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The Effects of Instrument Handle Design on Forearm Muscle Activity During Scaling by Dental Hygienists

Jessica Rae Suedbeck
Old Dominion University

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by

Jessica Rae Suedbeck
B.S. May 2011, Virginia Polytechnic Institute and State University
B.S.D.H. May 2014, Old Dominion University

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Approved by:

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Susan Lynn Tolle (Director)

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Gayle McCombs (Member)

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Martha Walker (Member)

ABSTRACT

EFFECTS OF INSTRUMENT HANDLE DESIGN ON FOREARM MUSCLE ACTIVITY DURING SCALING BY DENTAL HYGIENISTS

Jessica Rae Suedbeck
Old Dominion University, 2016
Director: Professor Susan Lynn Tolle

Purpose: The purpose of this study was to determine the effects of 4 different commercially available instrument handle designs (A. 16 grams and 12.7 mm diameter; B. 23 grams and 11.1 mm diameter; C. 21 grams and 7.9 mm diameter; D. 18 grams and 6.35 mm diameter) on the muscle activity of four forearm muscles during a simulated scaling experience. Methods: A convenience sample of 27 dental hygienists used a Columbia 13/14 curet with four different instrument handles to scale artificial calculus. While scaling, each participant's muscle activity was measured using surface electromyography (sEMG). Participants completed an end user opinion survey. Results: Similar muscle activity was generated when scaling with instruments at 16, 18, and 21 grams with varying diameter handles. Instrument B generated significantly more muscle activity when compared to each of the other 3 instrument handle designs ($p=0.001$, $p=0.002$, $p=0.039$). Additionally, the lower left quadrant displayed significantly less muscle activity during scaling than the right quadrants ($p=0.026$, $p=0.000$), although no significant interaction effect was found with instruments within quadrants. Most participants (62.96%) preferred instrument A, which was rated more comfortable based on weight when compared to the other instruments tested ($z=2.643$, $p=0.008$; $z=3.708$, $p=0.000$; $z=3.819$, $p=0.000$). The smallest diameter instrument was rated significantly less comfortable (A. $z=4.398$, $p=0.000$; B. $z=4.023$, $p=0.000$; C. $z=3.333$, $p=0.001$).

Conclusions: Instrument handle design has a significant effect on forearm muscle activity when performing scaling in a simulated environment. The heaviest instrument produced the highest muscle activity. Similar amounts of muscle activity were produced by instruments weighing between 16 and 21 g. Participants' instrument preferences were more affected by handle diameter than weight. The need for further research is needed to determine the impact of these results on arm muscle load related to risk of cumulative trauma disorders in a real-world setting.

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CHAPTER 1

INTRODUCTION

The physical stress of dental hygiene practice is an occupational risk factor for developing musculoskeletal disorders (MSD). The well-documented, high incidence rate of work related MSDs in dental professionals attest to the trauma exerted on the practitioner.[1-11] In practice, clinicians use highly repetitive arm, hand and wrist motions for extended periods of time causing physical stress. Dental hygienists perform repetitive tasks during each day making their job more vulnerable than any other dental professional.[7] Additionally, dental hygiene practices may require the clinician to hold his or her wrist in awkward positions for long periods of time adding to the risk for cumulative trauma, muscle disorders and carpal tunnel syndrome. Researchers have been challenged with determining exact etiologies and preventive strategies for dental practitioners since MSDs threaten work productivity, income, career longevity and health of the professionals affected.[1-12] Various strategies have been suggested to minimize risk factors associated with MSDs which include the use of powered scaling devices, larger diameter instrument handles and improved work pacing.[7,13-19]

PROBLEM STATEMENT

Developing new instrument designs to address the ergonomics of periodontal instrumentation and to decrease cumulative trauma disorders in dental hygienists is an ongoing area of research. Contemporary periodontal instrument handles vary in diameter, shape, weight and material in an attempt to address ergonomic concerns. Importantly, changing the diameter of the instrument handle has been promoted as a way to reduce stress on the practitioner, but minimal research has been conducted in this area. Dong and his colleagues used surface electromyography (sEMG) to evaluate the effects of changing the weight and diameter of periodontal handles on muscle load and pinch force in simulated dental scaling.[13] Results suggested significant differences in muscle load depending on the instrument handle design. For example, instruments with larger diameters (10 mm) and lighter weights (15 g) produced less muscle activity.[13] However, only one tooth was scaled and subjects used investigator designed instruments, not those currently available to practitioners. Clearly more research is needed to address the ergonomic impact of periodontal instrument handle design on the practice of dental hygiene with commercially available instruments. While ergonomic design improvements to periodontal instruments hold the promise of reducing workload, evidence-based research is needed to determine whether dental instruments achieve these goals.

The purpose of this study was to compare the effects of four commercially available periodontal instrument handle designs on forearm muscle activity during a simulated periodontal scaling experience.

DEFINTION OF TERMS

For this study, the following key terms are defined:

1. Surface electromyography (sEMG): A biomedical instrument which uses electrodes taped to the skin to convey a signal from a contracting muscle. sEMG detects electrical manifestation of the neuromuscular activation associated with a contracting muscle.[20]
2. Muscle activity: The electrical excitation of muscle fibers causing them to move, first in contraction and then in relaxation.[20] The dependent variable of the study, muscle activity, will be measured using surface electromyography (Appendix A).

3. Typodont: Artificial jaw containing artificial teeth, fastened into a manikin in order to simulate clinical conditions. Artificial plaque and calculus deposits are simulated by various paints and mixtures.
4. *Flexor digitorum superficialis*: Located in the forearm, this superficial muscle is responsible for flexing the metacarpophalangeal joints and proximal interphalangeal joints of the fingers.[20]
5. *Flexor pollicis longus*: This superficial muscle, located in the forearm, flexes the two joints of the thumb.[20]
6. *Extensor digitorum communis*: This superficial muscle, located in the forearm, is responsible for extending all three joints of the fingers.[20]
7. *Extensor carpi radialis brevis*: Located in the forearm, this superficial muscle is responsible for wrist extension.[20]

RESEARCH QUESTIONS/HYPOTHESES

This study intended to answer the following questions:

1. What are the comparative effects of instrument handles' weight and diameters on forearm muscle activity during hand scaling?
2. Which instrument handle is rated highest by participants in terms of overall preference and comfort, based on weight and diameter?

The following null hypotheses were tested at the .05 level:

1. There is no statistically significant difference in overall muscle activity when hand scaling using four different periodontal instrument handles as measured by surface electromyography.

2. There is no statistically significant difference in preference of instrument handles rated by participants.

SPECIFIC AIMS AND RELEVANCE

Dental hygienists use a variety of instruments to provide therapy, yet there is limited research on sound ergonomic theory to support use of specific instrument designs. Instruments identified to produce less muscle activity during hand scaling should be considered for use as less muscle activity equates to less risk for musculoskeletal disorders. This research most appropriately supported the ADHA National Dental Hygiene Research Agenda in the research priority area: *Occupational Health and Safety: Investigate the impact of exposure to environmental stressors on the health of the dental hygienist (aerosols, chemicals, latex, nitrous oxide, handpiece/instrument noise).*[21]

CHAPTER 2

REVIEW OF THE LITERATURE

Working ergonomically is a continual challenge for dental hygiene practitioners. Limited research exists on instrument characteristics that minimize forearm muscle activity and reduce the incidence of musculoskeletal disorders (MSDs) in dental hygienists. To provide a theoretical framework for this study the literature was reviewed in the following areas: occupational risk factors and prevalence, causes of MSDs, and the significance of instrument design/muscle activity on MSDs.

The high prevalence rate of MSDs among dental professionals is a significant occupational health hazard for oral care practitioners. Hayes found that around 64% of dental hygienists reported disorders in the wrists, 64% had disorders of the neck/shoulder, and 28% reported disorders of the neck only.[8] Additional studies indicate rates of MSDs have only increased over time.[22-26] According to the Bureau of Labor and Statistics, 79% of dental hygienists are exposed to repetitive motion and 65% of dental hygienists report having carpal tunnel syndrome.[27]

Musculoskeletal disorders often cause pain in the neck, shoulder, arm, wrist, and hands and individuals affected often have difficulty providing patient care.[22] Moreover, MSDs may cause early retirement among dental professionals. Several studies concluded that dental hygienists are experiencing occupation risk factors that increase their tendency to acquire MSDs, especially carpal tunnel syndrome (CTS).[23-28] Lalumandier and McPhee also found that the number of years the hygienist had worked in clinical practice was the most influential risk factor for diagnosing CTS, especially among those who scaled “heavy calculus patients” on a daily basis.[25] The researchers also found that other factors, such as the number of patients scaled per day, increase the risk for carpal tunnel syndrome.[25]

Research on musculoskeletal disorders of the upper extremities has focused on pressure related to generating inflammation, positioning of the fingers and wrists, and muscle fiber invasions. The present study examined four forearm muscles relative to different instrument handle designs. The specific muscles chosen for this study were selected because they provide movement and force for finger flexion and extension, thumb flexion and wrist extension. Since handheld instruments are held with the finger and thumb, these muscles are anticipated to be used in holding and manipulating manual scaling instruments (Appendix B).

