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Effects of Ultrasonic Scaling and Hand-Activated Scaling on Tactile Sensitivity in Dental Hygiene Students

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EFFECTS OF ULTRASONIC SCALING AND HAND-ACTIVATED SCALING ON TACTILE SENSITIVITY IN DENTAL HYGIENE STUDENTS

By

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ABSTRACT

EFFECTS OF ULTRASONIC SCALING AND HAND-ACTIVATED SCALING ON TACTILE SENSITIVITY IN DENTAL HYGIENE STUDENTS

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This study was conducted in order to determine if tactile sensitivity varies in dental hygiene students who use the ultrasonic scaler as compared to those who scale with hand-activated instruments. A convenience sample of 40 consenting, first year dental hygiene students were randomly assigned to one of two groups. The 40 students had not yet used the ultrasonic scaler nor had any history of injuries or disabilities to the dominant arm, wrist or hand. After establishing a baseline tactile sensitivity score with the *Vibratory Sensory Analyzer* (*VSA*), experimental group subjects used the ultrasonic scaler to remove 4cc's of artificial calculus from a typodont in a controlled, simulated clinical setting for 45-minutes while each control subject manually scaled 4cc's of artificial calculus on a typodont in a controlled, simulated situation for 45-minutes. Tactile sensitivity scores were obtained using the *VSA* immediately following exposure to either the ultrasonic scaler or hand-activated scaling instruments. Analysis of variance with one repeated measures factor was used to determine between group and within group differences on the pretest and post-test tactile sensitivity scores. Results revealed that following a 45-minute scaling session with the ultrasonic scaler, tactile sensitivity increased. Pre to post-test changes in tactile sensitivity for the ultrasonic scaling group exhibited a much larger threshold as compared to those in the hand-activated scaling group, supporting a gain in students' level of sensitivity with stimulus (vibration). Tactile sensitivity decreased in

those who used hand-activated scaling instruments. The thumb, index and middle fingers of students in both groups showed similarities in tactile sensitivity, with the index finger being the most sensitive. Ultrasonic scalers allow the hygienist to exert less pressure and decrease pinching and gripping forces, therefore implying a potential long-term reduction in musculoskeletal disorders. Results also underscore the potential importance of the index finger in detecting calculus and tooth surface irregularities. It was concluded that tactile sensitivity decreases with hand-activated scaling and increases with ultrasonic scaling over a 45-minute period. Short term vibration exposure from the ultrasonic scaler is insufficient to negatively affect tactile sensitivity. The long term effects of scaling with hand-activated and mechanized instruments on tactile sensitivity warrants further testing on clients in a clinical setting.

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INTRODUCTION

Tactile sensitivity is the ability to distinguish relative degrees of tooth surface roughness or smoothness through the sense of touch and proprioception (Tsutsui, 2003). A person's tactile sensitivity may be impaired because of musculoskeletal and nerve disorders associated with cumulative trauma, repetitive tasks, and *high frequency vibrations* (Setcos & Mahyuddin, 1998). Therefore, the use of ultrasonic scalers, with their high frequency vibrations and noise, may be a factor affecting tactile sensitivity in dental hygienists. This is particularly important because dental hygienists must use tactile sensitivity to assess their treatment immediately following hand-activated or ultrasonic instrumentation.

McDonald, Robertson, and Erickson (1988) and Pollack (1996) assert that oral health care practitioners have needed to be retrained for another occupation due to work-related musculoskeletal disorders. With appropriate usage, ultrasonic scalers may reduce musculoskeletal disorders in practitioners, save treatment time, and access periodontal pocket areas that cannot be reached with hand scaling alone (Drummer, 2003). Long hours at the dental chair and increased client volume as a result of managed care are motivating factors for high ultrasonic scaler usage rates among dental hygienists. With advances in mechanized instrumentation, tactile sensitivity in the practitioner using ultrasonic technology has been overlooked. Ultrasonic scalers diminish scaling time and load force on the hygienists' hands and arms, but tactile sensitivity may be compromised. The effects of ultrasonic and hand-activated scaling on tactile sensitivity was unknown prior to this investigation.

Statement of the Problem

The purpose of this research was to determine if ultrasonic scaler and hand-activated scaler usage affects tactile sensitivity of the thumb, index and middle fingers of dental hygiene students. In doing so, ultrasonic scaling was compared to hand-activated scaling in a simulated, controlled clinical setting. The specific research questions were:

1. What short-term effect does type of scaling (ultrasonic verses hand-activated scaling) have on the overall tactile sensitivity of aspiring dental hygienists?
2. Does tactile sensitivity change after scaling (ultrasonic verses hand-activated scaling) for 45 minutes?
3. Is there a difference in the tactile sensitivity of the thumb, index and middle fingers of dental hygiene students?

Significance of the Problem

Dental hygienists often use ultrasonic scaling devices to save their hands and arms from strain; however, they may be putting themselves, as well as patients at risk for disease if residual calculus deposits, and tooth irregularities are not detected following ultrasonic therapy. Every time an ultrasonic scaler is used, high frequency vibrations between 20,000 to 50,000 Hz are emitted (Akesson, Lundborg, Hortsmann & Skerfving, 1995). Ultrasonic vibrations affect the whole sensory system. Noise-induced disturbances in the ear may also cause disturbances elsewhere, such as the hand, eye, or brain (McCance & Huether, 1998). For example, a dental hygienist could experience altered proprioception from the high frequency vibrations, which in turn can cause several other disorders, such as vestibular nystagmus, vertigo and neuropathies (McCance & Huether, 1998). Moreover, reduced tactile sensitivity may evolve from nervous system

alteration. The disturbance of any one sensory organ can cause a diminished or absent sense of body position or a disturbance in ones ability to perceive their relation to their body parts (McCance & Huether, 1998). Researchers have documented that hand-reflex time to stimuli is lengthened after human subjects are exposed to noise, and that precision arm and hand movements are affected also (Setcos & Mahyuddin, 1998). Thus, the inability to accurately feel with the hands might cause problems detecting calculus, tooth structure or anomalies making it difficult to hand scale or evaluate a client following ultrasonic usage due to noise/high frequency vibrations. This reduced tactile sensitivity in the dental hygienist might ultimately affect the client's quality of care. Specifically, reduced tactile sensitivity in a dental hygiene practitioner can lead to inadequate removal of calculus deposits, which could play a role in oral disease progression, increase risk of malpractice, and potential litigation. Thus, diminished practitioner tactile sensitivity may put clients at risk for periodontal disease, and systemic diseases linked with periodontal disease may be exacerbated. Hodges (1998) states that, "if the bacterial irritants are removed within a reasonable time period or controlled to a reasonable level, a healthy host may be able to combat tissue destruction." She further states that an altered host response or systemic disease may cause more rapid tissue destruction regardless of the level of bacterial irritation and load (Hodges, 1998). This study provides information on how ultrasonic scaling and hand-activated scaling affect tactile sensitivity and ultimately quality of care. Results provide the beginning foundation for evidence-based clinical instrumentation protocols that improve clinical decision making about the use of mechanized verses hand-activated instruments and the preservation of tactile sensitivity.

Definition of Terms

For this study, the following key terms were defined:

Decibels- A measurement of the loudness, i.e., strength of vibration of a sound.

Sound- Vibrations in the air or water that stimulate the auditory nerves and produce the sensation of hearing.

Proprioception- Sensation originating within the body from ones own spatial position and muscular activity; the perception and awareness of the position of the body and its parts dependent on impulses from the inner ear and from receptors in joints and ligaments (McCance & Huether, 1998).

Sensorimotor neuropathies- A sensory dysfunction that occurs when peripheral nerves are affected, causing an inflammation leading to sensory, motor or reflex changes; can result from compression or vibration (McCance & Huether, 1998).

Tactile Sensitivity- Tactile sensitivity, the dependent variable, is the level of a person's ability to sense vibration in the thumb, index and middle fingers. Tactile sensitivity was determined using a *Vibratory Sensory Analyzer* which measures *vibration, as an indicator of sensory dysfunction associated with occupational injury* (Medoc, 2002).

Hand-Activated Scaling- Type of scaling based on the use of instruments that are manually activated by the dental hygienist. This was the active control variable of the study.

Vibratory Sensory Analyzer (VSA)- A computer-controlled device designed to quantitatively measure the action of large nerve bundles to determine sensory dysfunction. As such, it specifically measures a person's cutaneous perception of touch, vibration, and mild pressure (See Figure 1) (Medoc, 2002; Brooks, 2002). The large

nerve fibers, on which the principle of vibratory testing is based, mediate the sensations of touch, mild pressure and joint positions, all of which are directly related to the concept of tactile sensitivity.

Figure 1. *Vibratory Sensory Analyzer.* Courtesy of Medoc, Ltd. (2002). [On-line].Available:http://www.medoc-web.com

Ultrasonic Scaling- Mechanized form of scaling based on the conversion of electrical energy into mechanical energy in the form of rapid vibrations with frequencies per cycle ranging between 20,000-50,000 vibrations per second as measured in hertz (Hz) (Hodges, 1998). It requires the use of an ultrasonic scaling device. The SPS Cavitron ultrasonic scaling unit operates at 30K, which is designed for a 30,000 Hz unit (Hodges, 1998). This is the independent variable of the study.

Magnetostrictive Unit- A specific type of ultrasonic scaling unit that requires an insert consisting of metal stacks. When activated, the stacks conduct energy that magnetizes the core (coil of copper wire) creating an electromagnetic field that allows the tip to vibrate in an elliptical or orbital motion (Hodges, 1998).

Assumptions

The following assumptions have been made:

1. The ultrasonic scaler emits high frequency vibrations that can be felt by the dental hygienist during instrumentation and which may impair tactile sensitivity.
2. Hand-activated scaling requires a higher degree of skill than mechanized scaling; more physical strain is placed on the hygienist's hands, arms and shoulders with hand scaling than with mechanized scaling.
3. Hearing high frequency vibrations can disrupt the balance in the inner ear, which in turn can affect the whole body, especially those areas with sensory perception, such as the ears, eyes and hands in particular.
4. The *Vibratory Sensory Analyzer* is a valid and reliable device used to measure cutaneous perception of touch, vibration, mild pressure and position of joints at increasing amplitudes (Medoc, 2002; Brooks, 2002).

