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The Effects of Dental Hygiene Instrument Handles on Muscle Activity Production

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ABSTRACT

Purpose The objective of this study was to compare the effects of ten commercially available instrument handle designs' mass and diameter on forearm muscle activity during a simulated periodontal scaling experience.

Methods A convenience sample of 25 registered dental hygienists were recruited for this IRB-approved study. Ten commercially available instruments were categorized into four groups based on their masses and diameters: large diameter/light mass, small diameter/light mass, large diameter/heavy mass, and small diameter/heavy mass. Participants were randomized to four instruments with one from each group. Participants scaled with each instrument in a simulated oral environment while muscle activity was collected using surface electromyography. Muscle activity was compared among the four instrument group types.

Results Muscle activity of the flexor digitorum superficialis was not significantly influenced by instrument mass ($p=0.60$) or diameter ($p=0.15$). Flexor pollicis longus muscle activity was not significantly influenced by instrument mass ($p=0.81$); diameter had a significant effect ($p=0.001$) with smaller diameter instruments producing more muscle activity. For the extensor digitorum communis and extensor carpi radialis brevis, instrument mass did not significantly affect muscle activity ($p=0.64$, $p=0.43$), while diameter narrowly failed to reach significance for both muscles ($p=0.08$, $p=0.08$); muscle activity for both muscles increased with smaller diameter instruments.

Conclusion Results from this study indicate instrument diameter is more influential than mass on muscle activity generation; small diameter instruments increased muscle activity generation when compared to large diameter instruments. Future research in real-world settings is needed to determine the clinical impact of these findings.

Keywords dental, muscle activity, instrumentation, musculoskeletal disorder, ergonomics

NDHRA priority area, **Professional development: Occupational health** (determination and assessment of risks).

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INTRODUCTION

The tasks associated with clinical practice in dental hygiene are an occupational health hazard as many of them increase the risk for developing musculoskeletal disorders (MSDs) in clinicians. Research has indicated 60-90% of dentists and dental hygienists experience occupationally related MSDs depending on the study.[1-12] Dental hygienists use repetitive motions throughout each clinical day leading to a cumulative effect of trauma on the fingers, wrists, and forearms. Cumulative trauma on the musculoskeletal system and associated pain in the affected areas result in a specific subset of MSDs commonly referred to as cumulative trauma disorders (CTDs), repetitive strain injuries (RSIs), and/or overuse injuries.[1-12] The repetitive motions of dental hygiene appointments require prolonged gripping and positions outside of neutral further adding to the risk for CTDs.[7]

Preventing occupational hazards that relate to the development of MSDs has been a priority in dental hygiene.[7,12-15,17] Occupational hazards that contribute to CTDs have negative health outcomes for dental hygienists that result in increased medical costs, decreased production, increased sick days, and overall reduced career longevity.[2,12,13] Instrument design may contribute to occupational hazards; large diameters, tapered handles, and light mass instruments have been identified as potentially reducing the risk of developing CTDs for dental hygienists.[14-20]

Commercially available instruments come in a variety of diameters and masses to address ergonomic benefits and clinician preference. Additionally, instrument handles are manufactured in various shapes and materials to aid in grip during instrumentation and reduce overall mass of the instrument. Previous studies suggest increasing the diameter and decreasing the mass of instrument handles may help reduce risk for cumulative trauma effects.[14-20] However, minimal research has been conducted determining the effects of a wide range of commercially available instrument handle designs from multiple manufacturers on muscle activity production. Dong et al. used surface electromyography (sEMG) to evaluate the effects of changing the mass and diameter of periodontal instrument handles on muscle activity during instrumentation.[14] Results identified significant differences in muscle activity generation depending on the design of the instrument handle, with light mass instruments producing the least amount of muscle activity.[14] Using purpose built instruments allowed systematic variation of the instruments to readily quantify the effects of particular characteristics (internal validity), but limited application to commercially-available instruments (external validity). In a separate study, Suedbeck et al. examined scaling with commercially available instruments using sEMG to identify muscle activity of four muscles.[17] Results showed the instrument with the heaviest mass and relatively larger diameter produced statistically significantly more muscle activity. However, this study did not look at mass and diameter individually to determine which variable significantly affected muscle activity and only examined instruments from one company.[17] Though previous research indicated instrument handle designs may reduce muscle activity associated with repetitive instrumentation and practices, more evidence-based research is needed to determine the contribution of these designs in reducing cumulative trauma effects. Therefore, the purpose of this study was to compare the effects of ten commercially available instrument handle designs' mass and diameter on forearm muscle activity during a simulated periodontal scaling experience.