Akesson et al. used electromyography to measure extensor muscles in the forearm in a group of twelve dental hygienists doing authentic work.[29] Manual scalers were held by the dominant hand and the non-dominant hand held the suction or mirror. EMG was used to measure muscle activity in the extensor muscles of the forearm. Muscle activity was recorded during ultrasonic scaling, hand scaling and polishing. Results suggest higher muscular load on the right extensor muscles during manual scaling, than during ultrasonic scaling, likely due to forceful grip and repetitive forceful movements during hand scaling. This study found that the use of ultrasonic devices reduced the load on right forearm extensor muscles, thereby reducing muscle injury.[29]

Hortsman et al. conducted a pilot study to determine what occupational risk factors could lead to MSD in dental hygienists.[30] Three dental hygiene students were videotaped and observed during a normal work-day with time and motion analyses of various procedures such as scaling/planing, polishing and flossing. Results revealed that during scaling, hygienists have movement of the hands and wrists through all four directions—flexion, extension, radial and ulnar deviation. Researchers concluded that additional investigations were needed on instrument diameter and its relation to ergonomic practice.[30]

Limited research is available on how instrument handle designs affect muscle activity in the wrists and arms of dental hygienists. Rempel et al. conducted a four month study to determine the effects of varying curette handle weight and diameter on self-reported arm pain in 110 dental hygienists and dentists.[15] Participants performed scaling and root planing for ten or more hours per week and had more than one year of clinical experience. Participants were randomized among different weight and diameter instrument handles to perform their scaling and root planing. Results revealed pain scores were less in the shoulder region in participants that had lighter instruments with wider diameters compared to heavier instruments with smaller diameters. Results suggest scaling with different instrument handle designs has an effect on self-reported pain in dental hygienists. The researchers recommended that lightweight instruments with wider diameters be used in clinical settings.[15]

Simmer-Beck et al. did a comparison of muscle activity associated with structural differences in dental hygiene mirrors.[31] Nineteen dental hygiene students participated in the study that examined the diameter and weight of mirror handles in phase I and weight and padding in phase II. Muscle activity was measured while participants were grasping the instrument in thirty-second increments via sEMG. A questionnaire was used to determine which mirror seemed most comfortable. Results revealed padding had a statistically significant reduction in muscle activity in the *flexor pollicis brevis* (flexor muscle of the thumb). Results also revealed that the interaction between weight and diameter had a statistically significant difference on the *extensor digitorum* (finger extensor muscle), as well as weight by itself. Interestingly, self-reports by the students were not consistent with the results reported by the sEMG. Only 21% of students identified the mirror associated with the lowest sEMG activity as the most comfortable mirror. This may indicate that muscle activity is not the only factor hygienists used in selecting preferred instruments. The researchers concluded that handle adaptations of mirrors can have an effect on the muscle activity in the wrist and arm; however, the sample size of participants was small (n=19) and limited in variability.[31]

Dong et al. examined instrument handle shape on hand muscle load as measured by sEMG.[13] Eight custom-designed scaling instruments with different handle shapes were used in this study. Twenty-four dentists and dental hygienists performed a simulated tooth scaling task on one tooth using each instrument. Muscle activity of the *flexor digitorum superficialis*, *flexor pollicis longus*, *extensor digitorum communis*, and the *extensor carpi radialis* were examined. Results revealed instrument handle design did have an effect on muscle activity with the tapered, round shape handle of 10 mm diameter requiring the least amount of muscle load and pinch force when performing simulated periodontal scaling.[13] Limitations to this study include only one tooth was scaled and instruments tested were custom made.

In a similar study, Dong et al. also examined ten custom-designed dental scaling instruments and their effect on hand muscle load and pinch force.[14] Twenty-four dentists and dental hygienists participated in the study and the muscle activity of two flexors and two extensors of the forearm were recorded with sEMG. Results revealed periodontal instrument handle designs had significant effects on hand muscle load and thumb pinch force during the scaling tasks. The periodontal instruments with the larger diameters (10 mm) and lighter weights (15 g) demonstrated the lowest muscle load. Additionally, it was found that diameters above 10 mm had no additional benefit.[14]

Simmer-Beck and Branson completed an evidence-based review of ergonomic features of dental hygiene instruments that compared several studies.[7] The authors compared the length, diameter, mass and padding of 21 instruments and instrument grip combinations, as well as 22 mirrors and mirror grip combinations. Based on this information, they found that literature does not suggest an optimal length for dental instruments, but the optimal diameter is suggested to be at least 10 mm and the optimal weight is suggested to be 15.0 grams or less.[7]

In summary, dental professionals are at risk for MSD of the upper extremities. Limited research is available which examines what ergonomic practices are best to reduce risks associated with developing these disorders. This present study will help fill these gaps as it evaluates MSD risks associated with forearm muscle activity during scaling in each quadrant of the mouth, using a variety of commercially available instruments. While ergonomic design improvements to periodontal instruments hold the promise of reducing workload, evidence based research is needed to determine whether dental instruments achieve these goals. Dental hygiene professionals and educators may benefit from the study outcomes in terms of choosing more ergonomically sound instrument designs for use in in practice and academic settings.

CHAPTER 3

METHODS AND MATERIALS

TARGET POPULATION AND SAMPLING METHODS

A convenience sample of 27 licensed dental hygienists was used in this IRB approved study (Appendix C) to determine muscle activity during scaling with four different commercially available instruments as measured by sEMG. The sample size of this study was based on previous studies that focused on sEMG measures of the upper limbs. Power statistics showed that a minimum of 24 subjects were needed to achieve a 95% confidence internal and a 90% power.[14, 32, 33]

Participants were recruited by advertisements on the internet and by the Old Dominion University School of Dental Hygiene (Appendix D). Random assignment of participants to the various trials controlled for sequence effects, selection bias, investigator bias, and any unanticipated participant-relevant variable. Inclusion criteria included registered dental hygienists that were right-handed, had no previous musculoskeletal disorders, and no previous surgeries due to musculoskeletal disorders. Participants were excluded if they were left-handed, had been diagnosed with a musculoskeletal disorder or if they had surgery due to a musculoskeletal disorder. As an incentive for participating subjects received a $50.00 gift card, as well as the four instruments they used in the study.

RESEARCH DESIGN

The study used a counterbalanced 4 x 4 factorial design with participants acting as their own controls. The independent variables in this study were the four different instrument handles; the dependent variables were the four muscles in the forearm. Given that each participant was evaluated using each of the four instrument handles, the order of instrument use was randomized for each participant to control for sequence relevant variables.

PROCEDURES, MATERIALS, AND DATA COLLECTION INSTRUMENTS

Dental chair-mounted typodonts equipped with an artificial face were used to simulate a client's oral cavity during scaling. First molars (#3, 14, 19, 30 typodont teeth) in each quadrant were coated with one cc of artificial calculus on the mesiobuccal surfaces. The calculus was dispensed using a small brush to extend from the gingival margin to the crown of the mesiobuccal surface. To standardize the application process, a template was placed over each molar before the artificial calculus was applied.

Four different typodonts were set up for each participant with a different instrument handle (A. 12.7 mm 16 g; B. 11.1 mm 23 g; C. 7.9 mm 21 g; D. 6.35 mm 18 g) (Appendix E), participants were randomly assigned for use on each of the typodonts. Once informed consent (Appendix F) was obtained, standardized instructions (Appendix G) were provided to each participant. New Columbia 13/14 curets with one of four different commercially available handles were randomly assigned for use. Participants were instructed to hand scale the mesiobuccal surface of the first molars in each quadrant of the mouth using their normal technique. Participants were instructed to remove all of the calculus they could for up to one minute per tooth using the assigned instrument. One-minute rest periods occurred between the scaling of each tooth in the assigned typodont. Therefore, each subject scaled for one minute, rested for one minute, scaled for one minute, rested for one minute, etc. This allowed sufficient time for recovery from any muscle fatigue that might have occurred. A one-minute rest period was given between each instrument as well. The counterbalanced design of instrument assignment should have also eliminated any systematic error that fatigue might cause.

Considering the pace at which dental hygienists normally practice, the rest period was appropriate.

After one typodont was completed, the research assistant guided the participant to the next typodont until all four instruments were used, resulting in 16 readings per subject. To ensure standardization of the participants, a training and practice session was conducted by the principle investigator immediately before each hygienist participated in the experiment and the sEMG procedures involved were reviewed. To simplify the process, sub-gingival scaling was not considered for this study. The practice period occurred after the electrodes were placed on the arm so participants were comfortable scaling with these in place before sEMG measurements were recorded. Testing took approximately 50 minutes of time per participant.

