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The Effects of Occupational Ultrasonic Noise Exposure on Hearing in Dental Hygienists: A Pilot Study

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THE EFFECTS OF OCCUPATIONAL ULTRASONIC NOISE EXPOSURE ON HEARING IN DENTAL HYGIENISTS - A PILOT STUDY

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ABSTRACT

THE EFFECTS OF OCCUPATIONAL ULTRASONIC NOISE EXPOSURE ON HEARING IN DENTAL HYGIENISTS – A PILOT STUDY

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The purpose of this case-control study was to determine whether long-term ultrasonic noise exposure via the dental office environment is related to dental hygienists' hearing status. Registered dental hygienists (N = 698) who live in the Hampton Roads area were mailed a *Dental Hygiene Work History Questionnaire* to determine those meeting the inclusion criteria and willing to participate in the study. Consenting subjects were categorized into one of two groups according to ultrasonic scaler usage rate and matched on age. Persons with known hearing loss due to infection, disease, or congenital defect were excluded from the study. The final sample consisted of 20 dental hygienists with a high ultrasonic usage rate and a matched group of 20 dental hygienists who had a low ultrasonic usage rate. Once the groups were formed, a certified audiologist tested subjects' hearing in each ear via the pure-tone audiometer and tympanogram. Audiometric data were analyzed using the analysis of variance for repeated measures procedure to determine if degree of ultrasonic scaler noise exposure in the dental office environment is significantly related to hearing status in dental hygienists. Results revealed that the right and left ear were not statistically different in the hearing threshold levels regardless of group status. There was however a significant difference in the high ultrasonic usage group and the low ultrasonic usage group at the 3000 Hz. No differences were found at the 500, 1000, 2000, 4000, 6000, 8000 Hz. Based on these outcomes, the ultrasonic scaler is not considered to have a negative effect on hearing of dental hygienists at the 500, 1000, 2000, 4000, 6000, 8000 Hz, but may be related to hearing

loss at the 3000 Hz. It was concluded that the ultrasonic noise may in fact be affecting dental hygienists' hearing at the 3000 Hz, but loss of hearing at the higher frequencies may be attributed to other unidentified factors found in both groups.

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Chapter I

INTRODUCTION

More than 30 million Americans are exposed on a regular basis to hazardous noise levels (NIOSH, 1999). Occupational noise exposure contributes to over stimulation of the hearing, which in turn, can lead to permanent hearing loss. Persons can differ in their host susceptibility to noise damage. Unfortunately, once the damage occurs, hearing problems are irreversible. In private dental offices, dental hygienists continually use low speed handpieces, sonic and piezoelectric scalers, and ultrasonic cleaners and scalers in the process of care. Ultrasonic devices are the biggest potential noise hazard affecting hearing in dental hygienists (Stevens, 1999). Ultrasonic scalers can produce 68-75 dBA when used. Although this decibel average does not fall into the category of damaging, with the repeated use of an instrument emitting these decibels, hearing damage may be caused (Merrel & Claggett, 1992). Moreover, the literature supports the expanded use of ultrasonic instrumentation to treat periodontal disease non-surgically and to minimize cumulative trauma disorders of the skeleto-muscular system in practitioners. Therefore, the use of ultrasonic instruments is expected to escalate. In large group dental practices, multiple practitioners use these instruments, further increasing occupational noise levels and risk for hearing loss in the work environment. Little research has been done on hearing loss in dental hygienists and results have been mixed. Dental professionals need to be aware of the potential dangers of occupational noise exposure, the leading cause of noise-induced hearing loss in the country.

Statement of the Problem

The intent of this study was to determine if degree of usage of the ultrasonic scaler is related to the hearing status of dental hygienists. Specific questions included:

1. Is there a difference in the hearing status of dental hygienists who report high usage versus low usage of ultrasonic scalers?

3. Is there a difference in the hearing status at specific frequencies (500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz) in dental hygienists who report high usage versus low usage of ultrasonic scalers?

3. Is there an interaction between usage levels of the ultrasonic scaler (high versus low usage) and the frequencies (500, 1000, 2000, 3000, 4000, 6000, 8000 Hz)?

4. Is there a difference in the hearing status of the right and left ear in either the high or low ultrasonic scaler usage groups of dental hygienists?

Significance of the Problem

Occupational hearing loss is the most common occupational disease in the United States; it is so common that it is often accepted as a normal consequence of employment (NIOSH, 1999). Occupational hearing loss knows no boundaries. Any worker, young or old, male or female, risks hearing loss when exposed to hazardous noises. Unfortunately, once hearing loss is acquired, it is irreversible. The Environmental Protection Agency (EPA) estimated that a lifetime protection from noise-induced hearing loss will be attained for most, if within a 24-hour time period the average sound pressure is below 70 dBA (Merrell & Clagget, 1992). Setcos and Mahyuddin (1998) found that the ultrasonic scaler used in oral healthcare could produce sounds that range from 68-88 dB, depending on the amount of background noise present. Some of the ultrasonic noise recorded was above the 70 dBA threshold set by the EPA. The cumulative effect of noise at this

decibel level is undetermined.

Although noise-induced occupational hearing loss is the most common occupational disease and the second most self-reported occupational illness or injury, little has been done to monitor or understand the problem in the oral healthcare setting. Many studies have looked at the noise emitted from the ultrasonic scaler and the noise that dentists' experience in the dental environment, but no research has ever clarified if dental hygienists have hearing deficits due to ultrasonic scaler use. Most likely, efforts to prevent occupational hearing loss have been delayed, because the problem occurs without pain or visible physical abnormalities in affected workers. People are unaware of their hearing deficit until they have lost 28% (or 30 decibels) of their hearing ability (Setcos & Mahyuddin, 1998).

In addition to unrecognized hearing loss, problems created by occupational hearing loss include: (1) reduced quality of life because of social isolation and unrelenting ringing in the ears (tinnitus); (2) impaired communication with family members, the public, and coworkers; (3) diminished ability to monitor the work environment such as warning signals or equipment sounds; (4) lost productivity and increased accidents resulting from impaired communication and isolation; and (5) expenses for workers' compensation and hearing aids (NIOSH, 1999).

Mixed opinions about the effects of dental office noise still remain among occupational hearing loss researchers. Research by Setcos and Mahyuddin (1998) suggests that there is no threat to hearing in dental hygienists working with the ultrasonic scaler. However, these same researchers have documented that the precision movement of hands and arms are detrimentally affected in persons exposed to noise. In contrast, research by Ackerman (1999) indicates a potential problem with hearing threshold shifts in the long-term use of the ultrasonic scaler. This study helps to resolve the conflict found in the literature, particularly as it applies to practicing dental hygienists.

Definition of Terms

For the purpose of this study, the following key terms are defined:

Hearing - The sense that enables sound to be perceived; the major function of the ear. The full range of normal hearing extends from 20 to 20,000 hertz. Sounds above 140 dBSPL can be painful to the ears; sounds within 0 to 70 dBSPL are considered safe and within the normal hearing range.

Hearing loss - An inability to perceive the normal range of sounds, from 0 to 70 dBSPL, audible to an individual with normal hearing. Hearing loss may be greater at some frequencies than others, or all frequencies may be equally affected. The hearing status in dental hygienists is the dependent variable; it was measured at the 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hertz by an audiometer.

- **Pure-tone Audiometer** – This hearing test measures pure-tone frequencies within the speech range to determine hearing loss. It does not determine type of hearing loss acquired (Sataloff, 1993).
- **Tympanogram** – Tympanometry measures the mobility of the eardrum and connecting ossicles necessary to transfer vibrating energy for hearing (Sataloff, 1993).

Usage Rate - The number of repetitions of any phenomenon within a fixed period. Ultrasonic scaler usage rates as reported by dental hygienists, the independent variable, was measured by how frequently the dental hygienists reported using the ultrasonic scaler multiplied by the years of usage. The usage rate ranged from 0 to 300.

Noise - The random signals or disturbances that interfere with the normal flow

of data through pathways of computers and other electronic devices.

Sound - Consists of vibrations that travel in waves through the air, ground, or some other substances or surfaces. Sound varies in frequency and intensity. In some cases, intense sound or sound of long duration can permanently damage the ears.

Noise-induced hearing loss - A gradual loss of hearing caused by exposure to loud noise over an extended period of time; the hearing loss is sensorineural in nature and greatest in the higher frequencies, such as 140 dBSPL. Although an early hearing loss may be temporary, it becomes permanent with increased exposure to noise. The noise produced by the ultrasonic scaler as reflected in its frequency and duration of use, was the independent variable in the study.

Sensorineural hearing loss - A form of hearing loss in which sound is conducted normally through the external and middle ear, but a defect in the inner ear or auditory nerve results in hearing loss.

Longevity in private practice - The length of time, in years, that the dental hygienist has worked in a dental office, as reported on the *Dental Hygiene Work History Questionnaire*. This variable was factored into the dental hygienists' rate of ultrasonic scaler usage.

