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

Danielle L Ryan, Michele Darby, Deborah Bauman, Susan L Tolle and Dayanand Naik

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Purpose. This study was conducted 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.

Methods. 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. A convenience sample of 40 consenting, first-year dental hygiene students were randomly assigned to one of two groups (experimental or control). 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. Immediately following exposure to either the ultrasonic scaler or hand-activated scaling instruments, tactile sensitivity scores were obtained using the VSA. Analysis of variance with one repeated measures factor was used to determine between group and within group differences on the pretest and posttest tactile sensitivity scores.

Results. Results revealed that tactile sensitivity increased after a 45-minute scaling session with the ultrasonic scaler. Pretest to posttest 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.

Conclusion. 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.

Keywords: tactile sensitivity, clinical dental hygiene education, repetitive strain injury

Introduction

Tactile sensitivity is the ability to distinguish relative degrees of tooth surface roughness or smoothness through the sense of touch and proprioception.¹ A person's tactile sensitivity may be impaired because of musculoskeletal and nerve disorders associated with cumulative trauma, repetitive tasks, and high frequency vibrations.² 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:

What short-term effect does the type of scaling (ultrasonic versus hand-activated scaling) have on the overall tactile sensitivity of aspiring dental hygienists?

Does tactile sensitivity change after scaling (ultrasonic versus hand-activated scaling) for 45 minutes?

Is there a difference in the tactile sensitivity of the thumb, index, and middle fingers of dental hygiene students?

The use of ultrasonic scalers, with their high frequency vibrations and noise, may be a factor affecting tactile sensitivity in dental hygienists.

Review of the Literature

Noise Effects on Tactile sensitivity

Ultrasonic scaling devices produce noise that may be greater than the Environmental Protection Agency's recommended maximum of 70 decibels within 24 hours.³ In dentistry, ultrasonic frequencies range from 20,000 to 50,000 vibrations per second with a 68 to 75 average decibel range.^{4,5} The higher the vibration per second, the greater the calculus removal efficiency.^{3,4} Ultrasonic scalers emit high frequency vibrations, which have the potential to cause occupational hearing loss.⁶ In a 1995 study, levels of annoyance and discomfort from high frequency noise produced by ultrasonic cleaners revealed high ratings at all levels of exposure, ranging from 72 to 96 decibels.⁷ Researchers concluded that even the lowest level of noise (70 decibels) produced by the ultrasonic cleaner should be avoided.⁷ Noise exposure from ultrasonic instruments commonly produce hearing loss after long periods of time and can temporarily alter patients' hearing.⁸

Proprioceptive dysfunction can often be caused by noise exposure, which, in turn, can affect other sensory organs, including the sense of touch.⁹ Two common causes of proprioceptive dysfunction are vestibular dysfunction and peripheral neuropathy. One example of vestibular dysfunction 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.^{10,11} 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.¹² The disturbance of these sensory and motor components may have different effects on objective sensory performance tests, depending on the level of dysfunction.¹² Tinnitus can often occur, causing one to lose the 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.^{8,9}

Factors Affecting Tactile Sensitivity

Tactile sensitivity is reliant on several structures in the hand, including the median nerve, encapsulated nerve endings, and specialized capsules of connective tissues.¹³ The median nerve runs through and innervates the thumb, index, middle, and median aspect of the ring finger. The median nerve houses large nerve fibers, such as A-beta fibers, which are characterized by vibratory, proprioceptive, and tactile discriminatory sensation.¹⁴ According to Vinik et al., "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."¹⁴

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. 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.¹³ Its purpose is to aid in vibration detection.

