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Dental professionals occupational noise exposure and its auditory and non-auditory effects

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ABSTRACT

DENTAL PROFESSIONALS OCCUPATIONAL NOISE EXPOSURE AND ITS AUDITORY AND NON-AUDITORY EFFECTS

by
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The purpose of this study was to assess noise exposure and its auditory and non-auditory effects on workers in five clinical departments in the School of Dental Medicine at Rutgers Biomedical Health Sciences Campus in Newark, New Jersey. The study included environmental noise level measurement, dental instrument sound level measurement, personal noise dosimetry and a questionnaire survey to assess non-auditory effects. Octave band analysis of environmental noise levels showed that they are slightly above the standard noise criteria for clinics, and measurements from six dental instruments confirm that they contribute higher sound pressure levels at the frequencies of 1000, 2000, 4000, and 8000 Hertz explaining why instrument noise is annoying to dental professionals. Higher frequencies can be an annoyance factor even if they do not exceed the permissible exposure limit of 85 dBA. Noise dosimeters worn by 18 volunteer participants from five departments showed that eight-hour time weighted average of occupational noise exposures were less than 85 decibels (dBA), the limit for mandatory occupational noise induced hearing loss (NIHL) protection. Pediatric dentistry resulted in the highest decibels at 75.1 dBA and General Practice resulted in the lowest levels of 68.7 dBA. The analysis of questionnaire responses (n=18) revealed 44% of participants reported the noise to be annoying, 28% reported productivity was affected, 61% reported difficulty with communication, 39% reported trouble concentrating, 6% reported contribution to an accident, 22% reported ringing in their ears, and 11% reported the noise affected their sleep quality. This study confirms that in spite of occupational exposure to dental noise being within acceptable standards, dental workers are concerned with the quality of occupational noise they ae being exposed to.

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by
Alexis Frees

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APPROVAL PAGE

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CHAPTER 1

INTRODUCTION

Noise induced hearing loss (NIHL) is the most common occupational noise disease in the USA: about 22 million US workers are exposed to hazardous noise levels at work, and annually, an estimated US $242 million is spent on compensation for hearing loss disability (Basner et al. 2014). NIHL effects were first recognized in early noisy occupational settings, such as weaving mills, where high levels of noise were prevalent (Stansfeld, et al. 2000). Over time, regulatory agencies prescribed occupational noise standards to protect NIHL. If occupational noise levels exceed the permissible exposure limit, creating a hearing conservation program should protect NIHL, which will also help keep compensation costs down. "Hearing conservation programs strive to prevent initial occupational hearing loss, preserve and protect remaining hearing, and equip workers with the knowledge and hearing protection devices necessary to safeguard themselves" (United States Department of Labor, 2002). Despite the development of additional treatment options for NIHL, identifying potentially hazardous noise exposures and implementing control measures to reduce these exposures are strategies currently in existence that should be implemented (Basner et al. 2014).

Apart from NIHL, non-auditory health effects were noted in many environmental noise studies from aircraft and urban traffic noise (Stansfeld, et al. 2000), noise in hospital settings (Choosong, et al. 2011) and noise in dental clinics (Burk and Neitzel, 2016). Non-auditory effects identified in environmental noise include poor sleep quality and sleep disturbance, cardiovascular disease, and even impairment of cognitive performance in children. (Basner et al., 2014) Getting the right amount of sleep is imperative in order to be successful at work; however, sleep disturbance due to environmental noise exposure can create issues staying alert, which in turn can lead to work place accidents and an overall lower quality of health.

The present study specifically focusses on auditory and non-auditory effects in dentistry. In the U.S. there are 137,000 general practice dentists and 5,000 dental specialists (O*Net Online, 2019). Dental clinics are one occupational setting where noise monitoring has been performed (Burk and Neitzel, 2016; Choosong et al., 2011; Gijbels et al. 2005; Ma et al., 2017; Sorainen and Rytkönen, 2002). Previous assessments indicate occupational exposures do not exceed the eight-hour time weighted average action level of 85 dBA (Choosong, et al. 2011) but do suggest they may have an impact on dentist in terms of non-auditory effects of noise (Gijbels et al. 2005; Ma et al., 2017). Studies have also shown, noise exposure from dental equipment is gaining increased attention worldwide as a potential physiological and performance issue (Ma et al., 2017).

1.1 Objective

This study has been undertaken to assess environmental and occupational noise in newly remodeled dental clinics at Rutgers School of Dental Medicine located in Newark. The objective of this study is (i) to assess the environmental and occupational noise exposures in the dental clinics, (ii) assess the quality of dental instrument noise in terms of sound pressure levels at various octave bands (iii) to assess non-auditory effects on dental workers, and (iii) to understand the relationship between the quality of dental noise and the recorded non-auditory effects.

CHAPTER 2

LITERATURE REVIEW

Studies have been done around the world where they have investigated the non-auditory effects metrics and provided greater detail of how noise can have adverse effects to workers. A study was done in the pediatric dentistry clinic and the dental laboratory in Hong Kong where they were able to identify physiological and psychological conditions reported from negative impacts from noise exposure. "The negative symptoms of sleeping problems, fatigue, headache, irritation, dissatisfaction on the life, hypertensive heart diseases, and tinnitus were also found to be related to the noise exposure." (Ma, et al., 2017).

The literature we reviewed consisted of articles and journals referencing the background of psychoacoustics and studies done from different Universities who performed dosimetry and area monitoring on undergraduate students and graduate students. In addition, we also used professional textbooks and reference consensus standards to establish basic concepts and to provide benchmarks by which to compare our data.

2.1 Background

"Psychoacoustics is a branch of science dealing with the perception of sound, the sensations produced by sounds, and the problems of communication" (Psychoacoustics, 2019). Psychoacoustics is not a new term; for centuries, dating back to the early Greeks, there have been studies done to find the physical bases for perception and understanding of how certain pitches may affect hearing. Robert Hooke created a wheel that when spun, sound would be produced when the card vibrated, and as the wheel spun faster the sound rose. Felix Savart took this theory even further to study human hearing pertaining to sound frequency and pitch. Gustav Fechner, known as the “Father of Psychophysics” and wrote one of the first books, “On the Sensation of Tones”, and began controlled experiments focusing on pitch and sound source localization (Yost, 2015).

“Lord Rayleigh and others observed and reasoned that a sound presented to one side of the head would be more intense at the ear nearest the sound than at the far ear, especially because the head would block the sound from reaching the far ear (the head forms an acoustic shadow)” (Yost, 2015).

“The interaural time difference (or ITD) when concerning humans or animals, is the difference in arrival time of a sound between two ears. It is important in the localization of sounds, as it provides a cue to the direction or angle of the sound source from the head. If a signal arrives at the head from one side, the signal has further to travel to reach the far ear than the near ear. This path length difference results in a time difference between the sound's arrivals at the ears, which is detected and aids the process of identifying the direction of sound source” (Interaural Time Difference, 2018) This time difference was first looked at as being so small (milliseconds) that it was not considered to have any significant effect. “In 1907, Rayleigh argued that the interaural level difference (ILD) was a possible cue at high frequencies where the ILDs would be large due to the head shadow, and an interaural time (phase) difference could be a cue at low frequencies” (Yost, 2015).

Because the auditory mechanism is less sensitive to extremely high and low frequencies the loudness of audible sounds in those frequency regions will in general be less than that in middle frequency sounds of the same sound pressure level. For example, a tone of 40 dB will be heard clearly by a normal individual when its frequency is 1,000 Hz but it will be barely audible if its frequency is 100 Hz. Therefore, instruments were developed to measure the loudness of tones rather than intensities based upon equal loudness contours developed by listeners judged to be equal (Figure 2.1).