Surface electromyography (sEMG) was used to measure muscle activity on four superficial muscles, *Flexor digitorum superficialis, Flexor pollicis longus, Extensor digitorum communis, Extensor carpi radialis brevis,* which provided feedback independent of each other. Physical therapy consultants revealed the four muscles to be tested were appropriate and that sEMG muscle crosstalk susceptibility was minimized. sEMG, an electrodiagnostic test, is a valid and reliable measure of real-time muscle activity and has been used in multiple studies evaluating musculoskeletal disorders.[34-38]

To measure muscle activity while scaling, sEMG was used to record the electrical activity of the four test muscles. The skin of each participant was lightly wiped with an alcohol swab to remove dermis debris. Surface electrodes were secured with sports tape over the four muscles of interest by the physical therapy examiners (Appendix H). For all four muscles, lightweight wireless bilateral surface EMG sensors (Trigno,™ Delsys, Boston, MA) were attached to each subject to measure muscle activity during scaling. The location was determined by physical therapy examiners and attached to the *Flexor digitorum superficialis, Flexor pollicis longus, Extensor digitorum communis, Extensor carpi radialis brevis*. All sEMG data was sampled at 1,000 Hz and synchronized using a 64-channel data collection system (Trigno,™ Delsys, Boston, MA).

Data from the sEMG readings was collected during maximum voluntary isometric contraction (MVIC) for each of the muscles. The MVIC values were considered 100% activity for that muscle. The EMG activity that was measured during the scaling processes were then expressed as a percentage of MVIC activity. This is a standard method that has been recently re-evaluated and found to be reliable for use with surface electrodes.[13,14] It also controlled for any baseline activity/noise, because this noise was present in both the MVIC readings and the scaling activity readings, and is thus cancelled out.[36-38]

Prior to the study, a pilot study was conducted to test and refine the research methods. The pilot included placing the electromyography electrode sensors on the arms of the pilot participants and running the software for reading muscle activity during dental hygiene instrumentation. At the conclusion of the study, participants completed a 6 question end user survey rating each instrument. Participants rated each instrument on a 5-point Likert scale: 1 (not comfortable) and 5 (very comfortable), in regards to weight and diameter. Additionally, participants were asked to choose which one instrument they preferred the most and which one they preferred the least (Appendix I).

STATISTICAL ANALYSIS

sEMG measures were analyzed using a two-way repeated measures multivariate analysis of variance (RMANOVA) with 4 different instruments and 4 different quadrants. This analysis was appropriate for measuring the main effects of both muscle type, instrument handle type and quadrant on muscle activity, as well as the interaction between muscle and instrument handle types. If the results were significant, a Sidak post hoc test was used to evaluate one instrument handle in comparison to another instrument handle or one quadrant to another. A Friedman test was employed on quantitative survey responses. If the results were significant, a Wilcoxon signed rank test with Bonferroni correction was used to evaluate one instrument handle compared to another ($p<0.0083$). A Bonferonni correction was utilized because with each instrument paired together, six tests were conducted resulting in a significance value of 0.05 being incorrect and a value of 0.0083 more accurate for significance for this test. Statistical analysis for the EMG measures and quantitative survey responses were performed using SPSS 19 software and the significance level was set to $p<0.05$.

CHAPTER 4

RESULTS

This study determined the effects of varying instrument handle designs on muscle activity during a simulated scaling experience. Twenty-seven registered dental hygienists (26 females and 1 male) participated in this IRB-approved study. The age distribution was: 13 (48%) between ages 20 and 29, 10 (37%) between ages 30 and 39, 2 (7.5%) between ages 40 and 49, and 2 (7.5%) 50 or older. Among the 27 participants, 15 (55.5%) had 1-5 years of clinical hygiene practice, 6 (22%) had 6-10 years of clinical hygiene practice, 4 (15%) had 11-15 years of clinical hygiene practice, and 2 (7.5%) had 21 or more years of clinical hygiene practice. Table I displays the ranking of instruments from heaviest to lightest and their associated diameters for ease of interpreting the following results.

Hypothesis One: The first hypothesis predicted no statistically significant difference in overall muscle activity when hand scaling using four different periodontal instrument handles as measured by sEMG. The impact of instrument handle design was measured at three intervals: 10^{th} percentile, 50^{th} percentile and 90^{th} percentile, which are shown in Table II. The 10^{th} percentile is the static muscle load recorded during EMG recording, the 50^{th} percentile is the median muscle load and the 90^{th} percentile is the peak muscle load. A two-way RMANOVA revealed significant interaction effects at the 50^{th} and 90^{th} percentiles for instrument handles and muscle activity (F=6.243, df=3, p=0.000); therefore, the null hypothesis was rejected. Data analysis revealed no significant effects for instrument and muscles at the 10th percentile. Pairwise comparisons with Sidak post hoc test revealed Instrument B generated significantly more muscle activity when compared to instruments A and C (p=0.016) (p=0.041) at the 50^{th} percentile affecting the *flexor pollicis longus* and *extensor digitorum communis*, respectively.

Similarly, at the 90th percentile instrument B generated significantly more muscle activity for the *flexor pollicis longus* (p=0.008) when paired with instrument A and the *extensor digitorum longus* (p=0.039, p=0.016) when paired with instruments A and C.

In order to simplify results, combined muscle activity mean scores and standard deviations were determined for each instrument handle design (Table III, Figure 1). Mean total muscle activity was lowest for instrument C (x=26.9) and highest for instrument B (x=28.7). When comparing overall muscle activity for each instrument, a two-way RMANOVA revealed statistically significant differences (F=6.243, df=3, p=0.000). Pairwise comparisons determined only the heaviest instrument (B) generated significantly greater muscle activity when compared to all other instruments (A p=0.001, C p=0.002, D p=0.039) (Table IV). Results indicate no statistically significant differences in overall muscle activity when comparing instruments weighing 16 g, 18 g and 21 g. Significant differences in overall muscle activity were not generated until the instrument weighed 23 g (Table IV).

Additionally, overall mean scores for muscle activity were calculated for each of the four quadrants of the mouth: upper right (UR-1), upper left (UL-2), lower left (LL-3) and lower right (LR-4) (Table V, Figure 2). The highest mean total muscle activity was found when participants were scaling the lower right quadrant (x=28.7) and the lowest mean total muscle activity was produced in the lower left quadrant (x=26.2). When comparing overall muscle activity for each quadrant, two-way RMANOVA results revealed statistically significant differences (F=6.802, df=3, p=0.000) in muscle activity generated. Data from pairwise comparisons using Sidak post hoc tests revealed that when scaling, regardless of the instrument used, the lower left quadrant generated significantly less muscle activity when compared to both right quadrants (UR-1 p=0.026, LR-4 p=0.000) (Table VI). However, there was no significant interaction of instrument and quadrant on average muscle activity (F (1,9) = 0.49, p=0.881).

Hypothesis Two: The second hypothesis predicted no statistically significant difference in preference of instrument handles by participants. Subjective evaluations rating the comfort of the four handle designs were collected using a survey in an effort to determine if muscle activity was correlated with participants' preferences. Results reveal 62.96% of participants (n=17) preferred the instrument with the largest diameter and lightest weight: instrument A. About one fourth of the participants (25.9%, n=7) preferred the heaviest instrument with second largest diameter (instrument B). A small percentage of participants preferred one of the smaller diameter instruments (C and D) with three participants (11%) preferring instrument C, and no participants preferring instrument D. When participants were asked which of the four instruments they liked the least, 77.78% (n=21) of respondents chose instrument D, 15% (n=4) chose instrument C, 7% (n=2) chose instrument B, and no participants chose instrument A (Figure 4). Therefore, the null hypothesis was rejected.

A Friedman test was used to determine significant differences related to participants' perceptions of the four instrument handles based on weight and diameter, independently. Results revealed statistically significant differences in participants' ratings of both diameter ($x^2(3)=50.584$, p=0.000)(Figure 5) and weight ($x^2(3)=24.650$, p=0.000)(Figure 6). Post hoc testing with a Wilcoxon signed rank test and Bonferroni correction determined that the weight of instrument A was rated significantly more comfortable by participants compared to the other three instruments (B z=2.643, p=0.008; C z=3.708, p=0.000; D z=3.819, p=0.000) (Table VII).

Regarding diameter, Wilcoxon signed rank tests revealed instruments A, B and C were rated significantly more comfortable compared to instrument D (A z=4.398, p=0.000; B z=4.023, p=0.000; C z=3.333, p=0.001) (Table VIII). Additionally, participants rated instruments A and B more favorably in diameter than instrument C (A z=3.974, p=0.000; B z=3.521, p=0.000) (Table VIII).

CHAPTER 5

DISCUSSION

Cumulative trauma disorders continue to be a negative stressor affecting dental hygienists working in the clinical environment. Quantifying muscle workload during scaling through sEMG studies may assist dental hygienists in practicing more ergonomically and decreasing their risk of musculoskeletal disorders. This study compared the effects of four commercially available periodontal instrument handle designs on forearm muscle activity during a simulated periodontal scaling experience. Furthermore, participants' perceptions of these instrument handle designs were evaluated with an end user survey to determine if perceptions matched muscle activity produced.

Hypothesis One: Results demonstrate that instrument handle designs had a significant effect on forearm muscle activity when performing periodontal scaling. The heaviest instrument with a relatively large diameter (instrument B: 11.1 mm and 23 g) generated significantly more overall mean muscle activity compared to the other three instruments. This finding was also supported when evaluating individual muscles as instrument B resulted in significantly more muscle activity at the median and peak percentiles for both the *extensor digitorum longus* and the *flexor pollicis longus* muscles when compared to the other instruments. The most likely explanation for these findings is the higher weight of instrument B when compared to the other instruments.