Limitations

Internal and external validity of this experiment may be limited by the following:

1. Since it is not a longitudinal study, the long-term effects of ultrasonic scaling and hand-activated scaling on tactile sensitivity will be unknown.
2. Findings can only be generalized back to populations that are pretested; therefore, decreasing the study's external validity.
3. The lack of knowledge of entry-level dental hygiene students could be problematic. This was minimized by starting the study at a time in the

curriculum when students had been introduced to basic instrumentation principles.

4. Variations in grip strength, neutral wrist position and lateral pressure required of ultrasonic and hand-activated scaling groups could pose an extraneous variable.
5. The *VSA's* design is flat (See Figure 1) and does not mimic the shape of an ultrasonic scaler or hand-activated instrument. Tactile sensitivity scores from the *VSA* were not obtained while subjects used the modified pen grasp thereby decreasing external validity.

Hypotheses

The following hypotheses were tested at the .05 level:

1. There is no statistically significant interaction among group status (ultrasonic vs. hand-activated), time of test (pretest/posttest) and tactile sensitivity of the three digits, as measured by *VSA* scores.
2. There is no statistically significant interaction between group status (ultrasonic vs. hand-activated) and time of test (pretest/posttest) effect, as measured by *VSA* scores.
3. There is no statistically significant interaction between the group (ultrasonic or hand-activated) and tactile sensitivity level of the thumb, index and middle fingers of dental hygiene students, as measured by *VSA* scores.
4. There is no statistically significant change in the tactile sensitivity of the students' thumb, index and middle finger from the pretest to the posttest, as measured by *VSA* scores.

Chapter II

REVIEW OF THE LITERATURE

The literature contains studies on vibration exposure and its effect on tactile perception, neuropathies and syndromes induced by vibration, and these are discussed in the sections of the literature review that follow (Akesson, Lundborg, Hortsmann, & Skerfving, 1995; Akesson, Balogh, & Skerfving, 2001; Holmberg, Ulflandstrom, & Nordstrom, 1995; Flodmark, & Lundborg, 1997; CDC, 1983). Several studies on neuropathies and other syndromes, also discussed in the literature review, included dentists and hygienists as subjects; however, there have been no definitive studies on the effects of high frequency vibration exposure on tactile sensitivity in dental hygiene practitioners or students (Akesson et al., 1995; Setcos & Mahyuddin, 1998; Akesson et al., 2001; Hjortsberg, Rosen, Orbaek, Lundborg, & Balogh, 1989; Lundstrom & Lindmark, 1982). The relevant literature focuses on how noise (high frequency vibrations) produced by the ultrasonic scaler affects hearing and other sensory organs throughout the body; and how tactile sensitivity is affected following exposure to vibrations.

Noise and Its Effect on Hearing and Other Sensory Organs

Ultrasonic scaling devices produce noise that may be greater than the Environmental Protection Agency's recommended maximum of 70 decibels within 24-hours (Merrell & Claggatt, 1992). In dentistry, ultrasonic frequencies range from 20,000 to 50,000 vibrations per second with a 68-75 average decibel range (Hodges, 1998; Stevens, 1999). The higher the vibration per second, the greater the calculus removal efficiency (Akesson et al., 1995; Hodges, 1998). Ultrasonic scalers emit high frequency

vibrations, which have the potential to cause occupational hearing loss (Wilson et al., 2002). In a study conducted by Holmberg, Uflandstrom and Nordstrom (1995), levels of annoyance and discomfort to high frequency noise produced by ultrasonic washers revealed high ratings at all levels of exposure, which ranged from 72 to 96 decibels. They concluded that even the lowest level of noise (70 decibels) produced by the ultrasonic cleaner should be avoided. Noise exposure from ultrasonic instruments commonly produce hearing loss after long periods of time and can temporarily alter ones hearing (Moller, Grevstad & Kristorffersen, 1976). The effects of ultrasonic scaling on tactile sensitivity in dental hygienists remains unknown.

Proprioceptive dysfunction can often be due to noise exposure, which in turn can affect other sensory organs including the sense of touch (McCance & Huether, 1998). Two common causes of proprioceptive dysfunction are vestibular dysfunction and peripheral neuropathy. One example of vestibular dyfunction is the involuntary movement of the eyeball (nystagmus) caused by an ear disturbance. Peripheral neuropathies, common in dental practitioners, can cause difficulties in proprioception as well. Persons with peripheral neuropathies have little or no tactile sensitivity and are prone to self injury because of their inability to feel stimuli (Hjortsberg, Rosen, Orbaek, Lundborg & Balogh, 1989; Lundstrom & Lindmark, 1982). If this occurs in a dental hygienist, the ability to evaluate a client after therapeutic scaling would be impaired.

Like neuropathy of the hands in diabetic patients, peripheral neuropathy follows a distal to proximal pattern, affecting strength and balance, where large myelinated nerves house sensory and motor components (Resnick, Stansberry, Harris, Tirivedi, Smith, Morgan & Vinik, 2002). The disturbance of these sensory and motor components may

have different effects on objective sensory performance tests depending on the level of dysfunction (Resnick et al., 2002). Tinnitus can often occur causing one to lose ability to feel because of the loud ringing in the ears.

When an individual feels something, the sensation is transmitted by nerve fibers that in turn tell the brain that there is something there, and it is felt. If a sensory system (e.g., hearing) is disturbed, the ability to use other sensory organs such as tactile sensitivity may be impaired. This impairment may be temporary or long term depending on the individual and other relative factors (McCance & Huether, 1998; Moller et al., 1976). With vibration frequencies ranging anywhere between 20,000 to 50,000 Hz, and in the higher frequencies, the noise recorded in decibels increases close to 90, a dangerous level that elevates the opportunity for proprioceptive dysfunction. This in turn could affect a number of sensory organs that rely on nerve fibers for appropriate transmission of messages. Neuropathies may be caused by diabetes mellitus, unknown etiologies, metabolic disturbances or exposure to vibration (McCance & Huether, 1998; Hjortsberg et al., 1989; Lundstrom & Lindmark, 1982).

Factors that Affect Tactile Sensitivity

"[T]ouch is not a uniform sensory experience since it involves the fusion of several qualities, including modality, intensity, location and duration of the sensory stimulus (McCance & Huether, 1998) (See Table 1)." Abnormalities in tactile perception may be caused by alterations of the nervous system, from the receptor to the cerebral cortex. *Any factor that disrupts or alters reception, transmission, perception or interpretation of touch may also impair tactile sensitivity* (McCance & Huether, 1998).

Table 1. Qualities That Comprise the Sense of Touch.

Stimulus	Definition
Modality	The mode or manner in which the stimulus is delivered
Intensity	The strength or magnitude of the stimulus
Location	The site of stimulus exposure
Duration	The length of time in which the stimulus is delivered

Tactile sensitivity is reliant on several structures in the hand including the median nerve, encapsulated nerve endings and specialized capsules of connective tissues (Hunter, Schneider & Mackin, 1997). The median nerve runs through and innervates the thumb, index, middle and median aspect of the ring finger (See Figure 2).

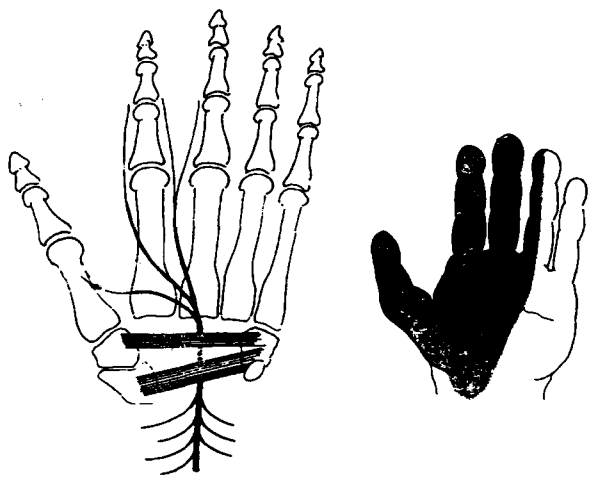

Figure 2. Median Nerve. The Motor Branches of the Median Nerve are Shown in the Left Figure; the Right Figure Shows Its Sensory Pattern. From Cailliet, R. (1994). *Hand Pain and Impairment.* (4th ed.). Philadelphia, PA: F.A. Davis Company.

The median nerve houses large nerve fibers, such as A-beta fibers, which are characterized by vibratory, proprioceptive, and tactile discriminatory sensation (Vinik, Suwanwalaikorn, Stansberry, Holland, McNitt, & Colen, 1995).

According to Vinik et al. (1995),

> tactile discriminatory sensation is mediated primarily via the large, but thinly myelinated, fast-conducting sensory afferents (A-beta fibers) innervating skin and underlying soft tissues. Due to difficulties in quantitatively detecting specific sensory deficits, little definitive data exists addressing the issue of nerve fiber involvement (See Figure 3).

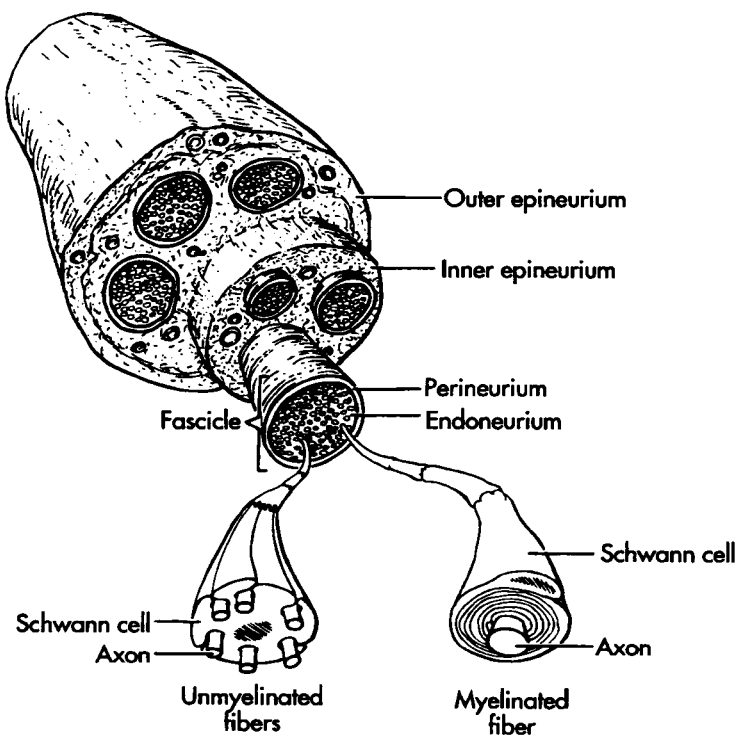

Figure 3. Cross Section of Unmyelinated and Myelinated Nerve Fibers. From Millesi, H., & Terzis, J.K. (1983). Problems of Terminology in Peripheral Nerve Surgery: committee report of the International Society of Reconstructive Microsurgery. *Microsurgery, 4,* 51-56.