Dental hygienist - A licensed primary healthcare professional with specialized education and training to provide preventive, educational, and therapeutic services under the supervision of a dentist. To practice as a registered dental hygienist, a person must complete at least two years of secondary education in an accredited community college, or university and meet established criteria of the state and regional board of dental or dental hygiene examiners.

Ultrasonic usage equation – Using the data from the *Dental Hygiene Work History Questionnaire*, an equation was formulated to include the self-reported patients treated per day with the ultrasonic scaler multiplied by the number of years the dental hygienists has used the ultrasonic scaler. This equation yielded a value that was used to determine the hygienists' assignment to either the high or low usage group.

Dental hygienists who have high ultrasonic scaler usage rate - Those dental hygienists whose ultrasonic usage equation generated a value greater than 66. These individuals comprised the case group.

Dental hygienists who have low ultrasonic scaler usage rate – Those dental hygienists whose ultrasonic usage equation generated a value equal to or less than 26. These individuals comprised the control group.

Assumptions

The following assumptions were made:

1. The audiometer is a valid and reliable instrument for measuring hearing loss (NIOSH, 1999). The same audiometer was used for all 40 subjects.
2. The dental hygienists were honest about the number of hours exposed to ultrasonic scaling devices and the duration of that usage while employed in a private dental office.
3. The audiologist conducting the audiometer evaluations was a reliable evaluator. Given the straightforward procedure for audiometric evaluation, reliability was not considered a problem.
4. Ultrasonic noise exposure over time can affect hearing status in dental hygienists. This can be detected by audiometric evaluations as a noise-induced hearing loss.

Limitations

The internal and external validity and reliability of this case-control study may be limited by the following factors:

1. Human error might affect the dental hygienists' recall and recording of the number of hours spent using the ultrasonic scaler in a private dental office. Given the small size of the sample, these variations could not be standardized and may be a problem.
2. Given the nature of a case-control design, no causal relationships can be concluded from the study.
3. Given that the final sample groups consisted of 20 matched pairs of subjects, from the Hampton Roads area, generalizability of the findings is limited.

Hypothesis

The following hypothesis were tested at the .05 level:

1. There is no difference in the hearing status of matched groups of high and low ultrasonic scaler users, as measured by pure-tone audiometry.
2. There is no difference in the hearing status of high and low ultrasonic scaler users at the frequencies of 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz, as measured by pure-tone audiometry.
3. There is no interaction between usage levels of the ultrasonic scaler (high and low usage) and the frequencies (500, 1000, 2000, 3000, 4000, 6000, and 8000Hz), as measured by pure-tone audiometry.
4. There is no difference in the hearing status of the right and left ear of dental hygienists in either the high or low ultrasonic scaler usage groups, as measured by pure-tone audiometry.

Chapter II

REVIEW OF THE LITERATURE

A review of the literature was conducted to provide a theoretical basis for this study. The topics reviewed include the effects of occupational noise on the hearing of dental professionals, noise levels produced by the ultrasonic scaler, and hearing assessment.

The Effects of Occupational Noise on Dental Professionals' Hearing Status

The study by Moller, Grevstad, and Kristoffersen (1976) was designed to determine if ultrasonic scaling of the maxillary teeth causes tinnitus and temporary hearing shifts in clients. Twenty healthy persons, 22-36 years of age, volunteered for the study. In the study, 50% of the participants experienced tinnitus or temporary threshold shifts. Tinnitus along with temporary hearing loss is frequently associated with noise-induced hearing loss, and is natures warning that noise levels are dangerously high (Steven, 1999). Moller, Grevstad, and Kristoffersen found that half of the subjects in the study did experience temporary hearing shifts and tinnitus when their maxillary teeth were scaled with the ultrasonic scaler. Dental equipment found to be annoying to ones hearing included: air compressors, amalgamators, ultrasonic instrument cleaners, darkroom buzzers, handpieces, and ultrasonic scalers. Moller, Grevstad, and Kristoffersen concluded that the undesirable side effects of ultrasonic instrumentation must not be ignored. The adverse effects of non-physiological stimuli to the inner ear are well established. Although the effects were temporary, there should be a more critical attitude towards their frequent and repeated application.

Although sound exposures that are potentially hazardous to hearing are usually defined in terms of sound level, frequency bandwidths, and duration, hearing experts agree that other exposures may be hazardous. For example, if the sound is appreciably louder than conversational levels for a sufficient period of time, it is potentially harmful.

Furthermore, noise may be hazardous if the listener experiences:

- Difficulty communicating while "in" the sound
- Ringing in the ear after exposure to the sound
- Muffled hearing after leaving the exposure area (Steven, 1999).

Research has been conducted on the use of ear protection and the reduction of noise. Earmuffs worn over the ears will decrease sound levels by 39 dBA. Earplugs placed in the canal decreased sound levels by 33 dBA. This research was conducted because of dentists' complaints of an inability to understand complete words and of tinnitus after a long day at the office (Standford, Fan, & Standford, 1987).

For 30 years, noise in dental offices has been suspected of contributing to hearing loss (Mittleman, 1965). If a noise is loud enough, or if one is exposed to it long enough, and/or if one's hearing mechanism is susceptible enough, any noise can cause hearing loss. Given these conditions, hair cells in the cochlea will be damaged and as a result cause hearing loss. Noise causes unwanted masking of sounds, interference with speech and communication, pain and injury, and temporary or permanent loss of hearing. Physiologically, noise increases blood pressure, quickens pulse, and constricts blood vessels. Researchers have documented that hand-reflex time to stimuli was lengthened after human subjects had been exposed to noise, and that precision movements of hands and arms were also affected (Setcos & Mahyuddin, 1998). Noise has also been found to cause emotional problems, nervousness, indigestion, headache, decreased ability to concentrate, decreased overall efficiency and decreased ability to perform complex or multiple tasks. These findings suggest that significant noise levels in the oral healthcare environment might affect skill performance of dentists and dental hygienists, thereby, affecting the quality of care rendered.

Noise-induced hearing loss may be undetected for years since it is estimated that individuals' may lose about 28% of hearing, or 30 dBA, before becoming aware of the problem. The degree of hearing risk to individuals depends on several factors: intensity

of noise; frequency spectrum of noise; duration of exposure; distance from the source; individual's age, physical condition, and susceptibility; the intensity of noise emitted; position of the head to the source of the noise; previous exposure to damaging noise resulting in permanent injury to hearing; and working environment (Setcos & Mahyuddin, 1998). A formula in the *Health and Safety at Work Act of* 1998 (HSWA) can be used to calculate the noise exposure for a worker during a day. When the daily noise exposure consists of different noise levels, the daily dose (D) shall not equal or exceed 100, as calculated according to the following formula.

$$D = [C_1 / T_1 + C_2 / T_2 + \ldots + C_n / T_n] \text{ H } 100$$

WHERE C_n = total time of exposure at a specified noise level and,

T_n = exposure duration for which noise at this level becomes hazardous.

The HSWA states that every employer should provide each employee who is likely to be exposed to 85 dBA or above, adequate information, instruction, and training on the risks of damage to that employee's hearing that such exposure may cause. Setcos and Mahyddan examined dental equipment in four different dental clinics. Although many of the precision sound meter tests revealed the noises emitted from the commonly used instruments in the dental office are not harmful, technicians and other personnel, such as dental hygienists or dental assistants, who spend many hours in noisy dental environments may be at risk if they choose not to wear ear protection (Setcos & Mahyuddin, 1998). Baratz (1990) also stated in work on minimizing health hazards in the dental workplace, that repetitive handpiece noise produces permanent high-end hearing loss for anyone exposed to the noise over an extended amount of time. In conclusion, the sound emitted from the ultrasonic scaler was not considered to have a negative effect on hearing. One limitation of the study was not knowing the amount of

ultrasonic noise exposure time these subjects experienced. Length of noise exposure was not accounted for in the study and this factor limits interpretation.

At the 1999 National Institutes of Health Consensus Development Conference, the Institute discussed occupational noise exposure and defined noise-induced hearing loss as sounds of sufficient intensity and duration that will damage the ear and result in temporary or permanent hearing loss. This hearing loss can range from mild to extreme. Most of the published studies associated with sound exposure and hearing loss in humans use measurements of the hearing sensitivities of numerous individuals correlated with their retrospective noise exposure (Baratz, 1990). The variability within these studies is large; and it is difficult to predict the precise magnitude of hearing loss that might result from a specific sound. Prospective studies of selected workers' hearing levels and noise exposure over time is carefully monitored, costly, time-consuming, questionable in ethics, and due to attrition, requires a large number of subjects; therefore, many studies have not been attempted on this subject. Although the Institute perceives occupational noise exposure as a problem, it is supported by little research (Baratz, 1990).

