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Jessica Suedbeck
Old Dominion University, jsuedbec@odu.edu

Emily A. Ludwig
Old Dominion University, eludwig@odu.edu

James Blando
Old Dominion University, jblando@odu.edu

Nathan Michalak
Macon & Joan Brock Virginia Health Sciences, michalne@odu.edu

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Effects of Ultrasonic Use on Hearing Loss in Dental Hygienists: A matched pairs design study

Jessica Suedbeck, MSDH, RDH
Emily A. Ludwig, MSDH, RDH
James Blando, PhD
Nathan Michalak, AuD, CCC-A

ABSTRACT

Purpose Dental professionals are exposed to hazardous noise levels on a daily basis in clinical practice. The purpose of this study was to compare the hearing status of dental hygienists who utilize ultrasonic scalers in the workplace compared to age-matched control participants (non-dental hygienists) who were not exposed to ultrasonic noise.

Methods A convenience sample of nineteen dental hygienists (experimental) and nineteen non-dental hygienists (control) was recruited for this study. A matched pairs design was utilized; participants in each group were matched based on age and gender to eliminate confounding variables. The testing procedure consisted of an audiologist performing a series of auditory tests including otoacoustic emissions test, pure-tone audiometry, and tympanometry on the experimental and control groups.

Results In the right ear, there were notable differences from 1000 Hz – 10,000 Hz and in the left ear from 6000 Hz – 10,000 Hz, with higher hearing thresholds in the experimental group of dental hygienists. While 56% of the univariate tests conducted on how many days were worked per week showed statistical significance, the regression line slope indicated those that worked more days had better hearing statuses. The variables for years in practice for dental hygienists, how many of those years were full-time employment, and how many years the dental hygienist had used an ultrasonic scaling device, also had many significant univariate tests for the experimental group only. These variables were more likely to serve as proxies representing true noise exposure. The paired t-test between the groups demonstrated statistically significant differences between the experimental and control group at 9000 Hz in both ears.

Conclusion While results from this study demonstrated various qualitative differences in hearing status of the control group (non-dental hygienists) and experimental group (dental hygienists), age was found to be the most critical variable. Furthermore, this data demonstrated differences in hearing status based on various frequencies between dental hygienists and age-matched controls that should be further explored with a larger population.

Keywords dental hygienists, ultrasonic instrumentation, hearing loss, occupational noise exposure

NDHRA priority area, **Professional development: Occupational health** (determination and assessment of risks).

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INTRODUCTION

Research dating back to the 1990's has indicated dental professionals are exposed to hazardous noise levels on a daily basis in clinical practice.[1] Since that time, the rate of harmful exposure to hazardous noise levels has grown with more frequent use of ultrasonic equipment for greater durations.[2-6] Several federal agencies currently have standards that address noise exposure, including the Hearing Conservation Standard of the Occupational Health and Safety Administration (OSHA) to prevent hearing loss in workers exposed to hazardous noise levels.[7] Employers are required by OSHA to implement hearing protection policies when noise exposure is at or above 85 decibels over the time frame of an average workday, approximately eight hours. According to OSHA, loud noises may cause permanent damage to nerve endings within the ear and continuous exposure may have a cumulative effect over time leading to permanent, irreversible damage which may impact the worker's ability to complete their job.[7] Noise exposure causes changes in pressure within the ear resulting in damage, either temporary or permanent, that impacts overall hearing status. The extent of the resulting damage is dependent on the intensity of the harmful noise as well as the duration of exposure.[7] Ultrasonic scaling devices used by dental professionals may increase the risk for hazardous noise exposure which may impact their hearing, and have been reported to produce decibels as high as 75.[1-6,8] Despite OSHA standards and the increased potential for noise hazards in dentistry, there is limited research on risk factors and consequences of hazardous noise levels in dental professionals including dentists, dental assistants, and dental hygienists.