METHODS

The experimental study used a counterbalanced design with participants acting as their own controls during data collection. A convenience sample of 25 registered dental hygienists were used in this IRB approved (Old Dominion University Institutional Review Board #18-240) study. The sample size of this study was based on previous studies that focused on sEMG measurements with dental hygiene instrumentation.[15] Power statistics shows that a minimum number of 24 subjects were needed to achieve a 95% confidence interval and 90% power with an effect size of 0.5 (moderate).[15] Participants were recruited via advertisements on social media. Incentives to participate included a $50 Amazon® gift card as well as the instruments used during the study after data collection. Participants completed a preliminary screening at the time of recruitment to ensure inclusion criteria were met. Participants were included if they were healthy adults (18 years or older), right-handed, and had a current license and were clinically practicing dental hygiene. Participants who had a diagnosed musculoskeletal injury or disability of the working hand, wrist, forearm, shoulder, neck, or trunk were excluded from the study.

Ten commercially available instruments from four different companies were used in this study (American Eagle®, Missoula, MT; Paradise Dental Technology®, Missoula, MT; Premier®, Plymouth, PA; and Hu Friedy®, Chicago, IL). These instruments were grouped according to their mass and diameter to create four instrument categories: large diameter and light mass (A), small diameter and light mass (B), large diameter and heavy mass (C), and small diameter and heavy mass (D). The determination of instrument groupings was based on previous studies on instrument handle designs.[14-20] In these studies, various masses and diameters were tested to determine differences in muscle activity and/or pinch force and determinations of heavy and light as well as large diameter and small diameter were determined.[14-20] Researchers from this study continued to use those parameters set by previous research, however it has not yet been identified in research the clinical impact these differences in mass and diameter may have on the clinician. Participants were then randomly assigned one instrument from each group (A, B, C, D) for a total of four instruments per participant. Table I shows the characteristics and groups of all ten instruments used in the study. Images of the instruments and their characteristics are shown in Figure S1.

Table I. Instrument characteristics and groups

Instrument	Group	Mass (g)	Diameter (mm)
1A	A: Light mass, large diameter	10	10
2A	A: Light mass, large diameter	15	10
3A	A: Light mass, large diameter	15	11.7
4A	A: Light mass, large diameter	15	12
1B	B: Light mass, small diameter	18.4	6.35
2B	B: Light mass, small diameter	18.4	9.5
1C	C: Heavy mass, large diameter	25	10
2C	C: Heavy mass, large diameter	25	11
1D	D: Heavy mass, small diameter	20	8
2D	D: Heavy mass, small diameter	20.8	9.5

Simulated oral environments with chair-mounted typodonts and an artificial face were utilized; the lower right quadrant, mesiobuccal surfaces of the teeth were coated with one cc of artificial calculus. Each instrument from the groups was a brand new universal curet to eliminate effects of dull instruments on scaling technique and muscle activity production. Participants scaled for two minutes in the assigned area with each instrument and a one-minute rest period occurred between scaling with each instrument. Four prepared simulated oral environments were set up for each participant with one of the four instruments randomly assigned to each typodont to combat sequence effects. The scaling time and rest ratio were less than dental hygienists normal pacing throughout the workday, thus eliminating possible scaling fatigue. In addition, the counterbalanced design of instrument assignment and rest period eliminated any systematic error that fatigue may cause.

