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Assessment of occupational noise-related hearing impairment among dental health personnel

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Abstract

Objectives: The purpose of the study was to examine hearing thresholds among dental personnel. The secondary aim was to evaluate sound levels among dental equipment that dental personnel are exposed to.

Methods: Two hundred forty-four dentists, dental technicians, dental assistants, and dental students participated. Sixty-two participated as a control group. Audiological thresholds for the test groups were compared to the control group. All participants were from Jordan University Hospital. Participants completed a questionnaire in addition to their audiometric testing. Otoscopy, tympanometry, and pure tone audiometry were included in their assessment. Three-factor ANOVA and *t* tests were utilized to assess the statistical differences of hearing thresholds among the groups and between the two ears. Pearson correlation test was used to assess the effect of age, experience, and duration of exposure on the degree of hearing loss in the test groups for both ears.

Results: The authors reported statistically significant differences among hearing thresholds between the control group and others. Left hearing thresholds were noted to be significantly poorer in the left versus right ear at 1000, 2000, 4000, and 8000 Hz in dental assistants. The authors also reported a significant relationship between the degree of hearing impairment among dental assistants and the daily duration of exposure to dental occupational noise, followed by age.

Conclusion: Hearing impairment was higher among dental professionals than the control group and especially among dental assistants and technicians. The authors recommended screening guidelines and adapting hearing protection methods for dental professionals and particularly for dental assistants and technicians.

KEYWORDS

audiometric analysis, dental instruments, dental professionals, hearing impairment, noise level

1 | INTRODUCTION

Despite the advanced technology and precautions in modern dentistry, many occupational health problems and hazards still exist, such as exposure to infectious diseases, radiation, skin dermatitis, respiratory disorders, eye injuries, psychological impact, and hearing problems.[1] In addition to the daily noise levels which the general population are exposed to, dental professionals are exposed to additional noise which is related to their area of work. This noise can be roughly divided into distracting noise or destructive noise.[2] Recently, the National Institute of Occupational Safety and Health[3] has incorporated work-related hearing damage in a list of 21 highly important fields of study in the upcoming century, in addition to other risk areas such as vibration and hand neuropathy; so as to determine whether these problems are related to practicing dentistry.

Many studies have evaluated the effect of occupational noise on dentists' hearing, either by comparing hearing thresholds levels between a group of dentists and a control group or between dentist groups using different durations of exposure.[1-16] However, only a limited number of studies attempted to compare the effect of workplace noise pollution on dentists with that on other dental personnel, such as dental technicians, dental hygienists, and dental assistants.[5,6,9]

In this regard, there are a number of studies available in the dental literature examining the hearing loss among dental professionals that warrant discussion. For example, Al-Rawi et al[4] found positive correlation between the length of service and the degree of hearing impairment among dental practitioners. Ma et al[5] found that the dental professionals with more than 10 years of experience and more than 8 hours of daily work are at the highest risk of developing hearing impairment. They also reported that the worse the hearing status of the dental professional gets, the more their health status is adversely affected. Lopes et al[6] compared the hearing thresholds of three dental professional groups (dentists, dental nurses, and prosthodontists) using a high-frequency audiometric testing method, and they reported that the prosthodontists were the most affected group at the mean frequencies of 500-2000 Hz and 3000-6000 Hz, while the dental nurses were the most affected group at the mean high frequencies of 9000 and 16000 Hz. They also highlighted that conventional audiometry testing is inadequate to detect early hearing loss among dental personnel, thus advocating the implementation of high-frequency audiometry as an essential assessment tool to regularly evaluate the hearing capacity of dental professionals. Gonçalves[7] also reported that the dentists with more than 10 years of work experience have a higher risk of developing hearing loss at frequencies ranging from 500 to 1600 Hz, as compared to their control group. Myers[8] found that dentists susceptibility to hearing loss is similar to that of the general population; however, they are more prone to tinnitus. Theodoroff and Folmer[9] reported that dental clinicians who use high-speed handpieces on a regular basis suffer more hearing loss than the dental professionals who do not use such handpieces and the dental students. Willershausen et al[10] showed that the dentists are at a slightly higher risk for hearing loss than the control group of academic professionals at the frequencies of 3000 and 4000 Hz. Gurbuz et al[11] demonstrated that the dentists have significantly higher hearing thresholds than their control group at frequencies ranging from 1000 to 8000 Hz, and that male and female dentists have similar thresholds. Al-Ali and Hashim[12] reported that the prevalence of hearing problems among dentists in United Arab Emirates was 5% on the basis of a self-reporting questionnaire. Bali et al[14] reported higher hearing loss (distortion product amplitude/temporary shift) among dentists, as compared to the control group, in the left ear at the range of 4000 and 6000 Hz, and in the right ear at the frequency of 6000 Hz. They also showed that male dentists suffer more hearing loss in the left ear than the female counterparts, with a significant difference of 3000 Hz. Weatherton et al[15] conducted a study on dental students and dental staff members, and concluded that there was no effect on hearing among dental students, while the staff showed minimal hearing loss at 4000-6000 Hz. However, Zubic et al[16] found that dentists had a higher hearing threshold at 4000 Hz than physicians, as a control group. In addition, an interesting observation they reported was that right-handed dentists had greater hearing loss in the left ear than the right one, and it was explained as being due to the proximity of the noise source.