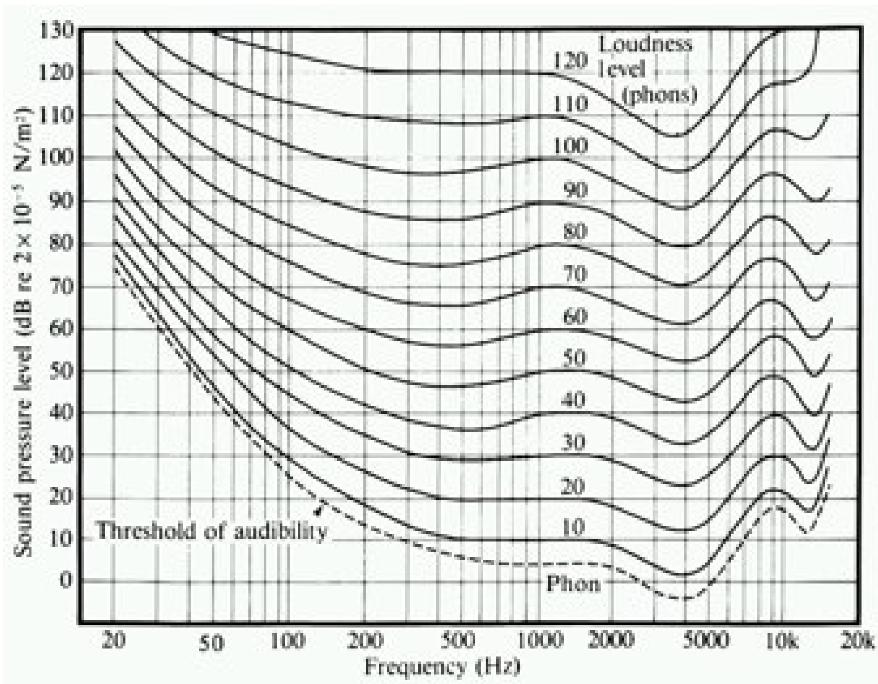

Figure 2.1 Equal-loudness contours of pure tones for field conditions. The numbers indicate the loudness level, in phons, of the tones that fall on each contour. This figure is from ISO 226:1987 and has been reproduced with the International Organization for Standardization, ISO.

2.2 Environmental Ambient Noise Monitoring

Looking at vibration, location, and noise control should all be considered to help alleviate any extra noise exposure in the dental clinics. "The American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Technical Committee 2.6, Sound and Vibration Control, has sponsored research that has greatly expanded the available technical data associated with HVAC acoustics, improving the ability of designers to make more accurate calculations relative to the acoustics characteristics of HVAC systems" (ASHRAE, 2003).

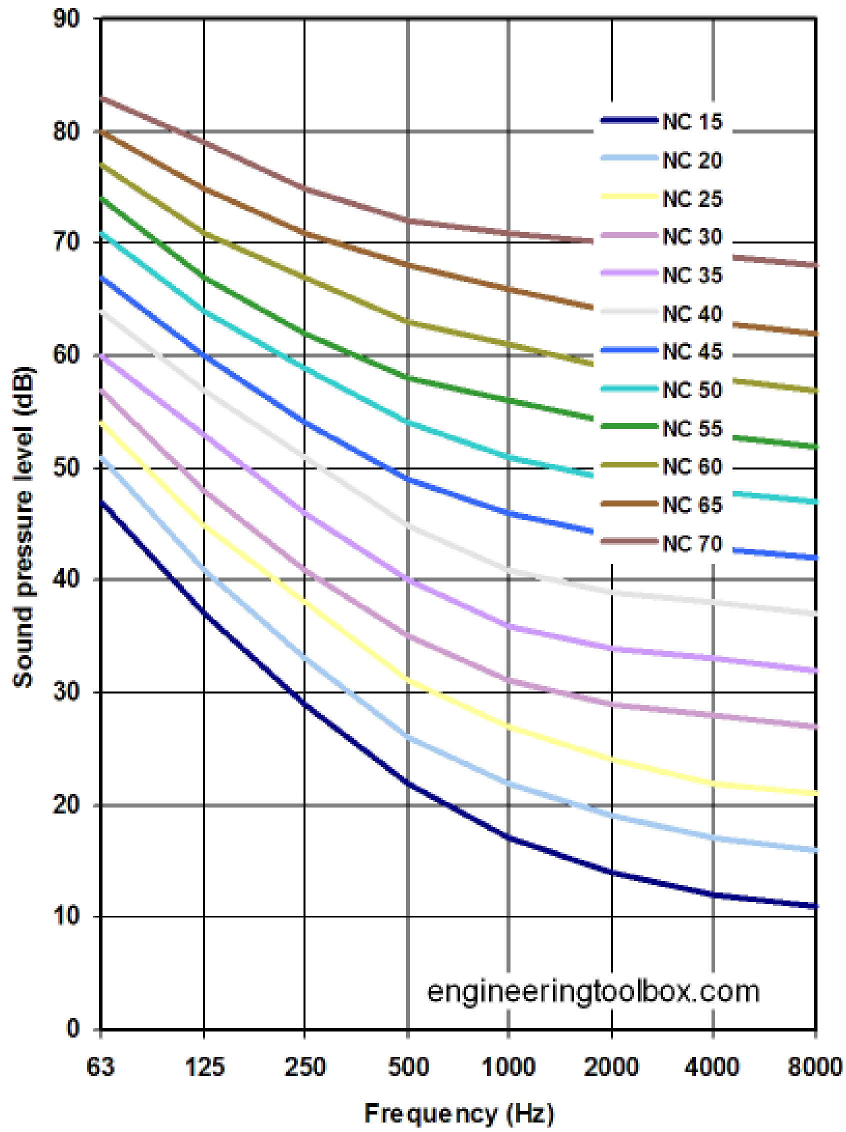

Figure 2.2 Noise Criteria Curve.

The noise criteria method is a single number rating used in North America for more than 30 years that is somewhat sensitive to the relative loudness and speech interference properties of a given noise spectrum (Engineering Toolbox, 2004). The criterion curves define the upper limits not to be exceeded to meet occupant acceptance in certain spaces (ASHRAE, 2003). For hospital and clinical wards, the recommended noise criteria (NC) are 30-40 (See Figure 2.2). These design guidelines provide a benchmark for sound levels appropriate to various types of space occupancies and is assumed to be neutral sounding and tolerable.

2.3 Dental Equipment Noise Measurements

The ultrasonic equipment used in dentistry may harm a dentist's hearing. Gijbels et al. (2005) performed a cohort study over a period of ten years, examining Flemish dentists' (n=112) ability to hear and detect sensation in their fingers. While the researchers did not find any statistical significance in the dentists' ability to detect sensation in their fingers, the researchers found a significant difference between the dentists' rate of hearing loss, comparing hearing loss in their right and left ears at various frequencies. For instance, they found an average reduction of 8.46 dB at 250 Hz and an average reduction of 6.15 dB at 4,000 Hz, both in the left ear. The researchers explain that this may be because the dentists were all right-handed and, by positioning their left ear closest to their patient, that ear was most affected by the ultrasonic equipment commonly used in dentistry. This shows that the equipment used in dentistry may be harmful to a dentist's hearing. Other researchers have examined the effects of ultrasonic equipment on hearing in the realm of dentistry. The instruments gave off a higher frequency noise ranging between 1 kHz and 3 kHz, which they found was consistent with readings from the octave band instrument. The dental equipment gave the greatest amount of noise compared to building facilities and human voices. Both hearing and health were found to be affected with dental professionals working more than 10 years for more than 8 hours a day. Ma, et al, (2017) found, that there were non-auditory effects found from exposure to high frequency. As in a study done in the Acoustics Laboratory of Kuopio Regional Institute of Occupational Health, they were also able to identify that hand pieces were a contributing factor to noise levels (Sorainen and Rytkönen, 2002).