Zubick and Tolentino (1980) conducted research on the hearing differences between dentists and physicians. A pure-tone air conduction audiometric evaluation was given to both groups. The researchers increased external validity by having 137 dentists and 80 physicians participate as subjects. In the evaluations, the physicians had better hearing threshold levels, especially around 4000 Hz. Zubick and Tolentino also discovered that right-handed dentists showed greater hearing loss in their left ear, probably related to their positioning and proximity to the noise. Those dentists working in a specialty area also showed hearing loss in the same pattern as those of the general practice dentists. Zubick and Tolentino (1980) concluded that there may be a cause and effect relationship between hearing loss and the use of the high-speed dental handpiece.

Noise Levels Produced by Ultrasonic Scaler

The term *ultrasonic* describes a range of acoustical vibrations that cannot be heard by the human ear. Ultrasonic is defined as a sound frequency above 18 kHz. In dentistry the ultrasonic frequencies range from approximately 20,000 vibrations per second to 50,000 vibrations per second. These ultrasonic vibrations are a unit of frequency often referred to as cycles per second (cps) or hertz (Hz). Some ultrasonic units are already preset for these different levels, while other units are adjustable. Herreman (1998) explains that if the ultrasonic produces the largest spray of water, not accompanied by large water droplets, along with a high-pitched, hissing noise, the correct adjustment has been achieved.

There are two types of ultrasonic units, the piezoelectric and magnetostrictive. The piezoelectric unit's vibrations occur when alternating electrical currents are applied to the crystal transducer creating a dimensional change that is transmitted to the tip in the form of a vibration. The movement produced by the vibration is a linear pattern. The disadvantage of this model is that only two sides of the working end are activated, which limits the ability to access certain areas on teeth, e.g., furcations. In contrast, the magnetostrictive unit has a core that becomes magnetized and demagnetized. This constant change in magnetic fields allows the working end to vibrate in an elliptical or orbital motion. The magnetostrictive unit design allows the tip to have all of its surfaces activated.

Dental professionals are accelerating their ultrasonic scaler usage because the ultrasonic provides practical benefits over traditional hand instrumentation. Some of those benefits include patient comfort, clinical efficiency, decreased risk of cumulative trauma disorders, and less hand fatigue for the clinician. It also provides therapeutic benefits in the treatment of periodontal disease. For example, cavitation, the inwardly collapsing bubbles of water that are produced as the water stream touches the vibrating ultrasonic tip, appears to have an antimicrobial effect in lysing bacterial walls and

flushing plaque and debris away from the periodontal pocket (Stutsman, O'Hehir, &Woodall, 1993). Moreover, the ultrasonic scaler is effective in detoxifying root surfaces. Root surface cytotoxic materials, or lipopolysaccarides, are removed by ultrasonic scaling with overlapping, light strokes.

Setcos and Mahyuddin (1998) attempted to determine the noise levels made by different clinical handpieces, laboratory engines, and other significant equipment such as ultrasonic scalers. Using the precision sound meter (Type 2232 Bruel and Kjaer), sound levels were measured at four dental practices and three dental laboratories. They were selected as representative of a variety of workplaces to reveal a range of occupational noises. Using seven workplace settings increased external validity. Furthermore, the precision sound meter was used to filter sound and display the electrical signal on an indicator in terms of decibels. A microphone was positioned at ear level and also at a two-meter distance from the dentist's ear to capture sounds at the intensity to which they impact the operator's ear. Each participant was the dentist in the different clinics. Results revealed that almost all the noise levels in the dental hygiene practice setting were below the limit of risk for hearing loss (see Table 1). (Note the limit for risk is 85 dBA rather than the 70 dBA currently set by the EPA). The ultrasonic scaler on average was found to be one of the highest decibel emitters in the different offices. The practitioner preferred the use of hand-scalers as he found the noise emitted by the ultrasonic scaler to be "irritating".

Table 1. Noise Level Maxima [dB (A)] Measured Near the Operator's Ear at Four Dental Clinics (Setcos & Muahyuddan, 1998)

Devices	Dental Clinic A	Dental Clinic B	Dental Clinic C	Dental Clinic D
Background	30	40	54	35
	Single Operator No Music	Single Operator and Music	Single Operator and Loud Music	Single Operator no Music
Amalgamator	68	64	65	66
High Volume aspirator	68	70	69	70
High Volume aspirator and touch mucosa	71	74	72	72
Ultrasonic scaler and suction	75	68	**88**	72
High Speed handpieces and suction	72	75	73	74
Low Speed Handpieces	68	72	69	70

Note: Measures > 85 dBA are in bold.

Although no research has been done, clinicians have reported that patients occasionally complain of tinnitus and dizziness following ultrasonic scaling (Moller, Grevstad, & Kristofferson, 1976). Some of the frequencies that the ultrasonic scaler produced may reach the patient's inner ear by bone or airborne conduction. Moller, Gravstad, and Kristofferson (1976) set out to measure ultrasonic scaling effects of maxillary teeth on the inner ears of healthy young adults by means of audiometry.

Twenty healthy subjects participated in the study; ages ranged from 22-36 with nine females and eleven males. All subjects presented with at least 13 erupted maxillary teeth in good condition. A pure-tone audiometric test was performed to attain the hearing thresholds for each ear. Hearing thresholds were tested in increments of 5 dB for every 1000 Hz. After the data were collect, results showed a shift in patients' hearing thresholds after ultrasonic scaling in eight participants (40%). Variations of 5 dB were not recorded as threshold shifts. The threshold shifts ranged from 10 to 20 dB and persisted for as long as 30 minutes after the ultrasonic scaling was terminated. Five of the participants had a threshold shift in the right ear and two showed shifts in the left ear. Seven participants showed a threshold shift at the 7,000 Hz or at the 8,000 Hz or both, and three participants showed a shift for several frequencies. In the control group only three individuals showed a shift. This shift was only at one frequency and was of a shorter duration. In the experimental group, three participants experienced bilateral high-pitched tinnitus after the ultrasonic scaling was experienced (Moler, Grevstad & Kristofferson, 1976). Moller, Grevstad, and Kristofferson (1976) concluded that the effects of the ultrasonic scaler were temporary, and should not prevent the use of ultrasonic instruments. It should be noted however that in the 1970's, ultrasonic instrumentation was less frequently used than in the 21st century. Ultrasonic instrument usage rates today demand a more critical attitude towards their frequent and repeated application and their potential effects on hearing.

Holmberg, Landstrom, and Nordstrom (1995) set out to evaluate the sensation of annoyance as well as the sensation of discomfort during exposure to the high-frequency sound and ultrasound from an ultrasonic cleaning unit. The study included ten subjects consisting of five men, ages 23 to 38, and five women, ages ranging from 23 to 44. Based on a pre-study audiometric evaluation, none of the subjects presented with a hearing loss. In a sound chamber, subjects were tested at exposures of 72, 80, and 96 dBA. The subjects were exposed to the noise while proof reading a text, simulating the work in an office. Afterwards they were asked to rate their sensation of annoyance (metal

effect) and discomfort (effect located at the ear) on a 100mm scale with verbal labels. The rated levels of annoyance were high at all amounts of exposure. The group average for the noise level of 96 dBA was 63 mm, which on the scale corresponds to "rather annoying" and "quite annoying". Holmberg (1995) concluded that the ratings of annoyance and discomfort in the investigation must be considered high enough to recommend an avoidance of even the lowest level of noise from the ultrasonic washer at 70 dBA.

Hearing Assessment

Hearing assessment with a pure-tone audiometer and a tympanogram should be conducted by an audiologist, a physician, or an occupational hearing conservationist certified by the Council for Accreditation in Occupational Hearing Conservation (CAOHC) or the equivalent. For audiometric testing to be beneficial, sufficient time should be allotted for the testing. The National Institute for Occupational Safety and Health (NIOSH) states that an audiometric testing shall, at a minimum, consist of pure air-tone air-conduction threshold testing of each ear at 500, 1000, 2000, 3000, 4000, and 6000 Hz. In pure-tone air-conduction testing, audiograms are displayed and stored as tables or charts of hearing thresholds measured in each ear at specific test frequencies. At each frequency the threshold is recorded for an ear at the lowest signal output level of the audiometer at which the individual responds in a specified percentage of trials or in two to three trials. Hearing thresholds are measured in dBHL (decibels hearing threshold levels), with 0 dBHL representing average hearing ability for young people with no otological pathology. Larger threshold values indicate poorer-than-average hearing; smaller threshold values (negative threshold such as 5 or 10 dBHL) indicate better than average hearing.

Noise exposure increases hearing thresholds, resulting in a threshold shift to the higher values. Occasionally, when exposed to intense noise, damage to the inner ear, called acoustic trauma, is done immediately. Most of the time, damage occurs over a

period of time with a less intense noise. Each time the ear is overexposed to noise, it develops a temporary reduction in sensitivity called a *temporary threshold shift*. When the ear is allowed to rest for a couple of hours or days, the threshold can be reversed. If these exposures are repeated, then the threshold may reach a point where it will not reverse.

