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Comparison of Muscle Activity Associated with Structural Differences in Dental Hygiene Mirrors

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Purpose. Ergonomic studies suggest that the commonly used pinch grasp, held in a static position, is a contributing factor for dental Hygienists' development of work-related musculoskeletal disorders (WMSDs) such as carpal tunnel syndrome (CTS), Trigger Thumb, de Quervain's stenosing tenosynovitis, and carpometacarpal (CMC) osteoarthritis. The pinch grasp is commonly used by the dental hygienist while holding the dental mirror in the non-dominant hand. In response to this concern, manufacturers are redesigning dental mirror handles. The value of these re-designed products is based solely on anecdotal evidence. To date, minimal research has been done to examine the non-dominant mirror hand. The purpose of this study was to objectively evaluate dental mirror handle design using surface electromyography (sEMG) to compare muscle activity associated with grasping the mirror.

Methods. This randomized controlled clinical trial utilized a two-by-two repeated measures statistical design. Data was collected on a convenience sample of 19 (N=19) healthy dental hygiene students in their last year of study. Data collection was divided into two phases to maintain a balanced study. The independent variables in phase I were diameter and weight. The independent variables in phase II were weight and padding. Muscle activity was measured while grasping various dental hygiene mirrors in 30-second increments using sEMG. Following data collection subjects designated which mirror felt most and least comfortable to compare subjective data with objective data.

Results. Three statistically significant results occurred. In phase II, padding ($p=.01$) demonstrated the largest reduction of muscle activity in the flexor pollicis brevis, by decreasing mean muscle activity by 3.7 µv. The interaction of diameter and weight ($p=.01$) in phase I reduced the mean muscle activity in the extensor digitorum by .8 µV and weight ($p=.02$) in phase II decreased the muscle activity in the extensor digitorum by .62 µV. Self-reports of comfort reported by the subjects in this study were not consistent with the measurements of muscle activity using sEMG.

Conclusion. Ergonomic adaptations to dental hygiene mirror handles were associated with increases and decreases in muscle activity. The clinical impact of this is amplified as force is exerted. Furthermore, it may be possible to reduce WMSDs for dental hygienists by using instrument designs during the workday. Self-reports of comfort by the subjects in this study did not calibrate with the measurements of muscle activity using sEMG. Additional research is needed to further isolate the external variables of the study and to determine what actual reduction in muscle activity is significant for maintaining musculoskeletal health.

Keywords: musculoskeletal disorders, ergonomics, instrumentation, mirrors, dental hygiene

Introduction

The occurrence of work-related musculoskeletal disorders (WMSDs) in dental hygiene is an occupational concern. Lalumandier and McPhee estimated that 75% of dental hygienists experience hand problems and 56% have classic symptoms of carpal tunnel syndrome (CTS).[1] Data from the Bureau of Labor and Statistics and the US Department of Labor2 revealed findings consistent with these. Numerous studies[1-6] estimate the prevalence of this problem; however, minimal research exists about the response and interaction of muscles when integrating ergonomic solutions.

WMSDs result in a loss of income, increase in medical expenses, increase in workman's compensation claims, and often result in higher levels of difficulty completing daily tasks. They frequently require days off work, permanently decreasing the number of days worked, or ultimately a change in career. As a result of findings such as these, prevention of musculoskeletal disorders has become a priority for dental hygienists. Many ergonomic devices have been developed and marketed to the dental community to increase the longevity of dental hygiene careers. The value of these devices is largely based on practitioner perception by self-reports and focus groups. Spielholz et al[8] evaluated three common methods of ergonomic assessment simultaneously: self report, video analyses, and direct measurement using indwelling EMG. Inter-method comparisons between extreme posture, repetition, and force and movement velocity were assessed in 18 subjects while processing tree seedlings. Self-reports were the least precise method of measurement when examining musculoskeletal disorders. The authors concluded that grip force was best quantified by direct measurement using EMG[8]

Common workplace risk factors contributing to WMSDs is the use of the pinch grasp to hold the instrument while applying pressing with the finger tips. Studies using physiological measurements noted increased pressure within the carpal tunnel when a pinch grasp was used when applying pressure[9,10] Biomechanical model predictions and tissue studies of exertion involving pinch grasp demonstrated an increase in the finger flexor tendons[11] when pressure was applied. Static biomechanical models developed at Mayo Clinic[12] and at University of Michigan[13] have been used to estimate tension in the finger flexor tendons during various work tasks. Results concluded that when a normal load is applied to the palmer side of the fingers while pinching, mechanical movements are created at the wrist and finger joints. The tensile force to oppose these movements is much higher than the normal force acting on the fingers when normal force is exerted with only the finger tips.[12,13] Pinch grasp is used for both the mirror hand and the scaling hand. It has been calculated that one pound of pinch between the thumb and index finger will produce six-to-nine pounds of pressure at the basal joint of the thumb.[14] In order to minimize the effect of the pinch grasp and to create a neutral position, it is recommended that dental instruments and dental mirror handles have a large diameter, be lightweight, and be padded.[15,16]

he current literature provides only anecdotal reports that study the effectiveness of diameter, weight, and padding of handles on reducing WMSDs. The purpose of this study was to use sEMG to objectively compare muscle activity associated with common structural differences in dental hygiene mirrors while applying simulated dental hygiene procedures. Furthermore, the intention of this study was to allow investigators to examine the interaction of three muscles in the hand and forearm when the pinch grasp is used. Phase I involved testing the effects of diameter and weight. Phase II involved testing the effects of weight and padding.