The sound sources which might affect hearing in a dental practice working area include high-speed and low-speed turbines, amalgamators, high volume suction devices, ultrasonic instruments, vibrators, model trimmers, and compressors.[17-26] Air conditioning and office music played at loud volume are also possible risk factors.[27-31] In this regard, there are number of manuscripts worth considering in the review of the research literature examining sources and levels of noise in dental practices.[17-26] Burk and Neitzel[17] compared four clinics in a main US dental school and reported that students from the dental students clinics show the highest variability in average exposure levels to occupational dental noise, and that the highest average and maximum exposures were in the Pediatric clinic. Kadanakuppe et al[18] measured the noise levels in three dental students teaching areas (ie preclinical, clinical, and laboratory areas) and found it ranging from 64 to 97 dBA, thus approaching the risk limit for potential noise-induced hearing impairment. They also reported that the laboratory devices generated the highest levels of noise as compared to high-speed and low-speed handpieces. In addition, they showed that used equipment generates more noise than brand-new ones. Besides, they demonstrated that the equipment-produced noise levels are higher during

cutting activities as compared to non-cutting (only turned on) status. Furthermore, they showed that cutting on metal generates more noise than the other cutting operations. Sorainen and Rytkönen[19] reported that, in a simulated setting, the average A-weighted sound pressure levels for the brand-new and used turbine handpieces, the high volume suction tube, the regular saliva ejector, and the ultrasonic scaler were found to be 76-82, 77, 75, and 83 dBA, respectively. They also mentioned that the measured average ultrasound level for the ultrasonic scaler was 107 dBA. Sorainen and Rytkönen[20] found that the noise levels of the air turbine and the micromotor handpieces, as measured in a simulated work, to be ranging from 80 to 89 dBA in the one-third octave band of 40 000 Hz, and they highlighted that the noise generated by the drills is highest in the high frequencies. Altinöz et al[21] demonstrated that high-speed drills under any working conditions generate frequencies that could result in hearing impairment. In a study of the noise levels of dental machines, Bahannan et al[23] found that the noise levels generated by laboratory machines during cutting are significantly higher than noises generated by the same machines without a cutting procedure; and that the noise level of laboratory machines without cutting was 77.51 dBA while during cutting it was 85.33 dBA. They also found that, for the laboratory electromotor headpiece, the noise level was in the range of 67.87-82.04 dBA; while, for the angled-design turbine headpiece, it ranged from 66.84 to 78.98 dBA and, for the low-speed angled headpiece, it was in the range of 67.53-71.89 dBA. Mueller et al[25] compared the noise level of various air turbine handpieces and relative positions and found that the maximum noise level generated by straight low-speed drills is at 18 inch distance in a direction parallel to their long axes and is 56.8 dBA; and by the high-speed ones is at 6 inch distance in a perpendicular direction and is 87.3 dBA.

There are also a number of studies conducted using self-administered questionnaires to assess the prevalence of noise-induced hearing loss (NIHL) among dental professionals.[31-33] These studies concluded that noise originating from dental machines appeared to have an effect on the tested groups which also contributed to their overall health status and hearing conditions.

As aforementioned earlier, the available reports in the literature addressing the difference in the degree of hearing loss among the various categories of dental professionals are inadequate. Thus the present study, primarily, aims at evaluating the hearing thresholds of dentists and other dental personnel including dental technicians and dental assistants at the Jordan University Hospital Department of Dentistry, and, secondarily, to assess sound levels among dental equipment that these dental personnel are exposed to. This secondary objective was decided to be included in the study because most of the dental equipment in workplaces being investigated in the present study is more than 7 year old and not regularly maintained. Therefore, it is likely that these devices generate more noise levels than what have already been reported in the literature, and thus possibly increasing the risk for hearing impairment among the test group of the current study.

2 | MATERIALS AND METHODS

The required ethical approvals were obtained for the study from both the Institutional Review Board of the University of Jordan Hospital and the ethical committee of the University of Jordan.

