Research

The Effects of the Traditional Scaling Technique Versus a Modified Scaling Technique on Muscle Activity and Pinch Force Generation: A pilot study

Jessica R. Suedbeck, MSDH, RDH; Cortney Armitano-Lago, PhD, LAT, ATC

Abstract

Purpose: Dental hygienists perform precision instrumentation tasks repetitively throughout the workday, placing them at increased risk for developing a musculoskeletal disorder. The purpose of this pilot study was to determine differences in muscle activity and pinch force generation between the traditional scaling technique and a modified scaling technique.

Methods: A convenience sample of dental hygienists (n=12) acted as their own controls in this counterbalance-designed pilot study. Muscle activity and pinch forces were assessed while participants performed traditional and modified scaling techniques with designated instruments on artificial calculus applied to the lower left quadrant of a typodont, for a period of five minutes. Surface electromyography was used to measure muscle activity; sensors attached to the instrument handle measured pinch forces. Participants were surveyed regarding the instruments used and scaling technique preferences at the conclusion of the session. Parametric and non-parametric tests were used to analyze the data. Descriptive statistics were used to analyze the exit survey.

Results: The modified scaling technique required less muscle activity than the traditional technique while scaling, however results were not significant (p>0.05). The traditional scaling technique required greater overall pinch force during scaling (p=.00). Pairwise comparisons revealed significant differences between pinch force generation in the thumb for the two scaling techniques (Z = -2.401, p= 0.016) and in the index finger (Z = -2.223, p= 0.026). The traditional scaling technique generated more pinch force (thumb x=7.25±4.99, index finger x=2.86±2.14) when compared to the modified scaling technique (thumb x=4.52±2.32, index finger x=1.65±1.28). Participants had a slightly higher preference for the instrument utilized for the modified scaling technique in terms of balance, maneuverability, overall comfort and the associated scaling technique as compared to the instrument utilized for the traditional scaling technique.

Conclusion: Use of a modified scaling technique may reduce muscle activity and pinch force generation as compared to the traditional lateral pressure scaling technique during instrumentation. Future research on ergonomic scaling techniques is needed to determine their efficacy and impact on musculoskeletal disorders.

Keywords: instrumentation, ergonomics, musculoskeletal disorders, modified scaling techniques, dental hygienists

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Introduction

Dental hygiene practitioners are at an increased risk for developing occupationally related musculoskeletal disorders (MSD).[1-6] The development of a MSD is multifactorial; work-related MSDs among dental hygienists have been attributed to the physical stressors of dental hygiene practice including repetitive motions, poor ergonomics, prolonged static positions, and wrist/forearm positions outside of neutral for extended periods of time.[1-6] These MSDs involve tendons, ligaments, nerves, muscles, and blood vessels in the affected area and include disorders such as carpal tunnel syndrome (CTS), tendinitis, and stenosing tenosynovitis (commonly known as "trigger finger").[7] Dental professionals have been identified as having high prevalence rates of occupationally-related MSDs resulting in lost time at work and increased medical care costs.[7-12] A systematic review conducted in 2009 determined the prevalence rates for MSDs in dental hygienists ranged from 60-96%, with the neck, shoulder, wrist, hand, and back all being negatively affected.[13] Additionally, dental

hygienists have been identified as the dental professionals to be most often affected by MSDs, with higher prevalence rates when compared to dentists and dental assistants.[13-16]

Dental hygiene practitioners perform precision tasks repetitively and continuously throughout the workday on each individual patient. Periodontal instruments are used to remove plaque and calculus during scaling and root debridement procedures. Scaling requires dental professionals to manipulate instruments, using their fingers, wrist, and forearm to remove hard deposits from tooth surfaces. These repetitive, fine motor skills combined with the forceful and prolonged gripping of periodontal instruments are among the factors placing dental hygienists at risk of developing a MSD.[6,17-21] The average pinch force produced during periodontal scaling and root debridement can range from 5% to 20% of the operator's maximum pinch force production.[15,20] In addition to increased pinch force production, increased muscle activity of the forearm and hand have been identified during scaling and root debridement tasks.[17,22-,24] Larger, more tenacious hard deposits require more muscle exertion for complete removal. Previous research studies have quantified the influence of scaling on MSDs through examining muscle activity of the hand, wrist, and forearm, as well as assessing the amount of pinch force produced to grip periodontal instruments.[17,18,20,21,23,24] The greater the number of muscle activations and degree of pinch force a practitioner exerts throughout their career, has been shown to increase the likelihood of developing a related MSD.[17,18,24]

In an effort to reduce the amount of pinch force and muscle activity experienced by clinicians during scaling, extensive research has been conducted in developing more ergonomic instruments.[17,21,23,24] Accordingly, the resulting recommendations are to use lightweight, large diameter instruments with a round, tapered handle, designed to reduce the musculoskeletal workload for dental hygienists.[17,21,23,24] While these studies have demonstrated several musculoskeletal implications of scaling, the assessment of scaling ergonomics has been limited to instrument design and have not examined the influence of scaling technique as a contributory factor to the development of MSDs.