The Dental School of the University of Porto completed a study where they measured various pieces of equipment such as, clinical hand pieces, turbines, and laboratory engines to name a few, in the frequency range of 20 Hz to 20 kHz with a sound level meter at ear level at a 1-meter distance from the operator. This study concentrated on the frequency of sound and its comparison to noise induced hearing loss. They found that their levels were slightly higher, +1 to +5 dBA, than other countries like the United Kingdom and Saudi Arabia.

A study was done at the Acoustics Laboratory of Kuopio Regional Institute of Occupational Health where they studied the noise levels of different pieces of equipment for dentists and physicians. This study researches a very controlled environment where the instruments were monitored at idling and while in use. Monitoring was completed while drilling into a polyacetal plate. Their results indicated that the new micrometer hand pieces were nosier than the old ones, but the new turbines were quieter than the old ones (Sorainen, and Rytkönen, 2002). Sampaio Fernandes et al. (2006) came to the conclusions that reducing the sound level of noise by 4-7 dBA can be possible by regular maintenance, early repairs, and replacement of defective items and use of newer less noisy models. Increasing the sound absorption of the room may decrease noise level by 3-5 dBA .

2.4 Personal Noise Dosimetry

Previous noise evaluations have utilized either ambient noise measurements at the clinicians hearing zone or dosimeters that evaluated noise over 225 second time intervals. The dosimeters used could not be modified to change the time interval for each measurement taken. The subjects were asked to record their procedures, the times they performed them and handed that in at the end of monitoring. The monitoring hours average time for each dosimeter was 5.5 +/- 3.1 hours. The mean Leq level was 63.6 +/- 13.3 dBA, the dental hygienists Leq being the highest (66.4 dBA) and students with the lowest (60.5 dBA). They also found that pediatrics had the highest average (76.9 dBA) and maximum exposures (92.1 dBA). They found that 4% of the 79 dosimetry measurements taken from 49 subjects exceeded the recommended exposure limit developed by NIOSH. (Burk and Neitzel, 2016)

Another study was completed at the Dental School of Prince of Songnkla University on 55 dentists, 49 dental assistants, and 9 laboratory technicians. Turbines, drills, and suction were used in most of the job tasks. Their results showed peak noise exposure in the 1000, 4000, and 8000 Hz and laboratory technicians had the highest peak level (137.1 dBC), with noise levels ranging from 49.7-58.1 dBA (Choosong, et al., 2011).

At the Ahmedabad Dental College and Hospital, noise measurements were taken at 30 second intervals at 31.5 Hz to 8000 Hz with Mini sound meters. The monitoring was completed in four different departments in which they performed different tasks ranging from trimming dentures, cutting and vibration of gypsum, use of suction pumps and high-speed rotors. They found that the gypsum lathe trimmer was the noisiest instrument ranging from 87.36 to 98.3 dBA (Parkar, et al., 2014).

2.5 Questionnaire Surveys

Noise induced hearing loss is not the only effect noise has on hearing. Even when noise levels may not be over the 85 dBA threshold, noise produced from equipment, humans, or the environment can have effects on a workers' physiological and psychological state, on how well they perform job duties, and can cause fatigue, headaches, and irritation. Identifying equipment and job tasks that may cause some of these effects can help workers become more aware of the general knowledge of occupational noise exposure and different ways to control and reduce their exposure to noise. A study was done in the Prince Philip Dental Hospital of Hong Kong where they investigated the psychoacoustic metrics and identified in greater detail how noise can have negative responses to workers. They related the data they collected from the noise monitoring and the results from objective data in order to understand their associations. They found that the noise levels in the laboratory were higher than those measured in the clinic. The risk of NIHL was found to be higher for those who worked in the field for more than 10 years and their daily work shift was over eight hours. They were also able to identify the impact on the workers' health state could be linked to how bad their hearing was damaged by noise. (Ma, et al. 2017)

CHAPTER 3

MATERIAL AND METHODS

The research study took place in the Rutgers School of Dental Medicine located in Newark, New Jersey. The dental school is one of the larger dental schools in this area and it awards 110 Doctor of Dental Medicine degrees and treats approximately 1200 patients yearly (Rutgers, the State of New Jersey, 2019). This study was conducted in five different departments: General Practice Dentistry, Orthodontics, Pediatric Dentistry, Periodontics, and Prosthodontics programs. The study included four different measurements– (i) Environmental ambient noise measurement, (ii) Dental equipment noise measurement, (iii) Noise dosimetry, and (iv) Questionnaire survey. The following section provides details of each step. All of the measurements were taken during the day, this helped to keep the study more uniform and keep most independent factors to be similar. The study was approved by the New Jersey Institute of Technology Institutional Review Board.

3.1 Environmental Ambient Noise Monitoring

The dental school is located in an urban area (Figure 3.1) with high traffic patterns, ambulances, etc. that may contribute substantially to environmental noise. To account for the ambient environmental noise, which included ventilation, urban noise, and other office noise, octave band sound level was measured prior to the start clinical activities.

Figure 3.1 The Urban Setting of the School of Dental Medicine.

Ambient noise data were collected in periodontics, prosthodontics, orthodontics, pediatric, and general practice clinical areas prior to the start of work activities. The goal was to collect ambient noise level to see if it was within the prescribed standards for similar workplaces. Figure 3.2 shows the layout of the dental clinics. Each bay consisted of eight dental workstations, four on each side with a five-foot aisle in the middle. Each dental workstation measures approximately 36 square feet and contains a patient chair, a dental instrument tray and stand, a stool for the dental professional, a sink, and a benchtop. The bay partitions are approximately five feet high to improve patient privacy. Each bay area is served with four supply diffusers and two exhaust grills that provide ventilation and thermal comfort to the clinic. The study team uniformly collected four stationary measurements from each bay, starting at the bay entrance and working toward the windows (Figure 3.2).

Figure 3.2 School of Dental Medicine Bays.

A Quest Model 1900 Type 1 Precision Sound Level Meter with the Model OB-300 Octave Filter was used for this measurement. The instrument was set to evaluate the room noise levels. Measurements included the linear sound pressure level (reference 0.0002 microbars or the threshold for hearing) (Olishifski, 1981), with A and C weighted curves, and the linear sound pressure level at the center of each octave. All readings were taken at slow response setting (one second time intervals).

Ambient noise measurements with the octave band were collected approximately four feet above the floor to estimate the position of the dental professional's head while working in each respective department. The study team manually collected each measurement averaged over a ten second time interval at each octave (63, 125, 250, 500, 1000, 2000, 4000, and 8000 Hz). The recorded levels were stored in a computer file for further analysis.

3.2 Dental Equipment Noise Measurements

Previous studies have identified several dental instruments as significant noise exposure sources to dental clinicians (Burk and Neitzel, 2016; Choosong, et al., 2011). These instruments emit high frequency noise which is also believed to be a source of significant non auditory effects on the clinicians (Sorainen and Rytkönen, 2002). Upon consultation with the program supervisors, the following instruments were selected to be monitored for this noise study: high and low speed hand pieces, suctions devices - with and without attachments, compressed air with and without syringe tips, and a cavitron (Figure 3.3).

Figure 3.3 Selected Dental Instruments for Octave-band Sound Pressure Level Analysis A- small suction, B- compressed air, C- large suction, D- cavitron, E- hand pieces.

The School of Dental Medicine employs three full-time mechanics to ensure all dental equipment and facilities are always operating properly. Any equipment that does not work is removed from use until it is repaired, and proper operation is verified. In addition, these mechanics ensure that appropriate calibration and other duties are performed to comply with facilities accreditation. All equipment is sterilized and sealed in plastic bags before being used on the clinical floors.

