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Workplace noise exposure and audiometric thresholds in dental technicians

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ABSTRACT

Noise is a well-known risk factor in occupational medicine. Several studies have been performed in workplaces with noise sources, especially in the industrial field; on the contrary, only a few studies have been carried to evaluate the noise exposure effects in non-industrial workplaces such as small factories, handicraft laboratories, and dental laboratories. The aims of this study were to evaluate workplace noise exposure and hearing thresholds in dental technicians. Four laboratories and 51 dental technicians were included in the study. Noise exposure levels during a nominal eight-hour working day (LEX, 8 h) were assessed in the included laboratories. Audiometric thresholds with pure tone audiometry were performed in 51 dental technicians, and results were compared with those expected in subjects not exposed to noise. The environmental noise measures showed moderate differences of the LEX, 8 h among the four laboratories (range 71.4 to 76.2); average LEX, 8 h was 73.9 ± 2.2 dB(A). The audiometric results showed a progressive increase of hearing threshold values at the frequencies mostly involved in noise-induced hearing loss (3, 4 and 6 kHz) and a correlation with age and working seniority especially in males ($p<0.005$). Nevertheless, in the 92.1% of subjects the threshold increases were in line with those expected in subjects of the same age and sex not exposed to noise and in the remaining 7.8% were not statistically significant ($p>0.05$). In 3.9% of the cases the increases were bilateral, typical of noise-induced hearing loss, and only 1.9% showed involvement of several frequencies with worsening of expected thresholds >25 dB. In conclusion, our study showed that exposure to noise in dental laboratories was not sufficient to represent a hazard to hearing, as demonstrated by the LEX, 8 h, which were below 80 dB(A) and therefore below the European exposure limit values and exposure action values for workers.

Keywords: Noise-induced hearing loss, environmental noise, dental laboratory, dental technicians.

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INTRODUCTION

Noise is a well-known risk factor in occupational medicine; it is considered the most widespread pollutant in the workplace and there are many international organizations involved in its management[1-9]. Specific effects on the auditory system, as well as specific and nonspecific effects on other organs, can be attributed to noise[10,11]. While non-specific effects are still under discussion, specific effects on the auditory system especially following oxidative stress - are well known and have been widely described in the literature[12-18], as well as possible interferences between noise and ototoxic substances[19-23]. Noise-induced hearing loss is typically a bilateral and symmetrical non-reversible sensorineural hearing loss that initially affects the 3-6 kHz frequencies and then extends to mid and low frequencies[24-29]. Several studies have been performed in workplaces with noise sources, especially in the industrial field[30-33]. On the contrary, only a few studies have been carried to evaluate the noise exposure effects in non-industrial workplaces such as small factories, handicraft laboratories, and medical facilities[34-38]. Dental technicians are a population subject to several occupational risks, such as skin allergy to acrylates (chemicals widely used in dental techniques)[39] respiratory irritation and infections[40-46] and accidents[47,48]. In this field, exposure to noise produced by turbine drills, micromotors, compressors, sandblasters, model trimmers, circular saws for plaster has been mainly studied in dentists and dental hygienists[49-53] however, there is a lack on specific studies that demonstrate unequivocally the presence or absence of auditory effects in dental technicians that have a peculiar role in dental practice. Furthermore, studies on hearing thresholds at different frequencies in this population are lacking. The purpose of this study is to explore the effects of noise exposure in dental technicians through observations conducted in dental laboratories, aiming at a) assessing the environmental noise levels in dental laboratories and 2) identifying alterations compatibles with occupational noise exposure in the audiometric profile of dental technicians, even at an early stage.

MATERIALS AND METHODS

This study included 52 subjects, 29 males (55.8%) and 23 females (44.2%) working in four different dental laboratories (laboratory 1-4). Inclusion criteria were age between 18 and 68 years working as dental technicians. Exclusion criteria were subjects with history of unrelated noise exposure, ipsilateral or contralateral middle ear pathology, retrocochlear pathology, previous ear surgery. The study was performed in accordance with the Helsinki declaration and its amendments. Informed consent was obtained from all the participants.

