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Abstract: Objectives: The purpose of this study is to 1) record and compare audiometric pure tone thresholds of dental professionals (who do or do not routinely use high-speed handpieces) and dental students; 2) determine the percentage of dental practitioners who use hearing protection devices while at work in the clinic; 3) measure the sound intensities generated by a few representative high-speed handpieces while they are being used on patients.
Methods: Participants included dental clinicians who regularly used high-speed handpieces (n=16); dental professionals who did not use high-speed handpieces (n=13), and dentistry students (n=8). A questionnaire was used to assess occupational and recreational noise exposure, use of hearing protection and to collect demographic information. A sound level meter was used to measure the sound intensity generated by dental instruments near the clinicians' ear.
Results: Dental clinicians who regularly used high-speed handpieces had worse hearing than the other two study groups. Only 1 of 16 noise-exposed clinicians, 0 out of 13 minimally-exposed dental professionals, and 1 out of 8 students reporting that they used ear plugs in the workplace. Sound intensities generated by high-speed handpieces can damage clinicians' hearing over time.
Conclusions: Dental clinicians should evaluate the intensity sounds they are exposed to in their work environment. Hearing protective strategies (including hearing protection devices) should be implemented as needed. Additional studies involving larger populations of clinicians should be conducted.
Clinical Significance: Implementation of protective strategies will help to reduce the prevalence of occupational hearing loss among dental clinicians.

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To: Editor
Journal of Dentistry

Please consider our manuscript, "Hearing Loss Associated with Long-Term Exposure to High-Speed Dental Handpieces" for publication in the *Journal of Dentistry*.

Sincerely,

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Title: Hearing Loss Associated with Long-Term Exposure to High-Speed Dental Handpieces

Short Title: Hearing Loss From High-Speed Dental Handpieces

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Key Words: Noise-induced hearing loss, high-speed handpieces, hearing protection

ABTRACT

Objectives. The purpose of this study is to 1) record and compare audiometric pure tone thresholds of dental professionals (who do or do not routinely use high-speed handpieces) and dental students; 2) determine the percentage of dental practitioners who use hearing protection devices while at work in the clinic; 3) measure the sound intensities generated by a few representative high-speed handpieces while they are being used on patients.

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Results. Dental clinicians who regularly used high-speed handpieces had worse hearing than the other two study groups. Only 1 of 16 noise-exposed clinicians, 0 out of 13 minimally-exposed dental professionals, and 1 out of 8 students reporting that they used ear plugs in the workplace. Sound intensities generated by high-speed handpieces can damage clinicians' hearing over time.

Conclusions. Dental clinicians should evaluate the intensity sounds they are exposed to in their work environment. Hearing protective strategies (including hearing protection devices) should be implemented as needed. Additional studies involving larger populations of clinicians should be conducted.

Clinical Significance. Implementation of protective strategies will help to reduce the prevalence of occupational hearing loss among dental clinicians.

INTRODUCTION

The cause-and-effect association between loud noise exposure and hearing loss is well established.[1] The National Institute on Deafness and Other Communication Disorders (NIDCD) claims that "Approximately 15 percent of Americans between the ages of 20 and 69 -- or 26 million Americans -- have high frequency hearing loss that may have been caused by exposure to loud sounds or noise at work or in leisure activities."[2] In an attempt to reduce workers' risk of developing noise-induced hearing loss (NIHL), the U.S. Occupational Safety and Health Administration (OSHA) established safety standards related to noise exposure (29 CFR Section 1910.95). Originally published in 1983, the standard states that the maximum permissible exposure limit (PEL) in an 8 hour day should not exceed 90 dBA SPL (90 decibels sound pressure level using an A-weighted scale).[3] OSHA's standard uses a 5-dB exchange rate, meaning that the PEL for 95 dB noise is reduced to 4 hours; the PEL for 100 dB sound is 2 hours, and so on. However, these standards are applied to large populations of people. Within these populations, some individuals are more susceptible to noise-induced auditory dysfunction than others.