In 2002, researchers examined risk factors for hearing loss in 40 dental hygienists in Virginia; this pilot study determined dental hygienists with high ultrasonic use at work had poorer hearing status than dental hygienists with low ultrasonic use.[3] This pilot study in dental hygiene determined there was a risk to dental hygienists who use ultrasonic instrumentation frequently in the workplace. Since the time of the pilot study, ultrasonic use has only increased among dental hygienists in an effort to reduce hand fatigue while scaling, promote ergonomics, and increase efficiency.[3] In 2001 Åkesson et al. determined the average amount of time spent using an ultrasonic scaler by dental hygienists was 12 minutes per day.[9] In contrast, a 2015 survey of dental hygienists in the United States found that dental hygienists reported using ultrasonic scalers 5-20 minutes per patient with some reporting use for more that than 50 minutes per patient.[2] Similarly, dental hygienist participants from another study from another study in 2015 reported using the ultrasonic for at least 50% of their instrumentation time.[10] Based on what has been previously reported, there is a need for more research in dental hygiene to determine the effects of the use of ultrasonic scaling devices on hearing status. Therefore, the purpose of this study was to determine hearing status of dental hygienists who utilize ultrasonic scalers during clinical practice compared to age-matched control participants (non-dental hygienists) who were not exposed to ultrasonic noise in the workplace.

METHODS

This study was approved by the Institutional Review Board (IRB) at Eastern Virginia Medical School (reference #20-01-FB-0005) and informed consent was obtained from each participant. A convenience sample of nineteen licensed dental hygienists and nineteen controls were recruited via social media and email advertisements for this study. The sample was divided into a control group (n=19) comprised of non-dental hygienists that were not exposed to ultrasonic noise in the workplace, and an experimental group (n=19) comprised of dental hygienists exposed to ultrasonic noise in the workplace. Power statistics indicated that a minimum of 16 subjects per group were needed to achieve a 95% confidence interval and 80% power.[3] Participants had to be over 18 years of age to be considered for this study. For the experimental group, participants had to be licensed dental hygienists who used an ultrasonic scaler in the workplace. Control group participants could not have used any tools that created ultrasonic noise while working, had not been exposed to other occupational noises at work, and were not dental hygienists. Exclusion criteria for both groups included a history of diagnosed hearing loss due to a medical condition and self-reported excessive noise exposure associated with recreational activities.

A preliminary questionnaire was conducted to ensure the participant met inclusion criteria and to collect demographic data necessary for age matching the two groups. Participants were asked a series of yes or no questions related to hearing loss such as "Do you have hearing loss due to a medication(s)?" to determine inclusion (Figure 1). Any yes responses resulted in exclusion from the study. The exclusion criteria allowed the researchers to control for hearing loss not associated with ultrasonic use and was collected at the time of the preliminary screening to determine eligibility for the study.

Figure 1. Preliminary screening survey to determine study eligibility

Preliminary Screening Questionnaire

What is your occupation? _______________

In non-RDH, are you exposed to ultrasonic noise at works? (If yes, excluded) ______

If RDH, do you use the ultrasonic scaler every day at work? ______

What is your age? ______

What is your gender? _____

Do you have any of the following (if yes to any of the below, they must be excluded)?

- Hearing loss due to infection? ___
- Hearing losse due to disease? ___
- Hearing loss due to congenital defects? ___
- Hearing loss due to a medications? ___
- Hearing loss due to previous jobs? ___
- Hearing loss due to recreational activities? ___

The study utilized a matched pairs design; participants in each group were matched based on age and gender to eliminate the confounding variable of age-related hearing loss. Once informed consent was obtained participants also completed a questionnaire about current and past audible noise exposure and ultrasonic noise exposure allowing for further confirmation of inclusion and exclusion criteria, as well as collection of demographic data.

The testing procedure consisted of an audiologist performing a series of auditory tests on participants in both groups. First, an otoacoustic emissions test (OAE) was performed as a screening to identify if participants were in an early stage of hearing loss development.[11] The OAE is used to identify how well the inner ear is working by measuring auditory emissions in response to specific acoustic stimuli. The outer hair cells of the cochlea respond as an auditory amplifier to the incoming stimuli and produce a separate and distinct auditory signal because of the non-linear properties of a normal functioning ear. This sound travels back out of the inner ear, through the middle ear, and can be measured at the level of the external ear canal.[11] Absence of an OAE response can precede a measurable decrease in auditory thresholds as measured by standard pure-tone audiometry.[11] For this test, the audiologist placed a small foam probe in the ear canal which produced two medium-volume sounds into the ear. The probe then detected the amplitude of the response in decibels if present.