Even more specific than peripheral neuropathies are sensory neuropathies, which can arise from dysfunctions in proprioception, noise or vibration. Microscopic mechanoreceptors involved in sensation lie within the Pacinian corpuscle, which is most sensitive to skin displacements (See Figure 4). The Pacinian corpuscle is a rapidly adapting receptor that lies on a nerve ending and consists of a multilayered connective tissue sheath that is approximately 1mm in diameter and 3mm in length (Hunter et al., 1997). Its purpose is to aid in the person's ability to detect vibration.

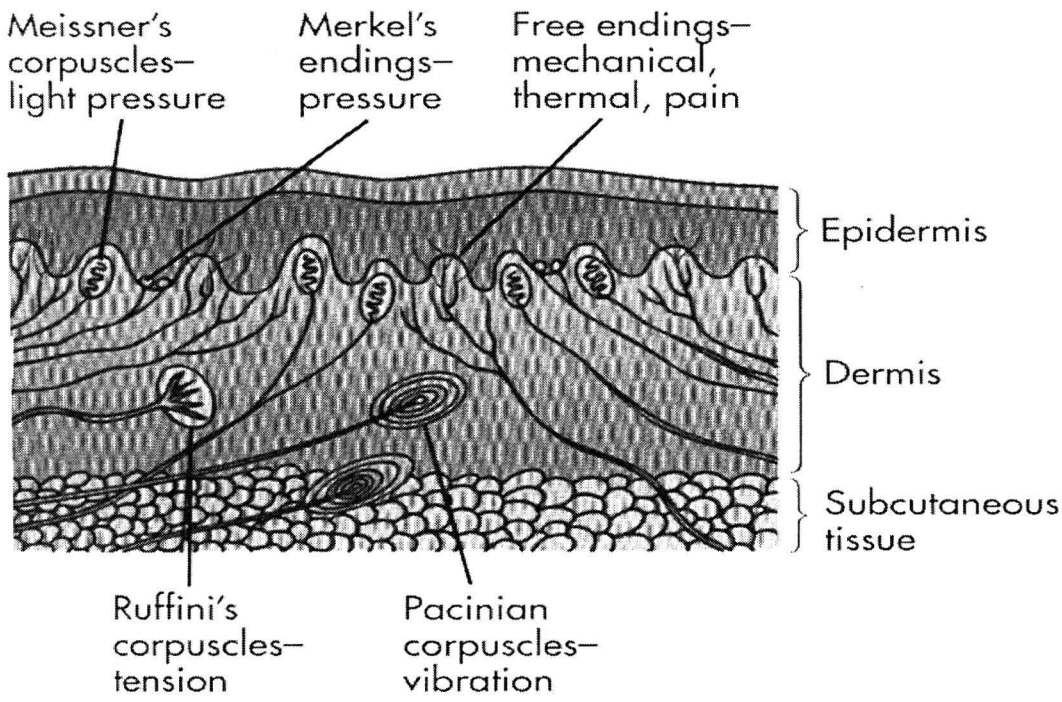

Figure 4. Diagram of Cross Section of Skin Demonstrating Various Layers and Sensory Endings. From Lindsay, D.T. (1996). *Functional Human Anatomy.* St. Louis, MO: Mosby.

The best frequency range for optimal sensitivity of the fingertip is within 100 to 200 Hz (Lundstrom & Lindmark, 1982). Once outside of this range, the sensitivity of the

Pacinian corpuscle, and hence, tactile sensitivity decreases (Lundstrom & Lindmark, 1982). The frequency range for most ultrasonic scalers is 20,000 to 50,000 Hz; therefore, tactile sensitivity may be affected with vibration within the ultrasonic Hz range (Akesson et al., 1995).

In one particular study, researchers measured 30 dental hygienists, 30 dentists, 30 dental technicians and 30 nurses on tactile sensitivity, strength, motor performance, sensorineural symptoms and signs, and vascular symptoms (Akesson et al., 1995). The researchers concluded that a decrease in strength was rather severe in the health professionals studied, and impairment in tactile sensitivity and performance, though not as severe, was notable. According to the researchers, dentists experienced more peripheral neuropathy than hygienists, because the dentists' hands were exposed to vibration for longer durations from using high and low speed handpieces. Interestingly, there was an increased vibrotactile perception threshold at low and high frequencies and decreased hand strength, leading the researchers to conclude that grip forces were lower among those groups exposed to vibration (Akesson et al., 1995). The researchers noticed a relationship between impaired vibrotactile sense and decreased muscle strength (Akesson et al., 1995). Hjortsberg et al. (1989) also reported reduced tactile sensitivity with exposure to higher frequencies (noise) above 1000 Hz. *Therefore, with vibration exposure, tactile sensitivity may be one of the first physiological components to be affected.* Such findings must be given serious consideration in light of the escalating rates of ultrasonic scaler usage as part of nonsurgical periodontal therapy provided by dental hygienists.

In a study conducted by Flodmark and Lundborg (1997), male workers who had been exposed to vibration in industry comprised the experimental group; those subjected to heavy manual work, but without vibration exposure, made up the case-control group. Results revealed that a decrease in vibrotactile sense may be one of the first changes found following exposure to vibration (Flodmark & Lundborg, 1997). Vibrotactile sense was expressed via a *sensibility index (SI)*, which is depicted as a ratio of the integrated area under the test curve and the area under an age-matched control curve (Flodmark & Lundborg, 1997). An *SI* of 1.0 indicates the highest level of vibrotactile perception (Flodmark & Lundborg, 1997). The results of this study concluded that out of the 171 healthy men who were not exposed to vibration or hard manual work, their *SI* was significantly higher (greater than 0.80) than the exposed subjects. The researchers suggested that not only vibration, but also manual work, may decrease vibrotactile sense (Flodmark & Lundborg, 1997). This may have implications for dental hygienists who use hand-activated instruments for scaling. Flodmark and Lundborg's results indicated that the ranges of 0.50-0.64 were critical because *SIs* greater than 0.50 suggests a rise in sensorinueral symptoms and less vibrotactile sense (Flodmark & Lundborg, 1997). In compression neuropathies, decreases in vibrotactile sense are early signs, which have not been studied in dental hygienist using hand instruments. Flodmark and Lundborg (1997) suggest that there may be correlations between the grip forces exerted while performing hand instrumentation and compression neuropathies. This is fertile area for dental hygiene research.

In a study conducted by Akesson, Balogh and Skerfving (2001), ultrasonic scaler exposure time was studied to measure the amount of daily vibration exposure. The study

was carried out over a three-week period using a time-registration device attached to the foot control of the ultrasonic scaling unit (Akesson et al., 2001). During this same time period, the dental hygienists were asked to estimate and record their time of exposure in minutes via a diary. The researchers concluded that there was a true variation of exposure time between all hygienists studied. The average time exposed according to the time registration device was approximately 12 minutes a day (Akesson et al., 2001). Despite the limited reported exposure time (12 minutes) to high frequency vibrations from ultrasonic scalers, dental hygienists experienced pathological *SIs* greater than 0.80 (Akesson et al., 2001). Akesson et al., utilized the same index used by Flodmark and Lundborg (1997). This particular study had variations in ultrasonic usage rates according to patient need; therefore, daily exposure levels to ultrasonic scaler vibrations were not as influential as anticipated. In a study conducted by Akesson et al. (1995), dentists were found to have a decrease in vibrotactile perception with increased exposure to vibration. This decrease in perception was noted in the dominant hand and less pronounced in the non-dominant hand. This finding was possibly attributed to the firm grasp or grip strength required in some dental procedures. This same pattern of decreased perception, also noted by dental hygienists, is attributed to using low speed handpieces and ultrasonic scaling devices (Akesson et al., 1995). More dentists were affected than dental hygienists primarily due to grip force, increased exposure time and use of high and low speed handpieces that run at frequency levels most likely to cause impairments. Grip forces tended to be lower among those exposed to vibration because they did not have to exert as much energy. The amount of energy transmitted to the dental hygienist may be lower if the instrument or device is being held loosely; however, workers exposed to vibration

often experience a decrease in muscular force. This impaired muscle function throughout the grip of the hand, may be due to injury to the muscle tissue, nerve tissue, or a combination of both because of vibration in and of itself (Akesson et al., 1995). Impairments in grip strength have also been found to occur among those in which low frequency vibrations (less than 50 Hz) are transmitted to the hand and forearm as opposed to higher vibrations that are absorbed by the hand.

Vibration-induced muscle injury also has been documented on laboratory rats (Necking, Dahlin, Lundborg, Lundstrom & Thornell, 1992). Following several days of vibration exposure at a frequency of 80 Hz, muscle fiber degradation and changes were noted in plantar muscle sections (Necking et al., 1992). Necking et al. (1992), found irregular muscle fibre profiles in the major portion of tissue cross sections from all vibrated legs. About 70% of the cross sections showed necrotic fibres or fibres undergoing necrosis. This has implications for oral health professionals who frequently use ultrasonic or sonic scaling devices that emit vibrations that operate within high and low frequency levels.

Dental hygiene practice demands that dental hygienists maintain pinch grasps on narrow sized instruments and use repetitive motions that require applied force for scaling and root planning (Michalak-Turcotte & Atwood-Saunders, 2000). According to Gerwatowski, McFall and Stach (1992), dental hygienists report that latex gloves reduce tactile sensitivity and could cause a tighter grasp or pinch in order to feel calculus and other irregularities. Gerwatowski et al. (1992) recommend the use of sonic and ultrasonic scalers because they require less grip and wrist motion of the dental hygienist. The large diameter handle design on mechanized instruments encourages a more open grasp,

therefore decreasing the amount of pinching (Gerwatowski et al., 1992). Researchers found that the amount of grasp force applied to instruments caused altered sensations as noted by 159 (out of 260) dental hygienists that responded to a survey on upper extremity pain and dysfunction (Stentz, Riley, Harn, Sposato, Stockstill & Harn, 1994). Stentz el al. (1994) underscored the need for better ergonomic instrument designs for practitioners.