Environmental Noise Level Assessment: An environmental noise level assessment was performed in four dental laboratories in the city of Rome, Italy, using an integrated sound level meter (Cel Instument Ltd, Type 573.CIT, version 98.0) and an acoustic calibrator (Cel Instrument Ltd, Model 284/2) class 1, according to IEC standards. Three measurements were performed in each workplace with several noise sources, placing the microphone at ear height of workers and at a distance of 10 cm. The “daily noise exposure levels" (LEX, 8 h) were used as specific indicators of occupational risk, according to the European legislation on minimum safety and health requirements for workers exposed to noise (Directive 2003/10/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents). These levels are defined by the International Standard Organization (ISO 1999/1990) and are substantially time-weighted average values, representing the average level of noise exposure during a nominal 8 hour working day. The LEX, 8 h detected in the dental facilities were compared with the exposure limit values and exposure action values (upper and lower) established by the European Union.

Audiological Evaluation: Dental technicians working in each of the four dental laboratories underwent full otolaryngologic examination, Pure Tone Audiometry (PTA) and auditory immittance testing. PTA was performed in a soundproof room after an acoustic rest of at least 16 h. The audiometer was calibrated according to 389-1979 ISO and PTA was performed according to 6189 ISO. The air and bone-conducted hearing thresholds were measured at the 0.25, 0.5, 1, 2, 3, 4, 6 and 8 kHz frequencies in both ears. The hearing thresholds were compared with those expected in normal subjects of the same age not exposed to work-related noise and without otological diseases, corresponding to the mean values of the group A of the international standard ISO 1999/1990. The reference frequencies were 3, 4 and 6 kHz.

Interview: All subjects were interviewed by an occupational medicine physician on individual clinical history, noise exposure and otolaryngologic symptoms. In details, the interview investigated systemic pathologies (arterial hypertension, diabetes, dyslipidemia, cranial trauma, intracranial hypertension), otorhinolaryngologic conditions (acoustic neuroma, neuritis), use of ototoxic drugs (salicylates, Nonsteroidal anti-inflammatory drugs, loop diuretics, antibiotics), infectious diseases (meningitis, herpes zoster, cytomegalovirus). The interview also investigated previous history of specific leisure activities, such as hunting and playing a musical instrument, and work history, with particular attention to the tools used, the length and frequency of daily exposure, duration of current work, and previous jobs.

Statistical Analysis: The data were processed statistically using SPSS (Statistical Package for Social Science) 17.0 software. The analysis of possible associations between increases of auditory thresholds compared to those

Table 2: The results of the comparison of the results of the survey for the psychosocial consequences of tinnitus with the parameters of the loudness of tinnitus.

Tinnitus Acceptable	No (n=65)		Yes (n=57)			
Loudness tinnitus (VAS; mm)	**Mean**	**SEM**	**Mean**	**SEM**	**P-value**	
Mean	68.8	3.4	57	3.4	0.016	Sign.
Minimal	45.5	4.3	41.7	3.5	0.493	
Maximal	84.3	3.1	73	2.9	0.004	Sign.
Difference Maximal and Minimal	32.7	3.3	40.2	4.1	0.155	
Concentration Disturbed	Yes (n=75)		No (n=49)			
Loudness tinnitus (VAS; mm)	**Mean**	**SEM**	**Mean**	**SEM**	**P-value**	
Mean	65.3	3.6	59.2	3.8	0.224	
Minimal	42.5	3.6	44.2	4.3	0.765	
Maximal	83.6	2.3	71.3	3.3	0.003	Sign.
Difference Maximal and Minimal	43.3	3.5	27.4	3.6	0.002	Sign.
Can resist their tinnitus	No (n=54)		Yes (n=63)			
Loudness tinnitus (VAS; mm)	**Mean**	**SEM**	**Mean**	**SEM**	**P-value**	
Mean	69.3	3.6	56.4	3.3	0.010	Sign.
Minimal	45.7	4.4	40.2	3.5	0.332	
Maximal	88.2	1.5	70.5	3.1	0.000	Sign.
Difference Maximal and Minimal	44	4.1	31.3	3.4	0.020	Sign.
Feeling Depressed	Yes (n=51)		No (n=71)			
Loudness tinnitus (VAS; mm)	**Mean**	**SEM**	**Mean**	**SEM**	**P-value**	
Mean	65	3.7	60.7	3.3	0.39	
Minimal	39.0	4.0	45.4	3.7	0.243	
Maximal	85.0	2.4	73.8	2.9	0.003	Sign.
Difference Maximal and Minimal	48.5	3.9	28.7	3.2	0.000	Sign.
Having Fear	Yes (n=39)		No (n=84)			
Loudness tinnitus (VAS; mm)	**Mean**	**SEM**	**Mean**	**SEM**	**P-value**	
Mean	63	4.3	62.8	3	0.964	
Minimal	37.3	4.4	45.9	3.4	0.128	
Maximal	85.3	2.9	75.7	2.5	0.014	Sign.
Difference Maximal and Minimal	47.8	4.7	31.7	3	0.005	Sign.
Having Anger	Yes (n=22)		No (n=101)			
Loudness tinnitus (VAS; mm)	**Mean**	**SEM**	**Mean**	**SEM**	**P-value**	
Mean	68.8	6.6	61.6	2.7	0.322	
Minimal	44.4	8.5	43.4	2.9	0.907	
Maximal	87.4	2.6	76.8	2.3	0.004	Sign.
Difference Maximal and Minimal	41.6	7.2	35.3	2.8	0.425	