Sound Intensity Generated by High-Speed Dental Handpieces

It has been suspected for decades that high speed handpieces might contribute to hearing loss exhibited by dental clinicians. Consequently, several investigators have measured the sound intensities generated by these devices. Barek et al.[4] analyzed sound intensities generated by high speed handpieces in both the audible (<20,000 Hz) and ultrasonic (>20,000 Hz) frequency ranges. They reported that the MicroMega brand handpiece generated a maximum of 95 dB SPL in the audible range, but 112 dB SPL at 50,000 Hz. Siemens and Kavo brand handpieces also generated high intensity sounds (101 and 115 dB SPL respectively) in the ultrasonic frequency range. Barek et al concluded that these instruments "reach levels that may provoke short- or long-term negative physiological disturbances and hearing-damage risk."

Kilpatrick[5] listed the sound intensities generated by high-speed handpieces (70-92 dB SPL), ultrasonic scalers (86 dB SPL), stone mixers (84 dB SPL) and low-speed handpieces (74 dB SPL). Sorainen & Rytkonen[6] reported that the A-weighted sound pressure level generated by a variety of handpieces ranged from 76 to 89 dB SPL. In Portugal, Sampaio Fernandes et al.[7] measured sound levels in different areas of a dental school and reported intensities ranging from 60-99 dB SPL. Kadanakuppe et al.[8] recorded a strikingly similar range of sound levels (64-97 dB SPL) at a dental school in India.

A key question: can these sound intensities cause hearing loss? The physiological effects of sound on hearing depend both on the intensity of sound and the duration of exposure. Because dental professionals do not use high-speed handpieces or other instruments continuously during the workday, they do not usually exceed OSHA's PEL or the more conservative PEL (85 dB) recommended by the National Institute for Occupational Safety and Health (NIOSH). However, Park[9] cautioned: "There is a danger, however, of finding comfort in the results of group studies and group standards. Every group is made of individuals, and individuals react to different things in different ways at different times." Merrell & Claggett[10] expressed similar sentiments: "Ears differ in their susceptibility to damage through exposure to noise, thus exposure in a common work environment may cause hearing loss in one person and not in another." Since most of us do not know our personal susceptibility to loud noise exposure, Park[9], Merrell & Claggett[10], and many other experts recommend that dental professionals implement strategies in the workplace to reduce their risk of occupational hearing loss.

Evidence of Noise-Induced Hearing Loss Among Dental Professionals

More than twelve published studies have assessed the hearing of dental clinicians to determine if they have significantly worse hearing compared to age-matched individuals who are not regularly exposed to noise generated by high-speed handpieces. One of the early studies was conducted in Dundee, Scotland by Taylor et al.[11] who tested the hearing of 30 dentists who used air turbine drills in their practice. The researchers concluded that the dentists exhibited elevated auditory thresholds at 4000 and 6000 Hz, which is a characteristic of noise-induced hearing loss.

Zubick et al.[12] compared the pure tone hearing thresholds of 11 dentists (average age = 48 years) with those obtained from 80 physicians (average age = 45 years). This study found that auditory thresholds for dentists were slightly worse than the physicians' thresholds at 4000 and 6000 Hz. Zubick et al concluded, "The findings suggest that there may be a cause and effect relationship between hearing loss and use of the highspeed dental handpiece."

Wilson et al.[13] tested the hearing of 20 dental hygienists who often used ultrasonic scalers (mean age = 43 years) and compared the results with 20 dental hygienists who seldom used ultrasonic scalers (mean age = 43 years). Results indicated that the high-scaler-usage group had significantly worse thresholds for 3000 Hz tones compared to the low-scaler-usage group. Again, because elevated thresholds at 3000 Hz can indicate excessive exposure to loud sounds, it is possible that noise generated by ultrasonic scalers contributed to occupational hearing loss exhibited by these hygienists. Evidence of greater-than-expected hearing loss in dental clinicians has also been reported by Fabry[14], Gijbels et al.[15], Bali et al.[16] and Messano & Petti[17].

However, other researchers who tested the hearing of dental practitioners concluded that noise generated in the clinic did not contribute to additional hearing loss.[18-20] Obviously, controversy exists regarding the contributions of high-speed handpieces to NIHL in dental clinicians. Attributing specific sources of noise exposure to hearing loss in adults is often difficult because of the many factors that contribute to auditory dysfunction: age, genetics, disease, and other sources of loud sound exposure. Each person's individual susceptibility to hearing loss from noise exposure should be considered when decisions are made regarding the implementation of hearing protection strategies in the workplace.