A mechanic operated each equipment, which was verified to be in proper operating condition. Noise measurements were taken approximately one foot away from the instrument, to simulate use on a patient. The same sound level meter was used to record sound pressure levels. The study team manually recorded sound levels averaged over a ten second time interval at each octave band from 63 to 8,000 Hz. The recorded levels were stored in a computer file for further analysis.

3.3 Noise Dosimetry

Personal noise exposure monitoring was performed in various clinical practices to verify the average noise exposure levels are within the NIHL limit. Post graduate students were selected randomly by contacting the supervisors from the previously stated five dentistry specialties and distributing a recruitment flyer approved by IRB. Post graduate students were chosen for this study because they have mastered basic dentistry skills and their work activities would closely resemble those of dentists in their respective practices. Post graduate students are supervised during their shift by faculty in their respective programs. Potential participants were given the opportunity to decline participation in this study and participation was voluntary. Prior to recruitment it was ensured that the participants had no hearing abnormality. Altogether 18 volunteer participants were recruited. The participants read and signed an informed consent form approved by IRB.

How the dosimeters would be worn was demonstrated to the participants. They were also assured that the microphone recorded sound pressure levels and not conversations and were advised to wear the dosimeter during lunch and break periods. At the end of the work shift, the dosimeters were paused, and a functional test was performed to ensure the instruments were functioning properly. Data was downloaded from the dosimeters using the Quest Suite Professionals 2 software developed by 3M to retrieve data collected by their instruments.

Quest Model NoisePro DLX Type 2 Dosimeters (Figure 3.4) were used to record exposure to clinicians working on patients. Personal noise dosimetry was collected from the lapel of each clinical participant at their hearing zone and recorded the A-weighted sound pressure level integrated over 15 second slow response (1 second) intervals to capture the short duration work activities with the various dental instruments. Dosimeters were calibrated and tested to ensure accuracy. The calibration was performed before and after every use using a Quest Sound Calibrator Model CA-12B (Figure 3.4).

Figure 3.4 Quest Noise Dosimeter and Calibrator.

The A weighing sound pressure levels are designed to approximate equal loudness curves at low sound pressure levels while the C weighing sound pressure levels are designed for high sound pressure levels. A-weighted SPL's do a poor job of measuring low frequencies (<500 Hz) but they are good for occupational noise measurements, which is why OSHA and ACGIH use them.

3.4 Questionnaire Survey

Research on non-auditory effects associated with noise exposure compared NIHL is gaining momentum in recent years (Basner et al. 2014; Gijbels et al. 2005). A questionnaire was developed to assess the non-auditory effects from the occupational noise in dentistry. A similar questionnaire was used in studies conducted by previous researchers (Burk and Neitzel, 2016; Ma, el al. 2017). The questionnaire was divided into two parts, with the first part administering pre-noise monitoring at the starting of the work shift and the second part administering post-noise monitoring, at the end of the work shift. The first part included questions on exclusion criteria, general demographic information, their dental practice, work experience, and three questions on how noise affects them. The second part was designed to collect information regarding the number of patients seen, whether they had a break, and subjective questions regarding psychological effects. Using a five-point Likert scale (Likert, 1932) the participants rated the effect of dental noise on annoyance, productivity, concentration, communication interference, contributory to accident, ringing in ear, and sleep quality. The participants also identified the noisiest equipment and dental procedure they encounter during the day of the study.

Before the start of the work shift, the participants completed the prequestionnaire, wore a personal noise dosimeter throughout their shift, and completed a post monitoring questionnaire at the end of the shift. The consent forms and questionnaires used in this study were reviewed and approved according to the requirements of the NJIT Institutional Review Board. Each consent form, questionnaire and dosimeter they wore, were numbered ensure confidentiality of participants' identities.

CHAPTER 4

RESULTS

4.1 Environmental Ambient Noise Monitoring

The environmental sound pressure levels at eight center octaves from 63 to 8,000 Hz measured before the starting of work shift at the patient bays were averaged for each of the five dental practices. The average sound pressure levels were then compared against the ASHRAE design guidelines for HVAC-related background sound for clinical environments. ASHRAE lower (LC-30) and upper (LC-40) design guidelines and the average environmental sound levels in Orthopedics, Periodontics, General Practice, Prosthodontics and Pediatrics departments are enumerated in Table 4.1 and illustrated in Figure 4.1. The ambient noise level in Prosthodontics bays was mostly within the limits, however, the other four departments showed excess ambient noise, especially in the 500 – 4000 Hz frequency bands. The results established that these departments should investigate noise sources and noise abatement measure to bring the environment noise level within the ASHRAE standard.

Table 4.1 Average Ambient Noise Levels in Clinical Bays

Octave band	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
	1	2	3	4	5	6	7	8
NC – 30	57	48	41	35	31	29	28	27
NC – 40	64	57	51	45	41	39	38	37
Orthopedics	55	54	53	57	54	46	45	41
Periodontics	60	53	52	55	53	47	42	38
General Practice	51	51	53	56	47	47	38	36
Prosthodontics	59	48	47	46	40	38	39	41
Pediatrics	64	60	57	56	51	45	41	36

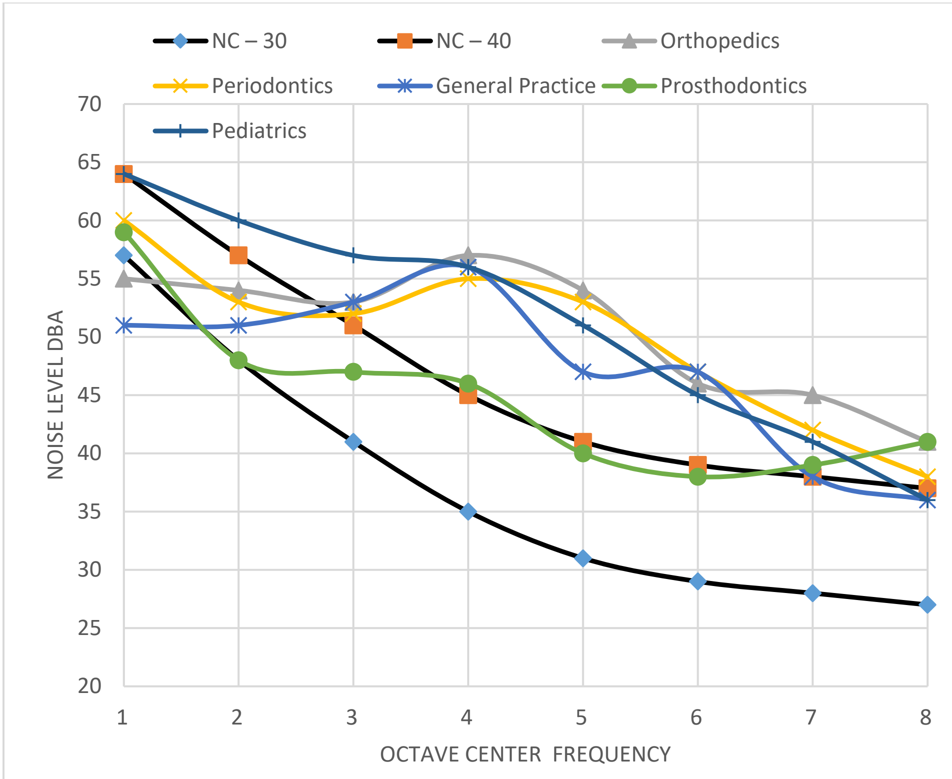

Figure 4.1 Ambient Noise Criteria and Octave Band Center Frequency at Dental Departments.