dB: decibel; Hz: Hertz; KHz Kilohertz; SEM: Standard Error of the Mean; Sign: Significant; Prev: Prevalence; VAS: Visual Analogue Scale; mm: millimetre

Table 3: The levels of the maximal loudness of the tinnitus and the results of the survey for the psychosocial consequences of tinnitus.

Maximal loudness tinnitus (VAS; mm)	**Less than 73**	**73 -77**	**78 - 83**	**More than 83**	**P-value**	
Not acceptable	31%	60%	33%	65%	0.009	Sign.
Concentration disturbed	34%	60%	60%	77%	0.001	Sign.
Feeling depressed	28%	40%	27%	58%	0.026	Sign.
Cannot resist their tinnitus	16%	40%	40%	64%	0.000	Sign.
Having Fear	19%	40%	20%	43%	0.070	
Having Anger	6%	20%	20%	23%	-	

expected was tested using the Chi-square test. The analysis of possible correlation between audiometric thresholds, the age and work seniority was tested using the r coefficient of Spearman. The level of significance was assumed at $p<0.05$.

RESULTS

The noise sources and daily noise exposure levels, measured in the four investigated laboratories, are summarized in Table 1. The average LEX, 8 h was 75.6 ± 0.5 dB in laboratory 1, 75.8 ± 0.8 dB in laboratory 2, 72.2 ± 0.6 dB in laboratory 3 and 71.9 ± 0.5 dB in laboratory 4. Fifty-two dental technicians were included in the study and underwent clinical interview and audio logical evaluation. One woman had a previous pharmacological-induced hearing loss and was excluded from the study. The general characteristics of the subjects are summarized in Table 2. In details, 29 subjects were males (55.8%) and 22 were females (42.3%). Mean age was 39.1 years (range: 20-68 years). Mean age of male subjects was 41.4 years (range: 20-68 years), mean age of female subjects was 36 years (range: 27-50 years). Mean working seniority was 15.4 years (range: 2-40 years); 16.8 years for males (range: 2-40) and 13.5 years for females (range: 7-23 years). Audiometric thresholds are detailed in Table 3. Measurements were taken in both ears and were classified into groups of values above or below 25 dB, which is internationally recognized as the limit for hearing "disability"[54,55]. Table 4 and Table 5 detail the mean values of the audiometric thresholds at 3, 4 and 6 kHz, classified according to sex, age and working seniority of the enrolled subjects. The comparison between the audiometric thresholds at 3, 4 and 6 kHz with those expected in same age subjects without otological diseases and not exposed to work-related noise, according to ISO 1999/1990, showed exceedance in four dental technicians. The

Table 1: Noise sources and daily workplace noise exposure levels (LEX, 8 h).