Use of Hearing Protection Devices by Dental Clinicians

In 1974, the American Dental Association (ADA) Council on Dental Materials and Devices issued a report[21] titled, "Noise Control in the Dental Operatory." The Council recommended that preventive measures for noise attenuation should include "personal protection through the use of ear plugs." Before and after publication of this report in 1974, many researchers and clinicians recommended that dental practitioners should utilize hearing protection devices (HPDs) when using noisy equipment or instruments in the clinic or laboratory.[6,9,10,13,14,22-29] Although the recommendation has been made repeatedly during the last four decades that dental clinicians should utilize HPDs while using noisy instruments, few studies of HPD implementation among dental professionals have been conducted. Serafini et al.[28] reported that only one of 23 dentists in their study used HPDs at work.

CURRENT INVESTIGATION

This pilot study was undertaken to: 1) record and compare audiometric pure tone thresholds of dental professionals (who do or do not routinely use high-speed handpieces) and dental students; 2) determine the percentage of dental practitioners and dental students who use hearing protection devices while at work in the clinic; 3) collect data from dental professionals and students regarding non-occupational noise exposure; 4) measure the sound intensities generated by a few representative high-speed handpieces while they are being used on patients.

Methods

Study participants were recruited and data were collected at the Oregon Health & Science University (OHSU) Dental School. Participants included dental clinicians who regularly used high-speed handpieces (n=16); dental professionals who did not use high-speed handpieces (n=13), and dentistry students (n=8). Pure-tone audiometric data were collected at 0.5, 1, 2, 3, 4, 6, and 8 kHz using a portable audiometer (Beltone model 119, Eden Prairie, MN). A questionnaire was used to assess occupational and recreational noise exposure, use of hearing protection and to collect demographic information. A Brüel & Kjær (Naerum, Denmark) Type 2250 sound level meter was used to measure the sound intensity generated by dental instruments near the clinicians' ear. Informed consent was obtained prior to any measurements or tests being performed. All research procedures were approved by the OHSU Institutional Review Board. Written informed consent was obtained from all study participants.

Results

Participants

Table 1 shows descriptive statistics for each of the study groups. The noise-exposed dental clinicians had a mean age of 53.5 ± 12.0 years. This group included 15 dentists and one denturist who had been in their professions for an average of 22.3 ± 12.3 years. The minimal noise exposure professional group had a mean age of 47.3 ± 11.5 years and included radiologists, radiology technicians, and clinic administrators who had been in their professions for an average of 21.8 ± 11.1 years. The third group was comprised of dental students and had a mean age of 28.9 ± 3.4 years. The students had been in dental school an average of 2.8 ± 0.4 years. A two-tailed t-test revealed no statistically significant differences between the mean ages of the noise-exposed professionals compared to dental professionals with minimal noise exposure ($p > 0.05$). The dental students were significantly younger than both of the other groups.

Audiometric Results

Grand averaged audiograms for each group are shown in Figure 1. Mean audiometric results for the group of noise-exposed clinicians revealed sloping high frequency hearing loss. The group of dental professionals with minimal noise exposure had hearing thresholds within the normal range of hearing, but their thresholds were poorer compared to the dental students. A one-way analysis of variance (ANOVA) and a Bonferroni correction for multiple comparisons showed a significant difference ($p < 0.05$) among the mean thresholds of the three groups for both ears from 3000 to 8000 Hz (see Table 2). Post-hoc testing revealed that the mean thresholds of the noise-exposed clinicians were significantly worse compared to the minimal noise exposure and student groups for 4000 to 8000 Hz in the right ear, and approached statistical significance at 3000 Hz ($p = 0.055$ compared to minimal noise exposure group; $p = 0.058$ compared to students) in the right ear. Left ear data revealed significant differences from 3000 to 6000 Hz between the noise-exposed clinicians and students, and significant differences between the noise-exposed clinicians and the other two groups at 8000 Hz (see Table 3). Audiometric mean thresholds for the minimal noise exposure group were not significantly different from the student group in either ear.