Review of the Literature

Work-related musculoskeletal disorders (WMSDs) can be acute and/or chronic, and are often a consequence of practicing clinical dental hygiene over time. The most frequently reported altered sensations include pain, tingling, and numbness in the hands due to the physical stress of performing dental hygiene procedures.[17] Reported hand problems, such as carpal tunnel syndrome (CTS), are consistently higher in the dental hygiene population than in the general population.[1-6]

Instrumentation affects a large portion of the modifiable WMSD risk factors. Problems associated with instrumentation include: forceful exertions, repetition, small diameter instrument handles, flexion and extension of wrists, pinch forces, static loading of the fingers and hands, awkward hand postures, and other prehensile motions.[15, 18,19] Intervention methods include alternating instrument handle sizes, using instruments with larger diameter handles, using lightweight instruments, and using instruments with rubber coating or padding.

There is a distinct difference between the instrumentation techniques of the scaling hand and the mirror hand. The non-dominant hand of the dental hygienist is used for holding the mirror to gain better field visualization and for retracting the tongue and cheek. Unlike the dominant hand, which performs multiple tasks in a variety of positions to complete the scaling procedures, the non-dominant hand remains in a static position and often requires a forceful grip in order to retract the tongue and cheek throughout most of the dental hygiene appointment,[15] which results in decreased circulation of blood and oxygen and increases the risk of developing a WMSD.[19] To date, no research has addressed this problem.

In a descriptive study by Horstman[15] dental hygienists were videotaped and observed during a normal workday. Using time and motion analyses, the investigators concluded that the non-dominant hand was in a static posture of wrist flexion while holding the patient's mouth open, and that it did not engage in wrist flexion and extension.[15] In an epidemiological study using indwelling electromyography (EMG) to examine female dentists performing authentic dental work, Akkeson et al documented more static work in the mirror hand than in the working hand. A combination of extreme palmer flexion and ulnar deviation in the mirror hand was also noted.[19]

Experimental and epidemiological research acknowledges the origin of a WMSD as multifactorial.[20] A conceptual framework for developing a WMSD has been completed by the National Research Council. In this model, the work environment, organizational factors, and social context are influenced by physical and psychological factors as well as non-work-related activities.[20]

Work environment preventive strategies for all upper extremity disorders are similar and suggest creating neutral environments for the hand, wrist, and thumbs.[9, 21, 22] In the landmark study, "The Biocentric Technique: A Guide to Avoiding Occupational Pain," Meador[22] defines a neutral wrist position as the "forearm and hand are in the same horizontal plane."[22] He advocates neutral positioning during dental hygiene instrumentation and shifting the workload of the muscles from the small muscle groups to the large muscle groups.[22]

The objective of ergonomics is to fit the job to the worker.[17] Ergonomic experts in the dental field have made recommendations for instrumentation modification and selection. These recommendations include decreasing hand forces during instrumentation and improving wrist posture18 Suggested instrument variations include increasing the diameter, choosing instruments that are lightweight and balanced, padding the instruments, adapting the shape of the handle and texture, and varying the sizes.[17,23, 24]

The utilization of surface electromyography (sEMG) allows the observer to objectively calculate the energy of the muscles. It is safe, easy, noninvasive, and frequently used to evaluate muscle responses to stimuli. When utilizing multiple sensors, it is possible to differentiate how different aspects of the muscles accomplish various tasks.[25] The basis of the sEMG signal is motor unit action potential. This is measured in microvolts (µv). At rest, this measurement is usually around 2 µv. At work, the muscles begin to contract and the measurement can increase up to approximately 200 µv.[25]

A common limitation of sEMG is the possibility of crosstalk error, which makes isolating the sEMG recordings to a specific muscle difficult.[25, 26] Utilization of sEMG requires calibration of equipment and analyses and knowledge of muscle anatomy to prevent crosstalk error.[26] Another shortcoming of sEMG is the complexity of the anatomy being studied. The motor neuron pool is comprised of signals from the brain, joints, and other muscles. Nerves transmit these signals. Neurotransmitters and biochemicals can affect the signal.[27] Basmajian and DeLuca[27] suggested the sEMG signal indicates the status of the muscle and the status of the nervous system around the muscle.

To date, no empirical evidence exists to support that instrument modification and selection recommendations will decrease the occurrence of WMSDs. Numerous studies have suggested the need of further research.[8,15,19,23,24] Results of a study by Spielholz et al indicated that self-reports were the least precise method of measurement.[8] Quantification by direct measurement, such as that of sEMG, would more accurately measure grip forces[8, 24] and allow dental hygienists to make more informed decisions. It has been recommended that quantification needs to be evaluated in both the scaling hand and the mirror hand.[19] A non-subjective approach to data collection is necessary in order to accurately assess the ergonomic effect of dental hygiene products. The sEMG technique allows the observer to view the muscle at rest and at work and to objectively quantify the energy of the muscle. When utilizing multiple sensors, it is possible to differentiate how different aspects of the muscles accomplish various tasks, and how the muscles interact with each other (25).

Statement of the Problem

The purpose of this study was to use sEM G for comparison of muscle activity associated with structural differences in dental mirrors when applying simulated dental hygiene positioning. Phase I involved testing the following null hypotheses:

The diameter of dental mirror handles will produce no significant differences in muscle activity when applying simulated dental hygiene procedures.