Laboratory no. 1	Laboratory no. 2	Laboratory no. 3	Laboratory no. 4
Model trimmers	Model trimmers	Model trimmers	Model trimmers
Polishing lathe with (dust) extraction	Polishing lathe with (dust) extraction	Polishing lathe with (dust) extraction	Polishing lathe with (dust) extraction
Centrifugal casting machine	Centrifugal casting machine	-	-
VapoKlein	VapoKlein	VapoKlein	VapoKlein
Air gun	Air gun	-	Air gun
Sandblaster	Sandblaster	Sandblaster	Sandblaster
Vacuum mixer	Vacuum mixer	-	-
Vibrator	Vibrator	Vibrator	Vibrator
-	-	-	Devestor
-	-	-	Casting machine
-	-	-	Dryer
-	-	Suspension motor	-
Micromotor	Micromotor	Micromotor	-
Micromotor with extraction	Micromotor with extraction	Micromotor with extraction	Micromotor with extraction
Curing unit	-	-	-
Work bench	Work bench	Work bench	Work bench
-	Extractor fan	Extractor fan	Extractor fan
-	Ultrasonic unit	-	-
-	Porcelaine furnace	-	-
-	Plaster box with (dust) extraction	-	-
LEX,8H=75.6 ± 0.5	**LEX,8H=75.8 ± 0.8**	**LEX,8H=72.2 ± 0.6**	**LEX,8H=71.9 ± 0.5**

Table 2: Demographic characteristics of subjects included in the study.

Subjects	Total	52
	Excluded	1
	Enrolled	51
	Males	29
	Females	22
Age (years)	Range (years)	20 – 68
	Mean and SD (years)	39.1 ± 8.2
	Range males (years)	20 – 68
	Mean and SD males (years)	41.4 ± 11
	Range females (years)	27 – 50
	Mean and SD females (years)	36 ± 11.3
Working seniority (years)	Range (years)	2 – 40
	Mean and SD (years)	15. 4 ± 9.2
	Range males (years)	2 – 40
	Mean and SD males (years)	16.8 ± 3
	Range females (years)	7 - 23
	Mean and SD females (years)	13.5 ± 7.8

Table 3: Distribution of audiometric thresholds measured by frequency.

Frequency (Hz)	Audiometric thresholds' values range (db)		N° Subjects (%)			
	Right	Left	Right >25	Right <25	Left> 25	Left < 25
250	10 – 25	10 - 40	-	51 (100)	2 (3.92)	49 (96.07)
500	10 – 25	10 - 55	-	51 (100)	2 (3.92)	49 (96.07)
1000	10 – 20	10 - 55	-	51 (100)	1 (1.96)	50 (98.03)
2000	10 – 50	10 - 55	1 (1.96)	50 (98.03)	3 (5.88)	48 (94.11)
3000	10 – 55	10 - 65	5 (9.80)	46 (90.19)	6 (11.76)	45 (88.23)
4000	10 – 55	10 - 40	7 (13.72)	44 (86.27)	7 (13.72)	44 (86.27
6000	10 – 55	10 - 65	7 (13.72)	44 (86.27	7 (13.72)	44 (86.27
8000	10 – 55	10 - 55	8 (15.68)	43 (84.31)	8 (15.68)	43 (84.31)
Total	10 – 55	10 - 65		51 (100%)		

Table 4: Mean audiometric thresholds' distribution by sex and age.

Age class (years)	Males				Females			
	N° subjects (%)	3 kHz	4kHz	6 kHz	N° Subjects (%)	3 kHz	4 kHz	6 kHz
20 – 30	5 (17.2)	10.0	10.0	10.0	8 (36.4)	12.5	12.5	11.2
30.1 – 40	10 (34.5)	14.2	14.9	15.7	4 (18.2)	10.0	10.0	10.0
40.1 – 50	7 (24.1)	17.6	18.2	19.6	10 (45.4)	12.5	16.2	15.0
50.1 – 60	6 (20.7)	22.1	26.7	30.0	-	-	-	-
> 60	1 (3.4)	42.5	42.5	65	-	-	-	-
Total	29 (100)	17.1	19.4	20.5	22 (100)	12.0	12.3	11.4

Table 5: Mean audiometric threshold distribution by sex and working seniority.

Working seniority class (years)	Males				Females			
	N° subjects (%)	3 kHz	4kHz	6 kHz	N° subjects (%)	3 kHz	4 kHz	6 kHz
<5	3 (10.3)	10.0	10.0	10.0	-	-	-	-
5.1–10	7 (24.1)	12.1	13.6	13.6	8 (36.4)	12.5	12.5	11.2
10.1–15	3 (10.3)	17.6	18.2	19.6	4 (18.2)	10.0	10.0	10.0
15.1–20	4 (13.8)	15.0	15.8	17.5	8 (36.4)	13.1	13.7	12.5
20.1-25	7 (29.1)	14.3	15.7	12.5	2 (9.1)	10.0	10.0	10.0
>25	5 (17.2)	29.5	33.0	41.5	-	-	-	
Total	29 (100)	17.1	19.4	20.5	22 (100)	12	12.3	11.4

