Original Article

Increased Signs of Noise-Induced Hearing Loss in Dental Students: A Multilevel Approach

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Abstract

Context: Despite the fact that the new generations of rotary tools emit less noise, some recent studies suggest that dental students are still at risk of hearing impairment. **Aims:** The aim of the study was to determine a possible association between noise exposure from dental equipment and early signs of noise-induced hearing loss (NIHL) in dental students. **Settings and Design:** A cross-sectional study was carried out with dental and non-dental students from two universities in Chile. **Methods and Material:** A group of 102 dental students routinely exposed to noise emitted from dental equipment was selected as the study group. A group of 251 non-dental students was selected as the control group. Pure-tone audiometry was carried out on all participants ensuring that they were not exposed to noise for at least 24 hours prior to testing. The presence of a notch was determined for each participant. **Statistical analysis used:** Simultaneous-quantile regressions were used to compare percentiles of the hearing threshold between both groups. Then, the notch prevalence ratio adjusted by gender and age was estimated for each group of participants. Finally, the prevalence of an audiometric notch was compared between both groups using logistic regression models and generalized linear methods. Both fixed effect and multilevel hierarchy models were constructed. **Results:** Significant differences between groups for the 75th percentile of hearing threshold distributions at 4 and 6 kHz in the left ear and at 6 kHz in the right ear were found. In addition, study group participants exhibited a significantly higher prevalence of a notch at 4 kHz in the left ear than control group participants. **Conclusions:** Exposure to noise derived from learning activities as a dental student is associated with early signs of NIHL. Such signs include poorer hearing thresholds than those of non-dental students at 4 and 6 kHz as well as the presence of a notch at high frequencies.

Keywords: Dental student, multilevel hierarchy models, noise-induced hearing loss, notch prevalence

Introduction

Dentists are exposed to potentially dangerous noise levels generated by the rotary instruments they use (e.g., drills, micro motors, and other handheld pieces). For example, it has been reported that dental drills can reach a noise level of 110 dB(A).[1] However, it has been hypothesized that due to newer generations of dental equipment that are less noisy than previous generations, dentists are no longer at risk of noise-induced hearing loss (NIHL).[2] In this regard, some studies are in agreement with this hypothesis finding no high-frequency hearing loss in dentists.[3,4] However, other studies have found high-frequency hearing loss in dentists.[5-7] These differences may be explained by the small sample sizes (type II error) used in most of the studies conducted so far along with unclear definitions for NIHL. For example, some studies have not specified the criteria for hearing loss[8] and others have just considered hearing loss as hearing thresholds poorer than 20 dB HL.[4]

Exposure to noise induces a characteristic drop in high-frequency hearing thresholds such as 3, 4, and 6 kHz.[9] This drop is commonly known as an audiometric notch.[9] This sign has been used in population-based studies such as

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the US American National Health and Nutrition Examination Surveys[10] and in cohort-type studies such as the Ohrkan Study in Germany to determine the prevalence of NIHL.[11,12] In addition, the presence of an audiometric notch has been used to determine early signs of NIHL in musicians with hearing thresholds across frequencies equal to or better than 15 dB HL.[13] Therefore, exploring the presence of an audiometric notch in populations at risk for NIHL seems to be a useful tool for early diagnosis. Dentists and dental students are an example of such populations. The presence of an audiometric notch to determine the prevalence of early signs of NIHL in dental students has not previously been reported in the literature.