Surface electromyography (sEMG) was used to measure muscle activity of four muscles in the forearm: flexor digitorum superficialis (FDS), flexor pollicis longus (FPL), extensor digitorum communis (EDC), and extensor carpi radialis brevis (ECR) based on previous research.[14,17] These muscles are utilized in instrumentation studies for their use during scaling and root debridement; Table II indicates their action and association with dental hygiene practice. sEMG is a valid and reliable measure of muscle activity and has been used in multiple studies evaluating musculoskeletal disorders.[14-17, 21-24] Four sEMG sensors (Noraxon®, Scottsdale, AZ, USA) recorded the electrical activity of the four test muscles that were involved in instrumentation and has been used in previous instrumentation studies.[14-17] Data from the sEMG readings were collected during maximum voluntary isometric contraction (MVIC) for each of the muscles. The MVIC values were considered 100% activity for that muscle. The sEMG activity that was measured during the scaling processes was 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. It also controls 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.[25-27]

Prior to data collection, a pilot test was conducted to refine the research methods. Pilot data was collected using two dental hygienists to test the sEMG equipment and software. Additionally, at the conclusion of the study, participants completed an end-user perception survey on the simulated scaling experience and four instruments used in the study. They were asked to rate each instrument in terms of comfort provided by the diameter, balance, maneuverability, comfort provided by the mass, and overall comfort of the instrument on a six-point Likert scale, with 1 being not comfortable at all/poor and six being very comfortable/excellent. Additionally, participants reported demographic information including age, number of days in practice, gender, and ethnicity.

Table II. Muscles evaluated with surface electromyography.

Muscle	Action	Association with Dental Hygiene Practice
Flexor pollicis longus (FPL)	Flexing of the thumb	Scaling and root debridement as well as gripping instruments
Flexor digitorum superficialis (FDS)	Flexion of the middle four fingers	
Extensor digitorum communis (EDC)	Extension of the middle four fingers	
Extensor carpi radialis brevis (ECR)	Extension of the hand at wrist joint	

Statistical Analysis

Hierarchical linear modeling (HLM) was performed, which provided model coefficients of the relationship between instrument mass and handle diameter as covariates with each dependent variable. The HLM has several advantages as it allows participants to only be tested on a sample of the handpieces and thereby avoid fatigue that could occur from performing with all ten handpieces. Additionally, it does not assume independence of data (contrary to standard linear regression) and it allows the testing of different covariance matrices rather than assuming compound symmetry.[28] The HLM was implemented using the maximum likelihood method. Instrument mass, handle diameter, and their interaction were potential fixed effects, and participant intercept, instrument mass, and handle diameter as random effects with different covariance matrix structures. These could be random effects as they may have different effects across participants.

The model with at least one significant fixed effect and the lowest Akaike's Information Criterion corrected for finite sample sizes was selected as the most appropriate model. Computed probabilities are provided, but $p<0.05$ was considered statistically significant. A Pearson Product Moment Correlation Coefficient (r) was computed to quantify the effect size of each independent variable based on the t-statistic and degrees of freedom (df):

Effect sizes were interpreted as small, $r=0.1$, medium, $r=0.3$, and large, $r=0.5$, based on Cohen (1988). All statistical measures were carried out using a statistical software program (SPSS v. 28, IBM; Armonk, NY, USA).

Friedman ANOVA test was employed to analyze qualitative scaled 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 ($p<0.0083$).

RESULTS

Twenty-five registered dental hygienists participated in the study. All participants were female and the majority (n=18, 72%) were Caucasian. Of the participants, ten (40%) were ages 18-29, nine participants (36%) were ages 30-44, five participants (20%) were ages 25-59, and one participant (n=1, 4%) was sixty years or older. All were licensed hygienists who practiced three or more days per week.