The weight of dental mirrors will produce no significant differences in muscle activity when applying simulated dental hygiene procedures.

The interaction effect of diameter and weight will produce no significant differences in muscle activity when applying simulated dental hygiene procedures.

Phase II involved testing the following null hypotheses:

1. The weight of dental mirrors will produce no significant differences in muscle activity when applying simulated dental hygiene procedures.

2. The padding of dental mirror handles will produce no significant differences in muscle activity when applying simulated dental hygiene procedures.

3. The interaction effect of weight and padding will produce no significant differences in muscle activity when applying simulated dental hygiene procedures.

Material and Methods

The Sample Power (version 2.0) program (SPSS, Inc., Chicago, IL) was used to estimate sample size. Data (means and standard deviations) from a pilot study were used to estimate effect size, alpha was set to 0.05, and power was set to 0.80. After entering these data into the program, we determined that a sample size of 10 subjects would provide sufficient power to detect statistically significant differences in electromyography (EMG) activity while gripping mirror handles of different sizes and cushioning.

The target population for the study comprised of 28 (N=28) female dental hygiene students in their final semester of study at the University of Missouri-Kansas City School of Dentistry. A convenience sample of nineteen (N=19) students volunteered to participate and met the inclusion criteria. Two students chose to participate but did not meet the inclusion criteria to participate. Seven students were not interested in participating.

Inclusion criteria included no significant history or evidence of musculoskeletal disorders within the last 30 days. The musculoskeletal disorder (MSD) criteria used by Lalumandier and McPhee[1] were adopted as inclusion criteria. This information was obtained through completion of the subject assessment form. Subjects reporting a diagnosis of carpal tunnel syndrome (CTS), history of hand surgery, or answering yes to three or more of the symptoms of past MSDs on the subject assessment form were excluded from the study. This was planned to control for external variables influencing the outcomes.

Demographics, medical conditions frequently related to the development of CTS, and anthropometric characteristics were also obtained to describe each subject. The same subjects participated in both phase I and phase II. Table I displays the means (± SD) and the range of demographics and relevant characteristics of the sample with respect to musculoskeletal factors. Overall this was a very homogenous sample. The sample exhibited a wide distribution of non-modifiable risk factors such as ages and weights; however, length, breadth, grip diameters, and grip strengths of the sample were all very similar. Nine of the subjects had prior dental experience and eight subjects reported one or two symptoms of MSDs within the last 30 days.

Table I. Characteristics of Subject Sample

Characteristics	Range	Mean (± SD)
Age	21-44 years	25.31 (5.7) years
Weight	104-218 lbs.	129.1 (25.3) lbs.
Hand Length	160-190 mm.	177.9 (6.8) mm.
Handbreadth	81-101 mm.	91.4 (5.8) mm.
Grip Diameter	152-190 mm.	175.7 (8.3) mm.
Grip Strength	45-79 ft. lbs.	62.6 (10.0) ft. lbs.
Years of Experience	0-5 years	1.42 (1.8) years

All subjects gave informed consent to participate in the study and signed the appropriate forms. Confidentiality was protected by assigning each subject a number. This study was approved by the Adult Social Science Institutional Review Board at the University of Missouri-Kansas City.

The design of this study for phase I and phase II was a two-factor, repeated measures statistical design. The within-subject approach examined the relationship of dental mirror handle diameter, weight, and padding as it related to muscle activity during simulated dental hygiene positions. The blue arrow brackets in Figure 1 display the mirror handles used to collect data when evaluating the independent variables, diameter and weight, during phase I of the study. The red arrow brackets in Figure 1 display the mirror handles used to collect data when evaluating the independent variables, weight and padding, during phase II of the study. This was necessary to keep the design balanced due to the inability to place padding on the large diameter mirror handles. Data was collected in two phases over a period of 30 days. A minimum of 24 hours of rest was required between collection of phase I and phase II data.

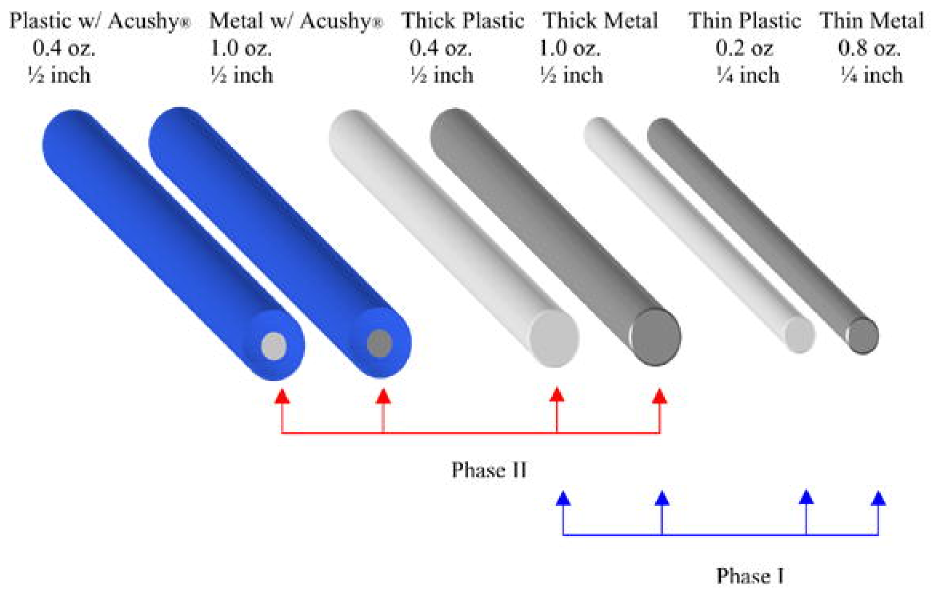

Figure 1. Comparison of mirror handles examined in phase I and II. Under each handle description, weight and diameter are designated.