As opposed to other professions, dentists are immersed in noisy environments since their university training. In addition, during their training, dental equipment is used in teaching facilities where many units run simultaneously, and thus the environmental noise can reach high levels.[14] It has been reported that noise levels in dental education facilities in India fluctuated between 64 and 97 dB(A), with the highest levels being generated in dental laboratories that used a gypsum vibrator.[15] Recently in Syria, it has been reported that in preclinical and clinical areas the noise fluctuated between 51.7 and 92.2 dB(A).[16]

Regarding dental students' hearing health in the United States, Bowman *et al*.[17] reported that dental students presented with temporary threshold shifts (TTS) in the 3 to 8 kHz range after attending practical sessions. Similarly, changes in the amplitude of otoacoustic emissions (OAEs) at 4 and 6 kHz in the left ear and 6 kHz in the right ear have been observed in dental students in India when comparing results before and after a day of practical dental work.[18]

Therefore, some research evidence suggests that dental students are exposed to noise levels above 85 dB(A) during their practical sessions and that such exposure may induce TTS and changes in OAEs. However, little is known about the prevalence of NIHL in dental students. This has important implications for the design and delivery of hearing conservation programs in this population. Thus, the aim of this study was to determine whether noise exposure from dental equipment is associated with an increased prevalence of signs of NIHL in dental students. For such purpose, a twofold approach was used: (a) the distribution of hearing thresholds across frequencies and (b) the presence of an audiometric notch as defined by previous authors.[10,19] Results for both analyses were compared between dental and non-dental students.

Subjects and Methods

A cross-sectional study was carried out between 2012 and 2013 in which students from two universities in Santiago, Chile were invited to participate. A group of dental students (study group) was compared to a group of non-dental students (control group). Each student signed a consent form and the research protocol was approved by the ethics committee of the Faculty of the Medicine of the University of Chile.

Dental students from the third to the sixth year were selected. These students were targeted because it was known that they had already attended practical sessions in which rotary instruments were used at least once a semester. According to the curricula of both educational institutions, first-year students were not involved in practical dental sessions and second-year students were so but only occasionally. None of the participants from the study group used some kind of hearing protection when attending practical dental sessions. A control group of non-dental students was selected from the same universities as dental students. With the aim to control age differences between groups, non-dental students attending the third year and above were selected.

Hearing assessment

All participants were evaluated without being exposed to loud noises 24 hours prior to testing. Initially, otoscopy along with tympanometry was carried out. Participants with excessive cerumen and/or visible abnormalities of the ear canal were excluded as well as participants with tympanometric results other than type A. Then, pure-tone audiometry was carried out in a soundproof booth meeting the requirements of American National Standards Institute (ANSI) S3.1-1999. An AC40 clinical audiometer (Interacoustics, Denmark) and TDH-39 headphones, both calibrated according to ANSI S3.6, were used to obtain air conduction pure-tone thresholds from 0.25 to 8 kHz. Testing conditions did not differ between both facilities (i.e., ambient noise levels, equipment, and calibration).

With the aim of excluding TTS, audiometric testing was carried out only on students who indicated that they had not been exposed to noise in the previous 24 hours.[20] For this, when the appointment for the hearing test was given, participants were instructed by the use of written information that they should not be exposed to noise during the 24 hours prior to testing. Noise exposure included recreational exposure (e.g., use of personal listening devices or attendance at concerts) as well as educational exposure associated with dental equipment during practical sessions. Prior to testing, participants were asked whether they followed the aforementioned instructions.

Notch definition

Given that TDH-39 headphones were used, a 6-dB correction was applied to the hearing threshold at 6 kHz to control the presence of an artificial audiometric drop.[21] The presence of a notch was determined based on the criterion proposed by Coles *et al*.[19] According to this criterion, the hearing threshold at 3 and/or 4 and/or 6 kHz should be at least 10 dB HL poorer than 1 or 2 kHz and 8 kHz. Thus, the presence of a notch was determined for hearing thresholds at 3, 4, and 6 kHz in the right and left ears.

In addition, with the aim to compare the results from this study with other published studies, the criterion used by Niskar *et al*.[10] was also used. According to Niskar *et al*.,[10] a notch is observed if the following three criteria are met: (1) thresholds at 0.5 and 1 kHz are equal to or better than 15 dB HL, (2) the poorest threshold among 3, 4, and 6 kHz is at least 15 dB worse than the poorest threshold between 0.5 and 1 kHz, and (3) the threshold at 8 kHz should be at least 10 dB better than the worst threshold at 3, 4, and 6 kHz.