Next, the audiologist performed pure-tone audiometry with the participants. This test is designed to evaluate the quietest sound a person can hear in a range of frequencies.[11] Participants wore headphones and raised their respective hand whenever they heard an audible sound as the audiologist recorded the responses. Insert-ear headphones along with extended-high frequency headphones were used to test the participants hearing across a broad range of frequencies to include 500-20,000 Hz. These frequencies include values that have a better correlation in detection of ultrasonic noise exposure.[11]

Lastly, the audiologist tested the hearing status of the middle ear with tympanometry by placing a small probe in the ear that measures both ear drum mobility and middle ear pressure by using a probe tone and applied pressure changes.[11] This test demonstrates whether or not the eardrum moves correctly and if the pressure of the middle ear space is normal. Abnormalities associated with this test suggest hearing loss of a mechanical nature, not related to noise, and would also contraindicate the patient from study participation.[11] At the conclusion of audiometric testing, participants completed a questionnaire including demographics, work life characteristics, and recreational activities that may include noise exposure.

Data Analysis

Data were reviewed and cleaned by inspecting frequency distributions of variables using a software program (SAS v9.4; SAS, Cary, NC, USA) and by visual inspection of the database (JB). Any data errors detected were immediately corrected. Cleaned data were analyzed in a progressive manner, first by descriptively inspecting the data, second by univariate analyses, and third by multivariate methods using SAS v9.4. Decisions about each additional analysis and specific variables for inclusion in models were based on the results of each prior analysis. Descriptive data (Table I) was useful in exploring the data to assess the magnitude of the values and evaluate how this data varied over the entire set of variables measured in the study. Simple univariate analyses allowed each variable to be analyzed in isolation and to be evaluated individually for statistically significant relationships. These analyses then allowed for an assessment of which variables might be meaningful for inclusion in multivariate models. This allowed the number of variables to be limited in the multivariate analysis to only those variables that may have influenced the relationship between outcome and explanatory variables, greatly reducing the potential for multiple comparison bias and enhanced the ability to clearly see relationships among the meaningful datapoints.

Data were descriptively assessed using "Proc Freq" and "Proc Univariate" (SAS v9.4) across all participants in the study (n=38) and by each group (experimental n=19 vs. control n=19). This allowed for an assessment of the data distribution, averages, median values, and standard deviations for each variable measured in the study. Then simple linear regression for each variable in the study was performed using "Proc Reg" (SAS v9.4). This regression utilized independent variables, such as age, as the explanatory variables and dependent variables related to audiometric hearing thresholds at different frequencies served as the outcome variable (Table I). Next, paired t-tests using "Proc TTEST" (SAS v9.4) were utilized to compare the average values for survey questions, tympanometry, and audiometry between the experimental and control group. All prior tests were then utilized to make decisions about which explanatory variables to include in a multivariate linear regression with audiometric hearing threshold values as the outcome variable (Table II).

RESULTS

Nineteen dental hygienists and 19 controls participated in the study. All participants were female (n=38). All the dental hygienists who used ultrasonic scalers (experimental group) practiced at least three days per week, with the majority practicing four days or more (n=16, 89%). All participants in the experimental group also reported using an ultrasonic scaling instrument on patients for 10 minutes or more per appointment with the majority reporting at least 20-25 minutes of use during a one-hour appointment. Participants in the experimental group ranged from 26 to 66 years old and were age-matched to a control participant; control group ages were within one year of the matched experimental participant (aged 25-66, respectively).

Data demonstrated there were qualitative differences in the average hearing thresholds between the experimental and control groups. In the right ear, there were notable differences from 1000 Hz–10,000 Hz; in the left ear from 6000 Hz–10,000 Hz, with higher hearing thresholds in the experimental group.