In 1972, the National Institute for Occupational Safety and Health (OSHA) recommended a significant threshold shift (STS) criterion. In 1992 and 1996, Royster examined the performance of this criterion against eight other criteria for significant threshold shift. The following criteria were evaluated:

- OSHA STS: in either ear, a change of 10dB or more in the average of hearing threshold at 2000, 3000, and 4000 HZ.
- OSHA STS TWICE: in either ear, a change of 10dB or more in the average of hearing thresholds at 2000, 3000, and 4000 HZ is present on one annual audiogram and is persistent in the same ear on the next audiogram.
- American Academy of Otolaryngology- Head and neck Surgery SHIFT: in either ear, a change of 10dB or more in the average of hearing thresholds at 500, 1000, and 2000Hz, or15dB or more at 3000, 4000, 6000Hz.
- 1972 NIOSH SHIFT in either ear, a change of 10dB or more at 500, 1000, 2000, 3000Hz, or 15dB or more at 4000or 6000Hz.
- 15dB TWICE: in either ear, a change of 15 dB or more at any test of frequency from 500 through 6000Hz.
- 15dB TWICE: in either ear, a change of 15 dB or more at any test frequency form 500 through 6000 Hz is present on one annual audiogram and is persistent at the same frequency in the same ear on the next audiogram.
- 15dB TWICE 1B4 kHz: in either ear, a change of 15 dB or more at any test frequency from 1000 through 4000 Hz is present on one annual audiogram and is persistent at the same frequency in the same ear on the next audiogram.
- 10dB AVG 3B4 kHz: in either ear, a change of 10dB or more in the average of hearing thresholds at 3000 and 4000Hz.

This study compared each of the eight criteria for threshold shifts by applying each criterion to 15 different industrial hearing conservation databases. Within each database, analyses were restricted to the first eight audiograms for male workers who had at least eight audiogram tests. The number of workers included from each database ranged from 39 to 1,056. Data were analyzed for a total of 2,903 worker's. For the

purpose of these analyses, a "tag" was identified when a worker's audiogram met the specified criterion, and a "true positive" was identified when the workers audiogram showed the same threshold shift specified in that criterion. A significant threshold shift for a worker, according to the four nonaveraging, any-frequency-shift criteria (1972 NIOSH SHIFT, 15dB SHIFT, 15dB TWICE, and15dB Twice 1-4 kHZ) was considered a true positive if the shift was confirmed by the succeeding audiogram-but only if the shift was persistent for at least one of the same frequencies in the same ear. Royster (1999) concluded that the 15dB TWICE yielded the highest percentages of the true positives with 70.9% and 73.3%. This means that there is still room for error but that this test was the best. Several limitations of the study included only using male subjects and the ages of the subjects were not denoted (NIOSH, 1999), therefore limiting the external validity of the study.

In conclusion, there are conflicting opinions about the relationship among the ultrasonic scaler, the noise it produces, and the noise damage to a dental hygienist's hearing. Dental hygienists are using ultrasonic scalers with increasing frequency. The ultrasonic scaler has allowed dental hygienists to work more efficiently and it provides a lavage system with therapeutic benefits for treating periodontal disease. Even though the noise produced is not at the damaging range, with repeated use of the instrument, a cumulative effect might contribute to permanent hearing damage. The safety of long term use of ultrasonic scaling equipment is yet to be determined.

Chapter III

METHODS AND MATERIALS

Research Design

A case-control design was used to examine the relationship between hearing loss and ultrasonic scaler usage in dental hygienists (see Table 2). The design enabled the researcher to determine if using the ultrasonic scaler at high usage rate over extended years related to the hearing status of dental hygienists. A hearing test (pure-tone audiometer) was given and scores recorded. At the Lion's Child Study Center at Old Dominion University, the same audiologist performed the two different tests (pure-tone and tympanogram when indicated) on each dental hygienist using the same audiometer. The attribute independent variable was the dental hygienists' ultrasonic scaler usage on patients. The dependent variable was the hearing status present in the dental hygienists at seven frequencies (500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz).

Table 2. Case-Control Design

Groups	**Frequency**						
	500	**1000**	**2000**	**3000**	**4000**	**6000**	**8000**
(M) E (Hygienists with high usage of the ultrasonic scaler)	R/L	R/L	R/L	R/L	R/L	R/L	R/L
(M) C (Hygienists with low usage of the ultrasonic scaler)	R/L	R/L	R/L	R/L	R/L	R/L	R/L

R = right ear, L = left ear

Threats to internal validity were controlled by excluding all subjects that had previous hearing damage, matching the high and low frequency groups by age, and using

the same audiologist to administer all audiology tests. Furthermore, the certified audiologist who was blinded to subjects' group status followed the same step-by-step audiometric testing procedure and used the same audiometer. Subjects also were blinded to their group status.

Having an adequate number of subjects matched from all Hampton Roads dental hygienists who met the criteria and who agreed to participate would have increased external validity. However, only 20 matched pairs of dental hygienists were obtained for the final sample. This decreases the generalizability of the research findings.

Sample and Sample Description

A prescreening instrument titled *Dental Hygiene Work History Questionnaire* was mailed to all registered dental hygienists in the Hampton Roads area (N= 698). This included both practicing and nonpracticing dental hygienists from the list of registered dental hygienists obtained through the Virginia Board of Dentistry website in February, 2001 (http//www.vbd.org, 2001). Twenty dental hygienists from each group allowed for an adequate representation of professional dental hygienists and the matching of intersubject differences (age and frequency of ultrasonic usage) between groups. Subjects who responded to the *Dental Hygiene Work History Questionnaire* and who met the following inclusion criteria were invited to participate:

Inclusion criteria for all subjects:

- Be 21 years of age and older.
- Be a registered dental hygienist (RDH).
- Not be presently participating in another study.
- Have no medical diagnosis of hearing loss in either ear due to infection, disease, or congenital defect.

Inclusion criteria for the experimental group:

- History of high frequent ultrasonic scaler use for patient care.
- History of an ultrasonic usage rate of 66 or greater.

Inclusion criteria for the control group

- History of minimal to no ultrasonic scaler use for patient care.
- History of an ultrasonic usage rate of 26 or less.

Exclusion criteria for all potential subjects

- History of a known hearing loss due to infection, disease, or congenital defect.

Based on the questionnaire responses and subjects willingness to participate, 20 dental hygienists were selected from hygienists who had a high ultrasonic scaler usage and were matched with 20 dental hygienists who had a low ultrasonic scaler usage. The overall sample had a mean age of 42.7, sd = 6.84, and a mean of 15.2 years in practice. The high ultrasonic usage group had a mean age of 42.75, sd = 6.36 and a mean of 18.65 years in practice; the low ultrasonic usage group had a mean age of 42.65, sd = 7.44, and mean of 11.8 years in practice. All participants were female.

Procedures, Materials, Data Collection Instrument

Phase I: Prescreening Questionnaires and Group Assignments

A prescreening instrument titled *Dental Hygiene Work History Questionnaire* was mailed to all registered dental hygienists in the Hampton Roads area (N = 698). The questionnaire was designed to measure dental hygienists on their age, longevity in practice, hours of ultrasonic scaler use each day, and whether they have a history of hearing problems (See Appendices A and B). The dental hygienists were instructed to return the questionnaire in the stamped envelope enclosed in the mail packet.

When the questionnaires were returned, respondents who indicated a desire to

participate and who met inclusion criteria were anonymously divided into two groups based upon their history of ultrasonic scaler use as computed from the ultrasonic usage equation. This equation comprised the self-reported number of patients treated per day with the ultrasonic scaler multiplied by the number of years the hygienist has used the ultrasonic scaler. Moreover, respondents from the two groups were matched on age and frequency of ultrasonic scaler usage. The matching procedure yielded 20 matched-pairs of subjects each. Questionnaire data were both nominally and ratio scaled.

Phase II: Audiometer Testing

The individuals selected from those who consented to participate were given 20-minute appointments for hearing status evaluation. After the informed consent forms were signed, each participant received a pure-tone audiometry evaluation (See Appendices C and D). A tympanogram was obtained on those individuals who had any hearing loss in the lower frequencies in order to rule out any pathology of the middle ear. The audiologist conducting the hearing evaluation was blind to participants' group status. One audiologist, using the same audiometer and procedure conducted each test. Therefore, the testing conditions ensured the reliability of the audiometric data. Effective communication and coordination were critical among the audiologist and the subjects. The same audiologist served as the record keeper.

Audiometry, at a minimum, consisted of pure-tone air-conduction threshold of each ear at 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz. The test was given in a soundproof room. At each frequency, the hearing threshold recorded for an ear was the lowest dBHL at which the individual responded to two of three trials. Data from the audiometer is continuous in nature and ratio scaled. A pure-tone audiometer test uses simple vibrations of various frequencies and intensities to measure hearing. This type of measurement of hearing is used annually in school-age children. Hearing threshold levels were recorded in increments of 5 dBHL.