Results suggest that instruments weighing less than 23 g did not significantly vary in the amount of muscle activity produced because similar muscle activity was generated for instruments weighing 16 g, 18 g and 21 g. These findings may indicate there is minimal ergonomic benefit when changing the weight of an instrument in these ranges. Muscle activity during scaling only increased significantly when the instrument weighed 23 g. Other studies revealed the lighter the weight and larger the diameter of an instrument, the less muscle activity generated and this was partially supported by this study.[7, 13-15] Results from this study suggest muscle activity is more affected by weight than instrument diameter. For example, while instrument A had the largest diameter (12.7 mm) and lightest weight (16 g), mean scores were almost the same for instrument A (x=27.5) when compared to instrument D with the smallest diameter (6.35 mm) and a relatively low weight (18 g)(x=27.4) as demonstrated in Table 3. Despite the instrument diameter for instrument D being half the size of instrument A, the similar weights could have resulted in similar amounts of mean muscle activity produced.

Dong et al. studied self-made instruments weighing 15 to 24 grams and found that instruments with the lighter weights demonstrated the lowest muscle activity.[13,14] Results from the present study did not find that the lowest weight instrument produced significantly less muscle activity. Differences between the studies might be attributed to only one tooth being scaled in the Dong studies compared to four first molar teeth being scaled in each quadrant of the mouth in this study, resulting in more valid readings. Differences might also be due to differences in diameter sizes of the instrument handles in the two studies. Dong et al. also found a significant increase in muscle activity generated and pinch force with heavier instruments.[13,14] The present study did not evaluate pinch force, but found no significant increase in muscle activity between the test instruments until the instrument weighed 23 g.

This study used commercially available instruments versus researcher designed instruments to enable results on muscle activity to apply to instruments used by practicing clinicians in real world settings. Results suggest clinicians might consider using instruments less than 23 grams for ergonomic benefits, but may not experience additional benefits when using instruments in the 16-21 gram range. While this research supports that lighter weight instruments produce less muscle activity, results suggest clinicians electing to scale with an instrument weighing 16 grams would likely experience the same ergonomic benefits in terms of reduced muscle activity as an instrument weighing 21 grams. However, diameter of the handle may also affect workload due to pinch force created, but this variable was not evaluated in the present study. Further research may be indicated to examine the effects of pinch force generated on commercially available instruments.

The current study measured overall mean muscle activity produced for each quadrant of the mouth while scaling: upper right (UR-1), upper left (UL-2), lower left (LL-3) and lower right (LR-4). Regardless of which instrument was used, the lower left quadrant had significantly less overall muscle activity than both quadrants on the right side. These results might be explained by the position of the fingers, wrists and forearm when scaling the right side of the mouth. The position for scaling the right quadrants of the mouth may require more movement and positions that deviate from an ergonomic neutral wrist and forearm position. Dental hygienists may be able to modify their work pacing by first scaling on the right side of the mouth since more muscle activity was generated when scaling these areas regardless of which instrument was used. This might minimize the probability of muscle fatigue that could lead to poor scaling outcomes. Because the lower left quadrant produced the least amount of muscle activity, a practical ergonomic suggestion may be to scale this area last or when the hygienists is feeling fatigued.

Hypothesis Two: Results from the end user survey indicate the majority of participants preferred the instrument with the largest diameter and lightest weight (A 12.7 mm, 16 g). Although instrument B (11.1 mm, 23 g) produced the most muscle activity, results demonstrated one fourth of the participants preferred this instrument, suggesting that diameter had more effect on participant preferences than weight or muscle activity. The diameter size of the instrument could have provided a more comfortable grip for these participants when scaling, therefore making diameter more influential than weight in terms of their overall preference. The instrument handle that had the smallest diameter and was the second lightest instrument (instrument D: 6.35 mm, 18 g) was least preferred by participants; this also lends support to the concept that diameter size of the instrument handle was more of a preference indicator than weight or muscle activity generated. The smallest diameter instrument handle might have been more difficult to comfortably grasp while scaling, even though it only weighed 18 g and produced similar muscle activity as instruments A and C. Overall, participants preferred the instruments with larger diameters despite the weight or muscle activity generated by these instruments.

When asked to rate instruments on weight and diameter independently, the majority of participants found the largest diameter and lightest weight instrument A was again the most comfortable for both weight and diameter. Participants rated both the smaller diameter instruments, C and D, least favorable for weight and diameter when compared to the instruments with larger diameters, A and B. Again, this can most likely be attributed to the larger diameter and lighter weight being easier to grasp for some participants regardless of muscle activity produced.

While dental hygienists use a variety of instruments to provide periodontal therapy, there has been limited research on sound ergonomic theory to support use of specific instrument handle designs. This research expanded evidenced-based knowledge concerning which commercially available instrument handles may be least traumatic to forearm muscles during scaling all quadrants of the mouth. While powered instruments have been recommended to reduce cumulative trauma disorders, there are many instances where dental hygienists must use hand instruments for optimal client care and calculus removal. Results from this study indicate the effort to remove artificial calculus as determined by the amount of forearm muscle activity is affected by varying the instrument handle size. Results suggest instruments weighing less than 23 g may decrease forearm muscle activity while scaling, therefore potentially reducing the clinician's risk for MSDs.

These results reinforce that dental hygienists might improve ergonomics of instrumentation by using lightweight instruments with larger diameter handles. According to this study, most participants preferred instruments with larger diameters and relatively lighter weights when scaling. These results benefit dental hygiene educators, future clinicians and current practitioners by providing evidence-based, quantitative information revealing the comparative effects of commercially available hand instruments of different weights and diameters. Results may assist practitioners and educators in making more educated decisions regarding selection of scaling instruments for ergonomic benefit.

Several limitations may have influenced the findings of this research. The minimal time participants used each instrument might not have been long enough to reflect their true preferences. The instrument handles had various textures, which could influence grasp and possible muscle workload. The study used a simulated periodontal scaling experience of a shorter duration than a hygienist scales in a typical day; muscle activity could vary over a longer workday. Therefore, future studies in a real world setting on instrument handle designs of similar textures are suggested. Safe muscle workload levels are undetermined and need to be investigated. Future studies are also needed to determine whether the reductions in muscle activity found in this study are enough to make a clinical difference. Finally, future studies may also want to evaluate pinch force generated by various commercially available instrument handles to determine impact on ergonomic practices.

CHAPTER 6

CONCLUSIONS

Results from this study suggest a similar amount of muscle activity was generated during scaling with instrument handles at 16 g and 12.7 mm diameter, 18 g and 6.35 mm diameter or 21 g and 7.9 mm diameter. Once the handle weight increased to 23 grams with a diameter of 11.1 mm, a significant increase in muscle activity occurred. Therefore, using instruments weighing less than 23 grams may reduce the muscle activity required for periodontal scaling with manual instruments. Regardless of which instrument was used less muscle activity was required to remove artificial calculus in the lower left quadrant. Subjective analysis indicated participants' instrument preferences were more affected by diameter than weight. The findings in this study emphasize the need for further research to more fully conceptualize the impact of instrument design on forearm muscle activity related to risk of cumulative trauma disorders.

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Figure 1. Overall Mean Muscle Activity (Means and Standard Deviation Error Bars) of the Four Instrument Handles

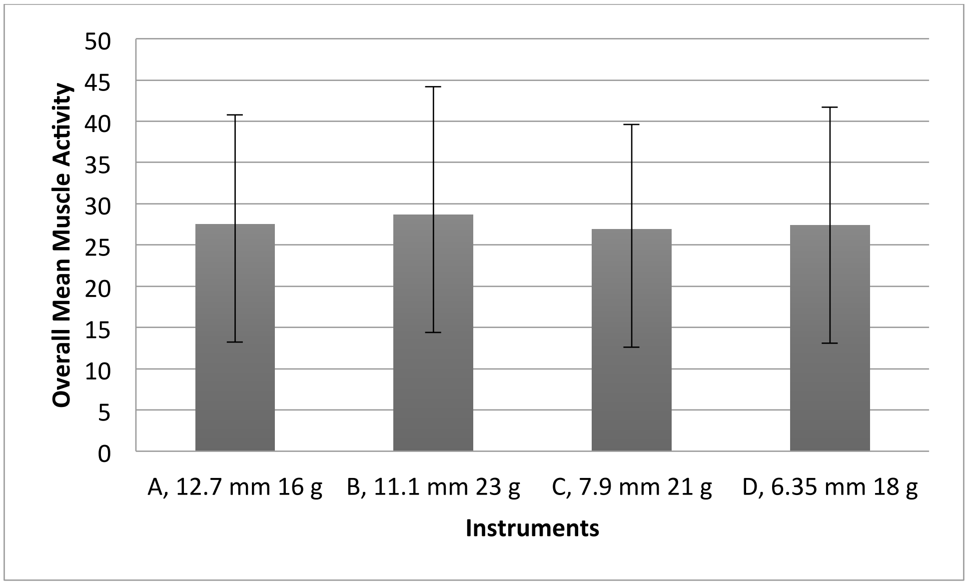


Figure 2. Overall Mean Muscle Activity (Means and Standard Deviation Error Bars) of the Four Quadrants Scaled