Neuropathies induced by vibration may include Raynaud's phenomenon, characterized by fingers which become white, blanched and very cold. Raynaud's phenomenon occurs in less than 15% of the population and 1% to 3% may actually worsen over time. A secondary form of Raynaud's, called vibration syndrome, is most often related to vibrating handpieces (CDC, 1983). This damage can occur from continued exposure to vibration even following short-term use coupled with time. Signs and symptoms such as tingling, numbness and blanching may progress leading to irreversible damage of the fingers. According to a study conducted by the National Institute for Occupational Safety and Health (NIOSH) of 385 shipyard workers exposed to vibrating hand tools and having symptoms of Raynaud's phenomenon, 47% had advanced stages of vibration syndrome while 19% had earlier stages of vibration syndrome (CDC, 1983). These findings suggest that practitioners exposed to vibration from ultrasonic scaling devices could develop Raynaud's phenomenon or vibration syndrome regardless of exposure time.

In summary, ultrasonic scalers remove calculus, plaque biofilm and endotoxins from the tooth surface when operating between 20,000 to 50,000 Hz. Ultrasonic scalers have the potential to produce noise at dangerous levels when exceeding 90 decibels and exceeding 3000 Hz (high frequency vibrations) thereby altering tactile sensitivity (Wilson

et al., 2002). These findings in the literature suggest a fruitful line of investigation that could improve dental hygiene practice and potentially increase understanding of occupational injury and its prevention.

Chapter III

METHODS AND MATERIALS

Sample Description and Selection

The participants for this study were first year entry-level dental hygiene students. These participants are representative of the population of aspiring dental hygienists to which these results can be generalized. The sample was appropriate because dental hygienists use ultrasonic scalers more than any other dental professional, and first year dental hygiene students, early in the first semester, have not been exposed to cumulative hours of scaling. First year, first semester dental hygiene students who had not used ultrasonic or hand scalers for a significant period of time, who were free of any past or current dominant arm, wrist or hand injury/disorder of any type, and free of medical problems were included in the study. Any first year dental hygiene students that had used the ultrasonic or hand-activated scalers for an extended period of time, and/or who had a current or past history of some form of dominant arm, wrist or hand injury/disorder or any medical problems, were excluded from the study (See Appendix A).

The exclusion criteria controlled for the possible confounding variables of medical conditions and cumulative trauma disorders and were appropriate because the researchers wanted to measure the *initial effects* of the ultrasonic and hand-activated scaling, rather than cumulative effects, on tactile sensitivity. So little is known about tactile sensitivity and the loss of tactile sensitivity in dental hygienists that a short period of 45 minutes, congruent with the average dental hygiene appointment time in private practice, was established as appropriate to determine initial effects. Initial effects must be documented before any longer term effects are investigated in future studies.

Subjects were recruited from the class of 50 first year dental hygiene students via informational flyers posted at numerous locations throughout Old Dominion University's School of Dental Hygiene (See Appendix B). Also, the principal investigator and co-investigator talked with the first year class during their orientation session in August 2002 and prior to a class in October 2002. Each subject who met the inclusion criteria and who agreed to participate signed the consent form (See Appendices B and C). Consenting students were individually assigned numbers and then placed into either the experimental or control group depending upon when their number came up on a table of random numbers. Random assignment of subjects to groups was used to control subject-relevant variables and unidentified confounding variables, decrease investigator bias, achieve initial group equivalence, and increase the internal validity of the design. The total sample size (N=40) consisted of 20 subjects for the experimental group and 20 subjects for the control group.

Research Design

A two-group, randomized subjects, pretest-posttest design was carried out mid semester for five weeks on 40 first year dental hygiene students who met the inclusion criteria of this study and who agreed to participate. All aspects of the investigation occurred in a simulated clinical setting in the Old Dominion University Dental Hygiene Research Center. The study design was appropriate to measure initial, short-term change both within and between groups in the format of a randomized, controlled laboratory trial (See Table 2). Since no research could be found on the effects of ultrasonic and hand-activated scaling on tactile sensitivity in dental hygienists or dental hygiene students, a short-term laboratory experiment was justified to begin this line of investigation.

Furthermore, the focus on initial change was supported by the Center for Disease Control's (CDC) findings on the short-term effects of vibrations in the development of neuropathy (1983).

Table 2. Two-Group, Randomized Subjects, Pretest/Posttest Design.

Group	Pretest	IV	Posttest
R E (n=20)	*Vibratory Sensory Analyzer* scores on Thumb, Index and Middle Fingers	45 minutes of ultrasonic scaling	*Vibratory Sensory Analyzer* scores on Thumb, Index and Middle Fingers
R C (n=20)	*Vibratory Sensory Analyzer* scores on Thumb, Index and Middle Fingers	45 minutes of hand-activated scaling	*Vibratory Sensory Analyzer* scores on Thumb, Index and Middle Fingers

Baseline data from the *Vibratory Sensory Analyzer* provided an initial measurement of tactile sensitivity and verified group equivalency prior to the experimental treatment. Post-test data provided tactile sensitivity information on each experimental subject after ultrasonic scaling and each control subject after hand-activated scaling.

Simple random selection and random assignment of subjects to groups controlled for threats to the design's internal validity. The possible confounding variables of age as well as unidentified confounding factors were controlled by the randomized subject design. Furthermore, use of a research assistant ensured double-blind conditions during

data collection. Ultrasonic scaling was the independent variable being studied, with hand-activated scaling serving as an active control variable. Tactile sensitivity was the dependent variable, measured using the V*ibratory Sensory Analyzer*. Threats to external validity were controlled by the size and characteristics of the sample, therefore increasing the ability to generalize findings to other aspiring dental hygienists who posses similar subject profiles. The sample profile consisted of 39 (99%) females and 1 (1%) male, with approximately 28 (70%) in their 20's, 10 (25%) in their 30's and 2 (5%) in their 40's. There were no significant medical conditions or history of arm, hand or shoulder injuries, which also included acute or prolonged exposure to vibration or noise.

Procedures, Materials, and Data Collection Instrument

Dental chair-mounted typodonts were used to mimic a client's oral cavity during scaling. Using a 6cc plastic gauge syringe, an equal amount of artificial calculus (4cc) was evenly distributed supragingivally along the gingival margin over the facial and lingual surfaces of the typodont teeth to provide a real-life scaling simulation. The amount of artificial calculus used exceeded what could be removed within a 45-minute scaling period. To maintain equivalent conditions, backup typodonts were available in the event all of the artificial calculus was removed by the student prior to the full 45 minutes of scaling. Before the start of data collection, typodonts were prepared and set up by the co-principal investigator who was also a registered dental hygienist. The principal investigator, co-principal investigator as well as the research assistant reviewed each subjects' informed consent at their scheduled appointment prior to data collection. Each individual subject was scheduled so the time between the pretest and exposure to the independent variable and posttest was the same.

In a quiet room near the Dental Hygiene Research Center, subjects were individually pretested according to the protocol by the research assistant using the *Vibratory Sensory Analyzer* (See Figure 5).

Figure 5. *Vibratory Sensory Analyzer* Showing Research Assistant on Left Measuring Tactile Sensitivity in a Subject.

Subject activity prior to scaling was controlled by including newly entered students into the dental hygiene program who had recently learned the same basic instrumentation in a pre-clinical course. Subjects were asked to refrain from using any type of vibratory equipment on the day of testing, e.g., electric shaver, powered toothbrushes, vacuum cleaner, etc. Subjects returned to the clinic according to a schedule so that they could review the same body positioning and basic scaling instructions for both the ultrasonic scaler and hand-activated instruments (See Appendix D & E). When scheduled, the experimental group subjects then used the ultrasonic scaler set at medium power on the

calculus-prepared typodont for 45 minutes to mimic the approximate time spent with clients in private practice (See Figure 6).

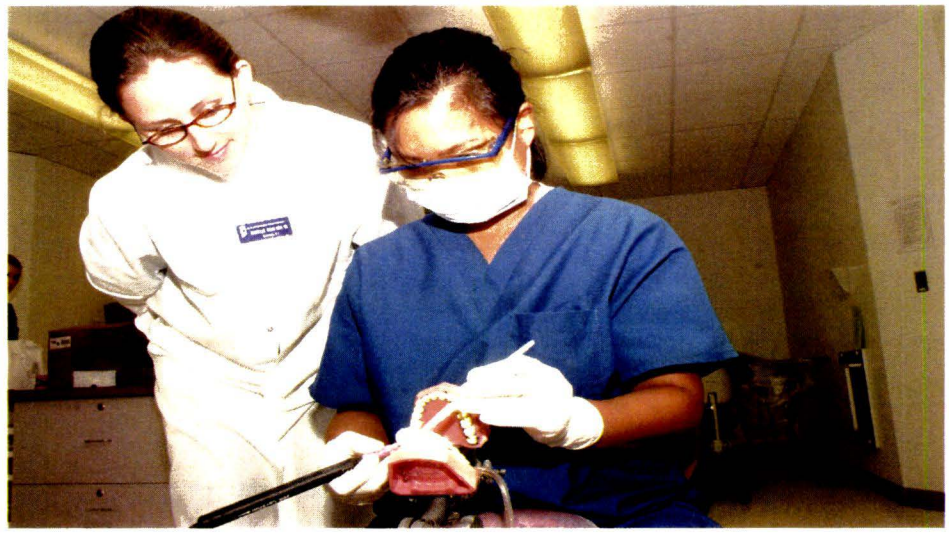

Figure 6. Ultrasonic Scaling Station for the Experimental Portion of the Study.

Once 45 minutes had expired, the co-principal investigator, who was responsible for the experimental portion of the study, advised subjects to stop using the ultrasonic scaler or hand instruments. Then, the research assistant, who was blind to the group status of the subjects, conducted post-testing with the *Vibratory Sensory Analyzer* (See Figure 5).

The time of day for scaling and measurement was balanced between both experimental and control groups, therefore, controlling the variable of time. A maximum of 8 subjects were tested a week; thereby, taking a total of 5 weeks to complete the data collection portion of the study.