Tympanometry followed the pure-tone testing only if the participant showed

hearing loss in the lower frequencies. Only one participant in the high usage rate group was required to have a tympanogram. Upon evaluation the participant's ear presented with adequate mobility suggesting that there was no middle-ear pathology. Of the 40 participants, 10 who scored 30 dBHL or higher at any frequency were asked to return for a repeated test free of charge. This was done to reevaluate the hearing thresholds for changes. Fifty percent of the subjects that needed to be re-tested were in the high frequency of ultrasonic use and 50% of the subjects were in the low frequency of ultrasonic use.

Statistical Treatment

An analysis of the pure-tone audiometric data, longevity in dental hygiene practice, and the amount of time dental hygienists have spent using the ultrasonic scaler allowed the researcher to determine the relationship among ultrasonic scaler usage and hearing status. Between and within group audiometric data were analyzed using the analysis of variance for repeated measures so that the main effect of ultrasonic usage, as well as the interaction effects of ultrasonic usage at the seven different frequency levels could be determined. All hypotheses were tested at the .05 level. Line graphs were designed to display relationships between amount of ultrasonic exposure and hearing status, both between and within groups at seven frequencies levels and in the right and left ears. Because data were not normally distributed, data needed to undergo a log transformation to ensure that analysis of variance could be used legitimately. The computerized SAS system was used for data analysis.

Chapter IV

RESULTS AND DISCUSSION

A case-control study was conducted to determine the relationship between ultrasonic scaler usage and hearing status in dental hygienists. There were 205 respondents to the *Dental Hygiene Work History Questionnaire* yielding a 29.4% response rate. Of those consenting to participate, one was excluded from the study because of previous hearing loss. Ninety-three of the respondents were not willing to participate in the study, 30 questionnaires were returned due to address changes, and one subject decided not to participate when called to set up an appointment. The large percentage of the population who chose not to participate may have been due to the time, travel distance, and inconvenience of having to participate in a hearing test, which might have had economic implications because of loss of work. Forty dental hygienists (20 matched pairs) who met all inclusion criteria consented to participate. The two groups of matched pairs were formed based on their usage rate of the ultrasonic scaler and age (See Appendix E). A hearing evaluation was conducted on each subject using a pure-tone audiometer. The tests were give by a certified audiologist at the Old Dominion University Lion's Child Study Center, Norfolk, Virginia. Data were analyzed using the analysis of variance for repeated measures to determine if there was a significant difference in the hearing status of dental hygienists with a high ultrasonic scaler usage levels as compared with dental hygienists with low ultrasonic scaler usage levels.

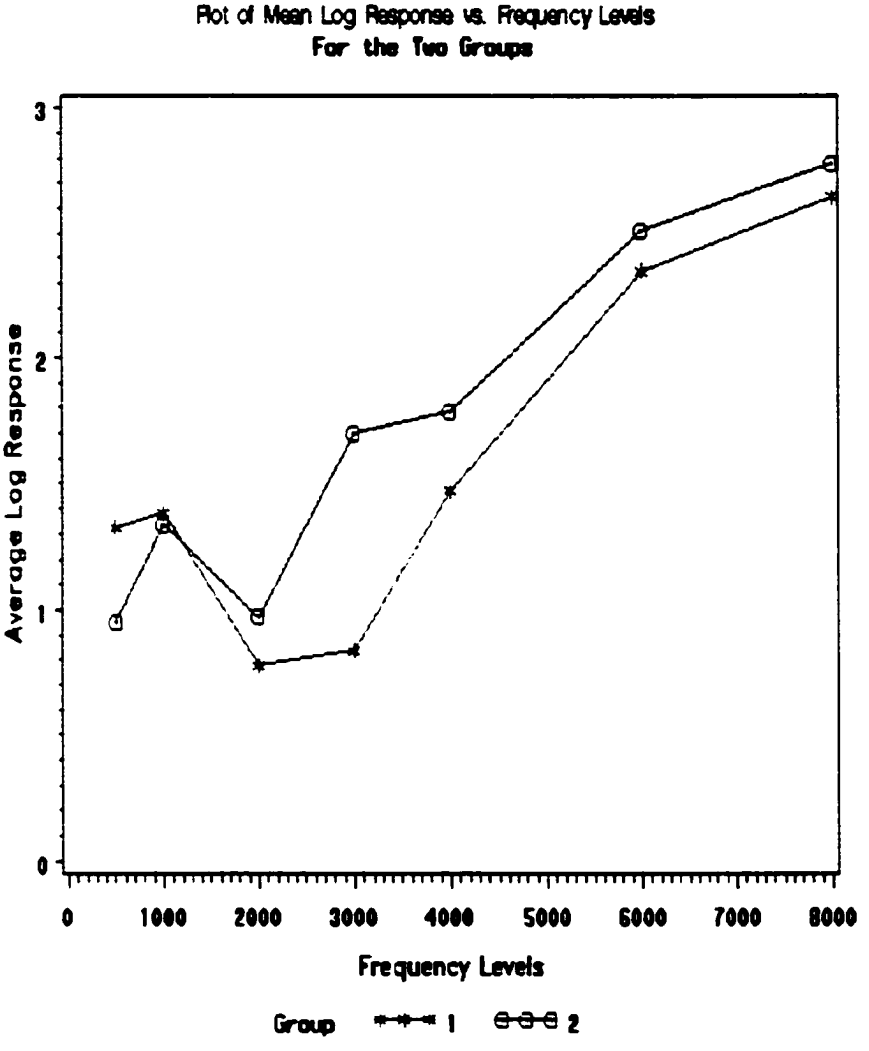
Results

Hypothesis One. The first hypothesis stated that there is no difference in the hearing status of matched groups of high and low ultrasonic scaler users, as measured by pure-tone audiometry. The analysis of variance for repeated measures revealed a statistically significant difference in the hearing of dental hygienists who have high ultrasonic scaler use as compared with dental hygienists who have low ultrasonic scaler use ($F = 2.79$, $df = 6$, $p = .01$). High ultrasonic users have significantly poorer hearing status than low ultrasonic users. Therefore, hearing status appears to be negatively affected by high ultrasonic scaler usage in dental hygiene practice (See Table 3 & Figure 1).

Table 3. Analysis of Variance Comparison of High and Low Ultrasonic Scaler Usage Levels in Two Matched Groups of Dental Hygienists.

Source	DF	SS	Mean Square	F value	Probability	
Group	1	4.48	4.48	4.5	0.0334	*
Subject	38	138.47	3.64	3.65	0.0001	*
Frequency	6	226.78	37.79	37.90	0.0001	*
Group & Frequency	6	16.84	2.8	2.82	0.0105	*

* Significance



Group 1 = Low ultrasonic usage group. Group 2 = High ultrasonic usage group.
Note: Higher mean log responses indicate poorer hearing.

Figure 1. Change in Hearing Ability of Two Matched Groups of Dental Hygienists (High Ultrasonic Usage Verses Low Ultrasonic Usage) at Seven Frequencies

Hypothesis Two. The second hypothesis stated that there is no statistically significant difference in the hearing status of high and low of ultrasonic scaler users at the frequencies of 500, 1000, 2000, 3000, 4000, 6000, and 8000Hz as measured by the pure-tone audiometry. Analysis of variance for repeated measures revealed a statistically significant difference in high and low usage groups at 3000Hz ($F = 5.81$, $df = 1$, $p = .02$), but no statistically significant differences at the frequencies of 500, 1000, 2000, 4000, 6000, and 8000 Hz. Hygienists with high usage rates had significantly poorer hearing at 3000 Hz, while those in the low usage group had significantly better hearing at 3000 Hz. Therefore, hearing status at 3000 Hz appears to be negativity affected by frequency of ultrasonic scaler usage (See Table 4).

Table 4. Analysis of Variance Comparison of Frequencies for High and Low Ultrasonic Scaler Usage Groups of Dental Hygienists.

Frequency	Source	DF	Type I SS	Mean Square	F value	Probability	
3000Hz	Group	1	14.86	14.86	5.81	0.02	*
500 Hz	Group	1	2.77	2.77	1.73	0.19	
1000Hz	Group	1	0.03	0.03	0.04	0.84	
2000Hz	Group	1	0.76	0.76	0.32	0.57	
4000Hz	Group	1	2.03	2.03	0.9	0.34	
6000Hz	Group	1	0.51	0.51	0.41	0.52	
8000Hz	Group	1	0.34	0.34	0.41	0.52	

* Significance

Hypothesis Three. The third hypothesis stated that there is no interaction between usage levels of the ultrasonic scaler (high and low usage) and the frequencies (500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz). Analysis of variance for repeated measures

revealed that dental hygienists with high usage levels have a higher hearing threshold level documented at 3000 Hz but not at the other frequencies (F =37.62, df =6, p=.0001). Therefore, there is significant interaction between high usage rate and hearing threshold at 3000 Hz (See Table 5). Results revealed that as frequency increased, hearing gets poorer for both groups but this difference in hearing status between the groups is not statistically significant. (See Figure 1 & 2)

Table 5. Analysis of Variance of Between and Within Group Data for High and Low Ultrasonic User Groups, at Seven Frequencies, in Both Ears.