Statistical analyses

Owing to a non-normal distribution for hearing thresholds, they are described using 50th and 75th percentiles. Hearing thresholds (1–8 kHz) were compared between dental and non-dental students using simultaneous-quantile regressions. Results were adjusted by gender and age. Audiometric thresholds at 3, 4, and 6 kHz were then dichotomized based on the presence/absence of a notch by using the definition proposed by both Coles *et al*.[19] and Niskar *et al*.[10]

The adjusted relative risk for the presence of an audiometric notch (for each ear separately), according to each definition proposed above, was estimated and interpreted as prevalence ratio (PR) due to the probability of overestimating the effect of the odds ratio.[22] For this, a logistic regression model was used, estimating predicted probabilities for the presence of a notch for both groups of participants, and adjusted by age and gender. Considering the asymmetrical distribution of the relative risk, the "transform the endpoints" method was used. This method provides a non-biased estimate of the confidence intervals.[23] As verification, the models were estimated using generalized linear models (GLM), specifying the "Poisson" family (link log) and the robust variance estimate.[24,25]

Additionally, GLM with a multilevel structure was created. The use of multilevel models was based on the fact that a single audiometric notch is initially observed in ears exposed to noise. Then, when exposure is continuous, other frequencies are also affected.[26] Thus, as frequencies within the same subjects are compared, a correlation among them is expected, producing biased estimates of the parameters if the aim is to compare the frequencies mainly affected by noise exposure (3–6 kHz).[27,28] Also, multilevel methods are appropriate since they represent the hierarchical structure of the data. The frequencies are grouped into a specific ear, with these belonging to the same individual.

For the statistical analysis of the data in this study, version 13 of the STATA software was used (StataCorp LP, College Station, TX, USA).

Results

A total of 102 dental students routinely exposed to noise were selected and further evaluated. The control group comprised 251 non-dental students. The study group was significantly older than the control group ($z = -2.38$; $P < 0.05$) and presented significantly more male students ($\chi^2(1) = 12.90$; $P < 0.001$). The median age of the exposed group was 22.9 years (range: 20–35) and 22.2 years (range: 18–33) for the control group. In addition, there were 56.9% of female students in the exposed group, while there were 76.1% in the control group.

Audiometric thresholds

The medians for hearing thresholds were all below 15 dB HL. However, the 75th percentile of the distribution of hearing thresholds at 4 and 8 kHz in dental students was worse than 15 dB HL. Outliers in the distribution of the hearing thresholds of both groups were observed [see Figure 1].

Using quantile regressions, no significant differences between both groups for the 50th percentile at either frequency (1–8 kHz) were observed. However, significant differences between groups for the 75th percentile at 4 and 6 kHz in the left ear and 6 kHz in the right ear were observed [see Table 1]. It should be noted that the biggest difference in hearing thresholds between groups was 5 dB HL. Dental