The univariate assessment of study variables demonstrated there were five variables that had a high percentage of univariate analyses that were statistically significant across all audiometric frequencies tested (Table III). While 56% of the univariate tests conducted on how many days were worked per week ("week") showed statistical significance, the beta values for the regression line slope were negative, meaning

Table I. Summary of variables utilized in the data analyses (n=38)

Variable	Variable Type	Corresponding Survey question or definition	Group
Age	Independent	Q2 What is your age?	Experimental and Control
Week	Independent	Q3 How many days a week do you provide dental hygiene care? (Experimental) Q3 How many days a week do you work? (Control group)	Experimental and Control
History	Independent	Q4 How long have you worked in a dental office providing direct patient care (years)?	Experimental
Part time	Independent	Q5 In your total dental hygiene practice, how many years have you practiced part-time (less than 4 days/30 hrs per week)?	Experimental
Full	Independent	Q6 In your total dental hygiene practice, how many years have you practiced full-time (4 days ormore per week)?	Experimental
Patients	Independent	Q7 How many patients per day, on average, do you use the ultrasonic scaler on?	Experimental
avg-time	Independent	Q8 How long, on average, do you use the ultrasonic scaler on these patients (minutes)?	Experimental
Ultra-time	Independent	Q9 How many years have you been using the ultrasonic scaler on patients?	Experimental
ECV	Independent	Ear canal volume (ml)	Experimental and Control
daPa	Independent	Middle ear pressure (deca pascals) daPa	Experimental and Control
ml	Independent	Tympanic membrane compliance (ml)	Experimental and Control
"R_" or "L_" followed by number	Dependent	Hearing threshold in decibels at given frequency in Hz (e.g. R_250 means patient's hearing threshold at 250 Hz in right ear) (decibels A scale) Total of 16 frequencies tested in each ear	Experimental and Control

participants with higher values for the "week" variable had lower hearing thresholds (better hearing). That is, the more often they worked during the week the better their hearing was found to be. The relationship of the "week" variable to "hearing thresholds" would be highly variable and meaningless if there were controls who had little noise exposure but worked a lot of days during the week. The variables for years in practice for dental hygienists ("history"), how many of those years were worked full-time (at least four days per week; "full"), and how many years the dental hygienist has used the ultrasonic ("ultra-time") also had a large number of significant univariate tests for the experimental group only and these variables were more likely to serve as proxies representing true noise exposure. Results also had positive beta values suggesting the simple linear regression line slope was positive, which meant that as the exposure proxy variable increased the hearing threshold also increased, which may suggest more ultrasonic noise exposure results in decreased hearing thresholds. The paired t-test between the groups demonstrated

Table II. Multivariate regression model

Multivariate regression	
Explanatory Variables	**Outcome Variables**
Age	R_XXX hearing threshold right ear
Full "How many years the dental hygienist has practiced full-time?" (4 or more days per week)	L_XXX hearing threshold left ear
Ultra-time "How many years the dental hygienist has used the ultrasonic?"	
	XXX = specific frequency in Hertz, ranging from 250 Hz to 20,000 Hz (range of human hearing)

statistically significant differences between the experimental and control group at 9000 Hz in both ears. Values approached statistical significance in the right ear at 1000 Hz and 8000 Hz (Table IV). The multiple linear regression demonstrated a statistically significant relationship for years using the ultrasonic scaler ("ultra-time") at one frequency and a statistically significant relationship for years worked full-time ("full") at two frequencies, all with positive beta slopes (Table IV). These findings indicate that even when adjusting for age, there was a weak association between exposure variables and hearing threshold shifts and therefore hearing loss. All other statistically significant multivariate findings showed that "age" was the only significant factor in the model.