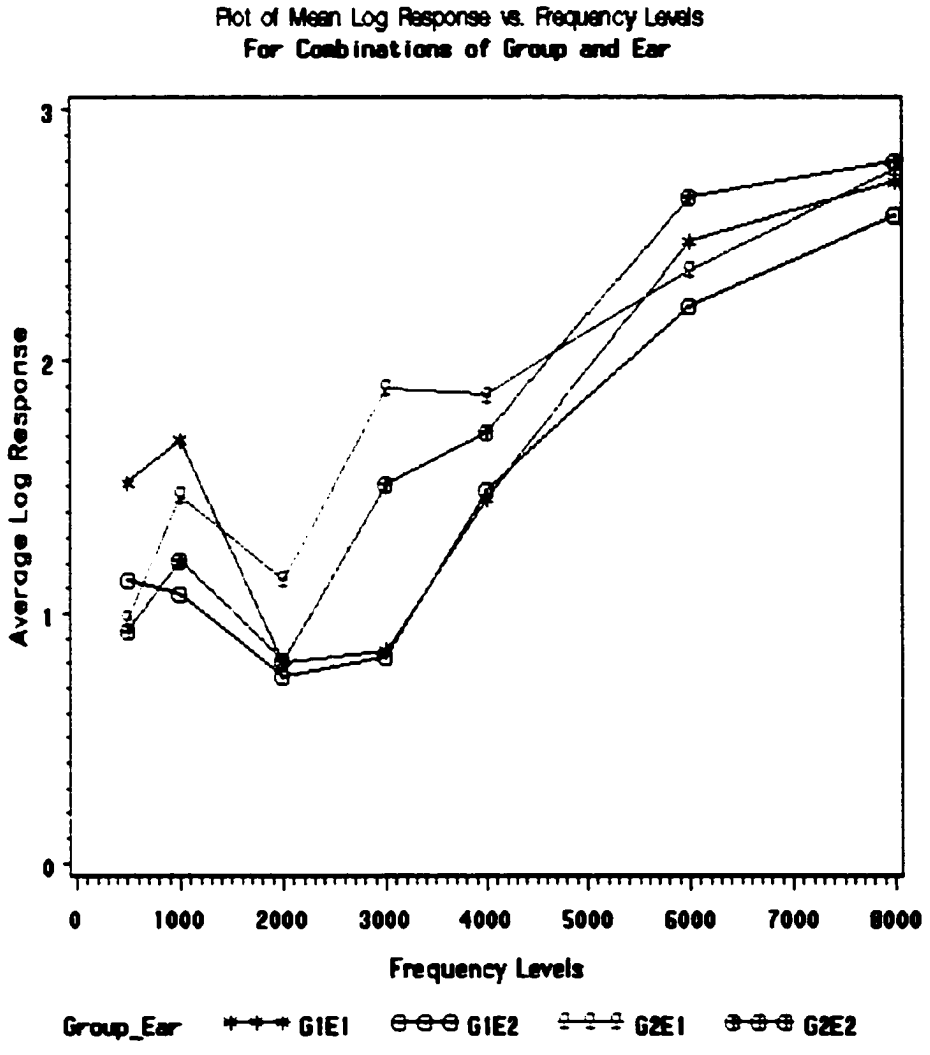
Source	DF	SS	Mean Square	F value	Probability	
Between Group						
Subject	38	138.47	3.64	3.63	0.0001	*
Within Group						
Frequency	6	226.78	37.79	37.62	0.0001	*
Ear	1	3.63	3.63	3.61	0.0579	

*Significance

Table 6. Sums and Averages of the dBHL at the Seven Frequencies for Both Low and High Ultrasonic User Groups

	500Hz	1000Hz	2000Hz	3000Hz	4000Hz	6000Hz	8000Hz
Low Usage							
Sum	205	205	120	160	290	555	720
Average	5	5.125	3	4	7.25	13.875	18
25 dBHL or greater	0	0	0	1	2	6	9
High Usage							
Sum	150	210	185	310	390	675	820
Average	3.75	5.25	4.625	7.75	9.75	16.875	20.5
25 dBHL or greater	0	0	1	0	2	7	11
Difference of sums	-55	5	65	150	100	120	100

Note: Higher values denote poorer hearing.



G1E1 = Low ultrasonic usage group tested in the right ear
G1E2 = Low ultrasonic usage group tested in the left ear
G2E1 = High ultrasonic usage group tested in the right ear
G2E2 = High ultrasonic usage group tested in the left ear

Note: Higher mean log responses indicate poorer hearing.

Figure 2. Change in Hearing Status in Right and Left Ears of Two Matched Groups of Dental Hygienists at Seven Frequencies

Hypothesis Four. The fourth hypothesis stated that there is no significant difference in the hearing status of the right and left ears of dental hygienists in either the high or low ultrasonic scaler usage groups. Analysis of variance for repeated measure results revealed no statistically significance difference in the hearing thresholds of the right and left ears ($F = 3.61$, $df = 1$, $p = .057$), regardless of high or low ultrasonic usage group status. The right and left ear showed little variation in the hearing patterns as a result of ultrasonic scaler usage in dental hygienists (See Table 5 & Figure 2).

In general, the percentages of persons in both matched groups with normal hearing and hearing deficits are presented in Table 7. Although the percentages were not hypothesized, it is interesting to note the overall similarities in both groups. These percentages were computed by calculating what percentage of the participants presented with a hearing threshold of 25 dBHL or higher and 25 dBHL or lower. The subjects presenting with 25 dBHL or higher have a greater hearing deficit then those who tested with a threshold level less than 25 dBHL.

Table 7. Summary of Hearing Status of Dental Hygienists in The High Usage (N=20) and Low Usage (N=20) Group

	500	**1000**	**2000**	**3000**	**4000**	**6000**	**8000**
Low Usage Group							
% Of Normal Hearing	100%	100%	100%	95%	90%	70%	55%
% Of Hearing Deficits	0%	0%	0%	5%	10%	30%	45%
High Usage Group							
% Of Normal Hearing	100%	100%	95%	100%	90%	65%	45%
% Of Hearing Deficits	0%	0%	5%	0%	10%	35%	55%

Discussion

Hypothesis One. The analysis of mean differences in the overall hearing evaluation revealed statistical significance between those dental hygienists who have a high frequency of ultrasonic usage as compared to those dental hygienists who have low ultrasonic scaler usage ($p = .01$). Results suggest that dental hygienists with high ultrasonic usage rates have poorer hearing than those with low usage rates. Although there is statistical significance, the clinical difference shows only a slight variation in dBHL levels. This implies that heavy use of the ultrasonic scaler may be contributing to noise-induced hearing loss in the dental work environment. The means for each group in the study are displayed in Table 6. As compared to other dental office noises, the ultrasonic might be a source of damaging noise. As reported by Setcos and Muahyuddan (1998), the ultrasonic scaler was recorded as emitting some of the highest frequencies of dental office noises (ranges of 75 to 88 dBA). The HSWA states that all workers who are exposed to sound 85dB or above should be given adequate information and the risk involved by their employers. The EPA has also stated that if a person in a 24-hour period is exposed to noise levels maintained at 70 dBA or below, for the most part hearing loss will not occur. All of the sounds recorded from the ultrasonic scaler were above 70 dBA. Dental hygienists are not exposed to this noise for 24 hours but the repeated exposure appears to be damaging. Findings of this study and that of Setcos and Muahyudden (1998) suggest that dental hygienists who use the ultrasonic scaler frequently in practice might want to use earplugs or ear muffs to protect their hearing and prevent the accumulated trauma associated with repeated exposure to ultrasonic noise.

Hypothesis Two. Statistical analysis revealed that the ability to hear different frequencies yield unusual results when comparing the hearing of high ultrasonic scaler users and low ultrasonic scaler users. At the frequencies of 500, 1000, 2000, 4000, 6000, and 8000 Hz, there was no statistically significant difference in the hearing status of the

low frequency and high frequency groups (F = 1.73, df = 1, p = 0.19), (F = .04, df = 1,p = .84), (F = .32, df = 1, p = 0.5765), (F = .90, df = 1, p = 0.34), (F = .41, df = 1, p = .52), (F =.41, df = 1, p = 0.52) respectively. In contrast, statistically significant differences were found at 3000 Hz (F = 5.81, df = 1, p =.02). The hearing threshold levels in the dental hygienists with high ultrasonic scaler usage was found to be higher than the threshold levels in dental hygienists with a low ultrasonic scaler usage at the same frequency. This suggests a hearing loss associated with ultrasonic usage at 3000 Hz. Why the 3000 Hz is unique cannot be explained by the data. Frequencies ranging from 3000 to 8000 Hz are most susceptible to noise induced hearing loss.