Examining scaling technique is another step towards reducing MSDs and ultimately improving the overall quality of life and career longevity for dental hygiene practitioners. The traditional method for scaling is to utilize increased lateral pressure to remove hard deposits on the tooth structure. A modified scaling technique, utilizing reduced lateral pressure, has been proposed as a more ergonomic approach to periodontal scaling.[25,26,27] There is a gap in the literature regarding the evaluation of scaling techniques that may have an ergonomic impact on dental professionals, particularly dental hygienists. The purpose of this pilot study was to examine differences in muscle activity and pinch forces generated during traditional lateral pressure scaling techniques using a standard ergonomically designed instrument versus those generated with a modified scaling technique using a novel instrument designed for reduced lateral pressure. Operator preferences regarding the scaling techniques and instrument designs were also examined.

Methods

This study was approved by the Old Dominion University Institutional Review Board. Prior to data collection, initial pilot testing was conducted on two volunteer dental hygienists not included in the study sample, to evaluate and improve the research methods and test the software for synchronized surface electromyography and pinch force data collection during instrumentation utilizing both scaling techniques. Since this was a novel pilot study, the sample size was based on a power calculation (Effect size (Hedge's G) = 1.95, $\alpha = 0.05$, $1\text{-}\beta = 0.95$) from a study that assessed the impact of experience levels of participants on pinch force generation during scaling.[18] Mean pinch force measurements were used for this calculation ($x = 26.3 \pm 7.1$, $x = 18.0 \pm 2.7$). Power analysis showed that a minimum of 10 subjects were needed to achieve a 95% confidence interval and a 96% power.[18]

Participants were recruited through social media advertisements and were offered the two instruments used in the study as incentives to participate. Inclusion criteria included right-handed, healthy adults, with a current dental hygiene license. Exclusion criteria included any past or present injuries or disabilities of the working fingers, hand, wrist, forearm, shoulder, neck, and/or trunk. Additionally, any contraindications for electromyography equipment use (e.g., open wounds or burned tissue) were additional exclusion criteria. Individuals were eligible to participate after completing the preliminary recruitment screening questionnaire and after a visual inspection of the wrist and forearm for possible contraindications to equipment use. A convenience sample of dental hygienists (n=12) met the inclusion criteria and provided written informed consent to participate in the pilot study.

A counterbalanced design, with participants acting as their own controls, was used to reduce the likelihood of sequence effects. A simulated oral environment was created using typodonts attached to dental chairs. Artificial calculus (Kilgore International, Inc., Coldwater, MI) was applied with a template to all supragingival, mesio-buccal surfaces of the teeth in the lower left quadrant. The template ensured the same amount was applied exclusively to the mesio-buccal

surfaces. Two typodonts were set up for each participant; with the scaling techniques and associated instruments randomly assigned to the typodonts to further ensure a reduction in sequence effects. Previous research has demonstrated how instrument weight and diameter may influence pinch force,[17] therefore both instruments used in the study were Columbia 13/14 curets and weighed 10 grams and were 10 mm in diameter. For the traditional, lateral pressure technique typodont station, a stainless-steel instrument was used (Talon Tough®, American Eagle Instruments®, Inc., Missoula, MT). This instrument material is associated with the traditional, lateral pressure scaling technique taught in entry-level dental hygiene programs.

