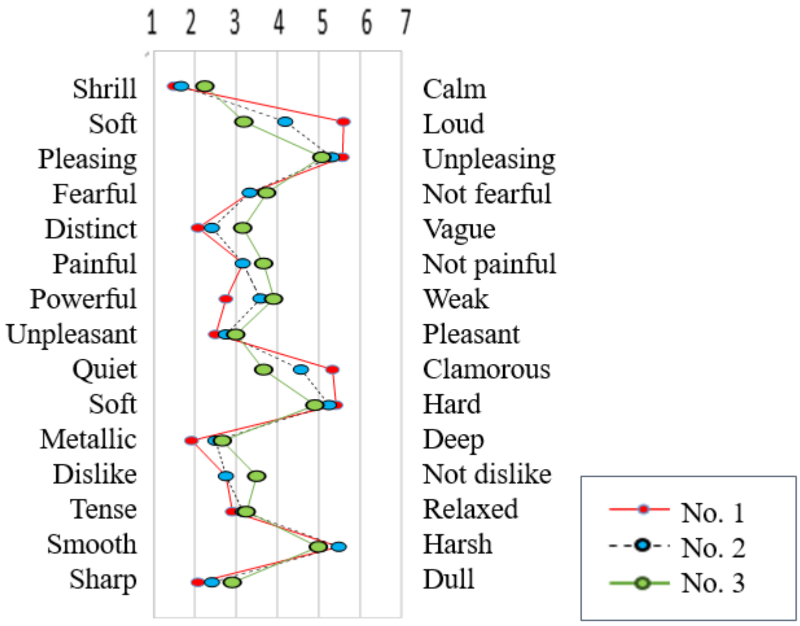

Figure 2 – Profiles of subjective impressions of the sound stimuli No.1-3.

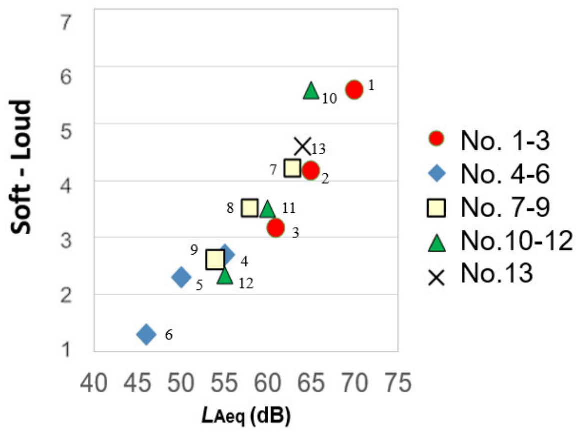

Figure 3– Relation between loudness judgement and L_{Aeq} values

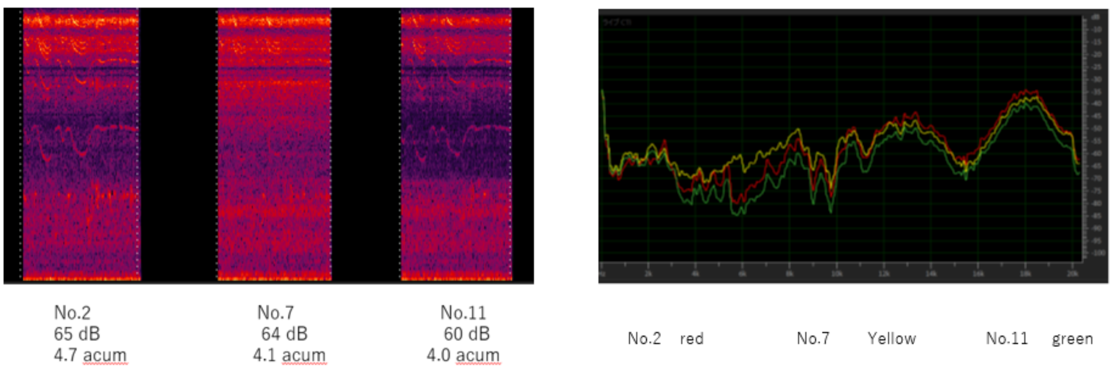

Figure 4 – Spectra and the average of FFT analysis Stimuli No, 2, 7 and 11

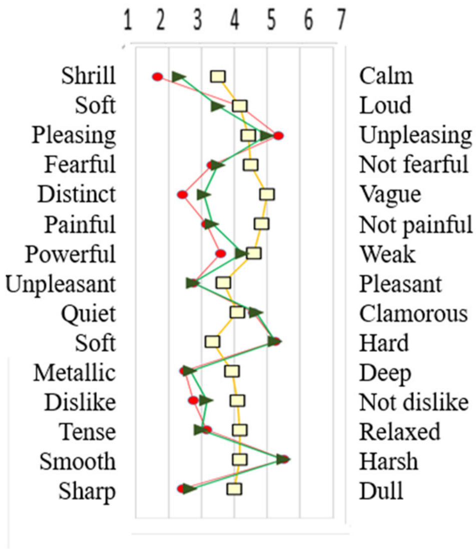

Figure 5 – Profiles of subjective impressions of the sound stimuli of Stimuli No.2(Red), No.7(Yellow) and No. 11(Green)