4.2 Dental Equipment Noise

Octave band noise levels for the dental equipment are presented in Table 4.3 and illustrated in Figure 4.2. Review of the data confirms significant contribution of the 1,000, 2,000, 4,000, and 8,000 Hz frequencies to the overall sound pressure level. The high and low speed Starhead hand pieces contributed highest sound pressure measuring at 77.5 dBA and 76 dBA. The noise levels are generally loudest in the 2000, 4000, and 8000 Hz for almost all instruments. For suction and air equipment, we measured higher sound pressure levels at all frequencies without the attachments used during dental procedures, which measured above the OSHA limit. However, dental clinicians would not use this equipment without the attachments, and therefore, attachment use results in lower noise exposure to the dentists. For suction and air, 2000, 4,000, 8,000 Hz contribute to the majority of the noise produced by the equipment. For the cavitron, 8,000 Hz contributes the highest noise exposure (See Table 4.2 and Figure 4.2).

Table 4.2 Dental Clinic Equipment Octave Band Sound Level Measurements (dBA)

Equipment Name	63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
High Speed Starhead Hand Piece	68	59	56	54	67	67	74	77.5
Slow Speed Starhead Hand Piece	68	59	55	53.5	54	58	68	76
Large Suction	52	47	49	50	55	61	66	72
Small Suction	53	45	44	41	44	49	57	67
Air	57	55	51	45	46	51	58	64
Cavitron	52	48	42	40	36	36	44	66

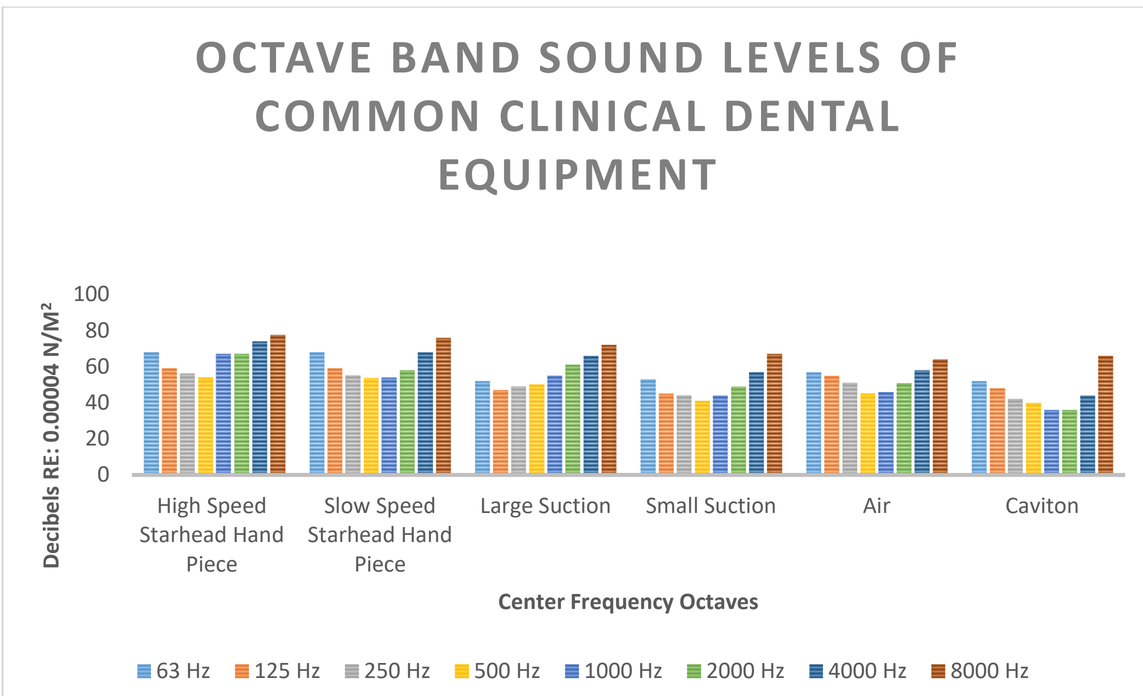

Figure 4.2 Octave Band Sound Levels of Common Clinical Dental Equipment.

4.3 Noise Dosimetry

A total of 18 personal noise dosimetry samples were collected from dental professionals representing five different practices (Table 4.3). The participants spent approximately 5.5 hours working on patients (including one hour for lunch) and the remaining three hours performing other activities with negligible noise exposure. One personal noise dosimeter malfunctioned when attached to a participant. The Quest Noise dosimeter integrates the recorded sound pressure levels at 1 second increments and reports it as an overall average sound pressure level (Lavg) over the recording time. The noise dosimeter also calculates a projected 8-hour time weighted average (TWA) if the monitoring period (instrument run time) is less than 8 hours. In our case, the TWA was lower because the other 3 hours of the day participants were exposed to much lower noise levels. Analysis of personal noise exposure monitoring data using the American Industrial Hygiene Association (AIHA) IHSTAT+ ® program, and average sound pressure level (Lavg) and eight-hour time weighted average (TWA) in dBA were calculated for each dosimeter. Table 4.4 presents the average Lavg and TWA values for each of the departments.

Table 4.3 Summary Dosimeter Results of Participants

Participant #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	**Avg**
Location	Perio	Perio	Perio	Perio	GPR	GPR	GPR	GPR	Ortho	Ortho	Pedo	Pedo	Pedo	Pedo	Prost	Prost	Prost	Prost	
Run Time (Hr	4:50	5:03	3:40	4:45	5:27	5:24	-	4:53	6:21	8:25	5:18	5:37	5:02	5:41	5:18	5:42	5:38	5:33	**5:27**
TWA (dBA)	68.7	68.8	71.5	73.6	70.7	66.4	-	68.5	71.1	79.1	77.8	70	72	77.1	77.8	69.5	74.7	66.1	**72.0**
Lavg (dBA)	72.4	72.1	77.1	77.3	73.5	69.2	-	72	72.5	78.7	80.8	72.6	75.3	79.5	80.8	71.9	77.2	68.7	**74.8**

Table 4.4 Average Sound Pressure Levels during a Work Shift at Various Departments

Department	Number of Participants	Average Sound Pressure level (Lavg)	Projected Eight-hour TWA
General Practice	4	71.6 dBA	68.5 dBA
Periodontics	4	74.7 dBA	70.7 dBA
Prosthodontics	4	73.3 dBA	70.7 dBA
Pediatrics	4	77.1 dBA	75.1 dBA
Orthodontist	2	76.0 dBA	75.8 dBA

The overall (n=17) eight-hour time weighted averages (TWA) found an exposure level of 71.3 dBA with a standard deviation of 3.76 dBA. Calculation of the geometric standard deviation, used to assess data variability was 1.05, indicating very little variability in all 17 participants. The 95th percentile for this data set is 80.9 dBA, meaning that 95% of all exposures will be less than 81 dBA and dental professionals are within the OSHA standard and will not be required to participate in an OSHA Hearing Conservation Program (HCP). This also means that the probability of dental clinical staff exceeding the occupational exposure limit of 85 decibels is less than 0.1%. For exposure monitoring data with a geometric standard deviation of 1.5% only two samples would be necessary to confirm exposure less than the occupational exposure limit. Pediatrics was identified to have the highest sound pressure levels and General Practice had the lowest level.

4.4 Questionnaire Survey

As has been described in section 3.4, the questionnaire aimed to identify the non-auditory effects from noise in dental clinics. The participants rated their perceived effects in a scale of 1 to 5, with 1 being no effect and 5 being extremely affected. The pre and post questionnaire survey results (n = 18) are presented in Table 4.5. The pre-questionnaire included 3 question assessing (i) how disturbing noise is to them, (ii) in the past 12 months how disturbed/annoyed/bothered they were with dental noise, and (iii) how concerned are they that noise will affect there hearing. The average ratings (n=18) for these three questions were 2.4, 2.1 and 2.5 - falling between the "slightly" and "moderately" assessments. It is also noteworthy that 50%, 30% and 44% of the respondents rated 3 (moderately) or higher, for the above three questions, showing that a substantial number of participants among this group were reasonably concerned with dental noise.