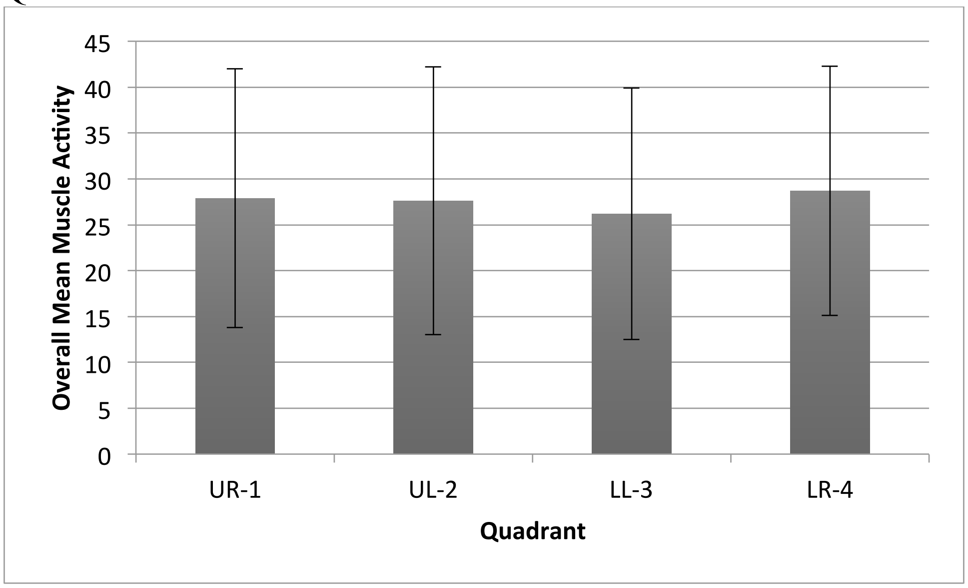
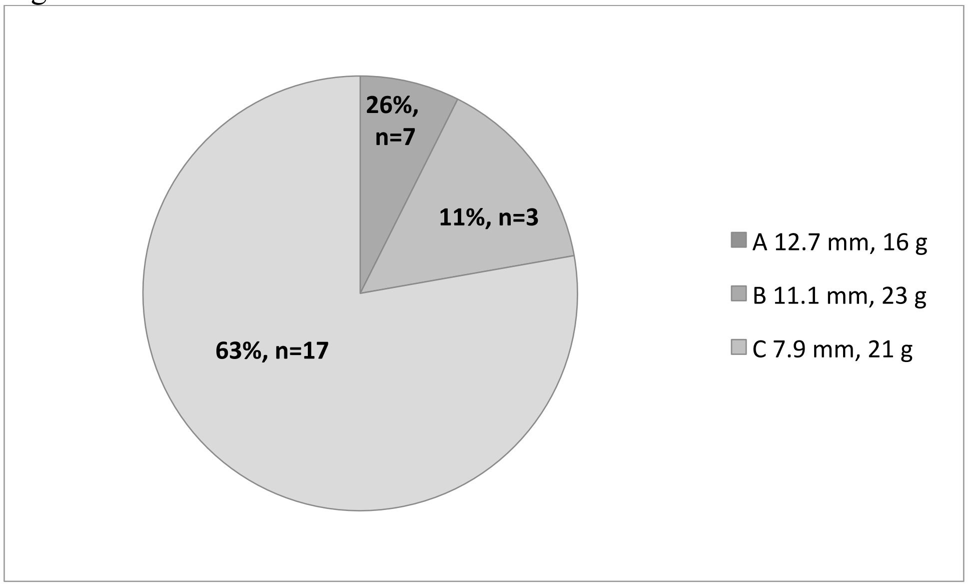
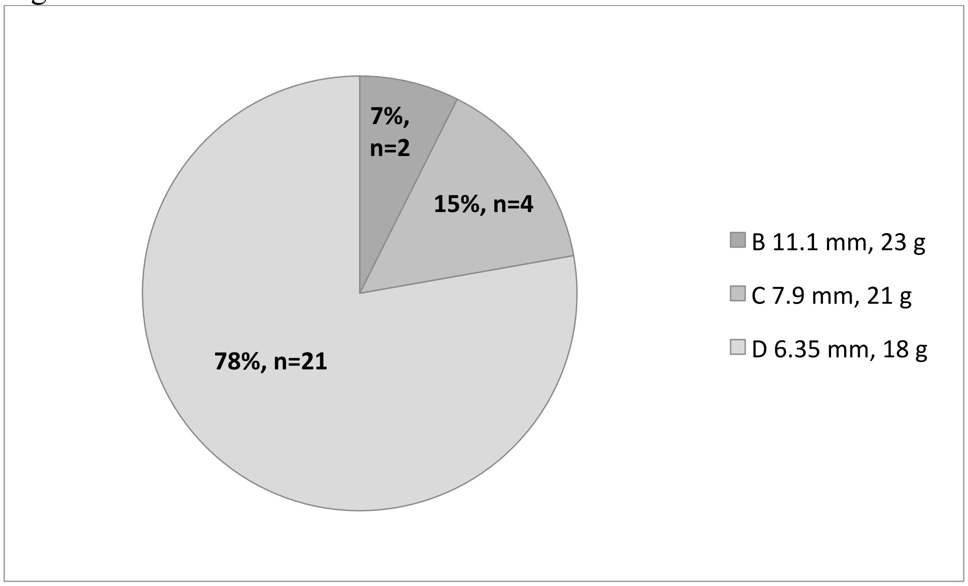


Figure 3. Results From Which of the Four Instruments Do You Like Best?*



*0%, n=0 D 6.35 mm, 18 g

Figure 4. Results From Which of the Four Instruments Do You Like Least?*



*0%, n=0 A 12.7 mm, 16 g

Figure 5. Results From Participants' Opinions of Diameter

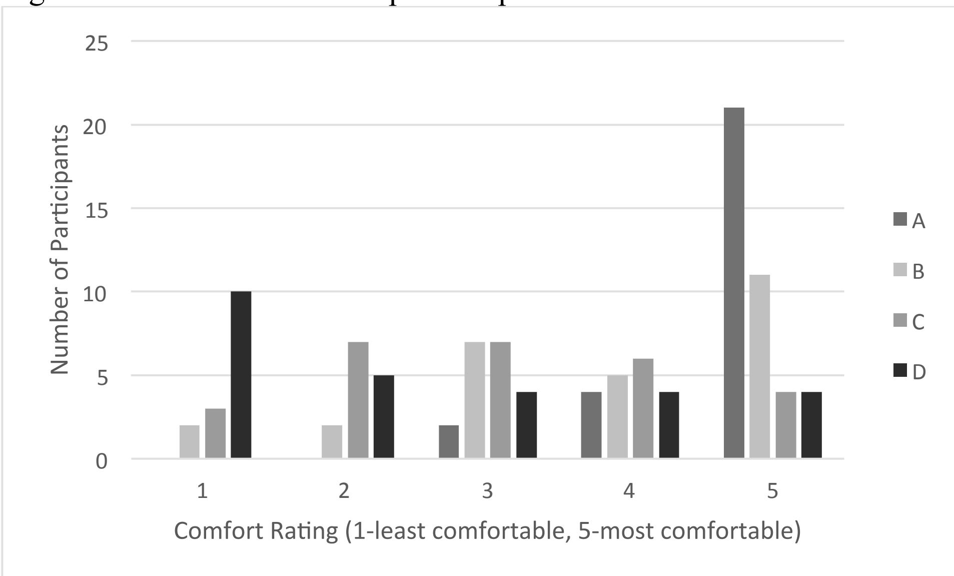


Figure 6. Results From Participants' Opinions of Weight

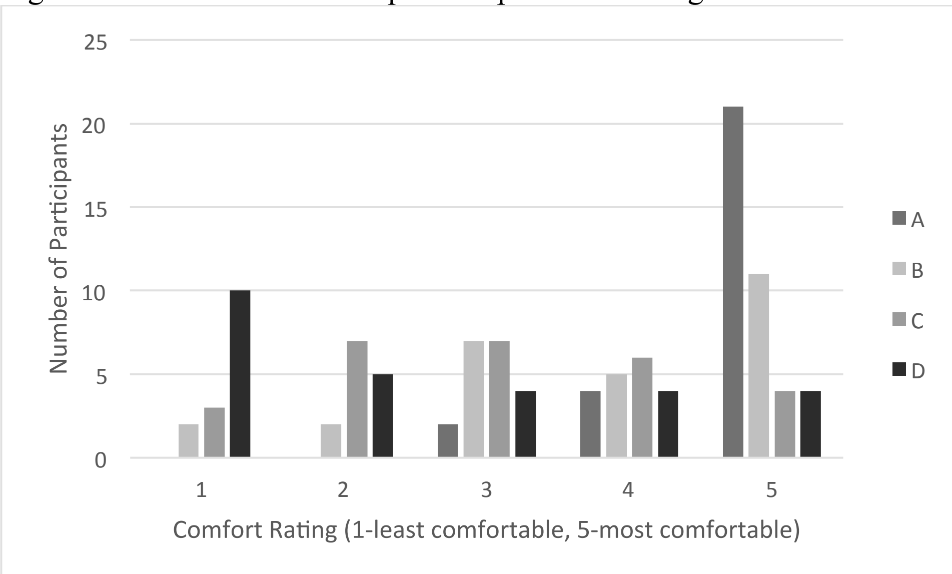


Table I. Instrument Ranked by Weight, Heaviest to Lightest

	Weight	Diameter
Instrument B	23 g	11. 1 mm (2^{nd} largest)
Instrument C	21 g	7.9 mm (2^{nd} smallest)
Instrument D	18 g	6.35 mm (smallest)
Instrument A	16 g	12.7 mm (largest)

