NEGATIVE EFFECTS OF DENTAL EQUIPMENT NOISE ON DENTAL PROFESSIONALS' HEALTH QUALITY

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Dental equipment noise is generally recognized as a major noise source in dental environment. Dental professionals unavoidably suffer the noise from different equipment operations and other noise sources in their daily work. The aims of this study were to assess the differences in the acoustical environment between different regular dental procedures, and to analyse the negative effects of noise on dental professionals' health quality. Oral surgery provisions (OSP) and dental casting preparations (DCP) are the dental procedures requiring the dental equipment operations. Sound quality assessments were conducted to assess the environmental changes in the A-weighted sound level (*LA*), total loudness (*N*), and sharpness (*S*) of the noise during the equipment operations. After that, the questionnaire surveys were conducted to assesses the perceptual influence of the noise on the surrounding dental professionals in the Prince Philip Dental Hospital of Hong Kong. The 5%-percentile values of *LA*, *N*, and *S* were significantly higher in the DCP than that of the OSP. Moreover, the degree of the professionals' perceptions of the influences from the dental equipment noise, health, satisfaction, indoor environmental quality (IEQ) condition were significantly higher in the DCP than that of the OSP. Furthermore, the degree of the professionals' perceptual influences from the noise sources, satisfaction, IEQ and hearing conditions were positively correlated to the change of loudness (*N_5 and N_diff*) in the environment. The results showed that the acoustical environment was significantly affected by the dental equipment applications and raised our attention on the designs of the noise precaution works for the dental professionals who suffer the occupational noise exposure from the dental equipment operations.

Keywords: dental equipment noise, dental equipment operation, dental professionals, health quality, sound quality assessment

1. Introduction

In building acoustics [1], not only the background noise from building facilities, but also different major noise sources in the building would affect the acoustical environment. A complete sound quality assessment is essential for a successful noise prediction in considering all possible noise sources in any building environment. Various dental equipment is required to applied in the different dental treatment as teeth is the hardest part of human body. For example, using high speed dental handpieces, ultrasonic scaler, triple syringe and saliva ejector in oral surgery provisions (OSP), or using dental grinder, air compressor, and ortho cut in dental casting preparation (DCP) are the two most common dental procedures in the routine work of dental professionals. Previous studies showed that the noise in the dental environment was in high sound pressure level [2] with the high frequency content [3], and the noise levels were variated in the different dental procedures [4-6]. Hence, dental equipment noise as a major noise source in a dental environment is unavoidably perceived by dental professionals in their daily work.

The previous systematic review [7] disclosed that the three major human perceptual dimensions of sound were "*Evaluation*", "*Potency*" and "*Activity*", which are referred to the general judgment, the sensation to magnitude and the temporal and spectral sensation to sounds. Therefore, the sound quality assessment in this study covered the measurements of A-weighted sound level (*LA*), total loudness (*N*), and sharpness (*S*) of the acoustical environment. *LA* and *N* are the indicators of the "*Potency*" component since the frequency weighting adjusted for the human ear response was included in the *LA* and *N* [8] calculations. The difference between *LA* and *N* is that *LA* is the variable of energy quantity and N is the variable of predicted human loudness perception. The *N* of a sound of 40 dB in 1 kHz is defined to be 1 sone. The doubling of *N* means the doubling of the loudness perception. Meanwhile, *S* is the indicator of the "*Activity*" component. The higher the ratio of the energy in high frequency component (> 1 kHz) to that of low frequency component, the higher *S* value will be measured.

Moreover, the environmental noise was found to be associated with the subjects' working performance [9, 10], health [11], hearing, and satisfaction conditions [12]. The understanding of how the acoustical environment is variated in the different dental procedures is important for reducing the occupational hazards [13, 14] to dental professionals from the long-term exposure [15] of dental equipment noise. Therefore, the additional subjective measurement was applied to assess the dental professionals' health quality in term of their perceptual influences of noise, indoor environmental quality (IEQ), health, hearing, and satisfaction conditions. Since the sound quality assessment measured the general acoustical environment as a whole. The subjective measurement having the individual questions specific to the certain noise sources can provide a more comprehensive investigation of the effects on dental professionals from the different noise sources in the dental environment.

The purposes of the study were to (1) access the differences in the acoustical environment in term of *L*, *N*, and *S* in the two different regular dental procedures (OSP and DCP), and to (2) analyse the negative effects of noise on the dental professionals at the environment.