Table 4.5 Summary Questionnaire Responses from Participants

	Partiticpant #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	AVG
Pre	Location	Perio	Perio	Perio	Perio	GPR	GPR	GPR	GPR	Ortho	Ortho	Pedo	Pedo	Pedo	Pedo	Prost	Prost	Prost	Prost	
	Experience noise as disterbing	2	3	2	3	3	2	1	2	3	3	2	1	3	2	2	3	3	3	**2.4**
	Past 12 months experience noise as annoying, disturbing or bothering	1	3	1	1	2	1	1	1	3	3	2	3	2	2	2	2	3	4	**2.1**
	Concern about noise affecting their hearing	3	4	1	4	2	1	1	1	3	3	2	4	2	2	1	3	3	5	**2.5**
Post	Annoyed with noise	1	1	1	1	1	1	1	1	2	3	2	2	2	3	1	1	3	3	**1.7**
	Affected productivity	1	2	1	1	1	1	1	1	1	1	1	2	1	3	1	1	3	2	**1.4**
	Affected communication	1	2	1	1	2	1	1	2	1	2	2	3	2	3	2	1	3	5	**1.9**
	Affected concentration	1	3	1	1	1	1	1	1	2	2	1	2	1	3	1	1	4	3	**1.7**
	Contributed to accident	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	1	**1.1**
	Caused ringing in ears	1	2	1	1	1	1	1	1	1	2	1	1	1	1	1	1	4	3	**1.4**
	Affected sleep quality	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	3	**1.2**
	Average effect	**1.0**	**1.7**	**1.0**	**1.0**	**1.1**	**1.0**	**1.0**	**1.1**	**1.3**	**1.7**	**1.3**	**1.7**	**1.3**	**2.1**	**1.1**	**1.0**	**3.0**	**2.9**	**1.5**

The post section of the questionnaire included seven questions. It was administered at the end of work the shift. On the average, each dentist saw approximately four patients per shift (range 2-6). The participants rated the effect of dental noise on annoyance, productivity, concentration, interference in communication, contributory factor in accident, ringing in ear, and sleep quality. The averages (n=18) were 1.7, 1.4, 1.9, 1.7, 1.1, 1.4, and 1.2, respectively, representing scores between "no" to "slight" effect. The highest average score at 1.9 was in affecting communication, followed by 1.7 for annoyance and affecting concentration. It was found that 44% of participants reported the noise to be annoying, 28% reported productivity was affected, 61% reported difficulty with communication, 39% reported trouble concentrating, 6% reported contributed to an accident, 22% reported ringing in their ears, and 11% reported that noise affected their sleep quality. The above percentages reflect ratings value of 2 or more. Out of 126 possible questionnaire responses, 38 or 30% of the responses were rated as a 2, 3, 4, or 5 for non-auditory effects, indicating that noise is of significant concern.

The last row in Table 4.5 shows the average of the seven non-auditory effects for each participant, which can be used as the measure of the overall non-auditory effect. In terms of the overall effect, the Prosthodontic department received the highest average effect of 2.0, followed by the Pediatrics and Orthodontic departments of 1.6 and 1.5, respectively.

We checked the correlation of the participants' average noise level recorded in their dosimeters and their responses in terms of overall non-auditory effect (Figure 4.3). The regression had an extremely low correlation (R^2= 0.004), which implied that non-auditory effects are not dependent on the average noise level experienced during the work shift.

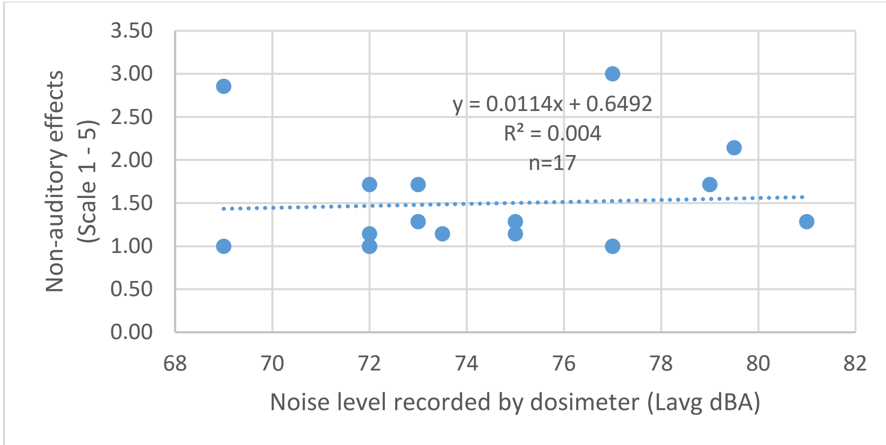

Figure 4.3 Correlation Analysis of Non-Auditory Effects and Noise Level in the Shift.

We also checked for possible correlation between the participants' post shift responses in terms of overall non-auditory effect and pre-shift responses on how concerned they were about dental noise affecting their hearing (question # 3). Although this analysis showed (Figure 4.4) the non-auditory effects increased with participants concern, however, the correlation was extremely weak (R^2= 0.0733), implying that the participants concern about effects on their hearing did not affect non-auditory noise effects at the end of the work shift.

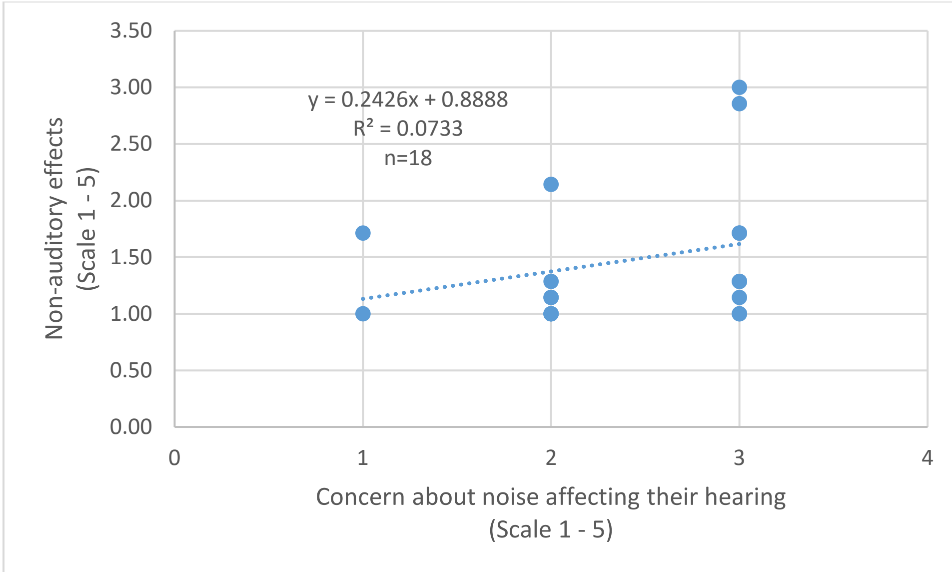

Figure 4.4 Correlation Analysis of Non-Auditory Effects with Personal Concern about Noise Affecting their Hearing.

Furthermore, we checked two more correlations: (i) Non-auditory effect versus Question # 1 (How disturbing is noise to you) (Figure 4.5), and (ii) Non-auditory effect versus Question # 2 (How annoyed, disturbed or bothered with noise in the past 12 months) (Figure 4.6). Both of these correlations were positive with strong R^2 values of 0.2726 and 0.5712.

The first two correlation studies, support the fact that non-auditory effects noted by the participants were not affected by the factors related to their auditory effects. The average noise level recorded by dosimeters were below 81 dBA, and the 8 hour TWA were well below the 85 dBA limit. At least at this level of noise, the noise dose did not explain non auditory effects in terms of annoyance, productivity, communication, concentration, contribution to accident, ringing in ears and sleep quality. Similarly, Question # 3, "How concerned you are about noise affecting your hearing" was also related to their auditory concern, which did not correlate to the participants' non-auditory experiences.