For each phase, under identical testing conditions, participants were asked to grasp mirror handles two times, according to the mirror sequence assignment, in order to assess consistency of grasping technique within each individual. The second round of testing occurred in the reverse order of the first. Motor unit action potential (MUAP), commonly referred to as muscle activity, was measured in μV, using the Noraxon® sEMG apparatus. Reliability was assessed using Pearson product moment correlation coefficient, significant at the 0.01 level (2-tailed), for each mirror handle within each muscle group. The coefficients for phase I ranged from 0.69 to 0.98. The coefficients for phase II ranged from 0.63 to 0.96. Based on the internal consistency of the sEMG readings, a mean score was completed for each mirror within each muscle group for each subject. The average score was computed to represent a single measure of muscle activity. This mean score was used for statistical analyses.

Dental hygiene positioning was reproduced through a simulated dental hygiene clinic. A dentoform mounted on a pole was placed in a standard patient chair in a supine position. The clinician sat on a standard operator stool.

Miniature, circular Noraxon® 2 cm diameter, dual silver-chloride surface electrodes were used to collect sEMG data from each muscle group. Figure 2 displays the bipolar sensor configuration recommended by Hermens et al.[26] A single, circular Noraxon®, 4 cm diameter, surface electrode was placed on the dorsal side of the wrist and used as a ground. All electrodes were pre-gelled. All surface sites were cleansed with alcohol on gauze pads prior to electrode placement.

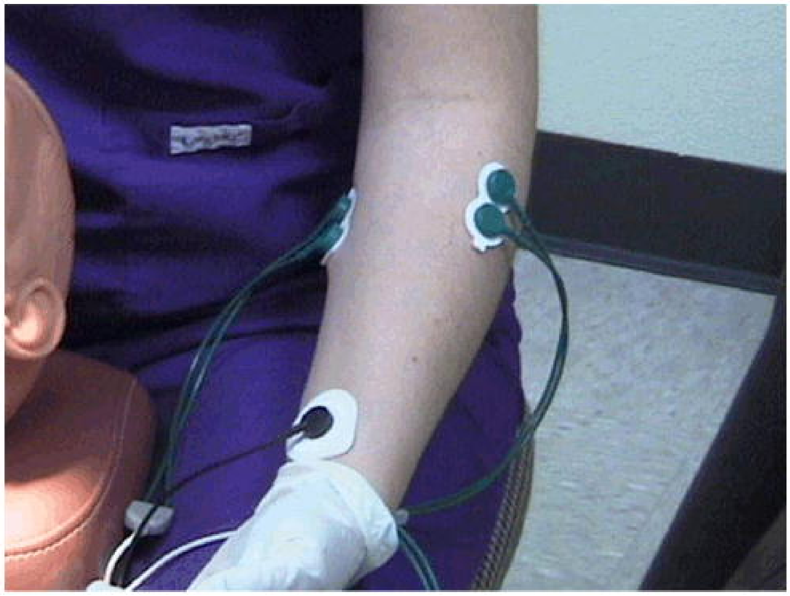

Figure 2. Bipolar sensor electrode configuration, used with a single circular electrode placed on the dorsal side of the wrist. The electrode on the upper right is on the *extensor digitorum, the* electrode under the glove is on the *flexor pollicis brevis*, and the electrode on the upper left is on the *flexor digitorum superficialis*. The electrode directly above the glove is the ground.

The electrodes were connected to electromyography (EMG) Module MyoSystem1200. The fullwave rectified outputs from the modules were fed into a Toshiba® laptop satellite computer. Figure 3 displays the three channels used to delineate MUAP (muscle activity) between each of the three muscles being measured. The computer interface converted the analogue signals to digital form. The operation of the interface was controlled by MyoResearch XP software.

Figure 3. Noraxon sEMG signals converted analogue signals to digital form displaying motor unit action potential for the *extensor digitorum, flexor pollicis brevis, and flexor digitorum superficialis.*

Surface electrodes were placed on the *extensor digitorum, flexor pollicis brevis,* and *flexor digitorum superficialis* by an experienced, licensed occupational therapist to determine correct muscle identification and electrode placement. An occupational therapist was chosen for muscle identification and electrode placement due to their skilled background of human anatomy and neuroanatomy.[28] The same occupational therapist was used throughout the data collection ensure intra-rater reliability. All surface electrodes were placed according to sEMG sensors and sensor placement recommendations developed at the European concerted action SENIAM (surface EMG for a non-invasive assessment of muscles).[26]

Surface electrodes were placed on the *extensor digitorum* muscle group by palpating the middle of the forearm approximately three quarters of the distance between the elbow and the wrist while having the subject extend her fingers. The inter-electrode distance was 2 cm. The sensors were placed in the distal part of this muscle between the innervation zone and the end zone. The orientation of the electrodes was parallel to the muscle fibers of the *extensor digitorium* [26] Once electrodes were placed, subjects were requested to extend fingers with resistance in order to ascertain the correct muscle was being evaluated.[25]