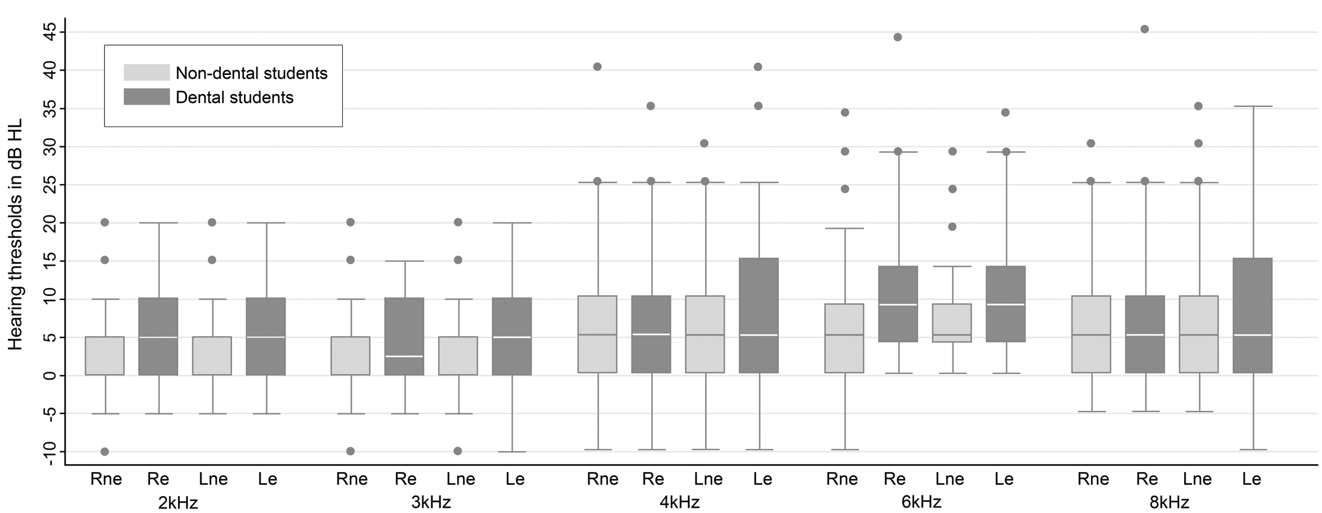

Figure 1: Box plots for the hearing thresholds (2–8 kHz) for the right and left ear in a group of dental students exposed to noise and a nonexposed control group. Rne = right ear, non-dental students; Re = right ear, dental students; Lne = left ear, non-dental students; Le = left ear, dental students

Table 1: Differences between groups for the 50th and 75th percentiles for the audiometric hearing thresholds in dB HL (1–8 kHz)*

	Right ear thresholds in dB HL		Left ear thresholds in dB HL	
	50th (95% CI)	75th (95% CI)	50th (95% CI)	75th (95% CI)
1 kHz	0.0 (–3.88–3.88)	2.5 (–4.19–4.19)	0.0 (–0.55–55.4)	0.0 (–2.43–2.43)
2 kHz	0.0 (–2.70–2.70)	–0.33 (–4.78–4.11)	0.0 (–1.64–1.64)	5.0 (–0.11–10.11)
3 kHz	0.0 (–3.72–3.72	0.24 (–4.33–4.81)	-0.76 (–3.40–1.86)	0.0 (–2.80–2.79)
4 kHz	0.0 (–2.10–2.10)	0.0 (–2.89–2.89)	0.0 (–1.67–1.67)	5.0 (0.45–9.54)†
6 kHz	0.0 (–4.48–4.48)	5.0 (1.31–8.69)‡	1.88 (–2.04–5.79)	4.17 (0.51–7.82)†
8 kHz	0.0 (–2.86–2.86)	–0.38 (–3.33–2.56)	0.0 (–2.13–2.13)	0.42 (–4.23–5.06)

*Bootstrapping with 10,000 replications was used for the estimation of 95% confidence intervals.†$P < 0.05$, ‡$P < 0.01$

Table 2: Notch prevalence (%) in both ears for dental and non-dental students

	Right ear Dental students prevalence (95% CI)	Non-dental students prevalence (95% CI)	Left ear Dental students prevalence (95% CI)	Non-dental students prevalence (95% CI)
Coles *et al.*'s criteria				
Notch in at least one frequency	17.65 (10.81–26.45)	7.17 (4.31–11.10)	19.61 (12.41–28.65)	8.77 (5.58–12.97)
Notch in at least two frequencies	2.94 (0.61–8.36)	1.59 (0.44–4.03)	3.92 (1.08–9.74)	1.99 (0.65–4.59)
Notch at 3 kHz	5.88 (2.19–12.37)	1.59 (0.44–4.03)	2.94 (0.61–8.36)	3.19 (1.39–6.18)
Notch at 4 kHz	6.86 (2.80–13.6)	3.98 (1.93–7.20)	15.69 (9.24–24.22)	5.18 (2.79–8.69)
Notch at 6 kHz	9.8 (4.80–17.29)	3.19 (1.39–6.18)	6.86 (2.80–13.6)	2.39 (0.88–5.13)
Niskar *et al.*'s criteria*				
Presence of a notch	4.9 (1.61–11.7)	0.8 (0.10–2.85)	10.78 (5.51–18.48)	0.8 (0.10–2.85)

*It is not possible to determine more than one notch in the same ear when the Niskar's criterion is used.

students presented with worse hearing thresholds than non-dental students.