Table II. Group Mean and Standard Errors for 10^{th}, 50^{th}, and 90^{th} Percentile Levels of Activity for the *Flexor Digitorum Superficialis, Flexor Pollicis Longus, Extensor Digitorum Communis* and *Extensor Carpi Radialis Brevis* Muscles During Scaling With Four Different Instrument Handles

	10^{th} Percentile				50^{th} Percentile				90^{th} Percentile			
	Inst -A	Inst -B	Inst -C	Inst -D	Inst -A	Inst -B	Inst -C	Inst -D	Inst -A	Inst -B	Inst -C	Inst -D
Flexor digitorum superficialis	11.4 ±1.9	10.6 ±1.9	11.1 ±1.9	10.8 ±1.9	19.3 ±3.4	18.9 ±3.4	18.6 ±3.4	18.3 ±3.4	29.7 ±5.2	30.2 ±5.2	28.7 ±5.2	28.6 ±5.2
Flexor pollicis longus	6.7± 0.6	7.0± 0.6	6.7± 0.6	6.7± 0.6	12.0 ±1.4	13.0 ±1.4	12.3 ±1.4	12.5 ±1.4	21.4 ±3.0	24.6 ±3.0	22.6 ±3.0	23.5 ±3.0
Extensor digitorum communis	22.8 ±3.5	24.6 ±3.5	22.7 ±3.5	23.4 ±3.5	34.6 ±5.5	37.5 ±5.5	34.3 ±5.5	35.5 ±5.5	51.2 ±8.5	56.7 ±8.5	50.7 ±8.5	53.5 ±8.5
Extensor carpi radialis brevis	17.2 ±2.0	18.0 ±2.0	17.1 ±2.0	17.0 ±2.0	29.0 ±3.2	30.8 ±3.2	29.0 ±3.2	29.0 ±3.2	47.3 ±5.0	51.2 ±5.0	47.8 ±5.0	48.4 ±5.0

Table III. Descriptive Statistics of the Combined Muscle Activity for Each Instrument*

Instrument	Number of observed trials	Number of observations used	Mean Muscle Activity	Standard Deviation	Minimum	Maximum
A, 12.7 mm 16 g	108	100	27.5	13.3	10.86	86.19
B, 11.1 mm 23 g	108	106	28.7	15.5	11.7	94.7
C, 7.9 mm 21 g	108	107	26.9	12.7	11.59	72.8
D, 6.35 mm 18 g	108	108	27.4	14.3	11.7	85.6

*Some observed trials were not used due to the files being corrupted.

Table IV. Sidak Post Hoc Significance Testing Comparing Muscle Activity Between Instrument Handles

Instrument A, 12.7 mm 16 g Mean: 27.5 SD: 13.3	Instrument B Sig 0.001* -	Instrument C Sig 1.000 +	Instrument D Sig 0.832 +
Instrument B, 11.1 mm 23 g Mean: 28.7 SD: 15.5	Instrument C Sig 0.002* -	Instrument D Sig 0.039* -	
Instrument C, 7.9 mm 21 g Mean: 26.9 SD: 12.7	Instrument D Sig 0.923 +		
Instrument D, 6.35 mm 18 g Mean: 27.4 SD: 14.3			

+ $p > 0.05$
- $p < 0.05$
*Significance

Table V. Descriptive Statistics of the Combined Muscle Activity for Each Quadrant*

Quadrant	Number of observed trials	Number of observations used	Mean Muscle Activity	Standard Deviation	Minimum	Maximum
UR-1	108	106	27.9	14.1	12.6	86.2
UL-2	108	106	27.6	14.6	10.86	94.72
LL-3	108	104	26.2	13.7	11.59	84.3
LR-4	108	105	28.7	13.6	12.6	77.0

*Some observed trials were not used due to the files being corrupted.

Table VI. Sidak Post Hoc Significance Testing Comparing Muscle Activity Between Quadrants

Quad 1- UR Mean: 27.9 SD: 14.1	Quad 2-UL Sig 0.996 +	Quad 3-LL Sig 0.026* -	Quad 4-LR Sig 0.498 +
Quad 2- UL Mean: 27.6 SD: 14.6	Quad 3-LL Sig 0.110 +	Quad 4-LR Sig 0.190 +	
Quad 3-LL Mean: 26.2 SD: 13.7	Quad 4-LR Sig 0.000* -		
Quad 4-LR Mean: 28.7 SD: 13.6			

+ $p > 0.05$
- $p < 0.05$
*Significance

Table VII. Wilcoxon Signed Rank Test Comparing Participants' Opinions of Instrument Weight

Instrument A, 12.7 mm 16 g	Instrument B Sig 0.008* -	Instrument C Sig 0.000* -	Instrument D Sig 0.000* -
Instrument B, 11.1 mm 23 g	Instrument C Sig 0.040 +	Instrument D Sig 0.005* -	
Instrument C, 7.9 mm 21 g	Instrument D Sig 0.047 +		
Instrument D, 6.35 mm 18 g			

+ $p > 0.0083$ (Bonferroni correction)
- $p < 0.0083$
*Significance

Table VIII. Wilcoxon Signed Rank Test Comparing Participants' Opinions of Instrument Diameter

Instrument A, 12.7 mm 16 g	Instrument B Sig 0.022 +	Instrument C Sig 0.000* -	Instrument D Sig 0.000* -
Instrument B, 11.1 mm 23 g	Instrument C Sig 0.000* -	Instrument D Sig 0.000* -	
Instrument C, 7.9 mm 21 g	Instrument D Sig 0.001* -		
Instrument D, 6.35 mm 18 g			

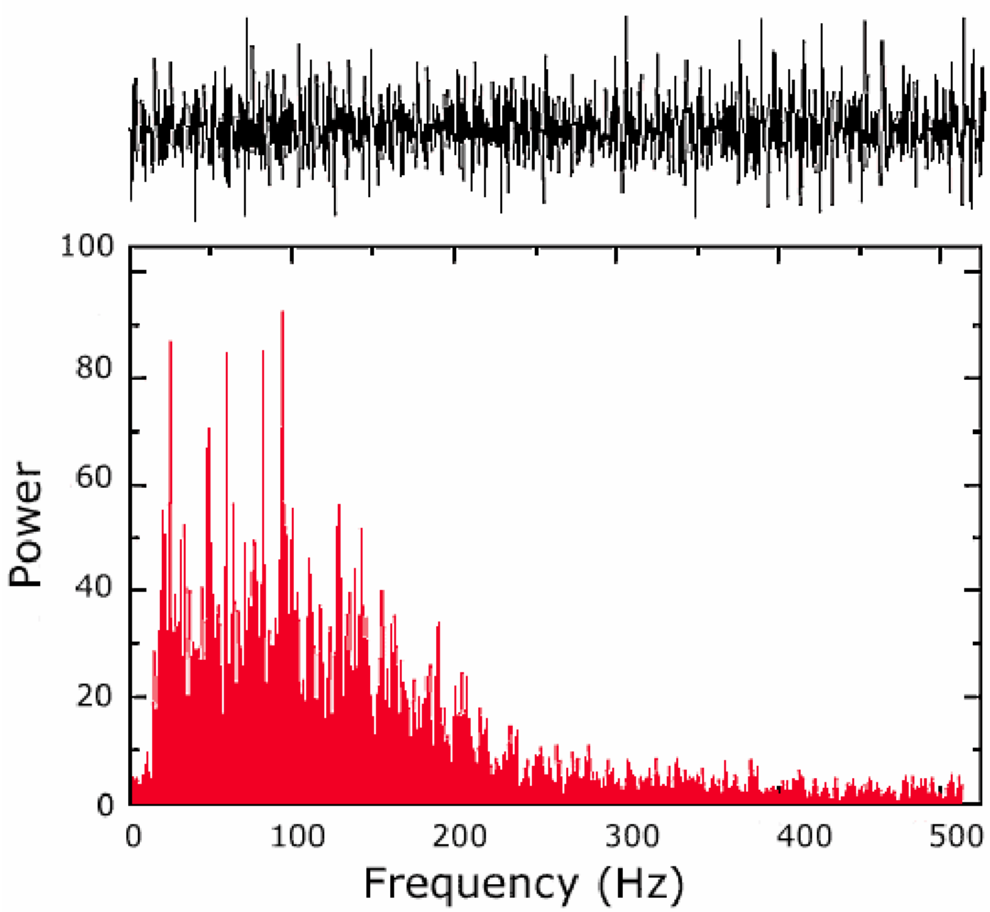
+ $p > 0.0083$ (Bonferroni correction)
- $p < 0.0083$
*Significance

APPENDIX A

CHARACTERISTICS OF THE EMG SIGNAL

It is well established that the amplitude of the EMG signal is stochastic (random) in nature and can be reasonably represented by a Gausian distribution function. The amplitude of the signal can range from 0 to 10 mV (peak-to-peak) or – to 1.5 mV (rms).
The usable energy of the signal is limited to the 0 to 500 Hz frequency range, with the dominant energy being in the 50-150 Hz range. Usable signals are those with energy above the electrical noise level. An example of the frequency spectrum of the EMG signal is presented in this figure.