Mean and standard deviations for normalized muscle activity results for each muscle can be found in Table III. Results revealed total activity of the FDS was not significantly influenced by instrument mass, $F(1, 95.35)=0.28$, $p=0.60$, $r=0.05$, or by instrument diameter, $F(1, 81.26)=0.2.11$, $p=0.15$, $r=0.16$. Additionally, total activity of the FPL was not significantly influenced by instrument mass, $F(1, 89.06)=0.06$, $p=0.81$, $r=0.03$, however, instrument diameter had a significant, medium effect on FPL activity, $F(1, 80.93)=10.83$, $p=0.001$, $r=0.34$. The overall parameter estimate for diameter was -3.52 (95% CI: -5.63 - -1.39), indicating a decrease in FPL activity with increases in instrument diameter. Note data suggests the effect is driven by increased FPL activity for the narrowest diameter of instrument, 6.35 mm. For the EDC, instrument mass did not significantly affect muscle activity, $F(1, 83.13)=0.22$, $p=0.64$, $r=0.05$, while instrument diameter narrowly failed to reach the level of significance, $F(1, 84.32)=3.14$, $p=0.08$, $r=0.19$, with a parameter estimate of -2.28 (95% CI: -4.85 - 0.28). Similarly, the ECR was not significantly affected by instrument mass, $F(1, 69.52)=0.64$, $p=0.43$, $r=0.10$, while instrument diameter narrowly failed to reach the level of significance, $F(1, 76.82)=3.09$, $p=0.08$, $r=0.20$, with a parameter estimate of -0.89 (95% CI: -1.90 - 0.12). No significant interaction effects for instrument mass and diameter were found for any dependent variable.

In the end-user survey, participants rated each instrument they used based on the group the instrument was in—group A: large diameter and light mass, group B: small diameter and light mass, group C: large diameter and heavy mass, and group D: small diameter and heavy mass. For each instrument, they rated comfort provided by the diameter, balance, maneuverability, comfort provided by the mass, and overall comfort of the instrument. Mean scores for each instrument group and question can be found in Table IV. Both instrument groups with large diameters, regardless of mass, were rated above average for overall comfort (large diameter, light mass: mean, x=4.92, large diameter, heavy mass: x=4.60) whereas the small diameter instruments, regardless of mass, were rated slightly lower on average for overall comfort (small diameter, light mass: x=3.48, small diameter, heavy mass: x=3.88). The instruments rated the lowest for all categories were small diameter, light mass instruments (Table IV); interestingly, participants rated the small diameter, heavy instrument as having greater balance (x=4.08), greater maneuverability (x=4.24), and better comfort provided by mass (x=4.04) on average than the small diameter, light mass instruments (x=3.88, x=3.64, x=3.56, respectively). The frequencies of

Table III. Mean and standard deviation of normalized muscle activity for each instrument[a]

Instrument	Group	FDS (%)	FPL (%)	EDC (%)	ECR (%)
1A	A: Light mass, large diameter	16 ± 9.2	21.8 ± 7.6	24.9 ± 3.9	23.6 ± 10.7
2A	A: Light mass, large diameter	26.7 ± 20.8	27.6 ± 21.1	16.4 ± 10.5	26.6 ± 24.9
3A	A: Light mass, large diameter	20.8 ± 6.0	22 ± 7.7	20.8 ± 8.1	20.2 ± 4.8
4A	A: Light mass, large diameter	20.7 ± 8.6	28 ± 20.9	17.1 ± 5.6	20.1 ± 7.7
1B	B: Light mass, small diameter	19.4 ± 7.3	31.6 ± 22.4	15.7 ± 5.9	19.1 ± 4.1
2B	B: Light mass, small diameter	22.4 ± 8.8	28.6 ± 11.7	22.9 ± 11.3	25.3 ± 7.6
1C	C: Heavy mass, large diameter	19.2 ± 12.3	24.2 ± 14.6	21 ± 10.8	21.6 ± 7.5
2C	C: Heavy mass, large diameter	19.6 ± 8.4	28.3 ± 15.5	19.2 ± 8.3	19.8 ± 6.6
1D	D: Heavy mass, small diameter	18.4 ± 8.3	24.6 ± 13.5	22.3 ± 10.6	24 ± 13.2
2D	D: Heavy mass, small diameter	19 ± 6.6	31.3 ±17.1	19.2 ± 8.1	18.7 ± 6.4

[a]Flexor digitorum superficialis (FDS), flexor pollicis longus (FPL), extensor digitorum communis (EDC), and extensor carpi radialis brevis (ECR)

Table IV. End user perception survey mean and standard deviation scores for instrument groups based on a six-point Likert scale[a]