Notch prevalence

Based on the definition proposed by Coles *et al*., 17.65% of the study group participants presented with a notch in at least one frequency in the right ear (95% CI 10.81–26.45) and 19.61% of them in the left ear (95% CI 12.41–28.65). For the control group, 7.17% (95% CI 4.31–11.10) presented with a notch in at least one frequency in the right ear and 8.77% (95% CI 5.58–12.97) in the left ear [see Table 2].

In dental students, the frequency most commonly observed with a notch was 4 kHz in the right ear with a prevalence of 15.69% (95% CI 9.24–24.22), and the least commonly observed frequency with a notch was 3 kHz in the left ear (2.94% (95% CI 0.61–8.36). In the control group, there was less variation, with the prevalence of a notch fluctuating between 5.18% for the left ear at 4 kHz (95% CI 2.79–8.69) and 1.59% for the right ear at 3 kHz (95% CI 0.44–4.03) [see Table 2].

Using Niskar's criteria, 10.78% (95% CI 5.51–18.48) of the study group participants presented with a notch in the left ear and 4.90% (95% CI 1.61–11.7) of them in the right ear. Regarding the control group, less than 1% of them presented with a notch at either ear. The prevalence of a bilateral notch in the study group was 2.94% (95% CI 0.61–8.36) as compared to 0.40% in the control group (95% CI 0.01–2.20).

Models without a multilevel structure

Coles et al.'s criteria

The ratio for the adjusted prevalence (adjusted PR) of an audiometric notch at 3, 4, or 6 kHz adjusted by gender and age showed significant differences [see Table 3] between groups. For the left ear, the prevalence of a notch at 4 kHz was 2.58 times higher in the exposed group than in the control group. This difference was statistically significant. Similarly, the prevalence of a notch at 6 kHz was 4.17 higher in dental students than in the control group. This difference was also statistically significant. Regarding the right ear, the prevalence of an audiometric notch at 6 kHz was 2.82

Table 3: Notch prevalence (%) and adjusted PR for both ears in dental and non-dental students*,†

	Right ear Dental students	Non-dental students	Prevalence Ratio (95% CI)	Left ear Dental students	Non-dental students	Prevalence Ratio (95% CI)
3 kHz	5.31	1.67	3.18 (0.88–11.46)	2.6	3.36	0.77 (0.20–2.93)
4 kHz	6.84	3.99	1.72 (0.66–4.49)	14.08	5.45	2.58 (1.28–5.21)
6 kHz	9.23	3.28	2.82 (1.11–7.12)‡	7.07	2.36	2.99 (1.01–8.97)‡

PR, prevalence ratios. *Adjusted by gender and age. All results are similar when using a generalized linear model with link log and binomial family. †The *transform-the-endpoints method* was used. ‡$P < 0.05$, $P < 0.01$

times higher in study group participants than in control group participants. This difference was also statistically significant.

Niskar et al.'s criteria

The ratio for the adjusted prevalence of a notch at 3, 4, or 6 kHz adjusted by gender and age was 12.12 times higher (95% CI 2.68–54.88) in the left ear and 5.28 times higher (95% CI 0.99–27.99) in the right ear in the study group than the control group. However, these differences were not statistically significant. The prevalence of at least one notch in either ear was 9.66 times higher (95% CI 2.75–33.89) in the study group than in the control group. This difference was statistically significant.

Models with a multilevel structure

This stratification reduces the computational demands, and the Akaike information criterion tends to be smaller. Akaike criterion penalizes according to the number of variables, and a smaller value indicates better model fitting.