Table III. Univariate analysis of predictor variable and hearing threshold outcome at specific frequencies tested in audiometry†

Predictor variable	Groups	Univariate analyses that were statistically significant across all 32 audiometric frequencies tested	Range of *p* values among statistically significant tests	Range of beta value (slope of regression line) among statistically significant tests
		n (%)		
Age	**Both**	**29 (91.0)**	<0.001 – 0.055	0.2 – 1.52
Week	**Both**	**18 (56.0)**	0.0002 – 0.05	-7.67 to -2.19
Week	Experimental	6 (19.0)	0.0007 – 0.055	-9.94 to -2.92
History	**Experimental**	**27 (84.0)**	0.0001 – 0.04	0.22 – 1.68
Part time	Experimental	2 (6.0)	0.05	0.36 – 0.47
Full	**Experimental**	**25 (78.0)**	0.001-0.05	0.32 – 1.51
Patients	Experimental	–	–	–
avg-time	Experimental	2 (6.0)	0.04 – 0.05	-0.82 to -1.45
Ultra-time	**Experimental**	**26 (81.0)**	0.0001-0.05	0.3 - 1.63
ECV	Both	–	–	–
daPa	Both	1 (3.0)	0.2	-1.03
ML	Both	1 (3.0)	0.055	-16.1

†16 frequencies in each ear for a total of 32 frequencies

*Bold variables indicate higher frequencies

Table IV. Paired t-test results of comparison between the groups. Matched on age (+/- 1 year).†

Comparison Variable	*p*-value
Age	0.06
R_1000 Hz	0.07
R_8000 Hz	0.06
R_9000 Hz	0.02*
L_9000 Hz	0.05*

† "R" is for right ear and "L" is for left ear. Number follow "R" or "L" is the audiometric frequency used to test subject hearing threshold.

* Statistically significant difference between groups at alpha 0.05.

DISCUSSION

Excessive noise exposure in the workplace is a risk factor for hearing loss and dental hygienists are frequently exposed to ultrasonic noise for long durations during clinical care.[7] This study examined several variables and their contribution to noise-associated hearing loss. In a 2015 survey of California dental hygienists, 40% of the respondents had self-reported hearing difficulties.[2] Based on the age of participants, the researchers concluded that there was a higher prevalence of hearing loss among the dental hygiene participants than the general population as compared to the National Health and Nutrition Examination Survey from 1999-2006. Additionally, the researchers state that one contributing factor to the hearing loss reported by participants was likely due to longer occupational exposure, as the eligibility criteria required respondents to have practiced for a minimum of 20 years.[2] However, audiometric tests were not conducted to confirm hearing status of the participants and therefore these results just indicate participant perceptions.[2] In the current study, age was the most significant factor for hearing status in participants. Older participants had more hearing loss not associated with work-related factors such as years worked full time, years in practice, or years using an ultrasonic scaler. This finding is supported by past research examining noise-associated hearing loss in dental hygienists where researchers found participants had hearing difficulties likely related to increasing age through various outcome measurements.[1-6]

Table V. Multiple linear regression including audiometric frequency hearing thresholds†

	p-value			Beta parameter		
HL @ freq	age	Full	ultra-time	Age	Full	ultra-time
R_250 Hz	0.55	0.2	0.04	-0.1	-0.26	0.5
R_4000 Hz	0.02	0.02	0.2	0.8	0.88	-0.56
R_6000 Hz	0.3	0.04	0.32	0.41	0.99	-0.52
R_16000 Hz	0.02	0.54	0.53	1.81	0.46	-0.53
R_20000 Hz	0.01	0.78	0.89	0.41	-0.039	0.02
L_12500 Hz	0.05	0.8	0.5	1.38	-0.18	0.59
L_14000 Hz	0.007	0.92	0.9	1.83	0.07	0.1
L_16000 Hz	0.009	0.18	0.2	2.13	7.49	-7.3
L_18000 Hz	0.002	0.58	0.44	1.49	1.61	-2.39

† "R" Right ear and "L" is left ear. Predictors are age, full, and ultra-time.

In contrast, research also indicates age is significantly associated with hearing loss for many multi-factorial reasons that may or may not include environmental exposures.[13] Therefore, it is difficult to determine whether occupational noise exposure in the 2015 survey study[2] and the current study was also contributing to participants' hearing status. This is likely true for all studies currently on hearing loss in this population. Furthermore, in the current study it is likely that many other exposure variables were obscured by the strongly related age variable due to the relatively low sample size and the fact that age would impact both the experimental group and their paired controls. Additionally, it is likely that the relationship of age to hearing loss is very strong due to potential for exposure misclassification by using exposure proxies and it may be that any robust statistically significant relationships between exposure proxies were obscured.