increase of audiometric thresholds measured in the four subjects were not statistically significant compared to the expected threshold (p>0.05). The correlations between audiometric thresholds at 3, 4 and 6 kHz with age and working seniority were significantly different in two sexes. In males, the audiometric thresholds were significantly correlated with the age and working seniority at 3 kHz (p=0.02 and p=0.01) and 4 kHz (p=0.04 and p=0.03), while at 6 kHz was observed lack of correlation (p=0.11 and p=0.12). Contrarily, in females the correlation of audiometric thresholds with the age and working seniority was not significant (p>0.05) at the frequencies investigated.

DISCUSSION

The analysis of noise exposure in the four laboratories included in the study showed moderate differences of the LEX,8 h values (range 71.4 to 76.2); average LEX,8 h was 73.9 ± 2.2 dB(A). The observed differences are attributable to the heterogeneity of the instruments available in the laboratory based on the type of processes and materials used. The noise levels are consistent with other studies[56,57] and are below the exposure limit values and the exposure action values provided by Art. 3 of the European Directive n. 2003/10/EC that establishes the minimum requirements to protect workers' health and safety against damage due to noise exposure. The results of the audiometric thresholds in the subjects included in the study revealed that hearing loss was worse in the 3-8 kHz frequency range. At these frequencies, hearing loss over 25 dB in both ears were observed in a proportion of cases between 9.8% and 15.7%. Examining the data as a whole, it emerged that there were slight differences between the right and left ear, the latter being more affected by hearing loss over 25 dB even at 250 Hz-1 kHz (present in 2-3.9% of cases). The differences decreased progressively with frequency increase up to 3 kHz and disappear completely at higher frequencies. This is consistent with other studies available in the literature that showed a prevalence of left-sided hearing loss[58,59], with an incidence between 4.7% and 36%. The higher vulnerability of the left ear may follow ambient exogenous noise-exposure factors, or may attribute to endogenous factors, such as neuroanatomic differences between the left and right parts of the auditory system, with involvement of the protective role of the efferent pathways to cochlea[26]. Analysis of the audiometric results at 3, 4 and 6 kHz, classified according to age and working seniority, revealed differences between males and females. In male subjects there was a progressive increase in the audiometric thresholds as age and working seniority increased, reaching its peak in the age >60 years and in the working seniority >25 years. On the contrary, there was no evidence of a relationship between audiometric thresholds and age group (from 20-30 to 40.1-50 years old) or working seniority (from 5.1-10 to 20-25 years) in females. In this regard, the history of women showed work discontinuity in the years and inhomogeneity in the working day. The data are confirmed by statistical analysis, which showed correlation between audiometric thresholds at 3, 4 and 6 kHz with age and work seniority statistically significant ($p<0.05$) in males and not significant ($p>0.05$) in females. The comparison between the mean thresholds at 3, 4 and 6 kHz and those expected according to the ISO international standard 1999/1990 reveal a limited number of cases (7.8% of total subjects) over the expected thresholds, including 1 female (4.5% of females) and 3 males (10.3% of males). Moreover, no differences were found statistically significant ($p>0.05$) between the 4 subjects' mean audiometric thresholds at 3, 4 and 6 kHz with those expected in same sex and age subjects without otological diseases and not exposed to work-related noise. Recent research studies have demonstrated that prolonged exposures to lower intensity noise may damage the inner ear, in particular outer hair cells. In a paper from[60] in rats, the authors showed that prolonged exposure to 16-20 kHz noise at 68 dB SPL caused a significant reduction in otoacoustic emission amplitudes at 30 kHz. As the exposure intensity rose from 68 to 92 dB SPL, amplitudes decreased primarily between 16 and 30 kHz. Such possible damage at levels that are not currently considered dangerous should be considered for workers exposed for prolonged periods, such as dental technicians. Limits of our study include the limited sample of subjects included, the absence of previous hearing exams, the absence of evaluation of outer hair cell function with otoacoustic emissions, and the lack of a control group.