Regarding the stratified model for the study group, an interaction between frequencies and ears (chi2(3) = 10.07; $P < 0.05$) was observed. The effect of the audiometric frequency was only significant in the left ear (chi2(3) = 13.05; $P < 0.01$). In the case of the stratified model that included control group participants, the interaction between frequencies and ears was not significant (chi2(3) = 1.98; P = 0.5766). The predicted probabilities for each model are shown in Figure 2.

As in all regressions, the term of the interaction corrected the estimates of the main effects. To obtain a measurement of the effect in each frequency, this term was added to the coefficient of the main effect. In this case, the PR was 2.29 times greater (95% CI 1.06–4.92; $P < 0.05$) in the left ear at 4 kHz than at 2 kHz in the right ear.

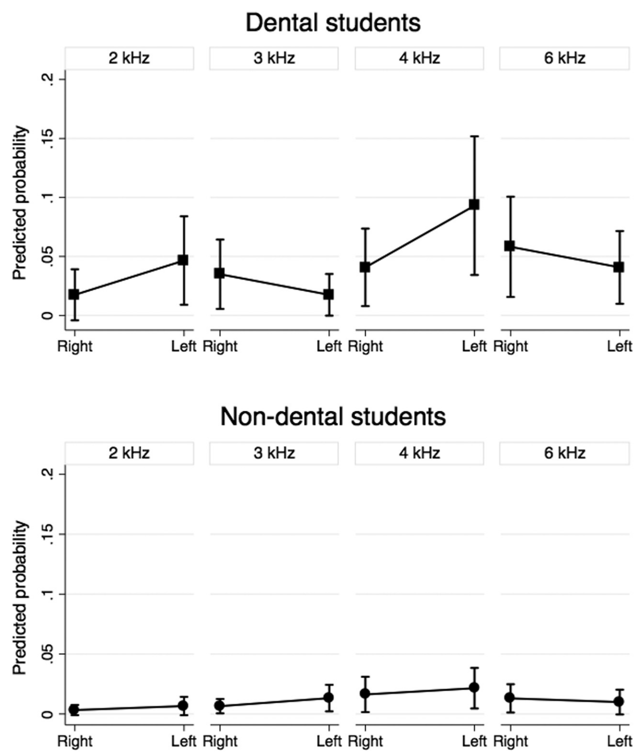

Figure 2: Predicted probability for an audiometric notch obtained from the multilevel model for dental students (top panel, N = 102) and non-dental students (bottom panel, N = 251). The effects of the audiometric frequency and ear are displayed for each group of participants

Discussion

The aim of this study was to determine if dental students presented with an increased prevalence of signs of NIHL. Hearing thresholds of 102 dental students routinely exposed to noise emitted from dental equipment along with 251 non-dental students were obtained.

Hearing thresholds

No significant differences between groups were observed for the 50th percentile of the distribution of hearing thresholds (1–8 kHz). This result is in agreement with that of Weatherton *et al.*,[29] who found that dental students did not present with significant changes in hearing thresholds after 1 year of dental noise exposure. The instructors in the Weatherton *et al*. study were also evaluated, and they presented with worse hearing thresholds than the students at 4 and 6 kHz. The authors interpreted such findings as a gradual change in hearing thresholds commencing at 4 and 6 kHz.[29] Despite no differences for the 50th percentile between groups in the present study, significant differences for the 75th percentile at

6 kHz in both ears and 4 kHz in the left ear were found. For this percentile, dental students exhibited on average hearing thresholds 5 dB HL worse than non-dental students. These results suggest that among dental students, some of them are more susceptible to NIHL than others. Previous research in humans has linked some factors with susceptibility to NIHL including gender[10] and genetic variation.[30,31] Indeed, in this study, the 75th percentile of the distribution of hearing thresholds across frequencies in female students was 5 dB HL (95% CI 1.5–8.5) better than the same percentile in male students.