The best frequency range for optimal sensitivity of the fingertip is within 100 to 200 Hertz (Hz).¹¹ Once outside of this range, the sensitivity of the Pacinian corpuscle—and, hence, tactile sensitivity—decreases.¹¹ 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.¹⁵

Akesson et al. 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.¹⁵ The researchers concluded that a decrease in strength was rather severe in the health professionals studied, and that impairment in tactile sensitivity and performance, though not as severe, was notable. According to the researchers, dentists experienced more peripheral neuropathy than dental 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.¹⁵ The researchers noticed a relationship between impaired vibrotactile sense and decreased muscle strength.¹⁵ Hjortsberg et al. also reported reduced tactile sensitivity with exposure to higher frequencies (noise) above 1,000 Hz.¹⁰ Therefore, with vibration exposure, tactile sensitivity may be one of the first physiological components to be affected.

In a study by Flodmark and Lundborg, 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.¹⁶ Results revealed that a decrease in vibrotactile sense as measured by the Sensitivity Index (SI) may be one of the first changes found following exposure to vibration.¹⁶ The researchers suggested that not only vibration, but also manual work, may decrease vibrotactile sense.¹⁶ 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 to 0.64 were critical because an SI score greater than 0.50 suggests a rise in sensorineural symptoms and reduced vibrotactile sense.¹⁶ Although not studied in dental hygienists using hand instruments, decreases in vibrotactile sense are early signs of compression neuropathies. Flodmark and Lundborg further suggest that there may be correlations between the grip forces exerted while performing hand instrumentation and compression neuropathies.¹⁶

Akesson, Balogh, and Skerfving studied ultrasonic scaler exposure time to measure the relationship between amount of daily vibration exposure and sensitivity.¹⁷ The average time exposed, according to the time registration device, was approximately 12 minutes a day.¹⁷ Despite the limited reported exposure time (12 minutes) to high frequency vibrations from ultrasonic scalers, dental hygienists experienced pathological SI scores greater than 0.80.¹⁷ Akesson et al. found dentists to have a decrease in vibrotactile perception with increased exposure to vibration.¹⁵ This decrease in perception,

which was noted in the dominant hand and less pronounced in the non-dominant hand, 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.¹⁵

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 or nerve tissue, or a combination of both, because of vibration in and of itself.¹⁵ Impairments in grip strength have also been found to occur among those in which low frequency vibrations (<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.¹⁸ Following several days of vibration exposure at a frequency of 80 Hz, muscle fiber degradation and changes were noted in plantar muscle sections.¹⁸ Necking et al. found irregular muscle fiber profiles in the major portion of tissue cross sections from all vibrated legs.¹⁸ About 70% of the cross sections showed necrotic fibers or fibers 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 planing.¹⁹ According to Gerwatowski, McFall, and Stach, 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.²⁰ Gerwatowski et al. recommend the use of sonic and ultrasonic scalers because they require less grip and wrist motion of the dental hygienist.²⁰ The large diameter handle design on mechanized instruments encourages a more open grasp, therefore decreasing the amount of pinching.²⁰ Researchers found that the amount of grasp force applied to instruments caused altered sensations as noted by 159 (out of 260) dental hygienists who responded to a survey on upper extremity pain and dysfunction.²¹ Stentz et al. underscored the need for better ergonomic instrument designs for practitioners.²¹

Neuropathies induced by vibration include Raynaud's phenomenon, characterized by fingers that 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.²² 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.²² These findings suggest that practitioners exposed to vibration from ultrasonic scaling devices might develop Raynaud's phenomenon or vibration syndrome regardless of exposure time.

Methods

Procedures, Materials, and Data Collection Instrument

The protocol was reviewed and approved by the Old Dominion University Institutional Review Board for the Protection of Human Subjects. A pre-screening questionnaire was filled out by first-year, entry-level dental hygiene students to determine who met the inclusion/exclusion criteria. If subjects had a current and/or past history of some form of dominant

arm, wrist, or hand injury or disorder, or any medical problems, they were excluded from the study. 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, rather than cumulative, effects of ultrasonic and hand-activated scaling on tactile sensitivity. Consenting students were randomly assigned to either the experimental or control group. A total of 50 subjects were asked to participate and, out of that group, the total sample size (N=40) consisted of 20 subjects for the experimental group and 20 subjects for the control group. The sample profile consisted of 39 (99%) females and 1 (1%) male, with approximately 28 (70%) in their 20s, 10 (25%) in their 30s and 2 (5%) in their 40s.