Hearing Protection Device Use

The use of HPDs in the OHSU dental clinics was rare, with only 1 of 16 noise-exposed clinicians, 0 out of 13 minimally-exposed dental professionals, and 1 out of 8 students reporting that they used ear plugs in the workplace.

Non-Occupational Noise Exposure

In addition to work-related noise exposure (e.g., high-speed hand pieces, suction devices or ultrasonic scalers), many study participants also reported histories of significant exposure to loud sounds outside of the dental clinic. For example, several noise-exposed clinicians and other dental professionals served in the U.S. military and were exposed to extremely loud sounds (gunfire, artillery fire, explosions) during training or combat. Some study participants also reported being exposed to recreational gunfire, fireworks, loud sounds from power tools, music, factory machinery or farm equipment. Participants reported that they "sometimes" or "never" wore HPDs during these activities. None of the participants "always" wore HPDs in these situations. The primary source of noise exposure for the dental students was loud music – at concerts, nightclubs, or via personal stereo equipment. It is impossible to quantify the amounts of these exposures for individuals or study groups, but it is important to remember that non-occupational noise in addition to noise from dental equipment contributed to the hearing loss exhibited by some participants.

Sound Intensities Generated by High-Speed Handpieces

A Brüel & Kjær Type 2250 sound level meter was used to measure the peak (A-weighted) sound intensities generated by the following instruments while they were being used during dental procedures. The sound meter's microphone was positioned near the clinician's ear that was closest to the handpiece during the procedure. The following peak sound intensities were recorded:

Midwest Tradition High-Speed Handpiece with Friction Grip Bur: 88-94 dB SPL

High-Speed Handpiece with Gates Glidden (endodontic) Drill: 98-102 dB SPL

Cavitron Select Ultrasonic Scaler: 92-98 dB SPL

These sound intensities are high enough to contribute to cochlear damage and noise-induced hearing loss over time. Although the dental clinicians' duration of exposure to these sounds might be relatively brief (as little as 30-45 minutes total per day), the cumulative effects of such exposures over years or decades of practice might very well contribute to occupational hearing loss and/or tinnitus for some individuals. Additional sources of loud sounds in a clinic (e.g., suction or other instruments being used in nearby operatories) can also increase clinicians' total noise exposure and risk for developing NIHL.

Discussion

Because this was a pilot study with a relatively small number of participants, the results are considered preliminary. Potential confounding factors – including age and gender of participants; duration and type of handpiece usage throughout each person's career; and precise measurements of occupational and recreational noise exposure – were not controlled for in this investigation. In spite of these limitations, the sloping high frequency hearing loss exhibited by dental clinicians in this study is consistent with long-term exposure to loud sounds. Measurements of sound levels generated by instruments in the current study revealed intensities that can contribute to the pattern of hearing loss observed in the group of noise-exposed clinicians. However, age, genetics and other sources of loud sounds also contributed to the hearing loss exhibited by subjects in this study.

The lack of HPD use by dental clinicians and students in this study is not surprising. Workers in noisy conditions – including industrial and military environments – often have low rates of HPD utilization, even after they are ordered to use the devices.[30-33] Reasons for not using HPDs during noisy dental procedures include 1) discomfort; 2) fear that HPDs will interfere with communication; 3) inconvenience; 4) negative feedback from co-workers or patients; and 5) the belief that noise levels from dental instruments will not damage hearing. In fact, ear plugs equipped with filters (known as "musician's ear plugs") will not interfere with a clinician's ability to understand co-workers or patients. Custom-made musician's ear plugs can be obtained from any practitioner (audiologist or hearing aid dispenser) who fits patients with hearing aids. Non-custom (and therefore disposable) musician's ear plugs (model ER20) are available from Etymotic Research, Inc (Elk Grove Village, IL). Even if these ear plugs provide only 15 dB of attenuation, this is enough to greatly reduce clinicians' risk of developing NIHL from noise generated by hand-held instruments.[6] Patients can also be given the opportunity to wear disposable foam ear plugs during dental procedures. However, patients who are exposed to noise from dental instruments only occasionally (perhaps rarely) have minimal risk of developing NIHL or tinnitus from this sound source.