To ensure optimal functioning and minimal variability, two preused, but calibrated ultrasonic scaling units made by Dentsply, and 20 new standard P-10 Cavitron ultrasonic tips were used for the ultrasonic scaling portion of the experiment. For similar

reasons, 20 new Barnhardt Universal 5/6 curets and 20 new anterior sickles manufactured by Hu-Friedy Manufacturing Company were used during the hand-activated scaling portion of the experiment. Expendable materials included clinical supplies such as standard personal protective equipment, barriers, disinfectants, and disposable products since these are a normal part of a dental hygienist's clinical treatment environment and would decrease external validity of the design if not used. Each scaling trial was accurately monitored with a standard timer. Approximately 12 typodonts (Columbia Dentoform) including mounts simulated the positioning of clients during dental hygiene care. The number of typodonts used enabled the co-principal investigator to prepare the artificial calculus on each typodont for use over a 2-3 day period of time. Once used in a trial, typodonts were cleaned by the co-principal investigator and prepared for the next group of scheduled subjects.

The data collection instrument was the *Vibratory Sensory Analyzer*, manufactured by Medoc Advanced Medical Systems, in Minneapolis, Minnesota. The *Vibratory Sensory Analyzer* consists of a microcomputer device with a vibratory button as the stimulator (See Figure 1). The *VSA* measured the soft tissue of the pulp of the thumb, index and middle fingers focusing on the large nerve fibers (Medoc, 2002). This instrument has been used as a measure of peripheral neuropathy of lower extremities in diabetic patients (Resnick et al., 2002). These neuropathies are similar to tactile sensitivity in their association with large nerve fibers. In Resnick et al. (2002), the *VSA* was used to detect large fiber sensations. The *Vibratory Sensory Analyzer* is a clinically valid method of rapid screening, early detection, and longitudinal evaluation of persons at risk of sensory dysfunction; it can record over 30,000 tests and does automated

comparisons to age-matched normative data (Medoc, 2002). The *Vibratory Sensory Analyzer* has proven to be valid and reliable through repeated testing in a number of different clinical trials (Medoc, 2002; Resnick et al., 2002). Several major universities all over the United States have utilized the *Vibratory Sensory Analyzer* and its components (See Appendix F) (Medoc, 2002). For example, it is currently being used by the Eastern Virginia Medical School Strelitz Diabetes Institute in Norfolk, Virginia to measure sensory disfunction in diabetics. Pfizer is currently using the *Vibratory Sensory Analyzer* in the study of a new chemotherapeutic agent on pain (Brooks, personal communication, January 11, 2002).

The manufacturer of the *Vibratory Sensory Analyzer* calibrates the instrument at the production facility and has developed a device to test for appropriate calibration of the instrument on site (Medoc, 2002). The on-site calibration device is based on a simple laser pointer, which is projected onto a mirror assembled on the vibrator head at a 45 degree angle to the beam. Behind the angled mirror, the beam is projected onto a test sheet positioned on a vertical wall 15 meters from the device. The vibrator is turned up to 130 microns causing the beam to spread on the test sheet. The operator should ensure that the projection of the beam onto the target sheet is of the required length as marked on the test sheet. If deviation is detected, the *Vibratory Sensory Analyzer must be returned to the manufacturer for calibration* (Medoc, 2002). This instrument was calibrated at the beginning of the study prior to the first subject; and did not need to be recalibrated during the course of the study (Medoc, 2002).

In cooperation with the Strelitz Diabetes Institute, Eastern Virginia Medical School, Norfolk, Virginia, a trained *VSA* technician oriented the principal investigator,

co-principal investigator and research assistant so that they developed proficiency using the *VSA*. Approximately six hours were spent learning how to operate the *VSA*. The *VSA* took approximately 10-15 minutes to measure and record data for each subject at each scheduled testing.

Specific Procedure Used for the Operation of VSA 3000

1. *Select a test*- Operator selected the specific test (Vibration) of the *VSA* testing capability, then opened the subject's file that was already created by the co-principle investigator.
2. *Select body site*- The pulp of the thumb, index and middle finger of the dominant hand was chosen for each individual subject.
3. *Personalized instructions*- The subject was read the specific vibration instruction protocol (See Appendix G).
4. *Connect subject to instrument*- The operator clicked on the continue button and a test screen was displayed. It was at this point in which the subject was asked to place the specified finger on the vibratory button. The subject's finger was placed on the vibrating button and opening around the button. The subjects nondominant hand was placed on the response unit (the mouse) (See Figure 7).
5. *Starting the actual vibratory test*- The vibratory button acted as the stimuli by either increasing in intensity until the subject's response was determined, or by decreasing in intensity until there was no subject sensation at all (Medoc, 2002).

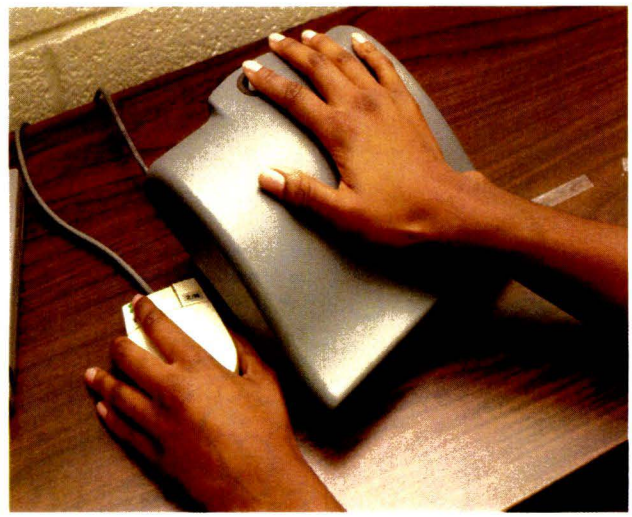

Figure 7. Vibratory Unit with Mouse.

The operator then started the test by clicking "run" or pressing the spacebar, and stopped the test by hitting "S". The subject was instructed to press either button on the response unit as soon as he/she feels the vibration. The vibration then stops and there is a short waiting period before the next stimulus begins. Eleven trials were taken with the first trial (a practice trial) being omitted. The purpose of the practice trial was to orient the subject to what was to be expected and therefore the practice trial measurements were not calculated into the final analysis. The operator then hit "save" to keep the results at the end of the 11 trials. Each trial emitted vibrations at random time intervals (5 seconds to 20 seconds), so they could not be predicted by the subject. This method allowed for a mean variance to be taken to verify the consistency of the test and to prevent response error on the part of the subject. Approximately four stimuli were administered for threshold determination and to increase the reliability of the data. This rate of vibratory change is between 0.1-4.0 microns per second with a

range of stimuli between 0-20 microns. The lower the number of microns, the greater the level of tactile sensitivity.

6. *Post-test measurement*- The operator pressed the continue button to enter the post-test menu which then allowed the operator to repeat the test, exactly as in the pretest trial.

Protection of Human Subjects

The following plan for the protection of human subjects was reviewed by the Old Dominion University Institutional Review Board and approved at its February 2002 meeting:

Potential Risks. The potential for physical risks existed in this study; however, risk was minimal and unlikely to occur. Injury to the arm, wrist or hand was possible from using the ultrasonic scaler and hand scale instruments. The risk was no more than would be expected if a dental hygienist had chosen to use the ultrasonic or hand scalers in clinical practice. There were no other methods that could have been used to eliminate such risks in this study.

Consent Procedures. Informed consent was obtained during the initial meeting from all subjects who qualified for the study. The principal investigator explained the study in detail and answered questions. Consent was voluntary and collected during the initial meeting and kept on file in room 253 of the Technology Building on the campus of Old Dominion University (See Appendix B for Informed Consent Form). Only those persons involved in the conduct of this study had access to these forms.

Protection of Subjects Rights. Subjects were initially issued a number; which was their individual form of identification throughout the study. All data collection forms were identified by the subjects' numbers and not their names. This method maintained

confidentiality for the subjects involved. All information collected from subjects and possible outcomes were maintained under their specified number throughout and after the study. Strict adherence to proper testing was under the direct supervision of qualified individuals. Data were reported in group-form only. After the study, data collection forms are kept for three years and then destroyed.

Potential Benefits The benefits for the individual subject are minimal; however, the benefits for the whole population are high. The results of this study could benefit all dental hygienists who use the ultrasonic and manual scalers and companies who manufacture these instruments. For example, if the ultrasonic instrument is shown to decrease tactile sensitivity, manufacturers will be motivated to design safer equipment. This includes those practitioners who will be using the ultrasonic scaler in the future. Knowledge of the ultrasonic scaler and tactile sensitivity will greatly enhance the dental hygienists' awareness of possible negative effects they could encounter from ultrasonic scaler usage. This knowledge may also benefit others who rely on tactile sensitivity in their professions.

Risk-Benefit Ratio The benefits resulting from the research far outweigh any minimal risk to the subjects. Dental hygienists will benefit from knowing if exposure to the ultrasonic scaler, or even hand scaling in itself, causes tactile sensitivity dysfunction.

Statistical Treatment

Inferential, parametric statistics were appropriate because randomization was used, sample size (N=40) was adequate and data were ratio scaled. The *Vibratory Sensory Analyzer* utilizes a Windows-based operating system and yields ratio data through sequential sets of exposure to the testing stimulus, providing a fixed ratio.

Three-way and two-way analysis of variance with one repeated measures factor analyzed for pre- to post-test changes in the tactile sensitivity of the thumb, index and middle fingers of each subject. Interaction effects of scaling (ultrasonic verses hand-activated), time of test (pretest verses posttest) and digit tested (thumb, index and middle fingers) were also determined.

Average raw *VSA* scores were recorded for the thumb, index and middle fingers during both the pretest and posttest for both the control and experimental groups. The averages were computed along with the corresponding standard deviation. The standard deviations were quite different; therefore, in order to validate the standard assumption of homogeneous variance of the dependent variable, the standardized average *VSA* score was computed by dividing the average raw *VSA* score by its standard deviation. The standardized average *VSA* scores were analyzed by using the square root transformation, which yielded and supported normality. The result further supported the use of the parametric statistical analyses.

Chapter IV

RESULTS AND DISCUSSION

After providing one practice stimulus that was not included in the analysis, *VSA* scores were obtained on each individual subject with ten stimulus replications on each finger (thumb, index, and middle) for both the pretest and posttest. A total of 480 *VSA* scores were obtained with their corresponding means and standard deviations.