The total number of participants was 244, including females and males, who were divided into four test groups and a control group (Table 1). The test groups consisted of 39 dentists, 28 dental technicians, 23 dental assistants, and 92 fifth year dental students. The control group consisted of 62 third year dental students. Participants' ages ranged from 22 to 42 years old, with an average of 29.8 years.

An invitation letter was sent to dentists, dental technicians and dental assistants through the faculty administration, inviting them for a free hearing test to be conducted by a research team of professionals at Jordan University Hospital investigating hearing problems among dental professionals. It was also explained to the participants that the test was an advantageous part of the health screening for their career.

Prior to testing, participants aged 45 years and above were excluded to eliminate the effect of aging on hearing loss; which is likely to start at the age of 45-50.[34] Furthermore, subjects with conductive hearing loss, previous exposure to occupational noise other than dental practices-related noise, familial history of hearing loss, systemic diseases that might cause hearing loss, or a history of medication-induced hearing loss were excluded from the study.

All participants were asked to sign a consent form and to fill out a questionnaire. The questionnaire included their personal data, smoking habits, handedness, length of use of medications, and any previous history of ear disease or any hearing loss symptoms. In addition, years of experience and an estimation of the number of working hours per day were recorded. The questionnaire also included the following YES or NO questions that are commonly asked in the literature questionnaires regarding noise-induced hearing impairment:

Q1. Do you find yourself asking others to repeat what they have said?
Q2. Do you suffer hearing issues while being in noisy places?
Q3. Do you feel the need to pay extra attention to understand what others are saying?
Q4. Do the people around you complain of you raising the sound of the TV?

TABLE 1 Number of tested individuals, age, years of experience, and duration of exposure to noise per day[24]

Comparison group	Number Tested subjects	Age range (mean age)	Years of experience	Duration h/d
Dentists	39 M (21) F (18)	24-40 (28.8)	3-19 (6.12)	3-5 (3.44)
Dental technicians	28 M (23) F (5)	25-44 (33.5)	3-24 (10.42)	3-6 (4.25)
Dental assistants	23 M (1) F (22)	21-44 (34.4)	2-23 (11.91)	2-5 (4.46)
5th year dental students	92 M (30) F (62)	21-24 (22.7)	—	—
3rd year dental students	62 M (20) F (42)	19-23 (20.7)	—	—
Total	244			

Abbreviations: F, female; M, male.

Q5. Have you been on medications for a long time?
Q6. Are you a smoker?
Q7. Do you feel that the people around you get annoyed about you not comprehending what they say?
Q8. Do you find it difficult to comprehend conversations with children or females?
Q9. Do you feel that you sometimes misunderstand some parts of what people say thus reply incorrectly?
Q10. Do you find it difficult to keep track of a conversation in the middle of a crowded place?
Q11. Do you find it difficult to hear what the caller is saying during a phone call?

Audiological evaluation was performed for all the dental professionals to assess their hearing thresholds. Prior to audiological testing, all participants were examined otoscopically using a monocular otoscope (ENT Otoscope AMD-2015, AMD Global Telemedicine). Normal otoscopy was decided on the basis of the absence of any sign of inflammation in the ear canal and or perforation in the eardrum. Pure tone air-conduction audiometry (MAICO audiometer MA 27, MAICO Diagnostics GmbH) and tympanometric testing (MAICO easyTymp Plus, MAICO Diagnostics GmbH) were administered to all participants. The audiometer was calibrated periodically and complied with the International Standards Organization (ISO Protocol, 19 389, 1991). The procedure was explained to the participants before starting the test. The pure tone test was performed in an isolated (sound-treated) cubical. The participant is seated in this cubical, listens to pure tone beeps ranging from just audible to just inaudible sound levels, and notify the examiner when these pulses are perceived. This test involves administration of these pulses as variable intensities for the various frequencies being tested (250, 500, 1000, 2000, 4000, and 8000 Hz), and recording the lowest sound level heard by the participant at each test frequency. This test procedure was employed to determine the hearing thresholds at each test frequency. Regarding the tympanometric testing, the most common 226 Hz probe tone was used, and normal tympanometry was determined based on the type of the tympanogram produced (ie only Type A tympanogram was regarded as normal). The aforementioned hearing evaluation tests were performed by specialized technicians supervised by a certified audiologist from the ENT department of the Jordan University Hospital. It is also noteworthy to mention that the hearing thresholds were measured after the lunch break which is about 1 hour to allow some time to at least partially recover hearing from the transient threshold shifts (TTS) by noise exposure. However, complete TTS recovery may take hours and days depending on the individual and on the noise level.[35,36]