Frequency spectrum of the EMG signal detected from the Tibialis Anterior muscle during a constant force isometric contraction at 50% of voluntary maximum.



APPENDIX B

FORFARM MUSCLES TESTED IN THE STUDY

Muscle	**Attachments**	**Actions**
Flexor digitorum superficialis	Origin(s): Common flexor tendon, coronoid process, radius Insertion(s): Sides of the middle phalanx of the four fingers	● Flexes joints of the second through fifth fingers
Flexor pollicis longus	Origin(s): Anterior surface of radius Insertion(s): Distal phalanx of thumb	● Flexes all the joints of the thumb
Extensor digitorum communis	Origin(s): Lateral epicondyle of the humerus Insertion(s): Base of the distal phalanx of the second through fifth fingers	● Extends all three joints of the fingers
Extensor carpi radialis brevis	Origin(s): Lateral condyle of humerus Insertion(s): Base of third metacarpal	● Extends the wrist

APPENDIX C

IRB APPROVAL

OFFICE OF THE VICE PRESIDENT FOR RESEARCH

Physical Address 4111 Monarch Way, Suite 203
Norfolk, Virginia 23508 Malling Address Office of Research
1 Old Dominion University Norfolk, Virginia 23529
Phone(757} 683-3460
Fax(757} 683-5902

DATE:June 29, 2015

TO: FROM:

gayle mccombs
Old Dominion University Institutional Review Board

PROJECT TITLE: [754510-2] The Effects of Magnification Loupes and Instrument Design on Posture and Muscle Activity During Instrumentation by Dental Hygienists

REFERENCE #:
SUBMISSION TYPE:

ACTION: APPROVAL DATE: EXPIRATION DATE: REVIEW TYPE:

15-087
New Project

APPROVED June 27, 2015
May 28, 2016
Expedited Review

Thank you for your submission of New Project materials for this project. The Old Dominion University Institutional Review Board has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a project design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This submission has received Expedited Review based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the project and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the project via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the signed consent document.

Please note that any revision to previously approved materials must be approved by this office prior to initiation. Please use the appropriate revision forms for this procedure.

All UNANTICIPATED PROBLEMS involving risks to subjects or others (UPIRSOs) and SERIOUS and UNEXPECTED adverse events must be reported promptly to this committee. Please use the appropriate reporting forms for this procedure. All FDA and sponsor reporting requirements should also be followed.

. .

All NON-COMPLIANCE issues or COMPLAINTS regarding this project must be reported promptly to this committee.

This project has been determined to be a Minimal Risk project. Based on the risks, this project requires continuing review by this committee on an annual basis. Please use the appropriate forms for this procedure. Your documentation for continuing review must be received with sufficient time for review and continued approval before the expiration date of May 28, 2016.

Please note that all research records must be retained for a minimum of three years after the completion of the project.

If you have any questions, please contact Adam Rubenstein at 757-683-3686 or arubenst@odu.edu. Please include your project title and reference number in all correspondence with this committee.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within Old Dominion University Institutional Review Board's records.

APPENDIX D

STUDY ADVERTISEMENT

IRB APPROVED
PROJECT NUMBER: 400259-010

Dental Hygienists needed to participate in research study!

Receive a $50 gift card for your participation.

If you are a registered dental hygienist, 18 and older, right handed, own magnification loupes, and have no history of musculoskeletal disorders, you could qualify!

The proposed study will examine the effects of instrument handle designs on muscles in the wrist and forearm. Additionally, the study will assess the effects of magnification loupes on posture. It requires one visit and approximately 1.5 hours of your time.

If you are interested in participating, please call 683-4719 today!

All research will be conducted at the ODU Dental Hygiene Research Center
Health Sciences Building, 47th and Hampton Blvd.

APPENDIX E

SPECIFICATIONS OF INSTRUMENT HANDLES

	A	B	C	D
WEIGHT	16 g	23 g	21 g	18 g
DIAMETER	12.7 mm	11.1 mm	7.9 mm	6.35 mm

APPENDIX F

INFORMED CONSENT DOCUMENT

OLD DOMINION UNIVERSITY

PROJECT TITLE: Effects of Four Different Instrument Handles on Arm Muscle Activity During Scaling by Dental Hygieneists

INTRODUCTION

The purposes of this form are 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. **Effects of Four Different Instrument Handles on Arm Muscle Activity During Scaling by Dental Hygieneists** in the Technology building School of Dental Hygiene, Dental Hygiene Research Center Room 1101 C.

RESEARCHERS

Susan Lynn Tolle, BSDH, MS, Professor and Director of Clinical Affairs Gene W. Hirschfeld School of Dental Hygiene at Old Dominion University, Responsible Project Investigator.
Gayle McCombs, BSDH, MS, Professor and Director of Clinical Affairs Gene W. Hirschfeld School of Dental Hygiene at Old Dominion University, Investigator.
Martha L. Walker, PHD, Associate Professor, School of Physical Therapy at Old Dominion University, Investigator.

DESCRIPTION OF RESEARCH STUDY

Few studies have been conducted looking into the subject of instrument handle design used in dental hygiene clinical care. Minimal evidence-based knowledge exists concerning what instrument handle designs pose the greatest risk for musculoskeletal disorders. Not many studies have done what is proposed in this study, comparing the effects of four different instrument handle designs on the forearm muscle activity of four muscles, (*extensor carpi radialis longus, flexor carpi ulnaris, biceps brachii* and *pronator teres)* during a simulated periodontal scaling experience using hand instruments. The instrument handles are the independent variables and the muscles are the dependent variables.

If you decide to participate, then you will join a study involving research of the effect of instrument handle designs on four forearm muscles while hand scaling the several surfaces of four teeth in each of four quadrants on typodonts. You will be provided with a new Columbia 13/14 curet to use and will be instructed to remove as much of the artificial calculus as you can for up to one minute using the assigned instrument per typodont. A one minute rest period will occur between the scaling of each tooth in the assigned typodont. Electromyography will be used to measure the arm muscles while scaling. The skin will be lightly wiped with an alcohol swab to remove skin debris. Surface electrodes will be secured with tape over the four muscles of interest by the physical therapy examiners. You will be guided by the research assistant from one typodont to the next typodont until all instruments have been used resulting in several

EMG readings per subject. You will be scaling a maximum of 20 minutes. If you say YES, then your participation will last for one hour at the ODU Dental Hygiene Research Center, Dental Hygiene Care Facility. Included in the one hour is the 15 minute training-practice period and the testing. Approximately 30 registered dental hygienists will be participating in this study.

EXCLUSIONARY CRITERIA
You should have completed the screening questionnaire. To the best of your knowledge, you should not have any past or present injury or disability of the working hand, wrist, forearm or shoulder that would 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. A non-invasive measure (EMG) of muscle activity will be used. 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 hygienist who is practicing in a private dental office. The researcher tries to reduce these risks by using a non-invasive measuring device, providing rest between testing, and using PHD physical therapy students to achieve accurate measures in an efficient time-frame. You will be wearing personal protective equipment (masks, goggles, gloves and clinic gowns) and using sterile instruments.

BENEFITS: The main benefit to you for participating in this study is acquiring personal experience about the importance of the instrument handle designs you use in your daily work as a dental hygienist. Others may benefit by applying this information to their daily clinical practice. Dental hygiene educators may benefit in teaching according to the findings from this study.

COSTS AND PAYMENTS
The researchers want your decision about participating in this study to be absolutely voluntary. The researchers recognize that your participation may pose some inconvenience and costs in time. You will be awarded a $50.00 gift card upon completion of 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
All information obtained about you in this study is strictly confidential unless disclosure is required by law. The results of this study may be used in reports, presentations and publications, but the researcher will not identify you.

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.

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 this research project, you may contact Susan Lynn Tolle at 683-5241 or Dr. David Swain the current IRB chair at 757-6836028 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:

Susan Lynn Tolle at 683-5241
Jessica Suedbeck at 262-9151

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, the current IRB chair, at 7576836028, or the Old Dominion University Office of Research, at 7576833460.

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 Printed Name & Signature	**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 Printed Name & Signature	**Date**

APPENDIX G

INSTRUCTIONS PROVIDED TO PARTICIPANTS IN THE STUDY

EMG PLACEMENT INSTRUCTIONS:

The first part of the study we are going to place 4 electrodes on your forearm. These electrodes will be placed on 4 different muscles so that we can see the muscle activity while you are exploring

Before sticking the electrodes on your arm we will mark where they are going to go. Then we will shave the area and then clean the area with alcohol pads. In order to find the exact locations for the EMG we will be measuring and palpating to find landmarks. We will also have you do some resistive test to make sure that we have the exact landmark. The electrodes will be stuck on your arm with double-sided tape and then lightly wrapped to ensure the electrodes do not fall off. You may feel the electrodes proprioceptively, however the electrodes and wrap will in no way prevent you from moving your arm.