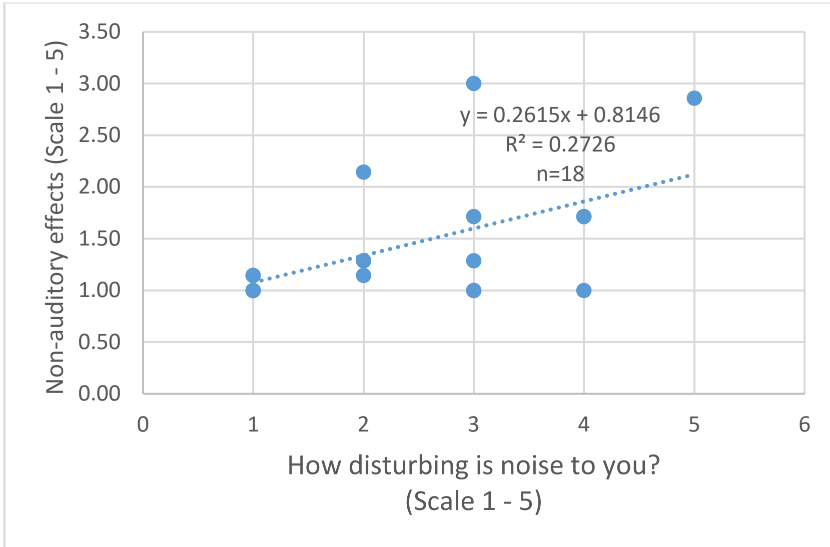

Figure 4.5 Correlation Analysis of Non-Auditory Effects and Experience Noise as Disturbing.

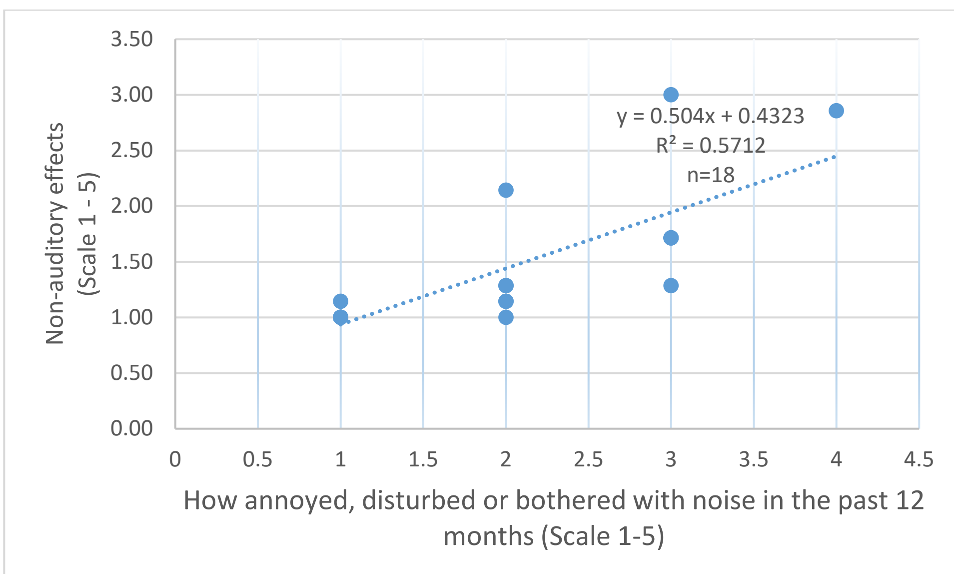

Figure 4.6 Correlation Analysis of Non-Auditory Effects and Experience Noise as Annoying, Disturbing or Bothering.

On the contrary to the above, Question # 1: “How disturbing is noise to you?” and Question # 2: “How annoyed, disturbed or bothered you were with noise in the past 12 months?” reflected personal sensitivity of the participants in terms of non-auditory effects of noise. In both cases the positive correlation supports the fact that persons with sensitivity to noise, are affected more from dental practice noise.

In the post work shift survey, the last two questions asked if participants were affected by any instrument and any procedure in particular more than others. Although 50% of the participants did not identify any instrument as being annoying to operate, 33% identified the high-speed drill as most annoying to operate, and 11% identified the suction and cavitron as most annoying to operate. Comparing these responses and the equipment octave band results (Table 4.2) noted a correlation between the high frequencies noise in the 1000, 2000, 4000, and 8000 Hz range and the responses. Cleary the high speed hand piece recorded highest dBA in the above frequencies, and was followed by the large suction instrument. Although the cavitron was identified as an offending instrument, its dBA values were not as high.

CHAPTER 5

DISCUSSION AND CONCLUSION

Evaluation of noise exposures in dental clinics with respect to noise NIHL has been evaluated by others (Burk and Neitzel, 2016; Choosong et al., 2011; Ma et al., 2017) and their results indicated this was not an issue. Evaluation of non-auditory effects in dental clinics is a fairly new topic that needs to be researched and assessed more closely to truly understand the full health effects associated with dental professionals (Ma et al., 2017; Burk and Neitzel, 2016). This study evaluated both issues and also considers the ambient noise levels in the dental clinic.

This research quantified the ambient noise levels in five departments within the School of Dental Medicine in Newark New Jersey, the linear sound pressure levels at the center octaves for commonly used dental instruments, and personal noise dosimetry from participants conducting typical dental procedures in their area of specialty. The study also quantified the non-auditory effects using a questionnaire survey.

Ambient noise evaluation indicated that four out of the five dental departments registered noise level above the recommended level. This result warrants a more detailed study for the determination of noise sources and an abatement program using appropriate noise insulation of the outdoor noise and noise from HVAC, ventilation or other ambient noise. The study also confirmed, using noise dosimeters, that the dental professionals' noise exposure was less than the OSHA action level of 85 decibels, thus a mandatory hearing protection program is not warranted.

Sound pressure levels at the center octaves for commonly used dental instruments showed similar results found by other researchers. Sound levels for the suction pump were 72 dBA in Portugal, and in the United Kingdom they were 68-70 dBA (Sampaio Fernandes, et al. 2006). This study found a comparable value of 70-73 dBA. For the contra hand piece the sound levels were 69-75 dBA in Portugal, in the United Kingdom were 72-75 dBA, and in Saudi Arabia they were approximately 68 dBA (Sampaio Fernandes, et al. 2006). This study produced a comparable value of 67-78 dBA, thus validated both the measurement procedure, as well as the quality of the dental instruments used.

The dental equipment produced higher decibel levels in the 1000, 2000, 4000, and 8000 Hz high frequencies than in the lower frequencies, which is the main concern about the quality of the dental noise that the dentists experience. The subjective questionnaire survey revealed that 44% of participants reported the noise related to dentistry to be annoying, 28% reported productivity was affected, 61% reported difficulty with communication, 39% reported trouble concentrating, 6% reported contributed to an accident, 22% reported ringing in their ears, and 11% reported the noise affected their sleep quality. The correlation study confirmed that the above subjective non-auditory effects of noise were not affected by the sound pressure level or hearing loss related concerns, but rather on the participants' previous experience with dental noise and their personal sensitivity about the noise quality.

Within the limited scope of the study, we could not determine the effect of sound quality on non-auditory effects. That may involve logging of tasks that were performed throughout the work shift and recording the sound level at various octave band frequencies throughout the shift. These are some of the items to be included in the scope of future studies that may be undertaken to understand the relationship of the dental noise quality and its relationship in producing the non-auditory effects.