	Group A: Large diameter, light mass (x ± SD)	Group B: Small diameter, light mass (x ± SD)	Group C: Large diameter, heavy mass (x ± SD)	Group D: Small diameter, heavy mass (x ± SD)
Comfort provided by diameter	5.16 ± 1.1	3.36 ± 2.1	5.24 ± 1.0	3.84 ± 1.7
Balance	4.96 ± 0.8	3.88 ± 1.8	4.56 ± 1.6	4.08 ± 1.3
Maneuverability	4.76 ± 1.2	3.64 ± 1.9	4.72 ± 1.0	4.24 ± 1.3
Comfort provided by mass	5.28 ± 1.1	3.56 ± 1.8	3.88 ± 1.6	4.04 ± 1.4
Overall comfort	4.92 ± 1.2	3.48 ± 1.9	4.6 ± 1.2	3.88 ± 1.6

[a] (1-not comfortable at all/poor and 6-very comfortable/excellent)

responses to the end user perceptions survey are shown in supplemental Table I.

Friedman's ANOVA results revealed statistically significant differences in participant ratings for diameter of the instrument handles, $\chi^2(3)=12.4$, $p=0.006$. Wilcoxon signed rank test with Bonferroni correction revealed significant differences in perceptions of the handle diameter between instrument group A (x=3.36) and B (x=5.16; $Z=-3.03$, $p=0.002$), instrument group A (x=3.36) and D (x=5.24; $Z=-3.20$, $p=0.001$), and instrument group C (x=2.26) and D (x=5.24; $Z=-2.91$, $p=0.004$). Friedman's ANOVA results also revealed statistically significant differences in participant ratings for mass of the instrument handles, $\chi^2(3)=14.6$, $p=0.002$. Wilcoxon signed rank test with Bonferroni correction revealed significant differences in perceptions of the handle mass between instrument group A (x=2.16) and B (x=3.30; Z=-3.13, p=0.002), B (x=3.30) and C (x=2.28; Z=3.17, p=0.002), and B (x=3.30) and D (x=2.26; Z=-2.89, p=0.004). There were no statistically significant differences in participant perceptions of instrument handles' maneuverability, balance, or overall comfort.

DISCUSSION

MSDs including repetitive strain injuries and CTDs, continue to be an occupational hazard for dental hygienists practicing in a clinical environment. Muscle activity production measurements using sEMG studies provide quantifiable information regarding MSD risk reduction as reduced muscle activity production may reduce risk. The current study compared the effects of ten commercially available instruments grouped together by common masses and diameters on muscle activity for four superficial forearm muscles utilized during scaling and root debridement by dental hygienists. Instruments associated with increased muscle activity may increase the risk for CTD when utilized repetitively throughout the workday.

Results from this study indicate instrument handle diameter is more influential on muscle activity production in the forearm muscles measured in this study than instrument handle mass during a simulated scaling experience. Instrument handle diameter had a moderate, significant effect on FPL activity, which increased as diameter decreased. The three other muscles (FDS, EDC, ECR) also increased activity with smaller diameter instrument handles, but the effect size was small, narrowly failing to reach the level of significance for both the EDC and ECR muscles. This supports previous findings in research that indicated diameter had significant impacts on muscle activity production.[14-17] Specifically, smaller diameter instruments increased muscle activity.[14-17] In the present study, instrument handle mass had a smaller effect on the activity of all four muscles ($r \leq 0.1$) than diameter and was not significant for any of them (p's>0.4). However, in previous studies, researchers could not attribute muscle activity changes specifically to diameter or mass and most researchers surmised mass had a bigger impact on muscle activity production.[14-17] From these findings, it is possible that both mass and diameter of the instrument handle influence muscle activity production, but the current study emphasizes using a larger diameter instrument handle to reduce muscle activity production and therefore musculoskeletal disorder risk. This is supported by previous research in both muscle activity production and pinch force generation, though clinical impacts have not yet been determined in research.[7,14-17,19-20]