A sound level meter (Precision Integrating Sound Level Meter 2218; Brüel and Kjær) with a microphone (Microphone Amplifier 2603; Brüel and Kjær) was used to measure the sound pressure levels (dBA) of all sound-generating equipment and machines to which the participants are exposed to at the workplace (Table 2). The microphone was annually calibrated by an accredited representative of the manufacturer according to IEC 61094 and to the manufacturer's specifications. Calibration of the microphone was conducted at 250 Hz. The A-weighted type of sound pressure levels was recorded (ie dBA) because it is designed to simulate the reaction of the ear. The measurements were taken from students' dental clinic, dental laboratory, and from different dental specialty clinics. The distance was standardized for all sound level measurements, which was

TABLE 2 The equivalent levels of sound emitted by each tested machine[25]

Instruments and machines	Sound level without cutting on a tooth	Sound level with cutting on a tooth
High-speed hand piece	77 dBAeq	85 dBAeq
Low-speed hand piece	70 dBAeq	78 dBAeq
Scalers	80 dBAeq	85 dBAeq
Amalgamator	55 dBAeq	—
Laboratory heavy duty hand piece	Cutting acrylic 83 dBAeq Cutting metal 87 dBAeq	—
Saliva suction	77 dBAeq	—
Laboratory heavy duty hand piece with suction on	95 dBAeq	—
Model trimmer	Without model trimming, 85 dBAeq	With model trimming, 95 dBAeq
Air vacuum	69 dBAeq	—
Laboratory air blow syringe	100 dBAeq	—

30 cm from the tested tools and machines to the operator's ears.

SPSS was employed for data analysis (SPSS, Version 17.0, Inc). Three-factor ANOVA and *t* tests were utilized to assess the statistical differences of hearing thresholds among the groups and between the two ears. Pearson's correlation statistical test was employed to evaluate the degree of the association between the degree of hearing impairment and the following variables: age, experience, and duration of exposure. Based on the literature, Pearson's correlation coefficients in the following ranges: 0-0.39, 0.40-0.59, 0.60-0.74, and 0.75-1; are respectively regarded as weak, moderate, strong, and very strong correlations. The Correlation was regarded significant statistically if the *P*-value was less than .05.

3 | RESULTS

A total of 244 respondents filled in the self-administered questionnaires with a response rate of 98.5%. Descriptive analysis was used to evaluate the information acquired from the questionnaires. The participants in the tested groups were asked some questions related to NIHL and the responses were YES or NO. There were positive responses to only three questions, while all the participants across all the groups responded negatively to the rest of the questions.

Q1. Do you find yourself asking others to repeat what they have said?

For this question, the results showed that 46% of the dentists, 55.3% of the dental technicians, 64.4% of the dental assistants, 21.7% of the 5th year dental students, and only 10.5% of the 3rd year dental students responded positively to this question.

Q2. Do you suffer hearing issues while being in noisy places?

For this question, 50.8% of dentists, 60% of dental technicians, 75.6% of dental assistants, 18.8% of the 5th year dental students, and only 9.4% of the 3rd year dental students responded positively to this question.

Q3. Do you feel the need to pay extra attention to understand what others are saying?

Forty-one percent of dentists, 52% of dental technicians, 60% of dental assistants, 20.4% of the 5th year dental students, and only 9.2% of the 3rd year dental students responded positively to this question.

Audiological thresholds for all tested groups were analyzed and compared with those of the control group. Hearing thresholds were examined with a three-factor ANOVA examining group, ear, and frequency in one omnibus analysis to compare the differences in hearing thresholds between the left and right ear in the four tested groups (Table 3). The probability level of .05 was used to assess statistical significance. There were three main effects and two two-way interactions that were statistically significant. The significant main effects can be ignored as the variables (ie, group, ear, and frequency) as they are involved in the significant two-way interactions. Two two-way interactions (Group*Ear, and Ear*Frequency) were found statistically significant. It is noteworthy to mention that the alpha level was adjusted to avoid erroneous conclusions about significant differences. This analysis demonstrated that there were consistent statistically significant differences in the auditory thresholds in two of the tested groups (dental technicians, and dental assistants groups) as compared to the control group at all tested frequencies in both ears, with the exception of the right ear of the dental assistants group at 1000 Hz. No statistically consistent significant difference was found in the dentists and

TABLE 3 A three-factor ANOVA test examining group, ear, and frequency in one omnibus analysis to compare the differences in hearing thresholds between the left and right ear in the studied groups (dentists, dental technicians, dental assistants, 5th year dental students, control group [3rd year dental students])[26]