The modified scaling technique typodont station required the use of a different instrument design. The modified scaling technique utilized shaving strokes with minimal lateral pressure, a technique that is contraindicated with a traditional stainless-steel instrument as it would result in burnished calculus. Therefore, the modified scaling technique was performed with a titanium nitride-infused, stainless-steel instrument (XP®, American Eagle Instruments, Inc., Missoula, MT).[25,26] This is considered to be a stronger and sharper material, allowing for the modified scaling technique to be performed without the negative consequence of burnishing calculus.[25,26]

Standardized instructions were given to each participant regarding the study procedures. To ensure all participants were familiar with the modified scaling technique, participants first completed a training video provided by the manufacturer with a slide presentation of training materials.[26,27] The three-minute video explained the sharpen-free technology of the instrument and featured demonstrations of the modified scaling technique with various instruments.[26,27] Following the training video, each participant was given the opportunity to ask questions of one of the investigators with experience educating on the modified scaling technique. Participants were allowed to practice the technique for fifteen minutes prior to data collection.

New universal curets (Columbia 13/14) for both scaling techniques were randomized for use. Participants were instructed to scale the mesiobuccal surfaces of the teeth in the lower left quadrant, using the randomly assigned scaling technique for a total of five minutes, regardless of the calculus level remaining on the surface. Exploratory strokes were not used in this study and it was not the aim of the study to determine calculus removal efficacy. Participants were instructed to use the sequence they were familiar with for scaling in this quadrant were allotted five minutes of rest between the two scaling techniques. Given the amount of time a calculus-removal stroke is utilized in clinical practice, this was considered a sufficient amount of rest to prevent fatigue.

Muscle activity of the forearm was collected using surface electromyography (sEMG) sampled at 1000 Hz, utilizing four lightweight, Noraxon sEMG sensors (2.8 grams; Noraxon®, Scottsdale, AZ). The muscles of the forearm assessed were the flexor digitorum superficialis, flexor pollicus longus, extensor digitorum communis, and extensor carpi radialis brevis, per previous research.[24] These muscles control the fine motor skills requiring small flexion and extension adjustments at each of the fingers, thumb, and wrist. Surface electromyography is a valid and reliable instrument for muscle activity measurements and has been used in multiple studies examining the risk for MSDs in dental hygienists.[17,21,23] One of the investigators, an athletic trainer, located each of the forearm muscles and placed the sEMG sensors on the corresponding muscles. Data were collected for a maximum voluntary muscle contraction (MVIC) of each muscle and were considered to be 100% of muscle activity the muscle could produce. The sEMG data collected during the five minutes of scaling with each instrument was expressed as an average percentage of the MVIC for that muscle,[24-26] as participants used the same calculus-removal stroke for the entire duration. Background noise was also measured at both MVIC and data collection, thus eliminating this confounding variable.[28-31]

Two pressure sensors (DTS Flexiforce Local Pressure Sensors, Noraxon®, Scottsdale, AZ) were attached to the instrument handles to measure the amount of force used by both the index finger and thumb to grip the instrument while scaling. Participants demonstrated their normal grip location for scaling the mesiobuccal surfaces of the lower left quadrant and the sensors were placed on the instrument to measure the thumb and index finger pinch force based on the individual's grip. Correct placement of the sensors and sEMG were confirmed prior to data collection and the participants verbally verified that the equipment did not interfere with the scaling tasks.

Pressure sensors are valid and reliable instruments for measuring pinch force generated by gripping dental hygiene instruments and have been used in multiple dental studies.[15,16,18,26] The sEMG and pressure sensors were tethered to the Noraxon® TeleMyo 2400T G2 transmitter, affixed around the participants waist, and all data was recorded using Noraxon® MyoResearch (XP) software (Noraxon®, Scottsdale, AZ). An average pinch force generation was determined for each finger because participants used the same calculus-removal stroke for the duration of the five minutes of

scaling. After completing both simulated scaling tasks, the participants completed an exit survey to assess perceived differences regarding balance, maneuverability, the scaling technique associated with the instrument and the overall comfort associated with the instrument. Responses were on a 6-point Likert scale, with 1 being not comfortable at all and 6 being very comfortable. Participants were also given the opportunity to make open-ended comments regarding their experience.

Prior to analysis, the assumptions for each of the parametric tests used were assessed. If the data were not normally distributed, outliers were removed from the data set, however if the assumptions were not met after this, non-parametric tests were used. For muscle activity 5 out of 104 datapoints were removed, for pinch force, 4 out of 52 data points were removed. For the comparison of muscle activity between the two scaling techniques, the sEMG data were analyzed using a two-way repeated measures ANOVA after outliers were removed. Additionally, if results were significant, a Sidak post hoc test was used to examine the specific difference between the two instruments and compare the amount of muscle activity of each muscle. A two-way Friedman ANOVA was utilized to analyze overall pinch force generated for each scaling technique. If results were significant, a Wilcoxon Signed Ranks test was used to compare the instruments to one another for each finger. Descriptive statistics were used for survey data. Data was analyzed using SPSS 24 software (IBM, Armonk, NY) with the significance level set to $p<0.05$.