Zubick and Tolentino (1980) looked at the differences of hearing thresholds in dentists and physicians. They found a statistically significant difference in the threshold levels in the dentists around 4000Hz. Although dental office equipment noises range from 20,000 to 50,000 Hz, the frequency of the noise emitted from the ultrasonic or other dental equipment will effect the hearing thresholds around 3000 to 8000 Hz which falls into the communication range of frequency. This finding was also documented in the research by Meoller, Grevstad, and Kristofferson (1976) on temporary threshold shifts after exposed to ultrasonic noise.

Hypothesis Three. Statistical analysis revealed that the dental hygienists with high ultrasonic use had a higher hearing threshold level as compared to the dental hygienists with low level of ultrasonic use at 3000 Hz. The finding suggests that high ultrasonic scaler usage is related to a hearing loss detected at 3000 Hz but not at the other levels. This could be due to the fact that limited subjects participated. When examining mean differences of the high ultrasonic usage group compared to the low ultrasonic usage group, the means increased in distance as the frequencies increased except for 500 Hz (See Table 6).

Hypothesis Four. Statistical analysis revealed no statistically significant difference in the hearing when comparing subject's right and left ear

($F = 3.61$, $df = 1$, $p = 0.0579$). This result may have been different if more participants participated because the significance is borderline. Perhaps the background noise level plus the ultrasonic noise in the dental office is sufficient to effect both ears similarly. Also, Zubick and Tolentino (1980) have found that in dentists, the ear that was closest to the noise emitted from the dental handpieces was the ear that presented with a high hearing threshold change. For example, a dentists that is right-handed will have closer proximity to the sound in the left ear, and hence, greater hearing loss in the left ear. Since left verses right-handedness of the subjects was not a variable collected on the *Dental Hygiene Work History Questionnaire*, this finding cannot be interpreted confidently. Right verses left-handedness may have implications for differential hearing loss in dental hygienists, and this variable needs to be explored in future research.

Chapter V

SUMMARY AND CONCLUSION

Summary

The complex nature of hearing loss generates many challenges for individuals not only socially but also in their working environment. As healthcare providers, dental hygienists need to be competent in their daily communication skills with clients. When a hearing loss has occurred, the quality of care given to the client may be affected and certainly the quality of life of the dental hygienist is affected. Given that ultrasonic scaler use is on the rise in practice, this study was conducted to determine if the ultrasonic scaler has a negative affect on the hearing status of dental hygienists. A total of 40 dental hygienists (20 matched pairs) who met all inclusion criteria consented to participate. The two groups of matched pairs were formed based on their usage rate of the ultrasonic scaler and age. Participants were given an audiometric evaluation using pure-tone audiometry at the Old Dominion University Lion's Child Study Center. The results of the pure-tone audiometer were analyzed using the SAS statistical analysis program. The analysis of variance for repeated measures was used to determine if there was a statistically significant difference between a high ultrasonic usage group and a low ultrasonic usage group.

Findings revealed a statistically significant difference in hearing thresholds between the high usage group and the low usage group at 3000 Hz. However, there was no statistically significant difference in the high and low usage group at the frequencies of 500, 1000, 2000, 4000, 6000, and 8000 Hz. Therefore, hearing status appears to be negatively affect by high ultrasonic scaler usage in dental hygiene practice at 3000 Hz.

At the 500, 1000, 2000, 4000, 6000, and 8000 Hz hearing status in the groups appear similar. Based on the averages of decibels calculated at each frequency, if more dental hygienists participated, the results may have been statistically significant at higher frequencies. Participants in the high frequency usage group presented with larger threshold results than the low usage group, indicating that hearing loss was greater in the group that used the ultrasonic scaler more often. A significant interaction effect was observed between frequency levels and the usage levels at 3000 Hz. Although no statistical significance was seen at 500, 1000, 2000, 4000, 6000 and 8000 Hz, there was a clinically significant difference between the high and low usage groups in terms of hearing. As frequency increased, the hearing thresholds also increased, revealing poorer than average hearing. No statistically significant difference in hearing status in the different ears of each participant was observed, resulting in retainment of the fourth null hypothesis. The analysis of variance for repeated measures showed no statistical significance ($p = .057$); however, the p-value was close to being significant. This p-value might have been altered had more dental hygienists participated in the study.

Based on the results of this investigation, the following conclusions are made:

1. Dental hygienists with a high frequency of ultrasonic scaler use have a greater chance of experiencing hearing loss then hygienists with a low frequency of ultrasonic scaler usage.
2. Dental hygienists need to protect their hearing if the ultrasonic is used over an extended period of time and/or if it is used frequently in practice.
3. At higher frequencies (>3000 Hz), dental hygienists show declines in hearing status, regardless of their ultrasonic scaler usage rates.

4. Both ears in dental hygienists seem to be affected similarly by noise exposure.

Considering the limitations and design of the study, the following recommendations for future research are offered:

1. Replication of this study using a larger sample of dental hygienists.
2. Replication of this study to screen the dental hygienists for temporary threshold changes that might occur as a result of ultrasonic scaler noise exposure.
3. Replication of this study using less than 5 dBHL increments.
4. Determination of hearing shifts that occurs in dental hygienists immediately after ultrasonic scaler use.
5. Determination of the effect of noise from ultrasonic scaler use on psychomotor skills and tactile sensitivity.
6. Development of a method to measure the cumulative effect of ultrasonic noise on dental hygienists who use mechanized instruments and on the other personnel in the office.
7. Determination if the location of the source of ultrasonic noise affects the hearing in the right and left ears differentially.
8. Determination if the wearing of ear plugs during ultrasonic scaler use causes temporary threshold changes.

Based on this study's findings, ultrasonic scaler instrumentation has some effect on hearing status of dental hygienists. With increased use of ultrasonic instrumentation, more research should be conducted to determine if the ultrasonic scaler causes hearing loss and if so, at what rate. The findings in the study do not warrant the elimination of the ultrasonic scaler; the findings underscore the need for more research to understand the

risk of hearing loss in dental hygienists who use mechanized instruments.

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APPENDICES

APPENDIX A

INVITATION TO PARTICIPATE

February 16, 2001

Dear Colleague:

A study is being conducted to evaluate whether use of ultrasonic scalers is related to hearing loss in dental hygienists. Your participation in this study will be of value in gaining knowledge to improve occupational safety for practicing dental hygienists. The enclosed questionnaire is being used to identify dental hygienists who might be qualified for and willing to participate in the study **(both practicing and nonpracticing dental hygienists are needed for the study)**. The questionnaire takes no longer than five minutes to complete. Please return the questionnaire by March 1, 2001.

Once you return the completed questionnaire, I will determine if you qualify for the study. If you are selected as a subject, you will be contacted to verify your willingness to participate and to schedule your free hearing test. Hearing tests will be conducted at the Child Study Center on the campus of Old Dominion University in March and April 2001. The hearing test and signing of the informed consent form will take 30 minutes of your time. Test results will be shared with you.

Thank you for your interest in the study. I hope that you will meet the criteria for the study and that you will agree to participate. If you have any questions about the study, please contact me at (757) 484-4525 or you may contact Michele Darby, my faculty advisor, at (757) 683-5232. Again, your participation is genuinely appreciated.

Sincerely,

Jennifer Dunning, BSDH
Masters Degree Candidate
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School of Dental Hygiene
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APPENDIX B

DENTAL HGYIENE WORK HISTORY QUESTIONNAIRE

Dental Hygiene Work History Questionnaire

Directions: Please complete the following eleven questions by filling in the blank or circling the response that best reflects your characteristics and experiences. This information will be used to identify dental hygienists for a hearing loss study. Your cooperation is appreciated and may contribute to improvement in occupational safety for dental hygienists. Please return the questionnaire by March 1, 2001.

1. What is your age at the time of your last birthday? _____

2. How many days a week do you work in a dental office providing client care? (circle one response)

0 days	1 day	2 days	3 days
4 days	5 days	6 days	

3. How long have you worked in a dental office providing direct client care? (circle one response)

< 3 years	>5-10 years	>15-20 years
3-5 years	>10-15 years	> 20 years

4. In your total dental hygiene practice career, how many years have you practiced?
   Full time (defined as 4 or more days per week) _____
   Part time (defined as less than 4 days per week) _____

5. On how many patients per day, on average, do you use the ultrasonic scaler?
   _____(specify)

6. On the average, how many years have you used or been using the ultrasonic scaler on patients? _____ (specify)

7. Have you had any previous hearing problems that have been diagnosed by a physician or audiologist?
   Yes (If yes, answer item 8 on back)
   No (If no, go directly to item 9 on back)

8. What is the cause of your hearing loss? (check all that apply)

Infection	Congenital defect	Other _____ specify
Disease	Loud noise exposure	

9. Do you have a family history of hearing loss?
   Yes (If Yes, please answer item 10)
   No (If No, please go directly to item 11)

10. Who in your family has had a history of hearing loss? (circle all that apply)

Mother	Siblings
Father	Other _____

11. Are you exposed to any loud noises outside of the dental office? (i.e., concerts, noise at home)
    Yes (please specify source of noise) _____
    No

If you would like to participate in this study, please sign below and fill in your telephone number. If you meet the requirements for the study, you will be called to schedule a free hearing test appointment at Old Dominion University. Thank you.