2. Methods

The on-site measurements of the study were divided into two sections. All the measurements were recorded in a random weekday at the Prince Philip Dental Hospital in Hong Kong.

2.1 Sound quality assessment

The first section was the sound quality assessment. An advanced, 2-channel, handheld analyzer (Type 2270; Bruel & Kjaer, Naerum, Denmark) was used to assess the acoustical environment during the regular dental procedures. Half of the 60 assessments were recorded for the OSP and others were for the DCP. The elapsed time of the assessments was three minutes. The sound quality of the acoustical environment was represented by the three objective variables *LA*, *N*, and *S*. In order to investigate the change in acoustical environment comprehensively, the seven percentiles (1%, 5%, 10%, 50%, 90%, 95%, and 99%) instead of the time-averaging value were reordered and analysed in the study. For example, the seven percentiles of *LA* are *LA_1, LA_5, LA_10, LA_50, LA_90, LA_95, and LA_99*. *LA_5* is the A-weighted sound level exceeded for 5% of the elapsed time while *LA_95* is the A-weighted level exceeded for 95% of the elapsed time. Thus, *LA_5* and *LA_95* can be treated as the variables corresponded to the sound levels of the dental equipment noise and the background noise in the dental procedures respectively. Furthermore, the variations of the variables were calculated from the difference between the 5% and 95% percentiles. i.e. *LA_diff = LA_5 – LA_95, N_diff = N_5- N_95, S_diff = S_5 – S_95*.

2.2 Subjective measurement

The second section was the subjective measurement. A self-administrated questionnaire survey was conducted to measure the negative effects of noise on the dental professionals. The questionnaires were distributed to and collected from the dental professionals after the sound quality assessments in the OSP or DCP. The questionnaire (see Table 1) was formed by the four questions about the dental professionals' personal background (Part 1), the seven questions about the degree of influences from the seven noise sources (Part 2), and the four questions about the general perceptions of the conditions (Part 3). A five-points Likert scale was applied in the questions of Parts 2 and 3. The degree of influence from "Not at all", "Occasionally", "Medium", "Often", to "Very often" was rated from 1 to 5. The condition of "Very good", "Good", "Medium", "Bad", and "Very bad" was rated from 1 to 5. All the data in the statistical analysis was coded and analysed by the commercial package SPSS, version 23.0 (IBM Corp., Armonk, NY, USA). The Mann-Whitney U tests were used to compare the differences between the values of acoustical variables in the two different dental procedures. Moreover, the Spearman's rank correlation tests were applied to test the correlations and to find the correlation coefficients (Spearman's ρs) between the acoustical variables and the negative effects on the dental professionals. All the significant level in the tests was set to be 0.05.

Table 1: Summary of the questionnaire in the subjective measurement.

Parts	Number of Questions	Questions	Scales
Part 1: Personal Background	4	(I) Type of Procedure; (II) Age Range; (III) Service Length; (IV) Daily Working Hours	Nominal and Ordinal
Part 2: Degree of Influences from the Noise Sources	7	(I) Own Operated Dental Equipment, (II) Others Operated Dental Equipment, (III) Other Machines e.g. Computers, (IV) Conversation, (V) Cell Phones, (VI) Air-conditioning System, and (VII) Broadcasting System	Five-point Likert scale
Part 3: General Perceptions of the Conditions	4	(I) Hearing Condition, (II) Health Condition, (III) Satisfaction Condition, and (IV) Indoor Environmental Quality	Five-point Likert scale

3. Results

3.1 Sound quality assessment

The distributions and the medians of the percentiles of recorded *LA*, *N*, *and S* were plotted in the Fig. 1. In general, the medians of the percentiles of the all acoustical variables were higher in the DCP than that in the OSP. All the 5%-percentile values (*LA_5*, *N_5*, *and S_5*) were significantly higher in the DCP (*ps* < 0.01; see Table 2). The 50%-percentile values of *LA* and *N* but not that of *S* were also significantly higher in the DCP (*ps* < 0.01). The loudness increment (*N_diff*) of the noise in the environment was significantly larger in the DCP (*p* = 0.019).

Table 2: Medians of the acoustical variables in the two regular dental procedures.