Results

All of the participants were female (n=12), 42% (n=5) were 18-29 years old, 33% (n=4) were 30-44 years old, and 25% (n=3) were 45-59 years old. Three participants (25%) had never used the modified scaling technique before, six participants (50%) reported using the modified scaling technique with the sharpen-free instruments previously but had never being trained on the technique associated with the instrument, and three participants (25%) reported having the instruments previously and had been trained on the specific scaling technique. Participant demographics are shown in Table I.

The average muscle activity was compared between the traditional scaling technique and modified scaling technique using a two-way, repeated measures analysis of variance. The mean percentage of muscle activity compared to the MVIC (100% muscle activity) for each muscle used during instrumentation is shown in Table II.

Table I. Participant demographics (n=12)

Category	n (%)
Gender	
Female	12 (100)
Male	0 (0)
Age	
18-29	5 (42.0)
30-44	4 (33.0)
45-59	3 (25.0)
Ethnicity	
White	10 (83.3)
Native Hawaiian or Other Pacific Islander	1 (8.3)
Asian	1 (8.3)
Experience level	
Used sharpen-free technology before without training	6 (50.0)
Used sharpen-free technology before with training	3 (25.0)
Never used sharpen-free technology before	3 (25.0)

Overall, there was not a significant effect of scaling technique on muscle activity generation, $F(3,21)=,461$ $p=0.713$. The modified scaling technique generated lower muscle activity for each individual muscle when compared to the traditional scaling technique, although these results were not significant.

The average pinch force was compared between traditional and modified scaling techniques. The overall pinch grip was determined using the pressure data from both the thumb and index finger while using the instruments. The traditional

Table II. Mean percentage of muscle activity compared to the maximum voluntary isometric contraction (MVIC;100% muscle activity)*

Muscle	Traditional Lateral Pressure Mean Percentage of MVIC (mV.) and standard deviation	Modified Shaving Mean Percentage of MVIC (mV.) and standard deviation
Flexor digitorum superficialis	8.03±3.74	6.71±3.14
Flexor pollicus longus	5.54±1.80	4.39±1.47
Extensor digitorum communis	8.96±4.85	8.14±5.24
Extensor carpi radialis brevis	6.71±2.85	5.71±2.44
Overall mean	7.31±3.31	6.24±3.07

*Measured in millivolts (mV.) p's>0.05

scaling technique required a greater amount of pinch force for both fingers individually (Table III). A Friedman ANOVA was used to determine if there was a statistically significant difference for the mean overall pinch force generated between the traditional and modified scaling techniques. There was a statistically significant difference in mean pinch force generation depending on which scaling technique was used, $\chi^2(3)=25.36$, $p=0.00$. Post hoc analysis with Wilcoxon signed-rank tests was conducted and revealed significant differences between pinch force generation in the thumb for the two scaling techniques ($Z=-2.401$, $p=0.016$) and in the index finger ($Z=-2.223$, $p=0.026$), with the traditional scaling technique generating more pinch force (thumb x=7.25±4.99, index finger x=2.86±2.14) when compared to the modified scaling technique (thumb x=4.52±2.32, index finger x=1.65±1.28).

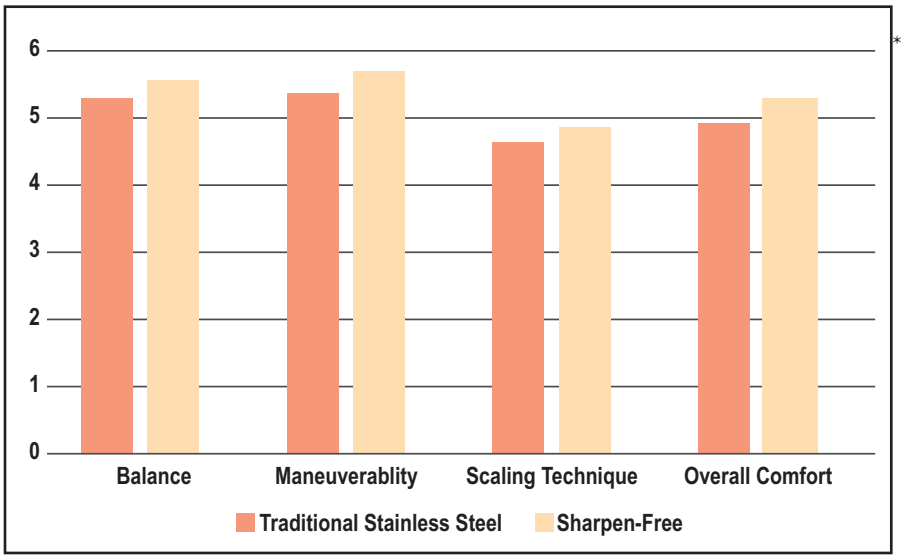
Table III. Individual and overall mean pinch force generation