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 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 that 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, also a registered dental hygienist. The principal investigator and co-principal investigator, as well as the research assistant, reviewed each subject's informed consent at their scheduled appointments prior to data collection. Each individual subject was scheduled so that the time between the pretest and exposure to the independent variable and posttest was the same.

In a quiet room of the Dental Hygiene Research Center, subjects were individually pretested according to the protocol by the research assistant using the Vibratory Sensory Analyzer (VSA) (Figure 1).



Figure 1 . Vibratory Sensory Analyzer (VSA) Showing Research Assistant on Left Measuring Tactile Sensitivity in a Subject.

Subject activity prior to scaling was controlled by including first-year students who had recently learned the same basic instrumentation in a pre-clinical course. On the day of testing, subjects were asked to refrain from using any type of vibratory equipment- electric shavers, powered toothbrushes, or vacuum cleaners, for example. All subjects were instructed to use the same body positioning. 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 (Figure 2).



Figure 2 . 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 VSA.

The time of day for scaling and measurement was balanced between both experimental and control groups, thereby controlling the variable of time. A maximum of eight subjects were tested in a week, for a total of five weeks to complete the data collection portion of the study. To ensure optimal functioning and minimal variability, two pre-used, 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. 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 two- to three-day period. 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 VSA, manufactured by Medoc Advanced Medical Systems in Minneapolis, Minnesota. The VSA consists of a microcomputer device with a vibratory button as the stimulator (Figure 3).

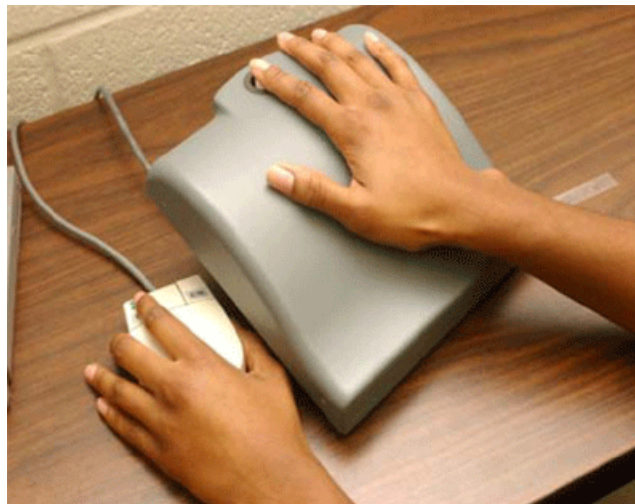


Figure 3 . Vibratory Unit with Mouse.

The VSA measures the soft tissue of the pulp of the thumb, index, and middle fingers, focusing on the large nerve fibers.²³ The VSA 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.²³ The VSA has proven to be valid and reliable through repeated testing in a number of different clinical trials.^{12,23} Several major universities across the United States have utilized the VSA and its components.¹² For example, it is currently being used by the Eastern Virginia Medical School Strelitz Diabetes Institute in Norfolk, Virginia, to measure sensory dysfunction in patients with diabetes.

The manufacturer of the VSA calibrates the instrument at the production facility and has developed a device to test for appropriate calibration of the instrument on site.¹² In cooperation with the Strelitz Diabetes Institute at Eastern Virginia Medical School in Norfolk, Virginia, a trained VSA technician oriented the principal investigator, co-principle investigator, and research assistant, so that they developed proficiency using the VSA. Approximately six hours were spent learning how to operate the VSA.

The actual vibratory test started when the stimuli in the vibratory button either increased or decreased in intensity and the subject felt no sensation at all. The research assistant then started the test. Eleven trials were taken, with the first trial (a practice trial) omitted. The purpose of the practice trial was to orient the subject to what was to be expected; therefore, the

practice trial measurements were not calculated into the final analysis. Each trial emitted vibrations at random intervals (five 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. The rate of vibratory change is between 0.1 to 4.0 microns per second with a range of stimuli between 0 to 20 microns. The lower the number of microns, the greater the level of sensitivity.