Tests of between-subjects effects						
Dependent variable: threshold						
Source	**Type III sum of squares**	***df***	**Mean square**	***F***	**Sig. *P*-value**	**Partial eta squared**
Corrected model	59 725.58[a]	59	1012.30	14.30	<.001	0.23
Intercept	82 638.88	1	82 638.88	1166.97	<.001	0.29
Group	30 602.35	4	7650.59	108.04	<.001	0.13
Ear	428.34	1	428.34	6.05	.014	0.00
Frequency	11 300.96	5	2260.19	31.92	<.001	0.05
Group*ear	864.24	4	216.06	3.05	.016	0.00
Group*frequency	13 524.92	20	676.25	9.55	<.001	0.06
Ear*frequency	552.56	5	110.51	1.56	.168	0.00
Group*ear*frequency	821.58	20	41.08	0.58	.929	0.00
Error	203 096.55	2868	70.82			
Total	319 155.00	2928				
Corrected total	262 822.13	2927				

[a]R^2 = .227 (Adjusted R^2 = .211).

5th year dental students as compared the control group at all frequencies in both ears.

Comparing the right and left ears, the results of the three-factor ANOVA analysis showed that there was no significant difference in the hearing threshold between the right and left ears in the tested groups, except for the dental assistants group where the left ear showed a higher hearing threshold than the right ear. This difference was statistically significant at the higher tested frequencies of 4000, and 8000 Hz and insignificant at the lower frequencies tested (ie, 250, 500, 1000, and 2000 Hz) (Figure 1).

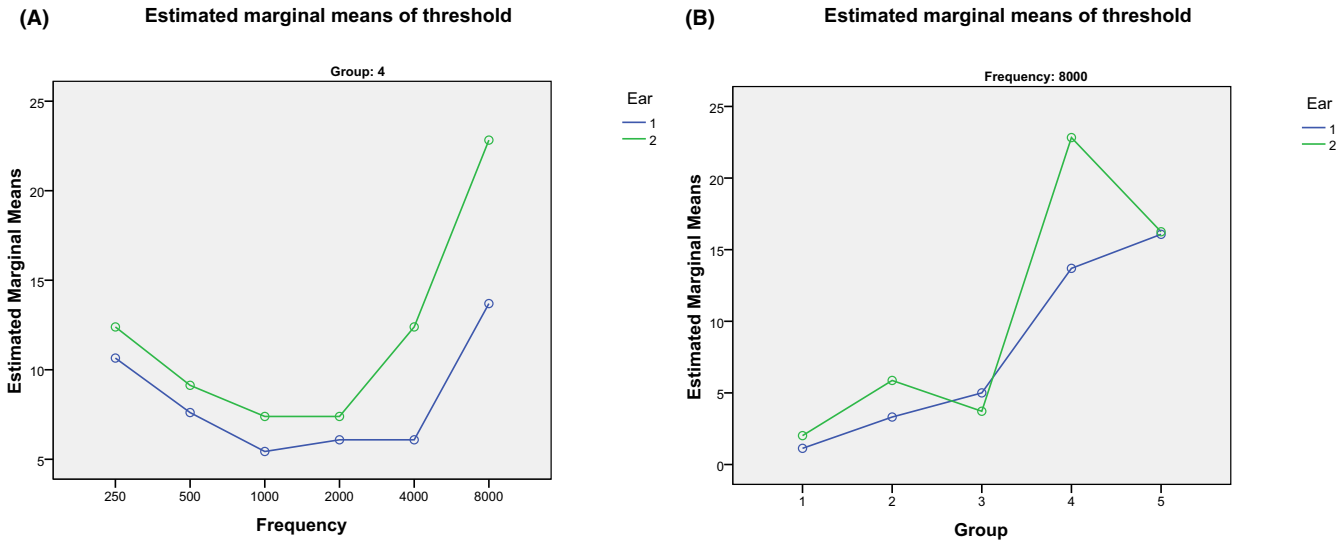

FIGURE 1 A, Comparison between the right and left ears for the hearing thresholds in the dental assistants group at frequencies ranging from 250 to 8000 Hz (Ear 1 = right ear, Ear 2 = left ear, vertical axis in dB HL), (B) comparison between the groups studied for the hearing threshold of the right and left ears at the highest frequency tested (i.e. 8000 Hz) (Ear 1 = right ear, Ear 2 = left ear, Group 1 = 3rd year dental students, Group 2 = 5th year dental students, Group 3 = dentists, Group 4 = dental assistants, Group 5 = dental technicians, vertical axis in dB HL).[29]

TABLE 4 Mean hearing threshold differences between right and left ears (right ear level minus left ear level)[27]