Though age is the strongest related variable to hearing loss in the current study, other exposure variables showed qualitative differences in statistical analyses. One such value was the average hearing thresholds in the 1,000-10,000 Hz range in the right ear and 6,000-10,000 Hz range in the left ear; this was consistent with frequencies used to identify occupationally related hearing loss by Attais et al.[12] It is possible that more differences may have been noted in a larger age matched population. Results from paired t-tests also found significant differences at 9,000 Hz in both ears. This further supports occupational hearing loss in the experimental group as determined by values reported by Attais et al.[12] These findings are also consistent with a clinical study by Wilson et al. that determined dental hygienists in a high ultrasonic usage group had significant differences in hearing threshold when compared to those in a low ultrasonic usage group.[3] In the last twenty years ultrasonic instrumentation in dental hygiene has increased in duration per appointment.[2] In the 2002 pilot study, the researchers did not find differences in hearing thresholds at lower ranges but determined that ultrasonic usage may be impacting dental hygienists specifically at the 3000 Hz area;[3] this was also found in the right ear for participants in the current study, however there were more ranges that demonstrated significant differences in the current study.

Results indicated that dental hygienists who worked more days per week ("week" variable) had better hearing status, or lower hearing thresholds. This is counter to what is known about noise exposure. This finding may be an artifact due to the fact that the values of the "week" variable were not necessarily related to noise exposure (ie. How many days per week did you work?) and the univariate analysis included both the control and experimental group together. A larger sample size may be able to tease apart the more frequent ultrasonic exposures and resulting impact on hearing status as reported in previous research.[2] Findings from Lazar et al. indicated that increased exposure to ultrasonic noise by increased days working, negatively impacts hearing status.[2] However, the self-report of hearing status in the Lazar et al. study may also be misleading, as audiometric tests would have more clinical implications.[2]

This study had limitations. The relatively small sample size may have impacted the findings as the participants' age may have obscured other variables. Future studies should continue to explore age matched groups with larger samples to limit the impact of this variable. Additionally, with a larger sample size, years in practice for total cumulative exposure to ultrasonic noise can be further evaluated. Additional research should be conducted to determine the temporary hearing threshold shifts directly after ultrasonic noise exposure and whether wearing ear plugs has an impact on those values. Also, utilization of noise dosimeters on hygienists while using ultrasonic scalers would be helpful in future studies because the actual noise exposure and dose would be measured rather than estimated by using proxies. Proxies of exposure are subject to misclassification because they do not directly measure the actual noise exposure. When misclassification occurs, any comparison between an experimental and control group will be weakened and subject to a null bias. Finally, it is important to note that exposure to hazardous noise levels and indications of diagnosed hearing loss were self-reported by participants and subject to recall bias.

CONCLUSION

While results from this study demonstrated various qualitative differences in hearing status of the control group (non-dental hygienists) versus the experimental group (dental hygienists), age was found to be the most critical variable. This is also true for the general population not exposed to ultrasonic noise in the workplace. However, this data does demonstrate differences in hearing status based on various frequencies between the experimental group and age-matched controls that should be further explored with a larger population. Based on the results of this study, exposure to the noise of the ultrasonic scaler in the workplace did not have a significant impact on hearing status to have clinical implications for the dental hygienist, however there were findings that indicate more research is needed.

DISCLOSURES

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Jessica Suedbeck, MSDH, RDH
Gene W. Hirschfeld School of Dental Hygiene
Old Dominion University
Norfolk, VA, USA

Emily A. Ludwig, MSDH, RDH
Gene W. Hirschfeld School of Dental Hygiene
Old Dominion University
Norfolk, VA, USA

James Blando, PhD
School of Community and Environmental Health
Old Dominion University
Norfolk, VA, USA

Nathan Michalak, AuD, CCC-A
Virginia Health Sciences Otolaryngology
Eastern Virginia Medical School
Norfolk, VA, USA

Corresponding author:
Jessica Suedbeck, MSDH, RDH;
jsuedbec@odu.edu

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