CONCLUSION

The present study shows that exposure to noise in dental laboratories was not sufficient to represent an hazard to hearing of dental technicians, as demonstrated by the LEX,8 h, which were below 80 dB(A) and therefore below the European exposure limit values and exposure action values for workers exposed to noise. The audiometric results showed a progressive rise in the auditory threshold values at the frequencies mostly involved in noise-induced deafness and a correlation with age and working seniority in the males. Nevertheless, in the majority of the subjects auditory thresholds were in line with those expected in subjects of the same age and sex not exposed to noise. Further studies on larger samples with more detailed analysis of the outer hair cell function are necessary to confirm our results.

CONFLICT OF INTEREST

The author declares no conflict of interest.

REFERENCES

1. Abbate C, Concetto G, Fortunato M, Brecciaroli R, Tringali MA, Beninato G, et al. Influence of environmental factors on the evolution of industrial noise-induced hearing loss. Environ Monit Assess. 2005;107:351-61.
2. Agrawal Y, Platz EA, Niparko JK. Risk factors for hearing loss in US adults: data from the National Health and Nutrition Examination Survey, 1999 to 2002. Otol Neurotol. 2009;30:139-45.
3. Axelsson A, Lindgren F. Hearing in classical musicians. Acta Otolaryngol Suppl. 1981;377:3-74.
4. Behar A, Chasin M, Mosher S, Abdoli-Eramaki M, Russo FA. Noise exposure and hearing loss in classical orchestra musicians: A five-year follow-up. Noise Health. 2018;20:42-6.
5. Hessel PA. Hearing loss among construction workers in Edmonton, Alberta, Canada. J Occup Environ Med. 2000;42:57-63.
6. Kurmis AP, Apps SA. Occupationally-acquired noise-induced hearing loss: a senseless workplace hazard. Int J Occup Med Environ Health. 2007;20:127-36.
7. Masterson EA, Tak S, Themann CL, Wall DK, Groenewold MR, Deddens JA, et al. Prevalence of hearing loss in the United States by industry. Am J Ind Med. 2013;56:670-81.
8. Nelson DI, Nelson RY, Concha-Barrientos M, Fingerhut M. The global burden of occupational noise-induced hearing loss. Am J Ind Med. 2005;48:446-58.
9. van der Molen HF, de Vries SC, Stocks SJ, Warning J, Frings-Dresen MH. Incidence rates of occupational diseases in the Dutch construction sector, 2010-2014. Occup Environ Med. 2016;73:350-2.
10. Basner M, Babisch W, Davis A, Brink M, Clark C, Janssen S, et al. Auditory and non-auditory effects of noise on health. Lancet. 2014;383:1325-32.
11. Tomei F, Fantini S, Tomao E, Baccolo TP, Rosati MV. Hypertension and chronic exposure to noise. Arch Environ Health. 2000;55:319-25.
12. Davis RR, Newlander JK, Ling X, Cortopassi GA, Krieg EF, Erway LC. Genetic basis for susceptibility to noise-induced hearing loss in mice. Hear Res. 2001;155:82-90.
13. Ishii EK, Talbott EO. Race/ethnicity differences in the prevalence of noise-induced hearing loss in a group of metal fabricating workers. J Occup Environ Med. 1998;40:661-6.
14. Fetoni AR, Garzaro M, Ralli M, Landolfo V, Sensini M, Pecorari G, et al. The monitoring role of otoacoustic emissions and oxidative stress markers in the protective effects of antioxidant administration in noise-exposed subjects: a pilot study. Med Sci Monit. 2009;15:PR1-8.
15. Fetoni AR, Mancuso C, Eramo SL, Ralli M, Piacentini R,

Barone E, et al. In vivo protective effect of ferulic acid against noise-induced hearing loss in the guinea-pig. Neuroscience. 2010;169:1575-88.

16. Fetoni AR, Ralli M, Sergi B, Parrilla C, Troiani D, Paludetti G. Protective effects of N-acetylcysteine on noise-induced hearing loss in guinea pigs. Acta Otorhinolaryngol Ital. 2009;29:70-5.

17. Mancini P, Atturo F, Di Mario A, Portanova G, Ralli M, De Virgilio A, et al. Hearing loss in autoimmune disorders: Prevalence and therapeutic options. Autoimmun Rev. 2018;17:644-52.