Finger	Traditional Lateral Pressure Mean Pinch Force (lbs.)	Modified Shaving Mean Pinch Force (lbs.)	*p*-values
Index Finger	2.86±2.14	1.65±1.28	.026*
Thumb	7.26±4.99	4.52±2.32	.016*
Overall Mean	5.06±3.57	3.09±1.8	.000*

*$p<0.05$

Participant preferences for the individual instruments utilized for the scaling techniques were examined with an exit survey to determine any perceived differences between the instruments. Both instruments were rated on a 6-point Likert scale, with 1 being not comfortable at all and 6 being very comfortable. Instruments were assessed on balance, maneuverability, scaling technique associated with the instrument, and overall comfort (Figure 1). The instrument utilized for the modified scaling technique (sharpen-free technology) averaged slightly higher in all areas when compared to the instrument utilized for the traditional scaling technique (stainless-steel). Measures of central tendency and spread were computed to summarize the data from the end-user survey. The modified scaling technique instrument had a mean score of 5.50±0.65 for balance, 5.67±0.62 for maneuverability, 4.92±1.38 for scaling technique, and 5.25±0.92 for overall comfort. The traditional scaling technique instrument had a mean score of 5.33±0.75 for balance, 5.42±0.76 for maneuverability, 4.67±1.93 for scaling technique, and 4.92±1.04 for overall comfort.

Figure 1. Exit survey ratings* by instrument type



*Likert scale: 1 being not comfortable at all and 6 being very comfortable

Discussion

To date, the majority of studies examining the scaling instrumentation ergonomics for dental hygienists have focused on the instrument (e.g. handle characteristics),[6,17,18,24] while none have investigated the ergonomic differences in scaling techniques that are currently being introduced to clinicians.[19,21] This pilot study explored the effects of a traditional lateral pressure scaling technique and a modified scaling technique on both average forearm muscle activity and average pinch force generation during scaling performed by dental hygienists. The repetitive nature of scaling has been strongly associated with the high prevalence of MSDs within the dental hygiene profession. The constant forceful gripping, or pinching, of instruments requires the repetitive use of fine motor skills at a prolonged force that result in high pinch forces.[31-34] Bramson et al. reported that on average, periodontal scaling requires 11-20% of maximal pinch force, an average 2.5 lbs,[22] placing dental hygienists at an increased risk of developing work-related carpel tunnel syndrome.[35] The average pinch force found for the traditional scaling technique in the current study was 5.06lbs (±3.57lbs), considerably higher than findings reported by Bramson et al.[22] However, these findings were more consistent with the pinch forces reported by Dong et al., where the average pinch force for a 10 mm curet ranged from roughly 6.5 lbs to 8 lbs (differing between instrument diameter and shapes). The methodological differences between studies could also

account for the differences in pinch force. For instance, the weight of the curets utilized in previous research range from 16 g to 24 g,[24,33] while the weight of both instruments in the current study were only 10 g. When investigating methods of reducing pinch forces, the weight and diameter of the instruments can influence the amount of force used while scaling.[17,24,32] The differences between the two studies further indicates that manual scaling can be modified through consideration of the weight of an instrument to reduce risk factors associated with the development of musculoskeletal disorders.[17]