Surface electrodes were placed on the *flexor pollicis brevis* muscle group by palpating the medial aspect of the thenar eminence while the subject flexed her thumb. The sensors were placed in the distal part of this muscle between the innervation zone and the end zone. The orientation of the electrodes was parallel to the muscle fibers of the *flexor pollicis brevis* muscle group. The inter-electrode distance was 2 cm.[26] Once electrodes were placed, subjects were requested to abduct their thumb in order to ascertain that the correct muscle was being evaluated.[25]

Surface electrodes were placed on the *flexor digitorum superficialis* muscle group by palpating approximately three quarters of the distance from the elbow to the wrist on the ventral side of the middle of the forearm while having the wrist supported. The inter-electrode distance was 2 cm. The sensors were placed in the distal part of this muscle between the innervation zone and the end zone. The orientation of the electrodes was parallel to the muscle fibers of the *flexor pollicis brevis* muscle.[26] Once electrodes were placed, subjects were requested to make a fist and flex their wrist in order to ascertain that the correct muscle was being evaluated.[25]

Signals from the sEMG apparatus that appear equally, and on two electrode conductors at the same time, are considered common mode disturbance, commonly referred to as noise. Noise is seen with respect to a system's ground reference point.[25] A single reference electrode was placed on the dorsal side of the wrist where the tissue was electrically inactive. This minimized risk for common mode disturbance.[26] The three muscle groups were studied simultaneously.

A predetermined, stratified mirror sequence was placed in separate envelopes and randomly assigned to each subject for both phases of the study. This ensured mirror order was balanced. The envelope was given to the investigator at the time of data collection.

Subjects were placed in a neutral operator position as defined by Nield.[29] Subjects had their arms at waist level, feet flat on the floor, thighs parallel to the floor, back at a 100-degree angle to the chair, head erect, and body evenly distributed. The typodont was open in a chin-up position. Subjects were required to sit in the 12:00 operator position and instructed to look down into the typodont's mouth as displayed in Figure 4. Subjects used a modified pen grasp in a gloved hand to pinch grasp the dental mirror while examining the lingual surface of the typodont model's maxillary anterior teeth in the mirrors reflection. Subjects were instructed to hold this posture for 30 seconds in order to create a static environment. The subjects had a minimum of 30 seconds of rest between each testing. Figure 5 displays subject stretching and changing positions in order to reach the required minimum resting threshold of 2.0 μV preceding taking measurements. The principle investigator instructed the subjects to stop and resume the pinching task as indicated by the sEMG timer and minimum threshold measurements.

Figure 4. Subject data collection procedures.

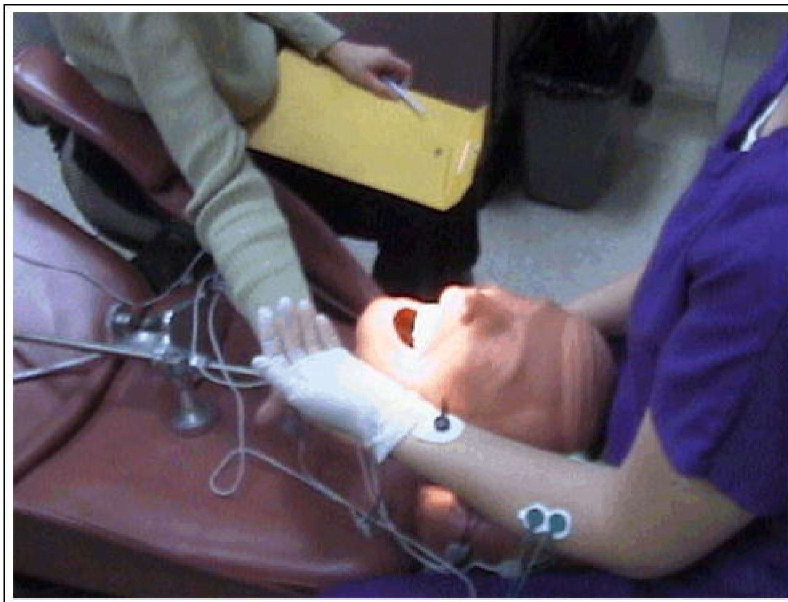

Figure 5. Subject rest period procedures.

Quantitative data obtained from the MyoResearch XP software were coded and entered into the Statistical Package of Social Science (SPSS) 12.0. RM ANOVA ($p \leq 0.05$) and appropriate descriptive statistics including frequency distributions and central tendencies were computed for both main and interaction effects. Two factors were measured in phase I (factor 1= thin and thick, factor 2=heavy and light). Two factors were measured in phase II (factor 1= heavy and light, factor 2=unpadded and padded). An estimation of effect size was determined by calculating partial eta squared, a standardized technique for this purpose.[30]

Results

Table II displays mean (± SD) values of muscle activity for the three muscles under each condition for phase I. Repeated measures (RM) ANOVA ($p \leq 0.05$) was applied to evaluate main and interaction effects. Individual means are reported for each mirror handle an the marginal means are reported to help interpret the main effects. Results show a statistically significant ($p=.01$, $\eta^2=0.29$) interaction of diameter and weight affecting muscle activity in the extensor digitorum. This result is further supported by the partial eta-squared statistically associated with this effect.[30] A greater level of muscle activity was present with the thin plastic handle, and the opposite effect occurred with the thick plastic handle. The main effects of diameter ($p=.14$, $\eta^2=.12$) and weight ($p=.58$, $\eta^2=.02$) were not determined to be statistically significant; however, the partial eta-squared indicates diameter had a low to moderate effect on muscle load during testing activities.[30]