18. Ralli M, Rolesi R, Anzivino R, Turchetta R, Fetoni AR. Acquired sensorineural hearing loss in children: current research and therapeutic perspectives. Acta Otorhinolaryngol Ital. 2017;37:500-8.

19. Fabelova L, Loffredo CA, Klanova J, Hilscherova K, Horvat M, Tihanyi J, et al. Environmental ototoxicants, a potential new class of chemical stressors. Environ Res. 2019;171:378-94.

20. Lewkowski K, Heyworth JS, Li IW, Williams W, McCausland K, Gray C, et al. Exposure to noise and ototoxic chemicals in the Australian workforce. Occup Environ Med. 2019;76:341-8.

21. Pleban FT, Oketope O, Shrestha L. Occupational Styrene Exposure on Auditory Function Among Adults: A Systematic Review of Selected Workers. Saf Health Work. 2017;8:329-36.

22. Kesici GG, Unlu I, Topcu AB, Bal CD, Tutkun E, Yilmaz OH. Arsenic related hearing loss in miners. Am J Otolaryngol. 2016;37:6-11.

23. Schaper M, Seeber A, van Thriel C. The effects of toluene plus noise on hearing thresholds: an evaluation based on repeated measurements in the German printing industry. Int J Occup Med Environ Health. 2008;21:191-200.

24. Carder HM, Miller JD. Temporary threshold shifts from prolonged exposure to noise. J Speech Hear Res. 1972;15:603-23.

25. Daniel E. Noise and hearing loss: a review. J Sch Health. 2007;77:225-31.

26. Mazurek B, Olze H, Haupt H, Szczepek AJ. The more the worse: the grade of noise-induced hearing loss associates with the severity of tinnitus. Int J Environ Res Public Health. 2010;7:3071-9.

27. Yong JS, Wang DY. Impact of noise on hearing in the military. Mil Med Res. 2015;2:6.

28. Ralli M, Greco A, De Vincentiis M, Sheppard A, Cappelli G, Neri I, et al. Tone-in-noise detection deficits in elderly patients with clinically normal hearing. Am J Otolaryngol. 2019;40:1-9.

29. Sheppard AS, Ralli M, Salvi R. A Review of Auditory Gain, Low-level Noise and Sound Therapy for Tinnitus and Hyperacusis. Int J Audiol. 2019.

30. Lie A, Skogstad M, Johnsen TS, Engdahl B, Tambs K. Noise-induced hearing loss in a longitudinal study of Norwegian railway workers. BMJ Open. 2016;6:e011923.

31. McBride DI. Noise-induced hearing loss and hearing conservation in mining. Occup Med (Lond). 2004;54:290-6.

32. Muhr P, Mansson B, Hellstrom PA. A study of hearing changes among military conscripts in the Swedish Army. Int J Audiol. 2006;45:247-51.

33. Rubak T, Kock SA, Koefoed-Nielsen B, Bonde JP, Kolstad HA. The risk of noise-induced hearing loss in the Danish workforce. Noise Health. 2006;8:80-7.

34. Di Stadio A, Dipietro L, Ricci G, Della Volpe A, Minni A, Greco A, et al. Hearing Loss, Tinnitus, Hyperacusis, and Diplacusis in Professional Musicians: A Systematic Review. Int J Environ Res Public Health. 2018;15:1-10.

35. Ivory R, Kane R, Diaz RC. Noise-induced hearing loss: a recreational noise perspective. Curr Opin Otolaryngol Head Neck Surg. 2014;22:394-8.

36. Phillips SL, Henrich VC, Mace ST. Prevalence of noise-induced hearing loss in student musicians. Int J Audiol. 2010;49:309-16.

37. Ralli M, Balla MP, Greco A, Altissimi G, Ricci P, Turchetta R, et al. Work-Related Noise Exposure in a Cohort of Patients with Chronic Tinnitus: Analysis of Demographic and Audiological Characteristics. Int J Environ Res Public Health. 2017;14:1-10.

38. Toppila E, Koskinen H, Pyykko I. Hearing loss among classical-orchestra musicians. Noise Health. 2011;13:45-50.

39. Syed M, Chopra R, Sachdev V. Allergic Reactions to Dental Materials-A Systematic Review. J Clin Diagn Res. 2015;9:ZE04-9.

40. Okamoto M, Tominaga M, Shimizu S, Yano C, Masuda K, Nakamura M, et al. Dental Technicians' Pneumoconiosis. Intern Med. 2017;56:3323-6.