The FPL was impacted the most by instrument diameter and data suggests muscle activity of this muscle increased as the diameter narrowed with the most muscle activity produced by instruments with diameters around 6.35 mm. This muscle is responsible for flexion of the thumb; this indicates that with smaller diameter instruments, the thumb has to grip the handle with increased muscle activity for use during instrumentation. Diameter likely has significant impacts on pinch force generation, especially of the thumb, during instrumentation which may also increase risk for musculoskeletal disorder development, but this variable was not researched in this study. However, it is supported in previous study results where pinch force was increased in the thumb for smaller diameter instruments.[14,15] The current study, in combination with these pinch force studies, would support the use of larger diameter instruments to reduce the impacts to muscle activity and pinch force.[14,15]

The EDC and ECR both narrowly failed to reach the level of statistical significance; however, they were clearly impacted by diameter as well. These muscles are responsible for extension of the middle four fingers and extension of the hand at the wrist joint. Therefore, these results indicate diameter of the instrument handle may cause increased muscle activity in extension movements during scaling and root debridement. Again, the smaller diameters showed increased muscle activity indicating that a large diameter may be beneficial for reducing muscle activity and associated musculoskeletal disorder risk. This supports previous findings in previous studies that recommend larger diameter instruments for muscle activity reduction as well as pinch force reduction.[7,14-17,19-20]

The end-user survey results indicate participants also did not find small diameter instruments favorable for comfort; the instrument group with a small diameter and light mass had the lowest scores for comfort in all areas and overall comfort (x=3.48). In addition, the small diameter and heavy mass instrument group was also rated low in all areas of comfort on the end user survey (overall comfort x=3.88). The instrument group with the large diameter and light mass was rated most favorably overall (x=4.92) and most comfort provided by the mass (x=5.28). Additionally, this group was rated favorably for comfort provided by the diameter (x=5.16) as was the instrument group with a large diameter and heavy mass (x=5.24). These participant surveys indicate instruments that are likely contributing to less muscle activity are already preferred by the participants. The participants' opinions of comfort highly favored large diameter instruments which was found to have the most influence on reducing muscle activity in this study.

Friedman ANOVA results showed statistically significant differences in participant ratings for instrument handle diameter. Interestingly, the instrument group with a large diameter and light mass was rated statistically significantly lower than the group with small diameter and light mass as well as small diameter and heavy mass. Additionally, the instrument group with a large diameter and heavy mass was rated statistically significantly lower than the group with a small diameter and heavy mass. These results indicate that diameter preferences did not match muscle activity results as expected. It is possible the mass and other features of the instrument handle designs impacted participant preferences. Similarly, Friedman ANOVA results revealed statistically significant differences in participant ratings for instrument handle mass. The participants rated the instrument with a small diameter and light mass statistically significantly better than the group with a large diameter and light mass. Additionally, participants rated this group, the small diameter and light mass, significantly better than both instrument groups with heavy mass, regardless of diameter size. These are more in line with previous research results as heavier instruments were not rated comfortably by participants in another study.[17] There were no other statistically significant differences in the survey results. This indicates diameter and mass are most influential for participants for comfort of the instrument handle during instrumentation, however mass is most influential in terms of preferences.

Limitations and Future Research

Several limitations may have impacted the findings of this research. The short duration of scaling with each instrument may not have provided enough time for participants to develop true preferences. Additionally, the instruments had varied textures and grips of the handle design which may have influenced how they were grasped and the resultant muscle activity during scaling. Finally, the years in practice may influence the use of instruments during scaling and root debridement. It is possible that new graduates have less exposure to instrument variation and utilize a more "textbook" technique with instruments when compared to seasoned dental hygienists. Future studies in a real-world setting may be indicated to be more comparable to a typical workday for a dental hygienist. Additionally, future studies are needed to further evaluate pinch force generation of the thumb and index finger where the instrument is grasped as this may have significant considerations for musculoskeletal disorder development. A culmination of findings using muscle activity production and pinch force generation are needed to determine clinical impacts and recommendations for dental hygiene practice.