Variables	Oral Surgery Provisions	Dental Casting Preparations	Unit	Remarks
LA_5	66.8	69.3	dBA	**
LA_50	59.2	61.9	dBA	**
LA_95	54.9	56.4	dBA	
LA_diff	12.9	13.2	dBA	
N_5	22.2	27.2	sone	**
N_50	12.3	15.5	sone	**
N_95	9.70	10.3	sone	
N_diff	13.2	15.8	sone	*
S_5	1.44	1.78	acum	**
S_50	1.53	1.59	acum	
S_95	1.52	1.51	acum	
S_diff	-0.40	0.12	acum	

* $p < 0.05$ or ** $p < 0.01$ in the Mann-Whitney U tests of the variables in the regular dental procedures.

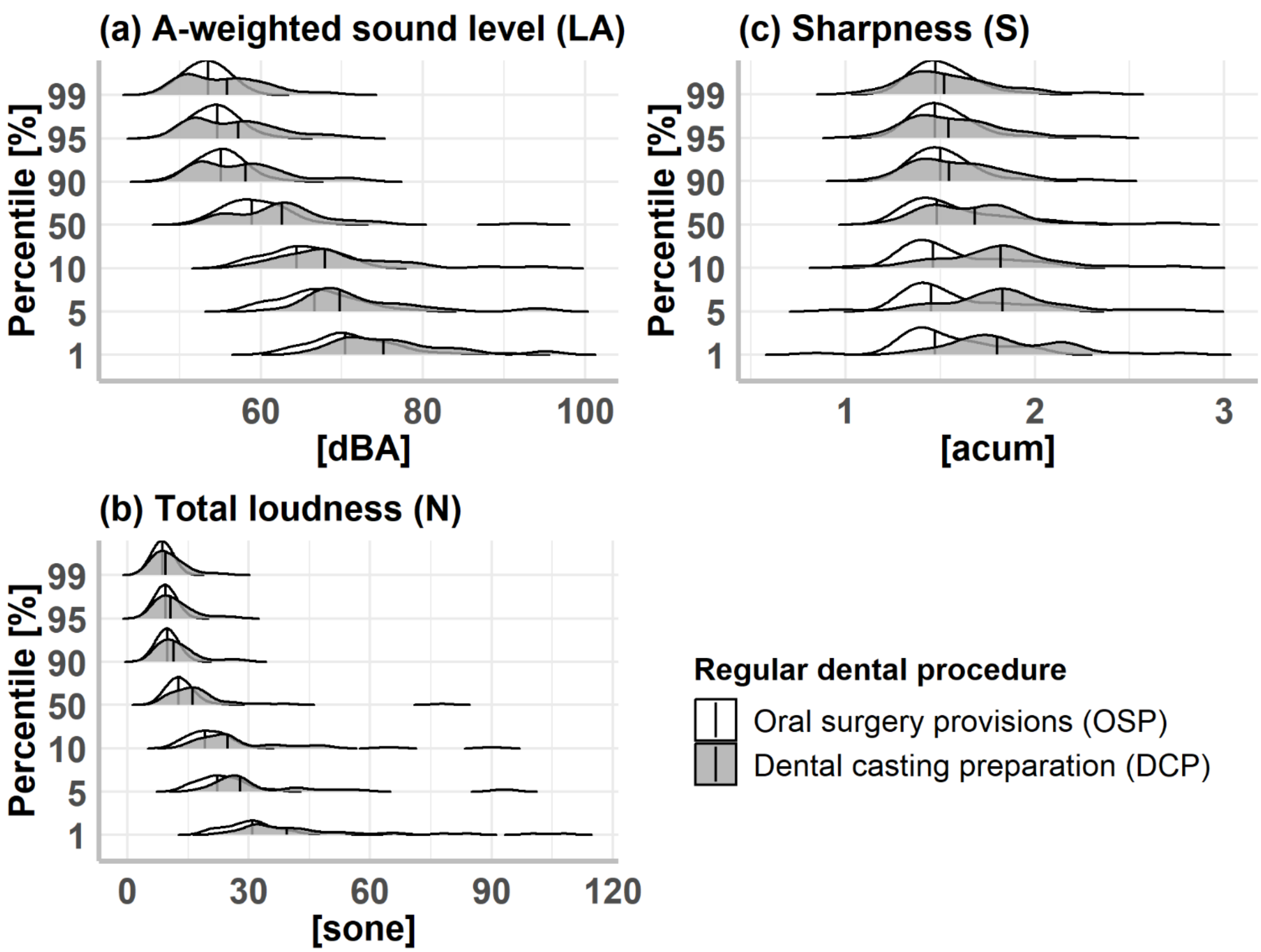

Figure 1: The distribution of the percentiles (1%, 5%, 10%, 50%, 90%, 95%, and 99%) of the (a) A-weighted sound level, (b) total loudness, and (c) sharpness of the noise in the regular dental procedures.