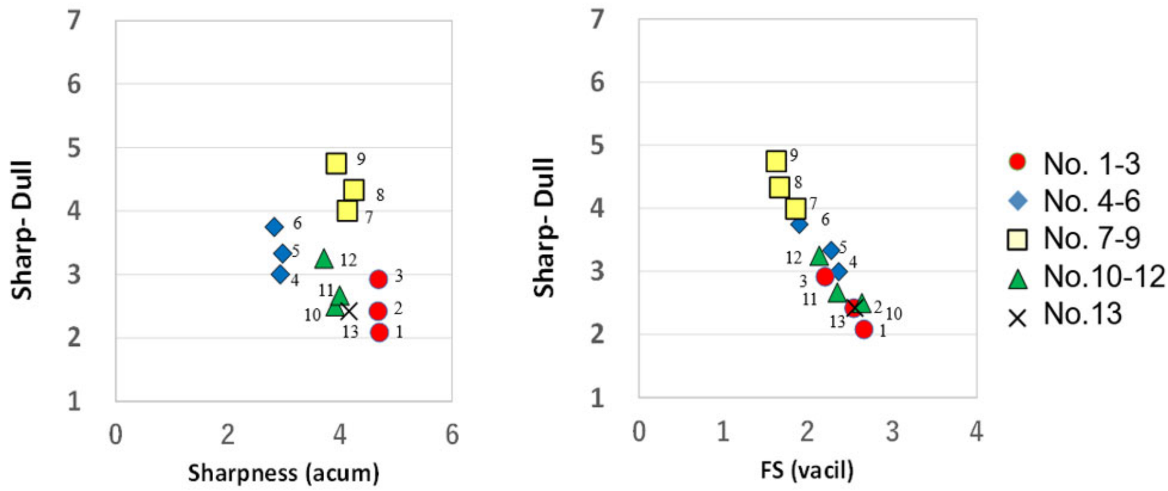

Figure 6 – Relation between the scales of “sharp- dull” and sharpness or Fluctuation strength.

Figure 6 (left) shows the relationships between the scales of “sharp-dull” and sharpness values of all stimuli. Stimuli No. 7, 8 and 9 were evaluated better on the several adjectives such as “distinct-vague”, “harsh-smooth”, “painful-not painful” than the other stimuli. The values of adjectives sharp” of No. 7, 8 and 9 were evaluated duller than Stimuli No.10-13 as the close sharpness values. And they seemed to deviate from the approximate line of the other values. The correlations between calculated sharpness and the adjective evaluations “sharp-dull” among all the stimuli (r=0.31). Figure 6 (right) shows the relationships between the scales of “sharp-dull” and Fluctuation strength of all stimuli. You can find the good correlation (r=0.98). It suggests that masking the characteristic frequency components changed fluctuation strength and affected the impression of the adjectives “distinct-vague”, “harsh-smooth”, “painful-not painful”, “pleasant-unpleasant” and so on.

Although we recognize that technical concerns often limit the capacity to reduce sound pressure levels and frequency components in reality, we conducted the experiment under the conditions of the stimuli prepared. We will examine the effect to sound quality in more details to realize the improvement of dental drills into consideration.

4. FINAL REMARKS

In this paper, we examined sounds emitted by dental high-speed air turbines as dental drill noise. We conducted psychological experiment using semantic differential to facilitate potential modifications of the sounds of dental drills.

The results showed that overall attenuation of the sound level and attenuation of the frequency components over 9 kHz of the original test stimuli statistically improved the scale of "soft-loud" in comparison with the original sound stimuli. Attenuation of the frequency components over 9 kHz and mixture of the frequency components were effective of the scale of "pleasing- unpleasing".

The present findings suggest that reducing the sound pressure level and refining the frequency characteristics of sounds emitted by dental drill considering acoustical characteristics is important for creating a comfortable sound environment in dental clinics.

ACKNOWLEDGEMENTS

This work was supported by a grant-in-Aid for Scientific Research (No. T15K111110 and 19K10148) from the Japan Society for the Promotion of Science.

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 2006;27:p. 305–8.
2. International Organization for Standardization. ISO 14457: Dentistry—Handpieces and motors. International Standard. Geneva, Switzerland, 2017.
3. Yamada T, Kuwano S, Ebisu S, Hayashi M. Statistical analysis for subjective and objective evaluations of dental drill sounds. PLoS One 2016;11:e0159926.
4. Kuwano S, Namba S, Takehira O, Fastl H. Subjective impression of copy machine noises: An examination of physical metrics for the evaluation of sound quality. Proc. InterNoise.09 23-26 August; Ottawa, Canada 2009.
5. Fastl H. Section 3: Psychoacoustics and product sound quality. In: Kuwano S, editor. Recent topics in environmental psychoacoustics, Osaka: Osaka University Press; 2008, p. 63–87.