CONCLUSION

This study found that diameter is more influential on muscle activity production than the mass of the instrument. Large diameter instruments had the most reduction in muscle activity production for the four muscles utilized during instrumentation. The mass of the instrument did not have a significant impact on muscle activity production. Participants in this study preferred the larger diameter instrument groups as indicated on end user survey results. Future studies should utilize this information and incorporate pinch force generation of the thumb and index finger to further quantify CTD risk.

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REFERENCES

1. Hayes MJ, Smith DR, Cockrell D. Prevalence and correlates of musculoskeletal disorders among Australian dental hygiene students. Int J Dent Hyg. 2009 Aug;7(3):176-81.
2. Hayes MJ, Taylor JA, Smith DR. Predictors of work-related musculoskeletal disorders among dental hygienists. Int J Dent Hygiene. 2012 Nov;10(4):265-69.
3. Vidal, HF, Soriano EP, Caldas AF, et al. Cumulative trauma disorders among dentists. J Musculoskelet Pain. 2014 Feb;22(2):193-98.
4. Morse T, Bruneau H, Michalak-Turcotte C, et al. Musculo-skeletal disorders of the neck and shoulder in dental hygienists and dental hygiene students. J Dent Hyg. 2007 Winter;81(1):10.
5. Carvalho MVD, Soriano EP, Caldas A, et al. Work-related musculoskeletal disorders among brazilian dental students. I Dent Educ. 2009 May;73(5):624-30.
6. Hayes M, Smith D, Taylor J. Musculoskeletal disorders in a 3 year longitudinal cohort of dental hygiene students. J Dent Hyg. 2014 Feb;88(1):36-41.
7. Simmer-Beck M, Branson B. An evidence-based review of ergonomic features of dental hygiene instruments. Work. 2010;35(4):477-85.
8. Hayes M, Cockrell D, Smith DR. A systematic review of musculoskeletal disorders among dental professionals. Int J Dent Hyg. 2009 Aug;7(3):159-65.
9. Hayes MJ, Smith DR, Cockrell D. An international review of musculoskeletal disorders in the dental hygiene profession. Int Dent J. 2010 Oct;60(5):343-52.
10. Morse T, Bruneau H, Dussetschleger J. Musculoskeletal disorders of the neck and shoulder in the dental professions. Work. 2010;35(4):419-29.
11. Kierklo A, Kobus A, Jaworska M, Botulinksi B. Work-related musculoskeletal disorders among dentists-a questionnaire survey. Ann Agric Environ Med. 2011;18:79-84.
12. Barry RM, Spolarich AE, Weber M, et al. Impact of operator positioning on musculoskeletal disorders and work habits among Mississippi dental hygienists. J Dent Hyg. 2017 Dec;91(6):6-14.
13. Crawford L, Gutierrez G, Harber P. Work environment and occupational health of dental hygienists: a qualitative assessment. J Occup Environ Med. 2005 Jun;47(6):623-32.
14. Dong H, Loomer P, Barr A, et al. The effect of tool handle shape on hand muscle load and pinch force in a simulated dental scaling task. Appl Ergon. 2007 Sep;38(5):525-31.

15. Dong H, Barr A, Loomer P, et al. The effects of periodontal instrument handle design on hand muscle load and pinch force. J Am Dent Assoc. 2006 Aug;137(8):1123-30.

16. Rempel D, Lee D, Dawson K, Loomer P. The effects of periodontal curette handle mass and diameter on arm pain. J Am Dent Assoc. 2012 Oct;143(10):1105-13.

17. Suedbeck J, Tolle SL, McCombs G, et al. Effects of instrument handle design on dental hygienists' forearm muscle activity during scaling. J Dent Hyg. 2017 Jun;91(3):47-54.

18. Centers for Disease Control and Prevention. National occupational research agenda: National occupational research agenda for musculoskeletal health [Internet]. Atlanta (GA): Centers for Disease Control and Prevention; 2018 Oct 25 [cited 2023 Jan 15]. Available from: https://www.cdc.gov/nora/councils/mus/researchagenda.html

19. Dong H, Loomer P, Villanueva A, Rempel D. Pinch forces and instrument tip forces during periodontal scaling. J Periodontol. 2007 Jan;78(1):97-103.