Results

Hypothesis One. The first hypothesis predicted no statistically significant interaction among group status (ultrasonic vs. hand-activated), time of test (pretest/posttest) and tactile sensitivity of the three digits as measured by *VSA* scores. Three-way analysis of variance with one repeated measures factor revealed no statistically significant interaction among experimental and control groups, pretest/posttest, and thumb, index and middle fingers of dental hygiene students (F=1.33, df=2, p=.2678) (See Table 3).

Table 3. Three-Way Analysis of Variance Comparison of Tactile Sensitivity Among Ultrasonic and Hand-Activated Groups, Pretest/Posttest, and Thumb, Index and Middle Fingers.

Source	df	SS	Mean Square	F-Value	Probability
Test	1	0.14	0.14	0.49	.4841
Test & Group	1	1.47	1.47	4.92	**.0285 ***
Test & Finger	2	0.87	0.43	1.46	.2373
Test & Group & Finger	2	0.80	0.40	1.33	.2678

*** Significance**

Hypothesis Two. The second hypothesis predicted no statistically significant interaction between group status (ultrasonic vs. hand-activated) and test (pretest/posttest) effect, as measured by *VSA* scores. Two-way analysis of variance with one repeated measures factor revealed a statistically significant interaction between the group and test following exposure to the independent variable and active control (F=4.92, df=1, p=.0285) (See Table 4). Data in Figure 8 clearly show that subjects in the hand-activated scaling group lost tactile sensitivity as they progressed from the pretest to the posttest measure. Specifically, the ultrasonic scaling group possessed significantly greater tactile sensitivity at the posttest. Note that lower scores are indicative of greater tactile sensitivity.

Table 4. Two-Way Analysis of Variance Comparison of Tactile Sensitivity Between Ultrasonic and Hand-Activated Scaling Groups and Pretest/Post-test Effect.

Source	df	SS	Mean Square	F-Value	Probability
Group	1	0.53	0.53	1.22	.2718
Test	1	0.14	0.14	0.49	.4841
Group & Test	1	1.47	1.47	4.92	**.0285 ***

***Significance**

A post-hoc analysis revealed that the significant difference in the two groups exists at the pretest (p=.0323), but not at the posttest level (p=.5722). A plot of average standardized VSA scores for both groups is demonstrated in Figure 8.

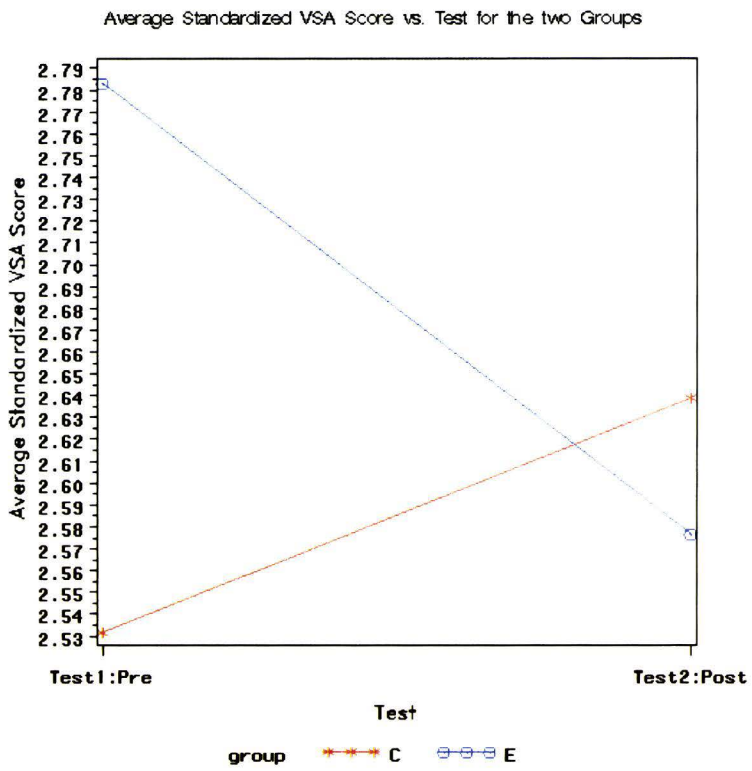

Figure 8. Average Standardized *VSA* Score for the Ultrasonic and Manual Scaling Groups During Pretest and Posttest Phases.

Because of the initial group differences observed in the pretest scores, a paired t-test was used to adjust for the initial differences between the two groups. Initial group differences were attributed to variation in the tactile sensitivity of the fingers of subjects within the control group. This variation was responsible for the initial group differences (p=.0323). Analysis of variance was then applied to the paired t-test data to analyze the differences between the groups. The analysis of the adjusted data revealed a statistically significant difference between the groups (p=.0285) (See Table 5) indicating that those subjects exposed to the ultrasonic scaler were more tactilely sensitive that those exposed to hand-activated scaling.

Table 5. Two-Way Analysis of Variance Comparison of Tactile Sensitivity Between Ultrasonic and Hand-Activated Scaling Groups and Finger Effect.

Source	df	SS	Mean Square	F-Value	Probability
Group	1	2.96	2.96	4.92	**.0285***
Finger	2	1.75	0.88	1.46	.2373
Group & Finger	2	1.60	0.80	1.33	.2678

***Significance**

The mean change between the post-test and pre-test for the control group is 0.1073 (S.D. =0.7157) and for the experimental group it is –0.2067 (S.D. =0.8403). These mean difference scores were the basis for computing the paired-t analysis. Given that the difference scores were variable, difference between the two groups at the posttest level were significant. The experimental group had significantly lower scores than the control group, thus showing greater tactile sensitivity.

Hypothesis Three. The third hypothesis predicted no statistically significant interaction between the group (ultrasonic vs. hand-activated) and tactile sensitivity level of the thumb, index and middle finger of dental hygiene students, as measured by *VSA* scores. There was no interaction between group status and the fingers tested (F=0.46, df=2, p=.6350); however, two-way analysis of variance with one repeated measures factor revealed a statistically significant difference between the thumb, index and middle fingers of both groups regardless of group status (F=4.79, df=2, p=.0101) (See Table 6).

Table 6. Two-Way Analysis of Variance Comparison of Tactile Sensitivity Levels in the Thumb, Index and Middle Fingers between Ultrasonic and Hand-Activated Scaling Groups.

Source	df	SS	Mean Square	F-Value	Probability
Group	1	2.96	2.96	4.92	**.0285***
Finger	2	4.21	2.10	4.79	**.0101***
Group & Finger	2	0.40	0.20	0.46	.6350

***Significance**

In both groups, of the digits tested, the index finger was the most sensitive with a threshold of 2.42-2.50, followed by the middle finger at 2.64. The greatest difference in sensitivity between the ultrasonic and hand-activated scaling groups was observed in the thumb, which had a threshold of 2.68-2.88, indicating it was least sensitive. The ultrasonic scaling group showed the most significant decrease in the thumb's level of tactile sensitivity.

The control group also showed little deviation in tactile sensitivity (.02 difference) between the thumb and middle finger, therefore, confirming that neither grip strength associated with hand-activated nor ultrasonic vibration associated with mechanized instrumentation effect tactile sensitivity in those two fingers over a 45-minute period (See Figure 9).

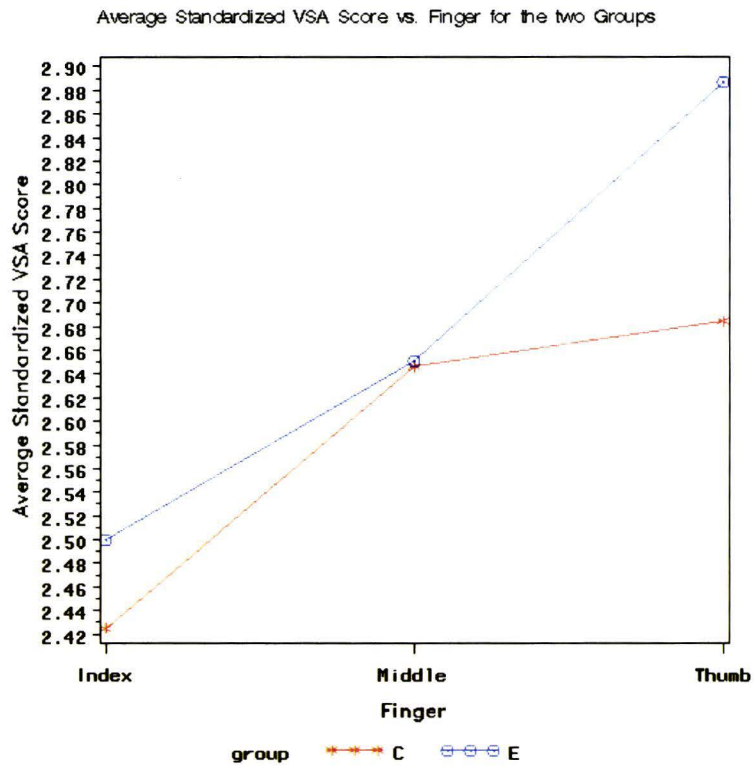

Figure 9. Average Standardized *VSA* Score for Thumb, Index and Middle Fingers of the Ultrasonic and Hand-Activated Scaling Groups.

Hypothesis Four. The fourth hypothesis stated that there is no statistically significant change in the tactile sensitivity of the students' thumb, index and middle finger from the pretest to the posttest, as measured by the *VSA* scores. Three-way analysis of variance with one repeated measures factor revealed no statistically significant interaction between the students' fingers and time of test (F=1.46, df=2, p=.2373) (See Table 3). Sensitivity of the thumb, index and middle fingers were not affected from pretest to posttest by ultrasonic or hand-activated scaling. The sensitivity of these digits, although different, remained stable over time, regardless of the scaling method used or time of measurement.

Discussion

Since no clinical data existed on the effects of scaling on tactile sensitivity in dental hygienists, it was prudent to initiate this line of investigation as a simulation on typodonts using first year, entry level dental hygiene students as subjects. Because the study was a simulation of what occurs in a clinical setting, findings are limited to the laboratory setting.