Results from this study are consistent with the findings of previous studies: clinicians who operate dental handpieces or other loud instruments are at risk of developing NIHL. Multiple factors contribute to this risk, including variations in the frequency composition of the noise; the number of hours per week that hand-held devices are used; and variations in sound intensity over time related to turbine speed and maintenance of the devices. Setcos & Mahyuddin[25] described these and additional factors in their 1998 article. It is unlikely that a dental clinician's daily exposure to high-speech handpieces will surpass OSHA's PEL for an 8 hour work day. However, OSHA standards are probably not stringent enough and also do not take individual susceptibilities to NIHL or tinnitus into account.

Conclusions

To decrease their risk of developing NIHL, dental practitioners are encouraged to follow recommendations published in 1974 by the ADA Council on Dental Materials and Devices[21], which stated, "preventive measures for noise attenuation should be directed in three areas: optimum maintenance of rotary equipment, reduction of the ambient noise level in the operatory (soundproofing, acoustical ceilings, baffle drapes, resilient floors, rational location of the compressor and other noise-making equipment), and personal protection through the use of ear plugs." Additionally, the Council recommended that "practitioners concerned about the potential impairment should have an otologic examination and have an audiometric evaluation in a silent room to assess the present condition. Noise levels in the individual offices should be studied with monitoring periods of more than a week. An audiometric evaluation should be made after a typical workday and again at the beginning of the next day to observe temporary threshold shift and apparent recovery. Annual tests of hearing should be taken." To these recommendations we add: hearing protection strategies should always be implemented during noisy recreational as well as occupational activities.

Regarding future research in this area, Hyson et al.[34] recommended that additional studies should be conducted to investigate: 1) the hearing loss potential among dental students, faculty members, practicing dentists and other dental staff members who work with air-turbine handpieces; 2) Is there a correlation between the use of the air turbine and hearing loss?; and 3) Should dentists and staff members wear ear protection? The following investigations would yield valuable information:

1) Longitudinal studies of dental students, faculty members, practicing dentists and hygienists to assess their hearing annually and to determine if they exhibit of NIHL or tinnitus. Regarding tinnitus, Devlin[27] wrote, "I have been practicing dentistry for 15 years now. About seven years ago, I developed tinnitus in my left ear. It is an annoying, high-pitched whine, sounding almost like a high-speed handpiece that runs 24 hours a day, seven days a week. Although it was uncertain as to why I developed this condition, I wish that I had started wearing earplugs in dental school, and had continued the practice throughout my dental career."
2) A large-scale study of the current hearing protection practices of dental clinicians. This should include questions regarding their attitudes and behaviors related to utilization of HPDs.
3) A study to determine if specific educational interventions related to hearing and noise exposure would affect the attitudes and behaviors of dental professionals regarding hearing loss prevention practices.
4) A study to determine which HPDs are preferred and would be used by dental clinicians.

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Table 1

Table 1: Descriptive Statistics of Study Groups

Group	N	Mean Age: Years ± S.D.	Male/Female	Average Number of Years in Profession ± S.D.
Noise-Exposed Dental Clinicians	16	53.5 ± 12.0	M=16 F=0	22.3 ± 12.3
MinNoiseExp	13	47.3 ± 11.5	M=4 F=9	21.8 ± 11.1
Students	8	28.9 ± 3.4	M=5 F=8	2.8 ± 0.4

MinNoiseExp=Minimal Noise Exposure Professional Group

Table 2

Table 2. ANOVA Comparing Audiometric Thresholds at Different Test Frequencies

		Sum of Squares	df	Mean Square	F	Sig.
RE .5 kHz	Between groups	150.104	2	75.052	1.728	.193
	Within groups	1476.923	34	43.439		
	Total	1627.027	36			
RE 1 kHz	Between groups	284.310	2	142.155	2.804	.075
	Within groups	1723.798	34	50.700		
	Total	2008.108	36			
RE 2 kHz	Between groups	712.695	2	356.347	2.598	.089
	Within groups	4662.981	34	137.146		
	Total	5375.676	36			
RE 3 kHz	Between groups	3821.053	2	1910.527	4.390	.020
	Within groups	14796.514	34	435.192		
	Total	18617.568	36			
RE 4 kHz	Between groups	4617.490	2	2308.745	4.807	.015
	Within groups	16329.808	34	480.288		
	Total	20947.297	36			
RE 6 kHz	Between groups	6322.853	2	3161.426	8.497	.001
	Within groups	12650.120	34	372.062		
	Total	18972.973	36			
RE 8 kHz	Between groups	6071.197	2	3035.598	8.313	.001
	Within groups	12051.026	33	365.183		
	Total	18122.222	35			