Table II. Mean Muscle Activity (± SD) in µV for Phase I

Extensor Digitorum			
	Wide Diameter	Thin Diameter	Marginal Means
Plastic (Light)	12.5 (4.6)*	13.8 (4.9)*	13.2 (4.8)
Metal (Heavy)	13.4 (5.6)*	13.3 (5.4)*	13.4 (5.5)
Marginal Means	13.0 (5.1)	13.6 (5.2)	
Flexor Pollicis Brevis			
Plastic (Light)	40.9 (32.1)	39.7 (30.9)	40.3 (31.5)
Metal (Heavy)	41.8 (31.2)	41.8 (31.1)	41.8 (31.2)
Marginal Means	41.3 (31.7)	40.7 (31.0)	
Flexor Digitorum Superficialis			
Plastic (Light)	13.0 (8.7)	13.0 (9.4)	13.0 (9.1)
Metal (Heavy)	14.1 (8.5)	13.5 (8.9)	13.8 (8.7)
Marginal Means	13.5 (8.6)	13.2 (9.0)	

* Indicates statistically significant interaction effect of weight and diameter.

For the *flexor pollicis brevis*, the interaction effect of diameter and weight (p=.53, ?2=.02), and the main effects of diameter ($p=.36$, $\eta^2 2=.05$) and weight ($p=.17$, $\eta^2=.10$) were not statistically significant. For the *flexor digitorum superficialis*, the interaction effect of diameter and weight ($p=.48$, $\eta^2=.03$), and the main effects of diameter ($p=.53$, $\eta^2=.02$) and weight ($p=.10$, $\eta^2=.14$), were not statistically significant.

Due to the following phase I results, we reject the following null hypothesis: There will be no interaction effect of diameter and weight that will produce significant differences in muscle activity when applying simulated dental hygiene procedures. We favor the following hypothesis: The interaction of diameter and weight will produce significant differences in muscle activity when applying simulated dental hygiene procedures. We failed to reject the following null hypothesis: The diameter of dental mirror handles will produce no significant differences in muscle activity when applying simulated dental hygiene procedures and the weight of dental mirrors will produce no significant differences in muscle activity when applying simulated dental hygiene procedures.

After phase I testing, the subjects delineated which mirror handle provided the most comfort and the least comfort. Table III displays the percentage of mirror preferences delineated by each subject. Individual's subjective assessment of comfort was also compared to their muscle activity to evaluate accuracy of each subject's preference. Forty-two percent of the subjects accurately identified which mirror was most comfortable within the *extensor digitorum* and the *flexor digitorum superficialis*. Thirty-two percent of the subjects accurately identified which mirror was most comfortable within the flexor pollicis brevis. Eighteen percent of the subjects accurately identified which mirror was least comfortable within the *extensor digitorum*. Thirty-two percent of the subjects accurately identified which mirror was least comfortable within the *flexor pollicis brevis*. Twenty-six percent of the subjects accurately identified which mirror was least comfortable within the *flexor digitorum superficialis*.

Table III. Subject Designation of Mirror Preferences for Phase I

% Reporting Most Comfortable			
	Wide Diameter Means	Thin Diameter Means	Overall Weight Preference
Plastic (Light)	68%*	16%*	84%
Metal (Heavy)	11%*	5%*	16%
Overall Diameter Preference	79%	21%	
% Reporting Most Discomfort			
Plastic (Light)	0%*	5%*	5%
Metal (Heavy)	21%*	74%*	95%
Overall Diameter Preference	21%	79%	

*A statistically significant interaction occurred between weight and diameter within the *Extensor Digitorum.*

Table IV displays mean (± SD) values for electromyography for the three muscles under each condition for phase II. Repeated measures (RM) ANOVA ($p \leq 0.05$) was applied to evaluate main and interaction effects. Individual means are reported for each mirror handle and the marginal means are reported to help interpret the main effects. Results show that weight ($p=.02$, $\eta^2=0.27$) had a statistically significant effect on muscle activity in the extensor digitorum with an associated partial eta-squared supporting this conclusion.30 The main effect of padding ($p=.60$, $\eta^2=.02$), and the interaction effect of weight and padding ($p=.39$, $\eta^2=.04$) were not significant.

Table IV. Mean Muscle Activity (± SD) in µV for Phase II

Extensor Digitorum			
	Non-padded Handle	Padded Handle	Marginal Means
Plastic (Light)	12.5 (6.1)	12.1 (6.3)	12.3 (6.2)*
Metal (Heavy)	12.9 (6.0)	13.0 (6.1)	12.9 (6.1)*
Marginal Means	12.7 (6.1)	12.5 (6.2)	
Flexor Pollicis Brevis			
Plastic (Light)	31.4 (18.8)	29.3 (16.1)	30.4 (17.5)
Metal (Heavy)	33.9 (19.6)	28.7 (17.3)	31.3 (18.5)
Marginal Means	32.7 (19.2)*	29.0 (16.7)*	
Flexor Digitorum Superficialis			
Plastic (Light)	7.9 (4.5)	7.6 (4.6)	7.7 (4.6)
Metal (Heavy)	7.5 (5.0)	7.9 (4.6)	7.7 (4.8)
Marginal Means	7.7 (4.7)	7.7 (4.6)	

* Indicates statistically significant main effect.