In order for us to see if we have the electrode on the correct muscle we will have you perform a maximal voluntary muscle contraction for each of the 4 muscles. When doing so we will have you push against our hand as hard as you can for 3-5 seconds then relax.

The second part of the study we will remove the electrodes from your forearm. This part of the study we will be placing 4 accelerometers down your spine, starting from your head and going down your back. We will be palpating down your back to find the exact landmarks for the 4 accelerometers.

Before sticking the accelerometers we will clean the area with alcohol pads. These accelerometers will be stick on you using double-sided tape to your skin. There will be one on the back of your head, for this we will have you wear a cap to avoid your hair.

Please let us know if you have an allergy to adhesive or alcohol pads before we begin.

STUDY INSTRUCTIONS:

As you read in the informed consent, this study will be conducted in two parts. For part one, we will be measuring forearm muscle activity in your right arm with sEMG equipment as you scale with four different instrument handles.

- You will scale with four instruments for this part of the study and be in cubicles 1 and 2 for this.
- I will give you one instrument at a time and you will scale the mesiobuccal of four first molars in a simulated mouth.
- You will be given up to one minute of scaling per tooth with a one-minute rest period in between each tooth and instrument.
- You will start with tooth number 3, proceed to 14, then 19 and finish with tooth number 30.
- Before the scaling begins, you will pick the correct end of the instrument for that tooth.
- I will instruct you when to begin scaling on each tooth and you will be instructed when to stop scaling on each tooth.
- If you have removed all of the calculus on the tooth before the one-minute limit is up, please stop scaling and say “STOP” out loud for everyone to hear.

- I will be standing here to observe you, but please focus on your scaling task. Please do not talk, stop, or look around the room as data is being collected because this could skew the results.
- I will instruct you as you go through each part and remind you of these things. Do you have any questions for me before we begin?

APPENDIX H

EMG SENSOR

APPENDIX I

END USER SURVEY

Post Opinion Survey Ludwig/Suedbeck

Dear Fellow Dental Hygiene Professionals,

Our names are Emily Ludwig and Jessica Suedbeck and we are currently graduate students at Old Dominion University. We are conducting research titled "The Effects of Magnification Loupes and Instrument Design on Posture and Muscle Activity During Instrumentation by Dental Hygienists." Few studies have been conducted looking into the subject of instrument handle design and muscle activity and the effects of magnification loupes on posture during dental hygiene clinical care. Minimal evidence-based knowledge exists concerning what instrument handle designs pose the greatest risk for musculoskeletal disorders and the effects of magnification loupes on posture. This study aims to address these concerns.

This survey should take approximately 2 minutes to complete. This study has been approved by the Old Dominion University Institutional Review Board (approval #15-504).

Participation in this survey is voluntary. Results will be reported in the aggregate at the completion of the study.

Once you have answered the last item, push the "Send Survey" button and your responses will be collected.

1. If you decide to participate in the following survey click the button below.

◯ I Agree to Participate

◯ I Do not Agree to Participate

Post Opinion Survey Ludwig/Suedbeck

Demographics

2. Age

- A. 20-29
- B. 30-39
- C. 40-49
- D. Over 50

3. Gender

- Male
- Female

* 4. How many years have you been in clinical practice?

- A. 1-5
- B. 6-10
- C. 11-15
- D. 16-20
- E. 21 and over

Post Opinion Survey Ludwig/Suedbeck

Loupes Opinion Questions

5. Overall, do you feel that wearing magnification loupes made it easier to explore in all areas of the mouth?

Strongly agree	Agree	Neutral	Disagree	Strongly disagree
◯	◯	◯	◯	◯

6. Overall, do you feel that wearing magnification loupes improved your posture during exploring in all areas of the mouth?

Strongly agree	Agree	Neutral	Disagree	Strongly disagree
◯	◯	◯	◯	◯

Post Opinion Survey Ludwig/Suedbeck

Instrument Opinion Questions

7. Please rate instrument A on the scale below with 1 being "Not comfortable" and 5 being "Very comfortable."

	1 (Not Comfortable)	2	3	4	5 (Very Comfortable)
Diameter Grip	◯	◯	◯	◯	◯
Balance	◯	◯	◯	◯	◯
Maneuverability	◯	◯	◯	◯	◯
Weight	◯	◯	◯	◯	◯

8. Please rate Instrument B on the scale below with 1 being "Not comfortable" and 5 being "Very comfortable."

	1 (Not Comfortable)	2	3	4	5 (Very Comfortable)
Diameter Grip	◯	◯	◯	◯	◯
Balance	◯	◯	◯	◯	◯
Maneuverability	◯	◯	◯	◯	◯
Weight	◯	◯	◯	◯	◯

9. Please rate Instrument C on the scale below with 1 being "Not comfortable" and 5 being "Very comfortable."

	1 (Not Comfortable)	2	3	4	5 (Very Comfortable)
Diameter Grip	◯	◯	◯	◯	◯
Balance	◯	◯	◯	◯	◯
Maneuverability	◯	◯	◯	◯	◯
Weight	◯	◯	◯	◯	◯

10. Please rate Instrument D on the scale below with 1 being "Not comfortable" and 5 being "Very comfortable."

	1 (Not Comfortable)	2	3	4	5 (Very Comfortable)
Diameter Grip	◯	◯	◯	◯	◯
Balance	◯	◯	◯	◯	◯
Maneuverability	◯	◯	◯	◯	◯
Weight	◯	◯	◯	◯	◯

11. Overall, based on diameter grip, balance, maneuverability, and weight, which of the four instruments do you like best?

◯ A

◯ B

◯ C

◯ D

12. Overall, based on diameter grip, balance, maneuverability, and weight, which of the four instruments do you like least?

◯ A

◯ B

◯ C

◯ D

APPENDIX J

PROTECTION OF HUMAN SUBJECTS

The following plan for protection of human subjects was reviewed by the Old Dominion University IRB at its monthly meeting.

Potential Risks: There were very few expected injuries or risks to participants in the study because they were registered dental hygienists accustomed to performing scaling using the test instruments in the Dental Hygiene Care Facility. Minimal risks possible to any registered dental hygienist include injury to the arm, wrist, hand, fingers or eyes. These risks however were not anticipated. The participants were wearing personal protective equipment and using brand new instruments. Injuries were expected to be no greater than those that could be experienced as registered dental hygienists in practice.

Potential Benefits: The benefits to participants were primarily knowledge-based but they were also paid a $50.00 gift card for their participation. Additionally, they received the four brand new Columbia 13/14 curets that were opened and used specifically for them. Participants' clinical experience were enhanced by the developing awareness of the muscles and instrument handles used while scaling typodont teeth. Findings may also benefit the participants in their careers as dental hygiene practitioners. The benefits for the world-wide population of dentists and dental hygienists may be high. The results of this study may benefit all dental hygienists who are in clinical practice or who teach dental hygiene.

Consent Procedures: An informed consent form (Appendix H) was explained to, understood, and signed by the participants. The principle investigator explained the study in detail and answered questions. Participants voluntarily consented to the study with no pressure to say yes.

Protection of Participants Rights: Participants were initially issued a number; this was their individual form of identification throughout the study. The participants' numbers and not their names, identify all data collection forms. This method maintained confidentiality for the participants involved. All information collected from participants and possible outcomes were maintained under their specified number during and after the study and kept in a locked file cabinet. Strict adherence to proper testing were under the direct supervision of qualified individuals. Data was reported in group-form only. Now that the study is complete and data was analyzed, the data collection forms are being kept for three years and then will be destroyed.

Risk-Benefit Ratio: In the interview process, participants were informed of the benefits and risks involved. The benefits of this study outweighed any risks. The registered dental hygienists acquired personal experience about the importance of the instrument handle shapes they will use in their daily work as dental hygienists.

VITA

Jessica R. Suedbeck, RDH, BSDH, MSDH
4608 Hampton Blvd
2011 Health Sciences Bldg
Norfolk, VA 23529

EDUCATION:
Virginia Polytechnic Institute and State University
Blacksburg, Virginia
Bachelor of Science in Human Nutrition, Foods, and Exercise
May 2011

Old Dominion University
Norfolk, Virginia
Bachelor of Science in Dental Hygiene
May 2014

Old Dominion University
Norfolk, Virginia
Master of Science in Dental Hygiene Candidate
Expected graduation May 2016

ACADEMIC APPOINTMENTS:

August 2014-present	Graduate Teaching Assistant School of Dental Hygiene Old Dominion University, Norfolk, Virginia. (part-time) Responsible for completing tasks for dental hygiene faculty such as grading assignments, proctoring exams and conducting literature reviews.

PUBLISHED BOOKS, MONOGRAPHS, BOOK REVIEWS, AND PAPERS:

Suedbeck J and Emily L. Graduate Student Learning Experience at the ADHA. *Access*. Jan 2016: p 23-26.*

MEMBERSHIP IN PROFESSIONAL SOCIETIES:

2012-present	American Dental Hygienists' Association (ADHA)
2014-present	Recording Secretary-Virginia Dental Hygienists’ Association (VDHA)
2015-present	President-Peninsula Dental Hygienists’ Association (PDHA)