Hypothesis One. There is no significant interaction in level of tactile sensitivity among the ultrasonic and hand-activated scaling groups, pretest/posttest, and thumb, index and middle fingers of dental hygiene students (p=.2678). Even though there was a significant interaction among the two groups and the test, there is not an interaction within the groups before or after exposure suggesting that the fingers are not affected by the method of scaling used regardless of group. Further study is needed to determine if effects are observable after a longer period of scaling or in a population of practicing dental hygienists.

Hypothesis Two. The results of the study revealed that using a mechanized instrument, the ultrasonic scaler, for 45 minutes actually increases a clinician's level of tactile sensitivity as tested with the *VSA* compared to scaling with hand-activated instruments. Initial group differences in tactile sensitivity levels could have been due to the relatively small sample size (N=40) or age could have been a factor. While this study was designed to mimic a typical 45-minute scaling session, further studies would need to be conducted in order to determine if this is true for longer exposure times. Tactile sensitivity is vital to a dental hygienists' ability to provide comprehensive instrumentation to patients throughout the day; therefore, it is essential to plan treatment

for each patient in such a way that hygienists are able to conserve their efforts. If using a P-10 ultrasonic insert, hand-activated instrumentation following ultrasonic debridement should be implemented not only for making tooth surfaces biologically acceptable, but because results clearly suggest that an increase in tactile sensitivity following ultrasonic scaling might enhance the clinician's ability to evaluate clinical outcomes. This interpretation is supported by Busslinger, Lampe, Beuchat and Lehmann (2001) who found that the root surface is roughened following ultrasonic instrumentation, thereby, suggesting the need for hand-activated instrumentation following ultrasonic scaling. A combination of ultrasonic and hand-activated scaling should be used in order to reduce the likelihood of decreasing tactile sensitivity following a routine 45-minute scaling session. This recommended protocol has implications for all types of practice in which nonsurgical periodontal therapy is performed.

Hypothesis Three. Statistical analysis revealed a significant difference among the thumb, index and middle fingers of the ultrasonic and hand-activated scaling groups. In the simulated situation, the index finger appears to be the most tactilely sensitive finger, with the thumb being the least sensitive. These findings, although observed in the laboratory, may refute Gehrig-Nield's (2000) belief that the middle finger is the most tactilely sensitive. Perhaps the index finger's position in the modified pen grasp, on top of the instrument handle, maximizes the opportunity to sense changes picked up by the instrument. Pinching (to squeeze between the thumb and a finger) and gripping (to maintain a secure grasp), common forces involved in grasping a hand-activated instrument during working strokes, might be related to the thumb and middle finger's decreased tactile sensitivity, as compared to the index finger. Findings of this study and

that of Turcotte-Michalak and Saunders-Atwood (2000) support the recommendation that dental hygienists vary the use of ultrasonic scalers with hand-activated scaling. A combined use of hand-activated scaling and ultrasonic scaling is recommended since there is minimal to no pinch force with the ultrasonic scaler, only repetitive motions, as compared to hand-activated scaling. Pinching and gripping could reduce tactile sensitivity if the nerve endings become pinched or isolated, further explaining why tactile sensitivity decreased in subjects in the hand-activated group. These findings conflict with those of Hjortsberg et al. (1989) and Flodmark and Lundborg (1997) who both found decreases in workers' tactile sensitivity associated with vibration exposure. Duration of exposure and variability between the simulated laboratory and clinical situation might explain these conflicting outcomes. While this study was conducted using 30,000 Hz units in a simulated clinical setting, Akesson et al.'s (1995) subjects showed impaired vibrotactile sense and decreased muscle strength at both low and high frequencies associated with dental hand pieces. Furthermore, in the dental hygienists studied by Akesson et al., the impaired tactile sense was greater in their dominant hand. Since first year, entry level dental hygiene students were used, pinching and gripping of instruments could be greater than found in experienced dental hygienists who have developed muscle strength and hand coordination. This study should be replicated in a population of experienced dental hygiene practitioners under normal clinical practice conditions to determine if hand-arm muscle strength affects tactile sensitivity.

Hypothesis Four. The results revealed no significant interaction between the students' fingers and time of test. Neither the thumb, index nor middle fingers were affected following exposure to the ultrasonic or manual scaling instruments. This could

be due to the fact that tactile sensitivity is a relatively stable variable over time, or that the 45 minutes devoted to scaling was inadequate to alter the tactile sensitivity. Since this study focused on initial effects in a simulated setting, follow-up studies need to be conducted in order to determine long-term effects under normal clinical practice conditions.

Chapter V

SUMMARY AND CONCLUSION

The complex neurophysiology surrounding tactile sensitivity has created many obstacles for practitioners and researchers alike. When tactile sensitivity is impaired, a dental hygienist's ability to provide therapeutic benefits of scaling is greatly decreased. Calculus, plaque biofilm, and other toxins can be left behind contributing to disease progression. These factors, if not controlled, can exacerbate pre-existing disease as well as initiate the periodontal disease process. The purpose of this study was to determine if tactile sensitivity varies in dental hygiene students who use the ultrasonic scaler as compared to those who scale with hand-activated instruments. Given that ultrasonic scaling devices are utilized in nonsurgical periodontal therapy, it is important to study the effects of high frequency vibration on tactile sensitivity in dental hygienists, the primary users of ultrasonic scaling devices. A total of 40 first year, entry level dental hygiene students, who qualified for the study consented to participate and were enrolled. Subjects were assigned to one of two groups, either the experimental (ultrasonic) or the control (hand-activated) group. Each subject was given a pre- and posttest *VSA* evaluation by the research assistant. Data were analyzed using the SAS statistical analysis program. One, two and three-way analysis of variance was used to determine significant main and interaction effects among group status, time of test, and fingers.

Findings revealed that following a 45-minute ultrasonic scaling session, tactile sensitivity is increased. In contrast, tactile sensitivity appears to be negatively affected by hand-activated scaling which decreased tactile sensitivity. There was no significant difference between the ultrasonic and hand-activated scaling groups at both the pretest

and postest. There was a significant difference between the groups and their level of sensitivity in their thumb, index and middle fingers as evidenced by *VSA* scores. Subjects in both groups presented with higher *VSA* scores for the index finger, than any other digit tested. Both groups also showed the least sensitivity in the thumb. The middle finger had similar sensitivity for both groups. Findings suggest that neither ultrasonic vibration nor hand-activated scaling (grip strength) affect tactile sensitivity in the thumb and middle fingers of dental hygiene students following 45 minutes of instrumentation. No statistically significant interaction was observed between group status, time of test and tactile sensitivity of the three digits, resulting in retaining the fourth null hypothesis. Also, no statistically significant change in tactile sensitivity of the students' thumb, index and middle finger from the pretest to the posttest was observed, suggesting that tactile sensitivity remained relatively constant over the 45-minute scaling session.

This study provides baseline data on tactile sensitivity that has implications for the initial development of evidence-based scaling protocols. Current literature in conjunction with the findings revealed that ultrasonic instrumentation can be advantageous not only for the client, but also the practitioner. According to the literature, the ultrasonic scaler is more efficient than hand-activated scaling (Drummer, 2003). Ultrasonic scalers allow the hygienist to use less hand pressure, implying that musculoskeletal disorders and pinch grip forces can be reduced due to the mechanized component of the instrument. Findings also highlighted the potential importance of the index finger in detecting calculus and other tooth surface irregularities; therefore, the "modified pen grasp" continues to be the grasp of choice for practitioners, due to its unique positioning of the digits (thumb, index and middle finger). Utilization of

mechanized instrumentation devices is not only more efficient, but provide the practitioner with an enhanced ability to scale and detect calculus. Ultrasonic scalers save practitioners time that would otherwise be spent scaling an entire appointment. Based on the results of this investigation in a simulated clinical setting, the following conclusions are made:

1. Tactile sensitivity is affected differentially by mechanized and hand-activated scaling over the short term. Dental hygiene students who use the ultrasonic scaler for 45 minutes are likely to experience increased tactile sensitivity. Dental hygiene students who use hand-activated instruments for 45 minutes are likely to experience decreased tactile sensitivity.
2. Greater tactile sensitivity is experienced in the index finger, than in the thumb and middle finger, regardless of whether a mechanized or hand-activated scaling instrument is used.
3. Tactile sensitivity remained relatively constant over a 45-minute period.

Given that this study was conducted on 40 first year students in a simulated environment, recommendations for future research are indicated:

1. Replicating this study using the same group of dental hygiene students a year later in the dental hygiene program when they are treating clients.
2. Replicating this study using experienced dental hygienists in private practice.
3. Replicating this study using dental hygienists over time to determine long term changes in tactile sensitivity.
4. Replicating this study using a VSA device/unit that resembles the handle of an instrument, so that the modified pen grasp can be employed under typical

clinical practice conditions.

5. Determining if age is a factor in dental hygienists' tactile sensitivity levels.
6. Determining if instrument size, weight, and shape affect tactile sensitivity.
7. Determining if grip forces exerted while performing hand-activated and mechanized instrumentation affect tactile sensitivity.
8. Determining the prevalence of Raynaud's phenomenon in dental hygienists.

Based on this study's findings, ultrasonic scalers enhance tactile sensitivity in first year-entry level dental hygiene students in a simulated clinical setting. With an increase in the use of mechanized instrumentation in nonsurgical periodontal therapy, more research should be conducted to determine if the ultrasonic scaler causes an increase in tactile sensitivity over time and if so, at what rate. Findings in this study do not support changes in clinical instrumentation protocols at this time, but emphasize the need for more research in order to better understand tactile sensitivity in oral healthcare professionals.

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APPENDIX A

SUBJECT SCREENING QUESTIONNAIRE

Questionnaire for Screening Subjects to Determine Inclusion/Exclusion Status

Participant Information

Name_____ Assigned Number_____

Date of Birth_____Gender_____

Address_____ Phone Number_____

Emergency Contact and Number_____

Inclusion Criteria/Exclusion Criteria

Year in Dental Hygiene Program_____

Have you ever used an *Ultrasonic Scaler or Hand Scaler*?_____
If yes, please
explain_____

Do you have any dominant arm, wrist or hand injury/disability?_____
If yes, please
explain_____

Have you ever had a dominant arm, wrist or hand injury/disability?_____
If yes, please
explain_____

Do you feel that there is anything including medical problems that will keep you from participating in this study?

_____

Meets Inclusion Criteria

Yes_____ No_____

_____
Signature of research assistant or principal investigator

APPENDIX B

SUBJECT RECRUITMENT FLYER

NEW Dental Hygiene Students!