LE .5 kHz	Between groups	242.421	2	121.211	2.148	.132
	Within groups	1918.389	34	56.423		
	Total	2160.811	36			
LE 1 kHz	Between groups	383.004	2	191.502	3.103	.058
	Within groups	2098.077	34	61.708		
	Total	2481.081	36			
LE 2 kHz	Between groups	760.457	2	380.228	2.292	.116
	Within groups	5639.543	34	165.869		
	Total	6400.000	36			
LE 3 kHz	Between groups	3010.320	2	1505.160	3.993	.028
	Within groups	12816.707	34	376.962		
	Total	15827.027	36			
LE 4 kHz	Between groups	3914.423	2	1957.212	4.000	.028
	Within groups	16635.577	34	489.282		
	Total	20550.000	36			
LE 6 kHz	Between groups	3971.521	2	1985.760	4.351	.021
	Within groups	15517.668	34	456.402		
	Total	19489.189	36			
LE 8 kHz	Between groups	5112.451	2	2556.226	4.810	.014
	Within groups	18068.630	34	531.430		
	Total	23181.081	36			

The mean difference is significant at the 0.05 level. RE= Right Ear, LE = Left Ear

Table 3

Table 3. Multiple Comparisons of Audiometric Thresholds at Different Test Frequencies

	Treatment Group (I)	Treatment Group (J)	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
RE .5 kHz	Dentist	Min Noise Exp	3.077	2.461	.659	-3.12	9.27
		Student	5.000	2.854	.266	-2.19	12.19
RE 1 kHz	Dentist	Min Noise Exp	5.577	2.659	.130	-1.12	12.27
		Student	5.625	3.083	.231	-2.14	13.39
RE 2 kHz	Dentist	Min Noise Exp	7.163	4.373	.332	-3.85	18.18
		Student	10.625	5.071	.131	-2.15	23.40
RE 3 kHz	Dentist	Min Noise Exp	19.303	7.789	.055	-.31	38.92
		Student	22.188	9.033	.058	-.56	44.94
RE 4 kHz	Dentist	Min Noise Exp	21.731*	8.183	.036	1.12	42.34
		Student	23.750	9.490	.052	-.15	47.65
RE 6 kHz	Dentist	Min Noise Exp	22.332*	7.202	.012	4.19	40.47
		Student	30.938*	8.352	.002	9.90	51.97
RE 8 kHz	Dentist	Min Noise Exp	23.487*	7.241	.008	5.22	41.75
		Student	29.833*	8.366	.003	8.73	50.93

LE .5 kHz	Dentist	Min Noise Exp	5.072	2.805	.238	-1.99	12.14
		Student	5.313	3.253	.335	-2.88	13.50
LE 1 kHz	Dentist	Min Noise Exp	6.635	2.933	.091	-.75	14.02
		Student	6.250	3.402	.225	-2.32	14.82
LE 2 kHz	Dentist	Min Noise Exp	6.226	4.809	.612	-5.88	18.34
		Student	11.563	5.577	.137	-2.48	25.61
LE 3 kHz	Dentist	Min Noise Exp	15.120	7.250	.134	-3.14	33.38
		Student	21.563*	8.407	.045	.39	42.73
LE 4 kHz	Dentist	Min Noise Exp	16.635	8.259	.156	-4.16	37.43
		Student	25.000*	9.578	.040	.88	49.12
LE 6 kHz	Dentist	Min Noise Exp	17.476	7.977	.106	-2.61	37.56
		Student	24.688*	9.251	.035	1.39	47.98
LE 8 kHz	Dentist	Min Noise Exp	22.091*	8.608	.045	.41	43.77
		Student	25.938*	9.982	.041	.80	51.08