20. Villanueva A, Dong H, Rempel D. A biomechanical analysis of applied pinch force during periodontal scaling. J Biomech. 2007 Sept; 40(9):1910-15.

21. Atroshi I, Gummesson C, Johnsson R, et al. Relevance of carpal tunnel syndrome in a general population. J Am Med Assoc. 1999 Jul;282(2):153-58.

22. Byström S, Fransson-Hall C. Acceptability of intermittent handgrip contractions based on physiological response. Hum Factors. 1994 Mar;36(1):158-71.

23. Jarvik JG, Yuen E, Kliot M. Diagnosis of carpal tunnel syndrome: Electrodiagnostic and MR imaging evaluation. Neuroimaging Clin N Am. 2004 Feb;14(1):93-102.

24. Burden A, Bartlett R. Normalisation of EMG amplitude: An evaluation and comparison of old and new methods. Med Eng Phys. 1999 May;21(4):247-57.

26. Bolgla LA, Uhl TL. Reliability of electromyographic normalization methods for evaluating the hip musculature. J Electromyogr Kinesiol 2007;17:102-11.

27. Netto KJ, Burnett AF. Reliability of normalisation methods for EMG analysis of neck muscles. Work. 2006;26(2):123-30.

28. Heck RH, Thomas SL, Tabata L. Multilevel and longitudinal analysis using SPSS. In. New York: Routledge/Taylor & Francis. 2010. 494 p.

Figure SI. Instrument Characteristics and Groups

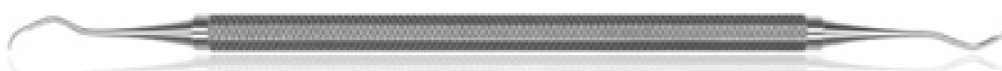
	Instrument	Mass (g)	Diameter (mm)	Group
1A	American Eagle EagleLite Resin	10	10	A: Light mass, large diameter
				
2A	Paradise Dental Technology	15	10	A: Light mass, large diameter
				
3A	Premier Air	15	11.7	A: Light mass, large diameter
				
4A	Premier Big Easy Ultralite	15	12	A: Light mass, large diameter
				
1B	Hu Friedy #2 Octagonal	18.4	6.35	B: Light mass, small diameter
				
2B	Hu Friedy #8 Resin	18.4	9.5	B: Light mass, small diameter
				
1C	American Eagle Stainless Steel	25	10	C: Heavy mass, large diameter
				
2C	Premier Big Easy	25	11	C: Heavy mass, large diameter
				
1D	Premier Light Touch	20	8	D: Heavy mass, small diameter
				
2D	Hu Friedy #6 Stainless Steel	20.8	9.5	D: Heavy mass, small diameter
				

Table SI. Frequency of Responses to End-User Perception Survey Likert Scale

	1 (Not comfortable at all/poor)	2	3 (Neutral)	4	5	6 (Very comfortable/ excellent)
Instrument Group A: Large diameter, light mass						
Comfort provided by diameter	0	1	2	1	9	12
Balance	0	0	0	9	8	8
Maneuver-ability	0	1	3	5	8	8
Comfort provided by mass	1	0	0	2	9	13
Overall comfort	0	1	3	4	6	11
Instrument Group B: Small diameter, light mass						
Comfort provided by diameter	8	3	3	1	3	7
Balance	4	1	6	4	3	7
Maneuver-ability	6	2	3	4	4	6
Comfort provided by mass	4	5	3	4	4	5
Overall comfort	6	3	3	4	4	5
Instrument Group C: Large diameter, heavy mass						
Comfort provided by diameter	0	0	2	4	5	14
Balance	2	1	3	3	7	9
Maneuver-ability	0	0	5	2	13	5
Comfort provided by mass	3	3	3	5	7	4
Overall comfort	0	1	4	6	7	7
Instrument Group D: Small diameter, heavy mass						
Comfort provided by diameter	2	6	2	3	8	4
Balance	0	4	5	4	9	3
Maneuver-ability	0	3	5	5	7	5
Comfort provided by mass	1	3	5	4	9	3
Overall comfort	2	4	4	3	9	3