___ No, I am not interested (no need to sign your name, just return the questionnaire)

___ Yes, I am interested, please contact me based on the information provided below.

Print name: _____ Telephone number: _____

Preferred time for hearing test: days/time_____ evenings/time_____

Signature: _____ Date: _____

Please return this form in the stamped envelope provided to:

School of Dental Hygiene
Old Dominion University
Technology Bldg.
47th Street & Hampton Blvd.
Norfolk, VA 23529-0499
Attn. Jennifer Dunning, BSDH

APPENDIX C

INFORMED CONSENT

Effects of Occupational Ultrasonic Noise Exposure on Hearing Deficits in Dental Hygienists

INFORMED CONSENT

The purpose of this form is to give you information that may affect your decision whether to say YES or NO to participate in this research, and to record the consent if you say YES.

Title of Research: The Effects of Occupational Ultrasonic Noise Exposure on Hearing Deficits in Dental Hygienists

Researchers: Jennifer S. Dunning RDH, BS, Masters Degree Candidate
Michele Darby RDH, BS, MS, Graduate Program Director, Eminent Scholar
Lynn Toll-Watts, BSDH, MS, Professor
Old Dominion University -School of Dental Hygiene Joseph Sever, Ph.D., Associate Professor Audiology
Old Dominion University

Description of Research Study:
Several studies have been conducted on the effects of occupational ultrasonic noise on the hearing of dental hygienists. None have documented a definite relationship between hearing loss and the noise produced by the ultrasonic scaling unit. The results have been inconclusive.

If you decide to participate, then you will join a study to measure your hearing status in relation to the amount of time you have been exposed to ultrasonic noise. If you say YES, then you will have a 30 minute hearing test here at Old Dominion University Audiology Clinic in the Child Study Center Approximately 50 registered dental hygienists will be participating in the study.

Exclusionary Criteria:
You should have completed the *Dental Hygiene Work History Questionnaire.* To the best of your knowledge, you should not:
1) have any previous medical diagnosis of hearing loss in either ear. 2) be presently participating in another study, or
3) younger than 21 years of age, that will keep you from participating in this study. If you have any of the above, you will not be able to participate.

Risk and Benefits:
Risk: If you decide to participate in this study, it is highly unlikely that you will experience any risks. The audiology test that you will receive is used to identify hearing deficits. And, as with any research, there is some possibility that you may be subject to risks that have not yet been identified.
Benefits: The main benefit to you for participating in this study is a free hearing test. The results may help to determine if your hearing status has been affected by occupational ultrasonic noise.

Cost and Payment:
The researchers want your decision about participating in this study to be absolutely voluntary. Yet they recognize that your participation may require some time off from work to have your hearing tested. In order to minimize or avoid time from work, the hearing test is scheduled to accommodate your work schedule.

New Information:
If the researchers find new information during the study that would reasonably change your decision about participating, then they will give the information to you.

Confidentiality:
The researchers will take reasonable steps to keep your questionnaire and audiology test findings confidential. The results of this study may be used in reports, presentations, and publications, but the researcher will not identify you. Of course, your records as a research subject may be subpoenaed by court order or inspection by government bodies with oversight authority. "

Withdrawal Privilege:
It is OK for you to say NO. Even if you say YES now, you are free to say NO later, and walk away or withdraw from the study--at any time. Your decision will not affect your relationship with Old Dominion University or otherwise cause loss of benefits to which you might otherwise be entitled, e.g. result of a hearing test. The researchers reserve the right to withdraw your participation in this study, at any time, if they observe potential problems with your continued participation.

Compensation for illness and Injury:
If you say YES, then your consent in this document does not waive any of your legal rights. However, in the event of injury arising from this study, neither Old Dominion University nor the researchers are able to give you any money, insurance coverage, free medical care, or any other compensation for such injury. In the event that you suffer injury as a result of participating in any research project, you may contact Michele Darby at 683-5232 or Martha Walker at (757) 683-3309 at Old Dominion University, who will be glad to review the matter with you.

Voluntary Consent:
By signing this form, you are saying several things. You are saying that you have read this form or have had it read to you, that you are satisfied that you understand this form, the research study, and its risk and benefits. The researchers should have answered any questions you may have had about the research. If you have any questions later on, then the researchers should be able to answer them:

Jennifer S. Dunning RDH, BS at (757) 484-4525

Michele Darby RDH, BS, MS at (757) 683-5232

If at any time you feel pressure to participate, or if you have any questions about your rights or this form, then you should call Martha Walker at (757) 683-3309, or the Old Dominion University Office of Research, at 757-683-3460.

And importantly, by signing below, you are telling the researchers YES, that you agree to participate in this study. The researchers should give you a copy of this form for your records.

Subjects Name and Signature: _____Date:_____

Witness' Name and Signature: _____Date:_____

Investigator's Statement:
I certify that I have explained to this subject the nature and purpose of this research, including benefits, risk, cost, and any experimental procedures. I have described the rights and protections afforded to human subjects and have done nothing to pressure, coerce, or falsely entice this subject into participating. I am aware of my obligations under the state and federal laws, and promise compliance. I have answered the subjects' questions and have encouraged him/her to ask additional questions at any time during the course of this study. I have witnessed the above signature(s) on this consent form.

Signature:_____Date:_____

APPENDIX D

DATA COLLECTION FORM FOR HEARING THRESHOLD LEVELS OF DENTAL HYGIENISTS

OLD DOMINION UNIVERSITY
CHILD STUDY CENTER
AUDIOLOGY CLINIC

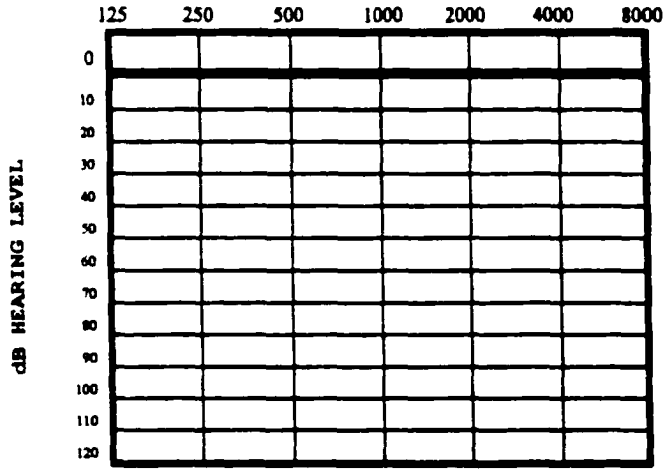
Name:_____Date:_____B/D_____(M)__(F)__Audiologist_____

Response Consistency: good moderate poor

LEGEND

		Right	Left
Air:	Unmasked	O	X
	Masked	Δ	□
Bone:	Unmasked	<	>
	Masked	[	]

FREQUENCY IN HERTZ



REMARKS:_____

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APPENDIX E

RAW DATA COLLECTION FORM

Appendix E

Matched Subject	Age	Years Using the Ultrasonic	Ultrasonic Use on Pt. Per Day	Usage Rate
Low Usage	48	10	1.5	15
High Usage	48	25	5	125
Low Usage	47	6	4.5	27
High Usage	45	20	5.5	110
Low Usage	35	8	3	24
High Usage	45	15	20	300
Low Usage	45	6	2.5	15
High Usage	45	24	4	96
Low Usage	32	10.5	1.5	6
High Usage	33	11	6	66
Low Usage	62	5	3	15
High Usage	57	30	5	150
Low Usage	47	20	1	20
High Usage	48	26	8	208
Low Usage	34	5	2	10
High Usage	34	12	7	84
Low Usage	42	11	2	22
High Usage	43	20	5.5	110
Low Usage	37	17	2	34
High Usage	37	13	10	130
Low Usage	42	7	3.5	24.5
High Usage	40	10	8	80
Low Usage	50	28	1	28
High Usage	51	15	9	135
Low Usage	46	7	1.5	10.5
High Usage	49	27	5	135
Low Usage	33	7	1	7
High Usage	35	16	5	80

Low Usage	35	3	5	15
High Usage	39	15	6	90
Low Usage	41	2	7.5	16
High Usage	39	15	7	105
Low Usage	50	1	3	3
High Usage	48	19	5.5	104.5
Low Usage	38	4.5	5	22.5
High Usage	35	11	7	77
Low Usage	48	5	3	15
High Usage	42	21	4.5	94.5
Low Usage	41	6	3	18
High Usage	42	19	8	152