Frequency	Dentists			Dental assistants			Dental technicians			5th year dental students			3rd year dental students		
	R	L	R-L	R	L	R-L	R	L	R-L	R	L	R-L	R	L	R-L
250 Hz	8.72	9.23	−0.51	10.65	12.39	−1.74	10.54	10.18	−0.36	8.40	7.60	0.80	7.26	6.61	0.65
500 Hz	5.31	9.23	−0.92	7.61	9.13	−1.52	6.46	7.14	−0.68	9.30	8.90	0.40	5.00	3.31	1.69
1000 Hz	4.36	4.62	−0.25	5.43	7.39	−1.96	7.14	6.25	0.89	2.72	1.20	1.52	2.02	1.13	0.89
2000 Hz	2.56	3.59	−1.02	6.09	7.42	−1.33	4.46	5.89	−1.43	0.38	−0.27	0.65	−1.45	−1.29	−0.16
4000 Hz	4.36	5.6	−1.3	6.06	14.42	−8.32**	16.6	18.2	−0.61	−1.36	−1.20	−0.16	−2.18	−0.89	−1.29
8000 Hz	5.0	3.7	1.3	13.73	24.63	−10.90**	16.1	16.3	0.18	3.32	2.90	0.42	1.13	2.02	−0.89

Abbreviations: R, right ear; L, left ear.

**The difference is statistically significant at the .01 probability level (two-tailed).

The paired samples *T* test was also adopted to assess the differences in hearing thresholds between the left and right ear among all the groups studied herein (Table 4). This was done to further confirm the results of the ANOVA analysis regarding the difference between ears in the hearing thresholds. Table 4 shows a comparison between the hearing thresholds of the right and left ears among these groups. It is clear that the dental assistants had statistically poorer hearing in the left ear at the higher frequencies of 4000 and 8000 Hz but not at the lower frequencies tested. Meanwhile, the other groups show similar hearing thresholds for both ears at all tested frequencies.

Pearson's correlation test was utilized to assess the influence of age, years of experience, and duration of exposure to occupational noise for all tested groups in both ears. The results demonstrated that there was no significant correlation between the hearing threshold and any of the three aforementioned variables in the dentists and 5th year dental students groups. However, a statistically significant correlation was found between the hearing threshold and the duration of exposure to occupational noise in the left ear of the dental technicians at 4000 and 8000 Hz ($P = .039$ and .024, respectively) and in the right ear at 2000, 4000 and 8000 Hz ($P < .05$). The results of the regression analysis showed that the hearing threshold of the dental assistants group was more affected by these variables, especially age and the duration of exposure to occupational noise, than all the other tested groups. To provide more details, the hearing threshold was found to be positively and significantly correlated with the duration of exposure to occupational noise in both ears of the dental assistants group at all tested frequencies excluding the 250 Hz; to age in the right ear at the higher frequencies of 2000, 4000, and 8000 Hz and in the left ear at only the frequencies of 2000, 4000 but not the 8000 Hz; and to years of experience in both ears only at the frequency of 2000 Hz and not the lower or higher tested frequencies (Table 5).

4 | DISCUSSION

A total of 244 participants including dentists from different specialties, dental technicians, dental assistants, 5th year dental students and the 3rd year dental students as a control group were tested for any hearing impairment or loss, both subjectively and objectively.

The results of the self-administered questionnaire in the present investigation revealed that there was a remarkable increase in hearing problems among dental professionals who were exposed to dental noise for more than 4 hours per day. These problems include "asking others to repeat what they have said," "hearing issues while being in noisy places," and "paying extra attention to understand what others are saying." The highest effects were among the dental assistants

TABLE 5 Correlation analysis of the influence of three variables (age, years of experience, and duration of exposure to occupational noise) on the hearing thresholds of the dental assistants group in both ears[28]

Right ear						Left ear				
Frequency	Mean	SD	Age R	Experience R	Duration R	Mean	SD	Age R	Experience R	Duration R
250 Hz	10.65	4.34	0.107	−0.214	0.228	12.39	7.05	0.106	−0.203	0.403
500 Hz	7.61	5.61	0.582**	0.201	0.532**	9.13	7.78	0.365	−0.037	0.586**
1000 Hz	5.43	6.20	0.462*	0.183	0.629**	7.39	8.77	0.374	−0.035	0.688**
2000 Hz	6.09	8.25	0.355	−0.012	0.643**	7.42	10.6	0.322	−0.110	0.619**
4000 Hz	6.06	8.65	0.552**	0.211	0.388	14.42	12.4	0.392	0.003	0.584**
8000 Hz	13.73	18.2	0.309	0.051	0.663**	24.63	22.8	0.069	−0.122	0.692**

Abbreviation: SD, standard deviation.