41. Ergun R, Ergun D, Evcik E, Ergan B. Evaluation of dental technician's pneumoconiosis using chest X-rayand HRCT: correlation between radiological and functional findings. Turk J Med Sci. 2017;47:252-9.

42. Ergun D, Ergun R, Ozdemir C, Ozis TN, Yilmaz H, Akkurt I. Pneumoconiosis and respiratory problems in dental laboratory technicians: analysis of 893 dental technicians. Int J Occup Med Environ Health. 2014;27:785-96.

43. Dogan DO, Berk S, Gumus C, Ozdemir AK, Akkurt I. A longitudinal study on lung disease in dental technicians: what has changed after seven years? Int J Occup Med Environ Health. 2013;26:693-701.

44. Stark M, Lerman Y, Kapel A, Pardo A, Schwarz Y, Newman L, et al. Biological exposure metrics of beryllium-exposed dental technicians. Arch Environ Occup Health. 2014;69:89-99.

45. Abakay A, Atilgan S, Abakay O, Atalay Y, Guven S, Yaman F, et al. Frequency of respiratory function disorders among dental laboratory technicians working under conditions of high dust concentration. Eur Rev Med Pharmacol Sci. 2013;17:809-14.

46. Collins A, Burhan H, Davies P. Dental workers' pneumoconiosis complicated by Mycobacterium avium-intracellulare complex (MAIC) infection. Occup Environ Med. 2011;68:82.

47. Veronesi L, Bonanini M, Dall'Aglio P, Pizzi S, Manfiedi M, Tanzi ML. Health hazard evaluation in private dental practices: a survey in a province of northen Italy. Acta Biomed. 2004;75:50-5.

48. Zakrzewska JM, Greenwood I, Jackson J. Introducing safety syringes into a UK dental school-a controlled study. Br Dent J. 2001;190:88-92.

49. Kadanakuppe S, Bhat PK, Jyothi C, Ramegowda C.

Assessment of noise levels of the equipments used in the dental teaching institution, Bangalore. Indian J Dent Res. 2011;22:424-31.

50. Morarasu C, Burlui V, Borta C, Ignat L, Borta B, Morarasu G. The evaluation of sound level in dental practice]. Rev Med Chir Soc Med Nat Iasi. 2001;105:785-9.

51. Altinoz HC, Gokbudak R, Bayraktar A, Belli S. A pilot study of measurement of the frequency of sounds emitted by high-speed dental air turbines. J Oral Sci. 2001;43:189-92.

52. Setcos JC, Mahyuddin A. Noise levels encountered in dental clinical and laboratory practice. Int J Prosthodont. 1998;11:150-7.

53. Bahannan S, el-Hamid AA, Bahnassy A. Noise level of dental handpieces and laboratory engines. J Prosthet Dent. 1993;70:356-60.

54. Giordano C, Garzaro M, Nadalin J, Pecorari G, Boggero R, Argentero P, et al. Noise-induced hearing loss and hearing aids requirement. Acta Otorhinolaryngol Ital. 2008;28:200-5.

55. Rossi G. Normal hearing, loss of hearing and general occupational disability. Acta Otorhinolaryngol Ital. 1990;10:181-6.

56. Brusis T, Hilger R, Niggeloh R, Huedepohl J, Thiesen KW. Are professional dental health care workers (dentists, dental technicians, assistants) in danger of noise induced hearing loss?. Laryngorhinootologie. 2008;87:335-40.

57. Szymanska J. Work-related noise hazards in the dental surgery. Ann Agric Environ Med. 2000;7:67-70.

58. Le TN, Straatman LV, Lea J, Westerberg B. Current insights in noise-induced hearing loss: a literature review of the underlying mechanism, pathophysiology, asymmetry, and management options. J Otolaryngol Head Neck Surg. 2017;46:1-41.

59. Nageris BI, Raveh E, Zilberberg M, Attias J. Asymmetry in noise-induced hearing loss: relevance of acoustic reflex and left or right handedness. Otol Neurotol. 2007;28:434-7.

60. Zhao DL, Sheppard A, Ralli M, Liu X, Salvi R. Prolonged low-level noise exposure reduces rat distortion product otoacoustic emissions above a critical level. Hear Res. 2018;370:209-16.