3.2 Subjective measurement

The mean and standard derivation (SD) values of the degree of influence from the seven noise sources were showed in the Table 3. The three most influential noise sources be reported by the dental professionals were the own operated dental equipment noise, others operated dental equipment noise, and conversation noise. The influence from all operated dental equipment noise was computed by adding up the degree of influences from own and others operated dental equipment noise. The degree of influences from the own operated equipment noise (p = 0.049), all operated equipment noise (p = 0.028), and noise of other machines (p = 0.021) were significantly higher in the DCP than that of the OSP. In addition, the health condition (p = 0.019), satisfaction condition (p = 0.011), and IEQ (p < 0.01) were reported to be significantly worse for the dental professionals in the DCP than that of OSP.

Table 3: Subjective measurement results of the dental professionals (n = 60) in the two dental procedures.

Questions	Oral Surgery Provisions	Dental Casting Preparations	Scale	Remarks
Own Operated Dental Equipment	2.50 ± 1.25	3.00 ± 0.83	1-5	*
Others Operated Dental Equipment	2.67 ± 1.09	3.17 ± 0.87	1-5	
All Operated Dental Equipment	5.17 ± 2.19	6.17 ± 1.56	1-10	*
Other Machines e.g. Computers	1.50 ± 0.73	1.17 ± 0.53	1-5	*
Conversation	2.77 ± 0.86	2.57 ± 1.19	1-5	
Cell Phones	1.60 ± 0.68	1.63 ± 0.77	1-5	
Air-conditioning System	1.73 ± 0.94	1.57 ± 0.73	1-5	
Broadcasting System	2.03 ± 1.19	1.57 ± 0.82	1-5	
Hearing Condition	2.80 ± 0.96	3.20 ± 0.81	1-5	
Health Condition	2.53 ± 0.90	2.97 ± 0.06	1-5	*
Satisfaction Condition	3.27 ± 0.91	3.80 ± 0.76	1-5	*
Indoor Environmental Quality	3.43 ± 0.73	3.93 ± 0.64	1-5	**

* p < 0.05 or ** p < 0.01 in the Mann-Whitney U tests of the variables in the two dental procedures.

3.3 Spearman rank correlation test results

The degree of influences from own and others operated equipment noise were found to be positively correlated with the values of *LA_5*, *N_5*, and *N_diff* (*ps* < 0.05; see Table 4). The degree of influences from noise of other machines was negatively correlated with the values of *LA_5, N_5, LA_50, N_50*, and *N_diff* (*ps* < 0.05). Moreover, the degree of influence from conversation noise was negatively associated with the value of *S_diff* (*ps* < 0.05). For the general perception of the conditions, the values of *LA_5, N_5, LA_50, N_50,* and *N_diff* were correlated with the professionals' perceptions of the hearing condition, satisfaction conditions, and IEQ (*ps* < 0.05). In the same time, the value of *S_5* was associated with the perceptions of hearing condition (p < 0.01) and IEQ (p < 0.05). While *S_50* was only associated with the hearing condition of the professionals.

Table 4: Spearman rank correlation coefficients between the variables in the sound quality assessment and the subjective measurement.

Variables	*LA_5*	*N_5*	*S_5*	*LA_50*	*N_50*	*S_50*	*LA_diff*	*N_diff*	*S_diff*
Own Operated Dental Equipment	0.27*	0.28*	/	/	/	/	/	0.26*	/
Others Operated Dental Equipment	0.30*	0.28*	/	/	/	/	/	0.28*	/
All Operated Dental Equipment	0.30*	0.30*	/	/	/	/	/	0.28*	/

Other Machines e.g. Computers	-0.35*	-0.33*	/	-0.31*	-0.28*	/	/	-0.32*	/
Conversation	/	/	/	/	/	/	/	/	-0.26*
Hearing Condition	0.30*	0.31*	0.33**	0.31*	0.30*	0.32*	/	0.26*	/
Indoor Environmental Quality	/	0.31*	0.27*	0.26*	0.26*	/	/	0.26*	/
Satisfaction Condition	/	0.34**	/	0.28*	0.26*	/	/	0.30*	/
Health Condition	/	/	/	/	/	/	/	/	/

* $p < 0.05$ or ** $p < 0.01$ in the Spearman rank correlation tests between the variables.