*The difference is statistically significant at the .05 probability level (two-tailed).

**The difference is statistically significant at the .01 probability level (two-tailed).

and dental technicians, with the dentists and dental students being the least affected groups. These findings are consistent with those of Al Wazzan et al[37] and Khan et al.[31] In addition, there was a consistency between the results of questionnaires and the results of audiometric measurement among all tested groups, and these results are in agreement with those of Dogan et al.[38]

In comparison to the control group, consistent statistically significant difference was found in the hearing threshold of the two dental professional tested groups (dental technicians and dental assistants groups) at all tested frequencies in both ears, except for the right ear of the dental assistants group at 1000 Hz. These findings are consistent with those reported by Roshan Kumar et al,[39] Daud et al,[40] Ahmed et al[41] and Willershausen et al.[10] In this regard, it is noteworthy to mention that there were no consistent significant differences found in the hearing thresholds of both the dentists and the 5th year dental students groups as compared to the control group in both ears; and this may be attributed to the less amount of exposure to noise pollution for these two groups.

Our analyses demonstrated significant differences in the hearing thresholds between the left and right ear in the dental assistants group, but not in the other tested groups, at the higher tested frequencies (4000 and 8000 Hz), where the left ear has consistently higher hearing threshold. Therefore, it is clear that the left ear is more adversely affected than the right ear among the dental assistant group as compared to the other groups. This is presumably due to the posture and the proximity of the dental assistant to the noise sources on the left side of the dental unit including the high- and low-speed hand pieces, dental scalers, high volume suction, and the saliva ejector; considering that 98% of the participants among this group in this study were right-handed. These findings support the findings of previous studies.[16,39,42,43]

The occurrence of noise-induced hearing loss that is associated with sustained exposure to noise levels greater than 85 dBA without the use of any precautions and protections is well-documented in the dental literature. Therefore, the noise generated in the dental clinics and dental laboratory should not be underestimated.[44-46] In the dental literature, many studies have shown that faulty or worn dental equipment, particularly the low- and high-speed hand pieces and scalers, increased the risk of hearing impairment by 3-20 times if they are not properly maintained.[18,29,47] Furthermore, the age of the dental equipment is also a contributing risk factor. Messano and Petti[42] have reported that aged dental hand pieces which are more than 1-year-old may affect hearing efficiency.

The age of the dental equipment in this study was 7 years old, without an effective regular maintenance. The noise level measured varied between 55 and 100 dBA. The noise levels generated by all cutting equipment tested were found to be significantly greater than those produced by non-cutting tools. This may be attributed to the frictional contact between the cutting equipment and the material being cut. This finding was reported by and Wagner[48] and Sampio et al.[29] The differences in sound levels were recorded when the items of dental equipment were turned on before and during cutting on the teeth. The sound levels recorded in this investigation were higher than or within the recorded range of sound levels in previous investigations.[18,28]

The work-related degree of hearing loss and impairment among dental professionals usually depends on several factors, such as frequency of vibration, intensity of loudness, length of exposure, aging, quality of instruments, and interval between exposures.[25,49] Pearson's correlation test was used in the present study to test the effects of age, experience, and duration of exposure on the degree of hearing impairment in all the tested groups and for both ears. The results revealed no significant correlation between the hearing threshold and

any of the aforementioned variables among the dentists and the 5th year dental students groups. This may be due to the students' shorter exposure time to occupational noise and the fact that most of the dentists who participated in the study were orthodontists, dental surgeons, and prosthodontists, who seldom use high-speed hand pieces and other machines like amalgamators and scalers. This finding is in close agreement with that of Wilson et al.[50,51]

With regard to dental technicians, it is noteworthy to highlight that while in this group no significant differences in the hearing thresholds were found between the left and right ear, both ears show significantly higher thresholds than the control group at all tested frequencies (ie, 250, 500, 1000, 2000, 4000, and 8000 Hz). This demonstrates that the dental technicians group is the most adversely affected group by dental-related occupational noise, and thus the most susceptible group to hearing impairment in both ears. This also indicates that the sources of noise to which the dental technicians are subjected are widely distributed within their workplace environment. This result supports those of Ünlü et al[52] and Doğan et al.[38]