*The mean difference is significant at the 0.05 level. RE= Right Ear, LE = Left Ear

Figure 1

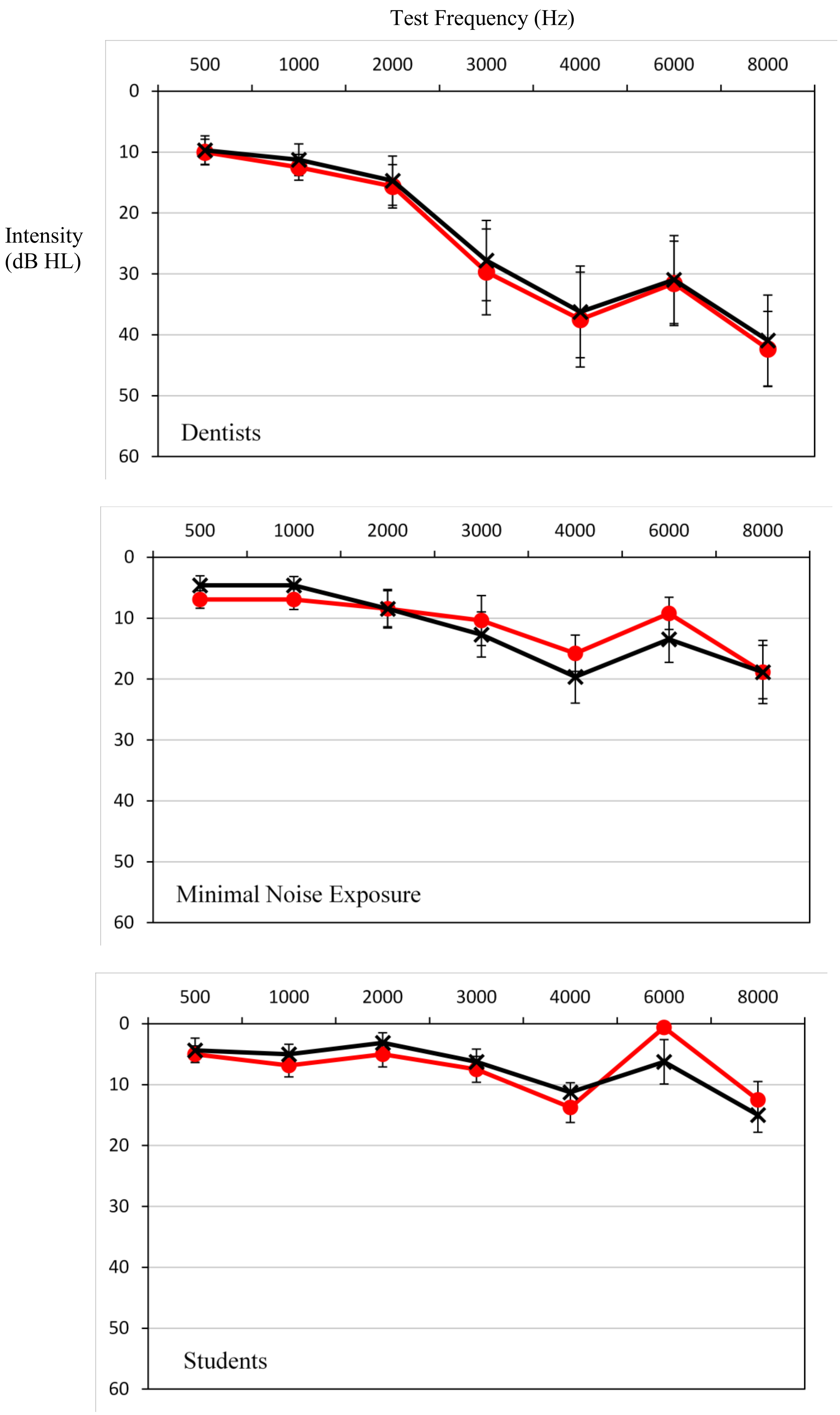

Figure 1. Mean audiometric data for each group (Dentists who use high-speed handpieces; Dental Professionals who do not use high-speed handpieces; and Dental Students). Circles represent right ear thresholds; Xs represent left ear thresholds.

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***Permission Note**

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We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

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