To the best of the authors knowledge, this is the first study in the literature to investigate whether scaling techniques influence muscle activity and pinch force. One of the goals of the modified scaling technique is to minimize musculoskeletal strain on practitioners, including the overall amount of muscle activity or pinch force produced during scaling, and ultimately reduce the development of MSDs. Findings from this pilot study demonstrated that the average muscle activity was reduced when using the modified scaling technique versus the traditional scaling technique. The modified scaling technique requires minimal lateral pressure and utilizes a calculus-shaving stroke for the removal of deposits when compared to application of lateral pressure utilized in the traditional technique. This calculus shaving technique is recommended for use with a titanium nitride-infused, stainless steel instrument (e.g., a sharpen-free instrument) due to the qualities achieved through the manufacturing process.[25] This modified shaving technique is not recommended for use with a traditional stainless steel instrument because the material is not as strong, sharp, or wear resistant.[25] Findings from this pilot study suggest that modifications to the scaling technique reduced muscle activation during the scaling process and may over the long term, reduce the rate clinicians develop hand and wrist MSDs. Quantifying these claims of risk reduction in terms of muscle activity and pinch force are important, as ergonomics plays a key role in the long-term health and career longevity for dental hygienists. Instrument materials that allow for modified scaling techniques requiring less pressure, should continue to be explored for their ergonomic implications. Furthermore, the overall weight of the instrument may also provide ergonomic benefits in addition to the modified scaling technique.

An investigator created exit survey was used to assess the participants' perceived differences of the two instruments and the scaling techniques and to gain insight based on the participants' professional opinions. Both instruments used in this study were the same weight and diameter. Participants reported that both instruments were comfortable in terms of balance, maneuverability, scaling technique, and overall comfort; however, participants rated the instrument used for the modified scaling technique slightly higher in all categories. These subjective findings yielded ratings that trended consistently with the sEMG and pinch force measurements. The modified scaling technique produced less muscle activity and pinch force and could have contributed to perceived comfort, balance, and better maneuverability.

Participants also provided open-ended responses on both scaling techniques in the exit survey and expressed some concerns with regard to the modified scaling technique. Even though participants rated that sharpen-free technology instrument higher in all categories, several participants (n=5) indicated concerns for the modified scaling technique, stating a "shaving technique could result in burnished calculus" and "required a higher number of strokes for complete deposit removal" when compared to the traditional scaling technique. However, participants who reported prior training with instruments using the modified scaling technique did not share these same sentiments. It is likely the single training session, especially for the participants who had never used this technique previously (n=3), on the modified scaling technique, was not enough for the participants to feel confident in complete calculus removal using the modified technique.

While the results of the study highlight important ergonomic differences between a modified calculus shaving technique and the traditional, lateral pressure scaling technique, there were limitations that should be considered when interpreting these pilot study findings. One limitation was the amount of training time and experience with the modified scaling technique. Instrumentation education occurs throughout the dental hygiene education program for practitioners to achieve competency in the traditional lateral pressure scaling technique using traditional stainless-steel instruments. For some of the participants, the training video and brief practice time were the only opportunities to use the modified scaling technique prior to testing. Additional training sessions could have resulted in increased participant confidence in utilizing the modified scaling technique and for complete calculus removal. Further, the novelty of the modified scaling technique may have influenced the exit survey results. While the participants experienced in the modified technique did not share the same concerns expressed in the open-ended responses as the inexperienced participants, future research is needed to elucidate the implications of the modified scaling technique on overall effectiveness for calculus removal.

Additionally, this study used a simulated oral environment with scaling at a shorter duration than is typical for one day of work by a dental hygienist; muscle activity and pinch force could vary more over a longer time period and fatigue would become a factor that influences these results. Therefore, future studies in a real-world setting are suggested. Finally, the evaluation of calculus removal success was not an aim of the study, but this would also be important to examine in future studies. It would be important to know which scaling techniques are most successful for effective calculus removal and require less time with increased muscle activity and pinch force production.

Conclusion

This pilot study suggests that using a modified scaling technique may reduce muscle activity and pinch force generation during scaling and root debridement instrumentation performed by dental hygienists. The modified scaling technique should be further studied for its ergonomic benefits and evaluate whether the reductions in muscle activity and pinch force are enough to make a clinical difference for dental hygienists. The efficacy of calculus removal utilizing the modified scaling versus traditional scaling should also be evaluated in future studies. Longitudinal studies with additional training and a larger sample size are recommended to determine long-term outcomes of the modified scaling technique and other ergonomically considerate scaling techniques.

Jessica R. Suedbeck, MSDH, RDH is an assistant professor in the School of Dental Hygiene, Old Dominion University**,** Norfolk, VA, USA**;** ***Cortney N Armitano-Lago PhD, LAT, ATC*** is a postdoctoral research associate in the Department of Exercise and Sport Science at the University of North Carolina, Chapel Hill, NC, USA.

Corresponding author: Jessica R. Suedbeck, MSDH, RDH; jsuedbec@odu.edu

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