The results of the correlation analysis also showed that hearing impairment among the dental assistants was mainly affected by the duration of exposure per workday followed by age, and least affected by the years of experience in the profession. The results also revealed that hearing impairment in the left ear was more strongly correlated with the duration of exposure than in the right ear. The obvious impairment in hearing among the dental assistants in this study appears to be multifactorial. The first factor is likely to be the almost continuous exposure to intensive noise-producing devices during their work shift which was on average about 4 hours per workday. In addition, their average years of experience and age were higher when compared to the other tested groups. According to the sound level measurements, it was very apparent that the noise produced from the tools and machines to which the dental assistants were exposed during daily practice had high level with most of them ranging from 77 to 85 dBAeq, given that the equivalent sound pressure level in the actual workplace was measured. An important and valid reason for the relatively more obvious hearing impairment in the left ear of dental assistants is their posture during work. It is known that the assistant's posture should be set with her left ear toward the patients, holding the saliva ejector or the high volume suction device, in addition to the effect of the sound generated by the high and low speed hand pieces and the ultrasonic scalers during dental procedures performed by the dentist. The results of this study regarding the hearing impairment in dental assistants are in agreement with those of Wilson et al[51] and Lazar et al,[53] particularly with regard to the effect of ultrasonic scalers. Unfortunately, none of the participants in the tested groups was aware of the importance of using hearing protection devices such as earplugs or earmuffs.

In criticism, it is noteworthy to highlight that the data reported in the present study do not completely support the notion that dental personnel are always at risk of hearing problems. This is because there are a number of concerns not addressed in the current research: First, the reported differences in hearing thresholds between the groups studied are not at frequencies known to be correlated with the decrease in hearing capacity as a result of noise, these frequencies are in the range from 2000 to 6000 Hz; Second, the amount of these effects is trivial proposing that these differences might not be clinically substantial despite of being statistically significant; and third, it is possible that the differences between the groups are associated with temporary threshold shifts occurring prior to the hearing test.[35,36] It is possible that the differences among the dental assistants group in the left ears are associated with left side prevalence for temporary threshold shifts.[54-58] Lastly, the average hearing thresholds reported were less than 25 dB HL and, thus, within the normal range. Henceforth, although differences between groups might be present, in general, these groups showed mean hearing thresholds that are within the normal range. Even the dental assistants group has been shown in the present study to exhibit mean hearing thresholds that are within the normal range. However, it is apparent that at least some of the dental assistants presented hearing thresholds that are above the normal in the left ear at 8000 Hz.

5 | CONCLUSION

Within the limitations of current research, the authors concluded the followings:

1. High noise pollution produced by various dental tools and machines are potentially of high risk to dental professionals who work in such an environment for a prolonged period of time.
2. Dental assistants and dental technicians were found to be the relatively most affected by noise pollution among the dental team.

5.1 | Recommendations

1. Precautions and protection programs should be mandatory issues for health authorities, academic institutions, and dental associations.
2. Decision makers should start to consider setting screening guidelines and adapting hearing protection methods to the needs of dental professionals, especially the dental assistants' category.

3. Enforcement of the use of hearing protection devices such as earplugs and ear muffs, and adoption of regular maintenance of hand pieces and sound absorbing materials for walls should be considered.
4. Periodic audiometric tests for early detection of hearing loss, particularly for dental students and young dentists as a reference point, should be adopted.

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DISCLOSURE

Approval of the research protocol: The required ethical approvals were obtained for this study from both the Institutional Review Board of Jordan University Hospital and the Ethical Committee of the University of Jordan. *Informed consent*: Informed written consent was obtained from each participant before starting the study. *Registry and the registration no. of the study*: The present study is registered by the Deanship of Academic Research of the University of Jordan under grant number 117. *Animal studies*: N/A *Conflict of interest*: The authors declare no conflict of interests.

AUTHOR CONTRIBUTIONS

Category 1—conception and design of study: Salah A. Al-Omoush, Kifah D Jamani; acquisition of data: Salah A. Al-Omoush, Khader J. Abdul-Baqi, Firas Alsoleihat, Wijdan R Elmanaseer, Kifah D Jamani; analysis and interpretation of data: Salah A. Al-Omoush, Khader J. Abdul-Baqi, Margaret Zuriekat, Kifah D Jamani. Category 2—drafting the article: Salah A. Al-Omoush, Khader J. Abdul-Baqi, Margaret Zuriekat, Kifah D Jamani; revising the article critically for important intellectual content: Salah A. Al-Omoush, Khader J. Abdul-Baqi, Margaret Zuriekat, Firas Alsoleihat, Wijdan R Elmanaseer, Kifah D Jamani. Category 3—final approval of the version of the article to be submitted: Salah A. Al-Omoush, Khader J. Abdul-Baqi, Margaret Zuriekat, Firas Alsoleihat, Wijdan R Elmanaseer, Kifah D Jamani.

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