4. Discussions

The results of the sound quality assessment showed that the acoustical environment was significantly affected by the dental equipment operations in the environment. The significantly higher 5%-percentile values demonstrated that the applied dental equipment in the DCP was significantly louder and sharper than that in the OSP. The results matched with the noise level measurement results of the other researchers [4, 16]. The noise level in the grinder operation was larger than that of the dental handpieces, ultrasonic scaler, triple syringe and saliva suction operations [16]. Since *N* is in linear scale but *LA* is in logarithm scale. The significant loudness increment in the DCP was shown by the value of *N_diff* but not *LA_diff*, even though both *LA* and *N* accounted for the human ear response in their calculations. It also explained why *N* is a more suitable variable in presenting the loudness changes by calculating the different between the 5%- and 95%- percentile values.

In the results of the subjective measurement, dental equipment noise and conversation noise were the two common noise sources existing in the all dental environment. It agreed with the study results of the unpleasantness perception from those noise sources [17]. Moreover, the significantly higher degree of influence from the dental equipment noise in the DCP than in the OSP was consistent with the results of the sound quality assessment. Meanwhile, the degree of influence of noise other machines was reduced when the loudness increment of dental equipment became more dominated. Also, the health condition, satisfaction condition and IEQ were found to be worse for the dental professionals in the DCP. It gave the insight of the negative effects of dental noise equipment noise on dental professionals' health quality.

The 5%-, 50%-, and 95%-percentile values were selected in the study because the values gave the information about the own operated dental equipment noise, the information about all operated equipment noise, and the information about the background noise respectively. The further statistical analysis hence strengthened the evidence of the influences of the acoustical environment on the dental professionals' health quality. The results of the Spearman rank correlation tests illustrated the importance of the *LA_5*, *N_5*, and *N_diff* in assessing the noise influences of the major noise source, which was the operated dental equipment noise in the study. The supplementary assessment of *N_50* and *LA_50* was needed if the study focus was on the overall influence of the combined noise from dental equipment and other machines. In addition, the importance of the values *LA_5, N_5, LA_50, N_50, and N_diff* in assessing the general health quality was supported by the positive correlation between the variables and the dental professionals' hearing condition, satisfaction condition, and IEQ. Furthermore, the value of *S_5* was decreased with the increment of the noise influence from conversation noise. It was because the dental equipment noise was a higher frequency noise than that of conversation noise. Since the health condition of the dental professionals was affected by many factors such as psychological factors [18] other than the acoustical environment. It was reasonable for the negative results of the direct correlation between the dental professionals' health condition and the acoustical variables. Nonetheless, the significant correlations between the values of *LA, N,* and *S* and the dental professionals' hearing condition were found in the study.

Noise prediction is a key factor in building acoustics [19]. The study results implied that the negative effects on dental professionals were predictable not only from the noise of outdoor sources [20, 21] and building faculties [22], but also from the major noise sources in the environment. It will benefit the future noise control [23, 24] and attenuation [25] designs from the advanced noise prediction work.

5. Conclusion

The acoustical environment was affected by the dental equipment operations in the regular dental procedures. The dental equipment noise produced in the DCP were worse than that in the OSP as the results of higher *LA_5*, *N_5*, and *S_5*. Also, the loudness increment (*N_diff*) was significantly larger in the DCP than that in the OSP. The sound quality assessment results were supported by the finding of the significantly higher degree of influences from dental equipment noise in the DCP than that in the OSP. Moreover, the correlation test results showed the dental professionals' hearing condition, satisfaction condition and IEQ were positively associated with the values of *LA_5, N_5, LA_50, N_50* and the *N_diff* of the environmental noise. The professionals' hearing condition was also associated with the value of *S_5*. The results implied that there were the negative effects of dental equipment noise on the dental professionals' health quality and the effects were predicable from the acoustical variables of the acoustical environment. The importance of the noise control in the building acoustics was hence demonstrated in the study.

6. Acknowledgements

This work was supported by a grant from the Hong Kong Polytechnic University (PolyU Project account: G- YBSJ).

REFERENCES

1 Mak, C.M. Special issue on building acoustics and noise control, Building and Environment, **94**(Part 2), 751, (2015).

2 Kadanakuppe, S., Bhat, P.K., Jyothi, C., and Ramegowda, C. Assessment of noise levels of the equipments used in the dental teaching institution, Bangalore, Indian Journal of Dental Research, **22**(3), 424-431, (2011).