Data Analysis

Three-way and two-way analysis of variance, with one repeated measures factor, analyzed for pretest to posttest changes in the tactile sensitivity of the thumb, index, and middle fingers of each subject. Interaction effects of scaling (ultrasonic versus hand-activated), time of test (pretest versus 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 results, along with sample size and the ratio-scaled data, supported the use of the parametric statistical analyses.

Results

Hypothesis One: Three-way analysis of variance with one repeated measures factor revealed no statistically significant interaction among experimental and control groups, pretest and posttest, and thumb, index, and middle fingers of dental hygiene students (F=1.33, df=2, p=.2678) (Table I).

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

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

Hypothesis Two: 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) (Table II). Data in Figure 4 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.

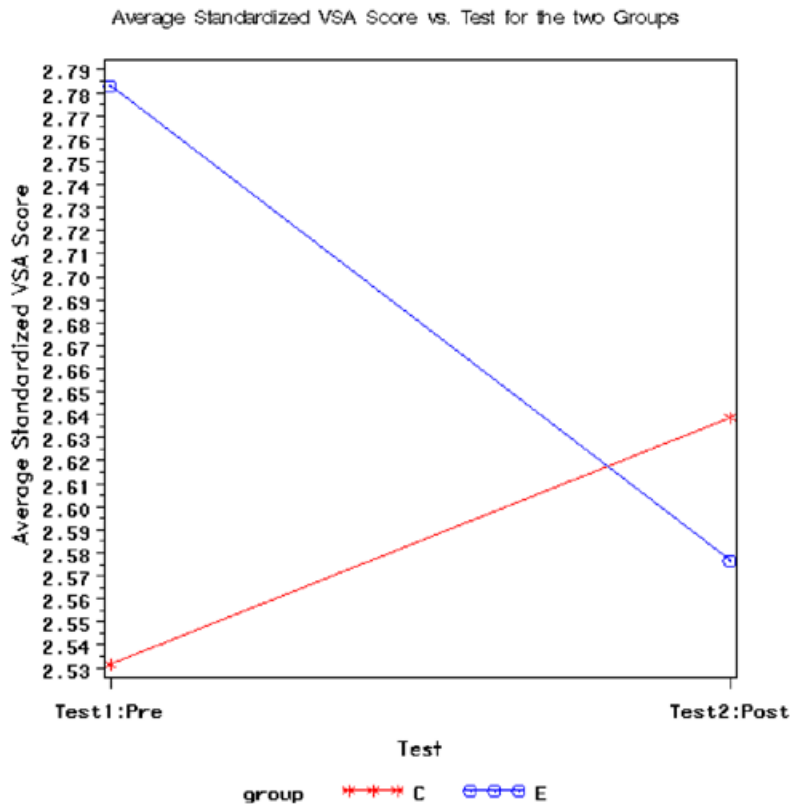


Figure 4 . Average Standardized VSA Score for the Ultrasonic and Manual Scaling Groups During Pretest and Posttest Phases.

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

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

A post-hoc analysis revealed that the significant difference in the two groups existed 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 4.

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 ($p=.0285$) (Table III), indicating that those subjects exposed to the ultrasonic scaler were more tactilely sensitive than those exposed to hand-activated scaling.

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

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

The mean change between the posttest and pretest for the control group was 0.1073 (S.D. =0.7157), and for the experimental group it was -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: 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 ($F=4.79$, $df=2$, $p=.0101$) (Table IV).

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

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

Of the digits tested, the index finger was the most sensitive in both groups with a threshold of 2.42 to 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 to 2.88, indicating it was the 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, confirming that neither grip strength associated with hand-activated instrumentation nor ultrasonic vibration associated with mechanized instrumentation affect tactile sensitivity in those two fingers over a 45-minute period (Figure 5).