Come Participate in a Study Here in Old Dominion University's Dental Hygiene Research Center!

Study: What effect does scaling have on the tactile sensitivity of aspiring dental hygienists?

When: In Two Weeks-so sign up quick!

Why: You will aid in the research process, promote your school, and you and your colleagues may benefit from further advances in work environment improvements!!!

If *Interested*:
A **Sign Up Sheet** is posted on the bulletin board on the dental hygiene locker room door.

If you have any questions feel free to contact Danielle Ryan 437-2284 or Michele Darby 683-5232

APPENDIX C

INFORMED CONSENT

Informed Consent Document

for

OLD DOMINION UNIVERSITY

INFORMED CONSENT DOCUMENT
The purposes of this form is to give you information that may affect your decision whether to say YES or NO to participation in this research, and to record the consent of those who say YES.

TITLE OF RESEARCH: Effects of Ultrasonic Scaling Devices on Tactile Sensitivity in Dental Hygiene Students

RESEARCHERS: Michele Darby, BSDH, MS (Principal Investigator) Old Dominion University School of Dental Hygiene, and Danielle Ryan, BSDH (co-investigator) Old Dominion University School of Dental Hygiene

DESCRIPTION OF RESEARCH STUDY:
Several studies have been conducted looking into the subject of ultrasonic scaling devices and their impact on tactile sensitivity in dental hygienists. None of them have explained the effects of ultrasonic scaling on tactile sensitivity.

If you decide to participate, then you will join a study involving research of tactile sensitivity in dental hygienists using an experimental pretest-posttest research design. Scaling for 45 minutes with either the ultrasonic scaler or hand instruments followed and preceded with a tactile sensitivity test using computerized stimulators is expected from participants. If you say YES, then your participation will last for one 2-hour session at the Old Dominion University Dental Hygiene Care Facility. Approximately 40 first year dental hygiene students will be participating in this study.

EXCLUSIONARY CRITERIA:
You should have completed a questionnaire during the screening/qualification process. The questionnaire provides us with basic information, such as: name, age, phone number, address, past work history, time spent in dental office(s), and why, educational level, knowledge in dental field. To the best of your knowledge, you should not have medical problems or any prior experience using the ultrasonic or hand scaler and should be free of any current or past injury/disability to the dominant arm, wrist or hand, which will keep you from participating in this study.

RISKS AND BENEFITS:
RISKS: If you decide to participate in this study, then you may face a risk of hand, arm or wrist problems, cuts from instruments or hearing shifts. The researcher tried to reduce these risks by allowing a short duration for the experiment and earplugs. And, as with any research, there is some possibility that you may be subject to risks that have not yet been identified. These risks do not exceed those of any dental hygiene student who is practicing in the dental hygiene care facility.

BENEFITS: The main benefit to you for participating in this study is a free tactile sensitivity test. Others may benefit from the information gathered from this study and may be able to apply this current information to clinical instrumentation choices and procedures.

COSTS AND PAYMENTS:
The researchers want your decision about participating in this study to be absolutely voluntary. Yet they recognize that your participation may pose some inconvenience and costs to your schedule. In order to help defray your costs you will receive $25 for your participation. The $25 fee will be paid only if you complete the study.

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

CONFIDENTIALITY:
The researchers will take reasonable steps to keep private and confidential any information collected from you, such as questionnaire data and laboratory findings. The researchers will store information in a locked filing cabinet prior to its processing and the examiner will only know each individual as a number to maintain anonymity, during the actual experiment. The results of this study may be used in reports, presentations, and publications; but the researcher will not identify you. All data collected about you will be presented in group-form only. Only the principal investigator will be able to connect your information with your name. Of course, your records may be subpoenaed by court order or inspected by government bodies with oversight authority. Data on individual data collection forms generated by the computer from your sense of touch (tactile sensitivity) will be destroyed 3 years after the completion of this study.

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 a loss of benefits to which you might otherwise be entitled. 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 harm, injury, or illness 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 participation in any research project, you may contact Michele Darby at 683-5232 or Dr. David Swain at 683-6028 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 risks 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: Danielle Ryan at 437-2284 or Michele Darby at 683-5232

If at any time you feel pressured to participate, or if you have any questions about your rights or this form, then you should call Dr. David Swain, at 757-683-6028, or the Old Dominion University Office of Research, at 757-683-3460.

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

Subject's Name & Signature _____ Date _____

Parent / Legally Authorized Representative Name & Signature _____ Date _____

Witness' Name & Signature (if Applicable) _____ Date _____

INVESTIGATOR'S STATEMENT:

I certify that I have explained to this subject the nature and purpose of this research, including benefits, risks, costs, 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 state and federal laws, and promise compliance. I have answered the subject's 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.

Investigator's Name & Signature_____ Date _____

APPENDIX D

INSTRUCTIONS FOR CALCULUS REMOVAL WITH HAND-ACTIVATED INSTRUMENTS

Directions for Calculus Removal Utilizing Hand-Activated Instruments

1. Sitting in a neutral position with thighs and forearms parallel to the floor, use a modified pen grasp to grasp either the **Anterior Sickle Scaler** or the **Barnhardt 5/6** (Universal Scaler).

2. Using an **intraoral fulcrum**, place your ring finger near the tooth in which you are working on and **adapt the tip 1/3** of the instrument to the tooth surface.

3. Place the tip 1/3 **apical** to the calculus deposit.

4. Angulate the face of the instrument approximately between ***70-80*** degrees.

5. Activate a pulling stroke using **moderate to firm** lateral pressure.

6. Use **vertical, horizontal** and **oblique** stroke directions as needed for calculus removal.

7. Calculus removal strokes should be **short** and **powerful.**

8. Following the completion of each stroke, **relax your grasp, fulcrum** and **lateral pressure and reposition.**

9. While exploring, **adapt the tip 1/3** to the tooth for calculus detection.

10. Anglulate the face of the explorer between ***50-70*** **degrees** and activate a **soft fluid stroke** using **light lateral pressure.**

11. **Continue until all the calculus is removed.**

APPENDIX E

INSTRUCTIONS FOR CALCULUS REMOVAL WITH THE ULTRASONIC SCALER

Directions for Calculus Removal Utilizing the Ultrasonic Scaler

1. Sitting in a neutral position with thighs and forearms parallel to the floor, use a modified pen grasp to grasp the **handpiece**.

2. Using an **extraoral fulcrum (For the purpose of using the typodonts)**, place your ring finger on the plastic part of the typodont.

3. Applies the shank **parallel** to the long axis of the tooth.

4. Explore the tooth surface with the **side of the tip of the working end.**

5. Use very **light pressure** to locate the calculus.

6. Once contact with the calculus is established, **activate the foot pedal.**

7. Move the tip like an **eraser** in a **vertical, horizontal or diagonal** direction applying light pressure. (THE INSTRUMENT DOES THE WORK FOR YOU: YOU DO NOT NEED TO APPLY MUCH PRESSURE) **(ONLY THE SIDES OF THE INSTRUMENT WORK)** IF TOO MUCH PRESSURE IS APPLIED, THE TIP WILL NOT VIBRATE; THEREFORE IT WILL NOT WORK!!!

8. **Release** the foot pedal as needed to re-explore.

9. While exploring **adapt the tip 1/3, angulate** the face of the explorer between ***50-70*** degrees.

10. Activate a **soft fluid stroke** using **light lateral pressure.**

11. **Continue until all the calculus is removed.**

APPENDIX F

INSTITUTIONAL LISTING OF MEDOC *VSA* UTILIZATION

INSTITUTIONAL LISTING OF MEDOC *VSA* UTILIZATION

The Diabetes Institute
Norfolk, VA

Johns Hopkins Hospital
Baltimore, Maryland

Massachusetts General Hospital
Boston, Massachusetts

Stanford Medical Center
Palo Alto, California

M.D. Anderson Cancer Center
Houston, Texas

Beth Israel Deaconess Hospital
Boston, Massachusetts

Duke University Medical Center
Durham, North Carolina

Montreal Neurologic Hospital
Montreal, Quebec

National Institutes of Health (NIH)
Bethesda, Maryland

Albert Einstein Medical Center
Philadelphia, Pennsylvania

University of CA San Diego
San Diego, California

Columbia Presbyterian
New York, New York

University of Connecticut
Farmington, Connecticut

University of Minnesota
Minneapolis, Minnesota

The University of North Carolina
Chapel Hill, North Carolina

Wake Forest University Medical Center
Winston-Salem, North Carolina

Childrens Hospital
Boston, Massachusetts

University of Wisconsin
Madison, Wisconsin

University of CA San Francisco
San Francisco, California

The Miami Project, Univ. of Miami
Miami, Florida

Tulane University Medical Center
New Orleans, Louisiana

University of Florida
Gainesville, Florida

University of Michigan
Ann Arbor, Michigan

University of Alabama
Birmingham, Alabama

APPENDIX G

VSA PROTOCOL FOR SUBJECT TESTING

VIBRATION INSTRUCTIONS FOR THE SUBJECT USING THE VIBRATORY SENSORY ANALYZER

This is a test of vibration sensation; it may feel like a vibration, buzzing, tingling, or other similar sensation. As soon as you feel the vibration, please press the green button on the mouse. The vibration will then stop, pause for a number of seconds and start again. You will be given the test 10 times. Each time you feel the vibration, please press the green button on the mouse. It is important that you press the green button when you feel the vibration. I will do one practice test on your finger to give you an idea of how it feels.

Ten vibration tests will be done on each of your three fingers, the thumb, index and middle finger of your dominant hand. We ask that you please be quiet and not speak during the testing period and if there are any questions we will be more than happy to answer them as best we can either before or after the test. We also ask that you look at the wall directly in front of you during the test. Do you have any questions?

Ok, lets start. Please place your index finger of your dominant hand on the white button of the vibrator and depress it until you feel the border of the opening around it. (conduct test)

- Please place your middle finger of your dominant hand on the white button of the vibrator and depress it until you feel the border of the opening around it. (conduct test)
- Please place your thumb of your dominant hand on the white button of the vibrator and depress it until you feel the border of the opening around it. (conduct test)

You are now finished with the test.

a. Please go directly down to the dental hygiene clinic in the area of cubicles 3, 4, 9, 12.

b. Thank you for your participation!!