3 Trenter, S. and Walmsley, A. Ultrasonic dental scaler: associated hazards, Journal of clinical periodontology, **30**(2), 95-101, (2003).

4 Dutta, A., Mala, K., and Acharya, S.R. Sound levels in conservative dentistry and endodontics clinic, Journal of conservative dentistry: JCD, **16**(2), 121-125, (2013).

5 Setcos, J.C. and Mahyuddin, A. Noise levels encountered in dental clinical and laboratory practice, International Journal of Prosthodontics, **11**(2), 150-157, (1998).

6 Bahannan, S., El-Hamid, A.A., and Bahnassy, A. Noise level of dental handpieces and laboratory engines, The Journal of prosthetic dentistry, **70**(4), 356-360, (1993).

7 Ma, K.W., Wong, H.M., and Mak, C.M. A systematic review of human perceptual dimensions of sound: Meta-analysis of semantic differential method applications to indoor and outdoor sounds, Building and Environment, **133**, 123-150, (2018).

8 International Organization for Standardization, ISO 532: Acoustics - Method for calculating loudnesslevel. 1975, International Standardization: Geneva, Switzerland.

9 Kang, S., Ou, D., and Mak, C.M. The impact of indoor environmental quality on work productivity in university open-plan research offices, Building and Environment, **124**, 78-89, (2017).

10 Mak, C.M. and Lui, Y. The effect of sound on office productivity, Building Services Engineering Research and Technology, **33**(3), 339-345, (2012).

11 Leggat, P.A., Kedjarune, U., and Smith, D.R. Occupational health problems in modern dentistry: a review, Industrial health, **45**(5), 611-621, (2007).

12 Ma, K.W., Wong, H.M., and Mak, C.M. Dental Environmental Noise Evaluation and Health Risk Model Construction to Dental Professionals, International Journal of Environmental Research and Public Health, **14**(9), 1084, (2017).

13 Ai, Z., Mak, C., and Wong, H. Noise level and its influences on dental professionals in a dental hospital in hong kong, Building Services Engineering Research and Technology, **38**(5), 522-535, (2017).

14 Ayatollahi, J., Ayatollahi, F., Mellat Ardekani, A., Bahrololoomi, R., Ayatollahi, J., Ayatollahi, A., and Owlia, M.B. Occupational hazards to dental staff, Dental research journal, **9**(1), 2-7, (2012).

15 Theodoroff, S.M. and Folmer, R.L. Hearing loss associated with long-term exposure to high-speed dental handpieces, Gen Dent, **63**(3), 71-76, (2015).

16 Choosong, T., Kaimook, W., Tantisarasart, R., Sooksamear, P., Chayaphum, S., Kongkamol, C., Srisintorn, W., and Phakthongsuk, P. Noise exposure assessment in a dental school, Safety and health at work, **2**(4), 348-354, (2011).

17 Wong, H.M., Mak, C.M., and Xu, Y.F. A four-part setting on examining the anxiety-provoking capacity of the sound of dental equipment, Noise and Health, **13**(55), 385, (2011).

18 Mak, C. Development of a prediction method for flow-generated noise produced by duct elements in ventilation systems, Applied Acoustics, **63**(1), 81-93, (2002).

19 Mak, C.M. and Wang, Z. Recent advances in building acoustics: An overview of prediction methods and their applications, Building and environment, **91**, 118-126, (2015).

20 Mak, C., Leung, W., and Jiang, G. Measurement and prediction of road traffic noise at different building floor levels in Hong Kong, Building services engineering research and technology, **31**(2), 131-139, (2010).

21 To, W.M., Mak, C.M., and Chung, W.L. Are the noise levels acceptable in a built environment like Hong Kong?, Noise & health, **17**(79), 429-439, (2015).

22 Mak, C. and Yang, J. A prediction method for aerodynamic sound produced by closely spaced elements in air ducts, Journal of Sound and Vibration, **3**(229), 743-753, (2000).

23 Ou, D. and Mak, C.M. The effects of elastic supports on the transient vibroacoustic response of a window caused by sonic booms, The Journal of the Acoustical Society of America, **130**(2), 783-790, (2011).

24 Cai, C. and Mak, C.M. Noise control zone for a periodic ducted Helmholtz resonator system, The Journal of the Acoustical Society of America, **140**(6), EL471-EL477, (2016).

25 Shi, X. and Mak, C.M. Sound attenuation of a periodic array of micro-perforated tube mufflers, Applied Acoustics, **115**, 15-22, (2017).