Audiometric notch

Based on the criteria for an audiometric notch proposed by Coles *et al*., the left ear showed a higher prevalence of a notch at either frequency between 3 and 6 kHz than the right ear (19.61%). The highest prevalence was found for 4 kHz (15.69%). However, when the criteria proposed by Niskar *et al*. were applied, the left ear showed a slightly lower prevalence of a notch than the right ear (10.78%). Alabdulwahhab *et al*.[32] using the criteria proposed by Niskar *et al*. reported a prevalence of 7.8%, which does not differ statistically (z = 0.51; P = 0.61) from that obtained in the present study.

The prevalence of an audiometric notch adjusted by gender and age was significantly higher in dental students at 6 kHz for both ears and 4 kHz for the left ear than in non-dental students. Similar results have been reported in previous studies.[1,5,18,33] Zubick *et al*.[5] compared hearing thresholds between dentists and physicians. The group of dentists was divided into two (a) dentists exposed to noise from equipment and (b) dentists without noise exposure. The most affected hearing threshold in the left ear was 4 kHz, differing among the three groups. Also, Gijbels *et al*.[1] found a 6.15 dB HL change on average at 4 kHz in the left ear after 10 years of noise exposure from dental equipment in Swiss dentists. Thus, the left ear consistently appears to be more affected than the right ear. This may be explained by (a) a smaller distance between the left ear and the dental drill in the case of right-handed subjects and (b) the head shadow effect, mitigating between 10 and 15 dB for high frequencies.[1,16]

It should be considered that despite the differences in the notch prevalence between groups, this does not necessarily represent a hearing threshold worse than 20 dB HL. This is because we have used the criteria proposed by both Coles *et al*. and Niskar *et al*. These criteria allow identifying differences between adjacent frequencies as low as 10 dB HL and thus early signs of NIHL can be detected.

Multilevel models

In this research, we have opted for applying a multilevel analysis with the aim of maintaining the hierarchical structure of the data. Therefore, using multilevel models, differences in notch prevalence between groups along with differences among frequencies (3, 4, and 6 kHz) and between ears (right/left) could be obtained. Identifying the initial frequency affected by dental noise exposure is key as research evidence suggests that noise exposure mainly affects the audiometric frequencies between 3 and 6 kHz.[21] Thus, using this statistical approach, we have found that noise from dental drills initially affects the left ear hearing threshold at 4 kHz. Despite the comparative advantages of multilevel models, their structure with many parameters to be estimated makes it difficult to be applied in small sample sizes studies.

Limitations and projections

Owing to limitations in this study, it is not possible to establish a causal relation between dental noise exposure and early signs of NIHL in dental students. The increased audiometric threshold found in the group of dental students exposed to noise – although below the harmful level – could have several explanations. This group of young people may also be exposed to other noise sources such as recreational noise. Several studies have shown that portable music player use is a widespread practice among young people.[34-36] Therefore, the effect of recreational noise exposure, which was not assessed, cannot be ruled out, and it is a limitation of the current study. Future studies should evaluate the effect of exposure to both noise sources (recreational and dental) on the auditory thresholds.

Conclusion and Clinical Implications

The results of the present study suggest that dental students may be at risk for developing NIHL even at an early stage of their careers. This was mainly evidenced by the presence of an audiometric notch at high frequencies, particularly at 4 and 6 kHz. This has important implications for hearing conservation programs. For example, none of the students utilized hearing protection during their practical activities with dental drills and other dental equipment. Therefore, it is hypothesized that they are not aware of the risks dental equipment can induce on their hearing level. Thus, it is suggested that dental students should receive educational programs about the risks of using dental equipment along with strategies to protect their hearing against noise exposure. Finally, dental students should be incorporated into hearing conservation programs including but not limited to routine hearing screening. In this research, we found that the presence of an audiometric notch at 4 and 6 kHz may be used for detecting NIHL in dental students. Thus we recommend applying this method when examining audiograms in dental students. Some previous reports have found that OAE amplitudes diminish after dental noise exposure. The utility of OAEs for detecting early signs of NIHL in dental students should be further investigated.

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Conflicts of interest

There are no conflicts of interest.

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