In the *flexor pollicis brevis*, results illustrate the main effect of padding had a statistically significant effect ($p=.01$, $\eta^2=.30$) on muscle activity while grasping mirror handles. Results for the main effect of weight ($p=.34$, $\eta^2=.05$), and the interaction effect of weight and padding ($p=.22$, $\eta^2=.08$) were not statistically significant.

The *flexor digitorum superficialis* had an interaction effect of diameter and weight ($p=.53$, $\eta^2=.02$) that was not statistically significant. The main effects of weight ($p=.90$, $\eta^2=.001$) and padding ($p=.88$, $\eta^2=.001$) were not statistically significant.

Due to the following phase II results, we reject the following null hypotheses: The weight of dental mirrors will produce no significant differences in muscle activity when applying simulated dental hygiene procedures and the padding of dental mirror handles will produce no significant differences in muscle activity when applying simulated dental hygiene procedures. We favor the following hypotheses: The weight of dental mirrors will produce significant differences in muscle activity when applying simulated dental hygiene procedures and the padding of dental mirror handles will produce significant differences in muscle activity when applying simulated dental hygiene procedures. We failed to reject the following null hypothesis: There will be no interaction effect of weight and padding that will produce significant differences in muscle activity when applying simulated dental hygiene procedures.

After phase II testing, the subjects delineated which mirror handle provided the most comfort and the least comfort. Table V displays the percentage of preferences delineated by each subject. Individual's subjective assessment of comfort was also compared to their muscle activity to evaluate accuracy of each subject's preference. Twenty-one percent of the subjects accurately identified which mirror was most comfortable within the *extensor digitorum* and the *flexor pollicis brevis*. Thirty-two percent of the subjects accurately identified which mirror was most comfortable within the *flexor digitorum superficialis*. Five percent of the subjects accurately identified which mirror was least comfortable within the *extensor digitorum*. Sixteen percent of the subjects accurately identified which mirror was least comfortable within the *flexor pollicis brevis*. Twenty-six percent of the subjects accurately identified which mirror was least comfortable within the *flexor digitorum superficialis*.

Table V. Subject Designation of Mirror Preferences for Phase II

% Reporting Most Comfortable			
	Non-padded Handle Means	Padded Handle Means	Overall Weight Preference
Plastic (Light)	10.5%	53%	63.5%*
Metal (Heavy)	5%	31.5%	36.5%*
Overall Padding Preference	15.5%**	84.5%**	
% Reporting Most Discomfort			
Plastic (Light)	31.5%	16%	47.% *
Metal (Heavy)	42%	10.5%	52.5%*
Overall Padding Preference	73.5%**	26.5%**	

*Weight had a statistically significant main effect on muscle activity within the *Extensor Digitorum.*

**Padding had a statistically significant main effect on muscle activity within the *Flexor Pollicis Brevis*

Discussion

Clinical Relevance

Unfortunately, research is not available that delineates how much muscle activity equates to the development of a work-related musculoskeletal disorder (WMSD), so the direct application of the data gathered in this study is narrow. The largest statistically significant reduction of muscle activity occurred during phase II of this study, in one of the largest muscles of the thumb, the *flexor pollicis brevis*. Padding reduced mean muscle activity by 3.7 µv. In phase I, the interaction of diameter and weight decreased the muscle activity in the *extensor digitorum* by 1.3 µV and in phase II, weight decreased the muscle activity in the *extensor digitorum* by .62 µV. Research indicates that muscle activity ranges from a resting state of 0-2 μV, and can reach as high as 200 μV. [25] It is difficult to ascertain if these rather small decreases in muscle activity would result in promoting musculoskeletal health.

When comparing the subjective data to the objective data in phase I, 68% of the subjects surmised the thick plastic mirror handles were the most comfortable. This is consistent with the mean muscle activity and the statistically significant interaction of diameter and weight within the *extensor digitorum*. Seventy-four percent of the subjects identified the thin metal mirrors were least comfortable. This calibrated with having the highest mean muscle activity in the extensor digitorum, however, it is inconsistent with the findings of the other muscle groups. Seventy-four percent of the subjects surmised the plastic handles were the most comfortable. Fifty-three percent of the subjects identified metal handles were the least comfortable. This is consistent with the statistically significant main effects of weight within the *extensor digitorum*. The mirror preferences are also consistent with the mean muscle activity in the *extensor digitorum*, wherein the padded plastic handle required the least amount of muscle activity; however, it is inconsistent within the other muscle groups. Eighty -five percent of the subjects surmised padded mirror handles were the most comfortable. Seventy-four percent of the subjects identified non-padded mirror handles were the least comfortable. This is consistent with the statistically significant main effect of padding in the *flexor pollicis brevis*. Within the *flexor pollicis brevis*, the padded metal handle required the least amount of muscle activity and the non-padded metal handle required the most muscle activity; however, it is inconsistent within the other muscle groups.

When comparing the overall subjective data to the statistically significant objective data, it appears that subjects had a good sense of what instrument required the least amount of work (μv). This was not true for the effects that were not statistically significant. When comparing each individual's mirror preferences with her muscle activity, less accuracy occurred, supporting the results of Spielholz et al; self-reports are the least precise measurement for evaluating ergonomics.[8] The self-reports by the subjects in this study were less precise than the measurements of muscle activity using surface electromyography (sEMG) when evaluating comfort of mirror handles.