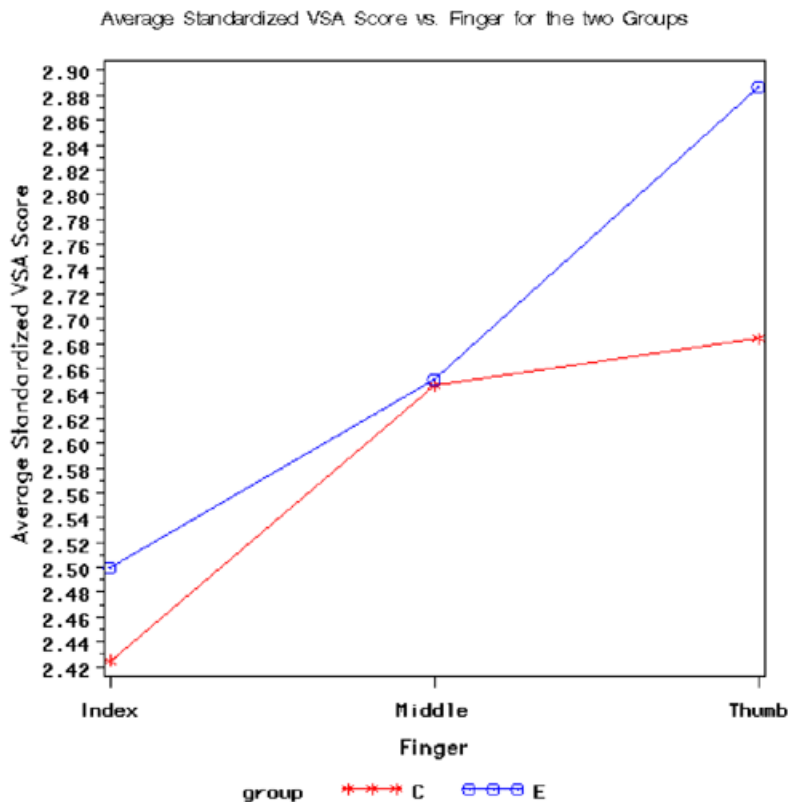


Figure 5 . Average Standardized VSA Score for Thumb, Index and Middle Fingers of the Ultrasonic and Hand-Activated Scaling Groups.

Hypothesis Four: Three-way analysis of variance with one repeated measures factor revealed no statistically significant interaction between the students' fingers and time of test ($F=1.46$, $df=2$, $p=.2373$) (Table I). 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

Hypothesis One: 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: 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 of subjects. This also could have been explained by statistical regression toward the mean. 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 hygienist's 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 dental 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 also 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, who found that the root surface is roughened

following ultrasonic instrumentation, thereby suggesting the need for hand-activated instrumentation following ultrasonic scaling.²⁴ 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 Nield-Gerig's belief that the middle finger is the most tactilely sensitive.²⁵ 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 Michalak-Turcotte and Atwood-Saunders support the recommendation that dental hygienists vary the use of ultrasonic scalers with hand-activated scaling.²⁶ A combined use of hand-activated scaling and ultrasonic scaling is recommended because 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. and Flodmark and Lundborg, who both found decreases in workers' tactile sensitivity associated with vibration exposure.^{10,16} Duration of exposure and variability between the simulated laboratory and clinical situations might explain these conflicting outcomes. While this study was conducted using 30,000 Hz units in a simulated clinical setting, subjects in Akesson et al. showed impaired vibrotactile sense and decreased muscle strength at both low and high frequencies associated with dental hand pieces.¹⁵ Furthermore, in the dental hygienists studied by Akesson et al., the impaired tactile sense was greater in their dominant hand.¹⁵ Because first-year, entry-level dental hygiene students were used, pinching and gripping of instruments could be greater than that 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: 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. Because 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.

Conclusions

Based on the results of this simulated clinical investigation using the VSA, the following conclusions are made:

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.

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.

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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Notes

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