APPENDIX I: QUESTIONNAIRE SURVEY

DATE: PARTICIPANT NUMERBER:

NOISE MONITORING PARTICIPANT QUESTIONNAIRE

<u>QUESTIONNAIRE TO BE FILLED OUT BEFORE NOISE MONITORING</u>

If you are presently suffering from any hearing related disorder, or use hearing aid, or medically diagnosed for hearing related disorder, then you are NOT ELIGIBLE TO PARTICIPATE IN THIS STUDY.

If that is not the case please answer the following questions:

1. What is your gender? Female / Male / Prefer not to answer
2. Are you 18 years or older? Yes / No
3. Which is your dominant hand? Left / Right
4. What field of dentistry are you working in? (Please print clearly) ___________________
5. How many years have you been in this field? (Please print clearly) ___________________
6. What are your normal working hours? (Please print clearly) ___________________
7. People experience noise in different ways. Do you experience noise generally as ..., "Extremely disturbing", "Very disturbing", "Moderately disturbing," "Not very disturbing", or "Not at all disturbing"
8. Over the past 12 months or so, when you are at the clinic, how much are you bothered, disturbed, or annoyed by noise?
   "Extremely", "Very", "Moderately", "Slightly", and "Not at all."
9. How concerned are you that noise from dental procedures or tools might affect your hearing?
   "Extremely", "Very", "Moderately", "Slightly", and "Not at all."

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DATE: PARTICIPANT NUMERBER:

QUESTIONNAIRE TO BE FILLED OUT AFTER NOISE MONITORING

1. How many patients did you see today? (Please print clearly) ________________
2. What time did you go to lunch/ take a break? (Please print clearly)

   ____

   ____

3. Did you feel ANNOYED with the noise you experience today from dental work

   ○ *Not at all* ○ *Slightly* ○ *Moderately* ○ *Highly* ○ *Extremely*

4. Did you feel noise from dental work affected your PRODUCTIVITY?

   ○ *Not at all* ○ *Slightly* ○ *Moderately* ○ *Highly* ○ *Extremely*

5. Did you feel noise from dental work interfered with COMMUNICATION?

   ○ *Not at all* ○ *Slightly* ○ *Moderately* ○ *Highly* ○ *Extremely*

6. Did you feel noise from dental work Interfered with your CONCENTRATION?

   ○ *Not at all* ○ *Slightly* ○ *Moderately* ○ *Highly* ○ *Extremely*

7. Did you feel noise from dental work might have CONTRIBUTED TO AN ACCIDENT?

   ○ *Not at all* ○ *Slightly* ○ *Moderately* ○ *Highly* ○ *Extremely*

8. Did you notice RINGING IN YOUR EARS after working with dental equipment?

   ○ *Not at all* ○ *Slightly* ○ *Moderately* ○ *Highly* ○ *Extremely*

9. Do you feel noise from dental work interfere with your SLEEP QUALITY?

   ○ *Not at all* ○ *Slightly* ○ *Moderately* ○ *Highly* ○ *Extremely*

10. Is noise from an instrument affects you more than others? If yes, identify instrument.

    Yes. ______________________________________
    No

11. Is noise from a dental procedure affects you more than others? If yes, identify the procedure

    Yes.______________________________________
    None.

Thank you for your participation

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REFERENCES

American Society of Heating, Refrigerating and Air-Conditioning Engineers. (2003). 2003 Ashrae handbook: heating, ventilating, and air-conditioning applications. Atlanta, GA.

Basner, M., Babisch, W., Davis, A., Brink, M., Clark, C., Janssen, S., & Stansfeld, S. (2014). Auditory and non-auditory effects of noise on health. The Lancet, 383(9925), 1325-1332. doi:10.1016/S0140-6736(13)61613-X

Burk, A., & Neitzel, R. L. (2016). An exploratory study of noise exposures in educational and private dental clinics. Journal of Occupational and Environmental Hygiene, 13(10), 741-749. doi:10.1080/15459624.2016.1177646

Choosong, T., Kaimook, W., Tantisarasart, R., Sooksamear, P., Chayaphum, S., Kongkamol, C., . . . Phakthongsuk, P. (2011). Noise exposure assessment in a dental school. Safety and Health at Work, 2(4), 348-354. doi:10.5491/SHAW.2011.2.4.348

Engineering ToolBox, (2004). NC - Noise Criterion. [online] Available at: https://www.engineeringtoolbox.com/nc-noise-criterion-d_725.html[Accessed December, 2019]

Gijbels, F., Jacobs, R., Princen, K., & Debruyne, F. (2005, September 22). Potential occupational health problems for dentists in Flanders, Belgium. Retrieved from https://link.springer.com/article/10.1007/s00784-005-0003-6.

Interaural Time Difference. (2018). Babylon's Software. Retrieved from dictionary.babylon-software.com/interaural%20time%20difference/.

Laszlo, H. E., McRobie, E. S., Stansfeld, S. A., & Hansell, A. L. (2012). Annoyance and other reaction measures to changes in noise exposure - A review. Science of the Total Environment, 435-436, 551-562. doi:10.1016/j.scitotenv.2012.06.112

Likert, Rensis. "A Technique for the Measurement of Attitudes". Archives of Psychology. (1932) 140: 1–55

Ma, K. W., Wong, H. M., & Mak, C. M. (2017). Dental environmental noise evaluation and health risk model construction to dental professionals. International Journal of Environmental Research and Public Health, 14(9) doi:10.3390/ijerph14091084

Muzet, A. (2011). Sleep disturbance in adults by noise. Encyclopedia of environmental health (pp. 83-87) doi:10.1016/B978-0-444-52272-6.00249-X Retrieved from www.scopus.com-

Olishifski, J. B. (1978). INDUSTRIAL NOISE. Natl Saf News, 117(5), 59-66. Retrieved from www.scopus.com-

O*Net Online. "Summary Report for: 29-1021.00-Dentists, General." Available at http://www.onetonline.org/link/summary/29-1021.00 (updated October 15, 2019)

O*Net Online. "Summary Report for: 29-1029.00-Dentists, All Other Specialists." Available at http://www.onetonline.org/link/summary/29-1029.00 (updated October 15, 2019)

Parkar SM, Parekh SH, Shah LM, Sharma AS. Assessment of noise levels in clinical and laboratory areas of dental teaching institution, Ahmedabad. Int J Health Allied Sci 2014;3:244-7.

Psychoacoustics. In The Merriam-Webster.com Dictionary. Retrieved December 1, 2019, from https://www.merriam-webster.com/dictionary/psychoacoustics

RUTGERS, THE STATE UNIVERSITY OF NEW JERSEY. Rutgers School of Dental Medicine, Information for Students [online] 110 Bergen St Newark, NJ. November 26, 2019.http://sdm.rutgers.edu/departments/periodontics/info-students.html.

Sampaio Fernandes, J. C., Carvalho, A. P. O., Gallas, M., Vaz, P., & Matos, P. A. (2006). Noise levels in dental schools. European Journal of Dental Education, 10(1), 32-37. doi:10.1111/j.1600-0579.2006.00393.x

Sorainen, E., and E. Rytkönen. "High-Frequency Noise in ." Aihaj, vol. 63, no. 2, 2002, pp. 231–233., doi:10.1202/0002-8894(2002)0632.0.co;2.

Stansfeld A, Haines M, Brown B. Noise and health in the urban environment. Rev Environ Health 2000; 15: 43-82

"UNITED STATES DEPARTMENT OF LABOR." Occupational Safety and Health Administration, 2002, www.osha.gov/SLTC/noisehearingconservation/hearingprograms.html

Yost, W.A. (2015). Psychoacoustics: A Brief Historical Overview From Pythagoras to Helmholtz to Fletcher to Green and Swets, a centuries-long historical overview of psychoacoustics. from https://www.semanticscholar.org/paper/Psychoacoustics-:-A-Brief-Historical-Overview-From-Yost/6ba5591d2accb4f4c4c4e857df0c08014f748843.