Previous studies demonstrated an increase in intracarpal tunnel pressure[9, 10] and an increase in tension forces in the finger flexor tendons[11] when force is exerted. Results from evaluating static and biomechanical models concluded the tendon force is a function of hand size, position, and load. Opposition of movements in the finger flexor tendons is much higher than that of normal force acting on the fingers when normal force is exerted with only the finger tips.[12, 13] Studies by Hagg et al[31] supported that different dose definitions of muscle activity should be applied depending on the tissue at risk. He also stated that the overexertion risk increases more than proportionally with increasing mechanical load.[31] Dental hygienists pinch grasp mirrors several hours of the workday, often with pressure due to retracting the cheek and tongue. When applying the above research to the task of performing dental hygiene procedures, one might assume that as force is exerted during gripping and pinching activities, the magnitude of tensile strain in the tendons will increase, which augments the risk of muscle overexertion. Consequently, when considering force and the magnitude of tensile strain, the impact of even a small reduction of muscle activity may be significant in the prevention of WMSDs.

Recommendations for ergonomic instrumentation focus on alternating instruments and using a variety of handle diameters and weights within each instrument kit.[17, 21, 23] Data from this study support this recommendation. The muscle activity response between the best and worst handle for each muscle group was of interest. Sixty-eight percent of the subjects in phase one and fifty-eight percent of the subjects in phase II had at least one mirror handle that was best for one muscle group and worst for a different muscle group at the same time. One could conclude that alternating instrument handles throughout each appointment would allow for varying muscles to work and rest throughout each appointment, which could improve musculoskeletal health.

Upon examining the data of each individual, it is notable that due to the complexity of the muscles and nervous system, the muscle response to the external load (mirror handles) was different for each subject. Some subjects had a decrease in muscle activity with lightweight handles while others had an increase in muscle activity associated with lightweight handles. This was also true for diameter and padding. Optimal handle trends were suggested by the main and interaction effects; however, there was no "one size fits all" handle. Tactile cues available at the end of finger movements provide a powerful stimulus for the control of the finger muscles.[32] In a study that evaluated temporal synergies of hand movement and sensory cues, Santello et al found that tactile cues influenced hand postures as the hand contacted objects.[33] Weight and texture are external variables that provide tactile cues and could affect muscle activity. This may perhaps explain why lightweight instruments decreased muscle activity in many of the subjects; however, in a limited number of subjects it caused an increase in muscle activity. A variety of handle textures are available to clinicians; however, this variable was not controlled for or measured in the present study. This needs to be an additional parameter proscribed in future studies.

Limitations

Due to prescribed manufacturer features (set diameters and weights); it was not possible to conduct a fully balanced design. The Acushy® grip, used to pad instrument handles, was not compatible with the wide diameter instrument handles. This is why it was necessary to design the study to collect data in two phases. Although measures were taken to totally balance the study, they were not fully accomplished.

The pilot test used for power analysis was completed on three experienced dental hygiene faculty members. The subjects (N=19) used in this study were senior dental hygiene students. Overall, the subjects used in this study did not reflect the characteristics of the subjects in thepilot test. Using this population allowed for greater control of the external variables that could affect the study results, however, it greatly limited the variability of the data. Over half of the subjects used in the study were inexperienced in the dental field, which we hypothesize may have contaminated the power analysis. The power of the study was impaired by the predetermined sample not being large enough.

Hagg et al[31] stated, "The indication of muscular fatigue in occupational field applications comprises a general problem since both, the EMG amplitude as well as the spectrum, depend not only upon the fatigue state but also on the produced force." Force was not measured in this study, which makes comparing phase I and phase II data problematic because we cannot ascertain that equal force was used from one phase to the next. Data from each phase must be looked at as individual entities.

General Remarks

This exploratory study is the first randomized controlled trial exploring empirical evidence to support instrument modification choices in dental hygiene mirrors. While trends in muscle activity were observed under varying instrument characteristics, only some were statistically significant. Further research is necessary to ascertain the results.

This study had a homogenous anthropometry of hand demographics. The mean female hand breadth is 92 mm (± 6 mm).[34] This was very comparable to our sample. Future ergonomic studies examining muscle activity should include examining diameter, weight, and padding on a larger, more diverse sample by which additional analyses to determine what role anthropometrics of the hand play in muscle activity should be explored. It is also of interest to explore the effects of load (resistance), such as that while retracting the cheek or tongue, while grasping dental hygiene mirrors. Examining muscle activity while scaling calculus with any of the above variables would also be beneficial. Ultimately, the utilization of biomechanical models and temporal neural networks to map and predict the interaction of muscle activity in a cross-sectional sample of dental hygienists is necessary to completely understand the relationships between muscles and external variables.

Conclusion

Altering the weight, diameter, and padding of dental hygiene instrument handles appears to have an affect on muscle activity; however, further research is needed to determine optimal handle design. Ergonomic adaptations to dental hygiene instrument handles seem to impact muscle activity; it may be possible to reduce work-related musculoskeletal disorders for dental hygienists by altering instrument designs during the workday. Self-reports of comfort by the subjects calibrated well with the statistically significant effects; however, they did not calibrate well with non-statistically significant effects. Each individual's subjective assessment of comfort did not parallel the amount of muscle activity objectively measured using surface electromyography (sEMG). The individual sEMG data suggests instrument handles should be tailored to best fit each individual. Ultimately, a biomechanical means of predicting muscle activity would allow for better selection of ergonomically focused instruments.

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Notes

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