

# The Effects of Finger Rest Positions on Hand Muscle Load and Pinch Force in Simulated Dental Hygiene Work

Hui Dong, D.D.S., M.P.H.; Alan Barr, M.S.; Peter Loomer, D.D.S., Ph.D.; David Rempel, M.D., M.P.H.

*Abstract:* One of the techniques taught in dental and dental hygiene programs is to use finger rests to stabilize the instrument while performing dental scaling or other types of dental work. It is believed that finger rests may also reduce muscle stress and prevent injury due to muscle fatigue. In this study the effects of three different finger rest positions on hand muscle activity and thumb pinch force were compared. Twelve pre-dental students performed simulated dental scaling tasks on a manikin using three different finger rest positions: 1) no finger rest, 2) one finger rest, and 3) two finger rests. Muscle activity and thumb pinch force were measured by surface electromyography and a pressure sensor, respectively. Using two finger rests was always associated with reduced thumb pinch force and muscle activity, as compared to not using any finger rests ( $p < 0.05$ ), while using one finger rest reduced thumb pinch force and muscle activity in most cases. Hence, using finger rests plays an important role in reducing the muscle load of the hand in students performing simulated dental hygiene work. It is concluded that dental and dental hygiene students may benefit from instructions for using finger rests at an early stage of their clinical training. Including biomechanical and ergonomic principles in dental and dental hygiene curricula will raise awareness of ergonomics among dental practitioners and help them incorporate these principles into daily practice.

Dr. Dong is Doctoral Student, School of Dentistry, University of California, San Francisco and School of Public Health, University of California, Berkeley; Mr. Barr is Engineer, Ergonomics Program, Department of Medicine, University of California, San Francisco; Dr. Loomer is Professor, School of Dentistry, University of California, San Francisco; and Dr. Rempel is Professor and Director, Ergonomics Program, Department of Medicine, University of California, San Francisco. Direct correspondence and requests for reprints to Dr. David Rempel, University of California, San Francisco, 1301 South 46<sup>th</sup> Street, Bldg. 163, Richmond, CA 94804; 510-231-5721 phone; 510-231-5729 fax; drempel@itsa.ucsf.edu.

This publication was supported in part by Grant T43/CCT 918726 from the Centers for Disease Control/National Institute for Occupational Safety and Health.

*Key words:* dentistry, training, scaling, hand, ergonomics, electromyography, force, biomechanics

*Submitted for publication 12/5/04; accepted 2/7/05*

Dentists and dental hygienists have been reported to have an increased prevalence of upper-extremity musculoskeletal disorders, including carpal tunnel syndrome.<sup>1-3</sup> A 1997 survey by the American Dental Association<sup>4</sup> reported that 9.2 percent of dentists had been diagnosed by a physician as having a repetitive motion disorder; among them, approximately 19 percent required surgery and more than 40 percent reduced their work hours. A UK survey conducted between 1981 and 1992 also indicated that premature retirement among 29.5 percent of dentists was due to musculoskeletal disorders.<sup>5</sup>

In 1997 and 1998 the American Dental Association's Annual Health Screening Program evaluated 1,079 dentists with a symptom questionnaire and standard electrodiagnostic study of the median nerve in the dominant hand.<sup>6</sup> Of those dentists screened, 13 percent were diagnosed with a

median mononeuropathy, and 32 percent of the diagnosed individuals had symptoms consistent with carpal tunnel syndrome. The prevalence of carpal tunnel syndrome among dentists was significantly higher than that among the general population.<sup>7</sup>

The risk factors associated with carpal tunnel syndrome and other hand disorders include repetitive hand motions, forceful pinching or gripping, sustained awkward wrist postures, and vibration.<sup>8</sup> Most of these risk factors are present in dental practice: holding dental instruments may require a high level of pinch force, and the wrists may be held in awkward positions for prolonged periods. Scaling and root planing pose a high ergonomic risk for both dentists and dental hygienists. A small cohort study<sup>9</sup> measured muscle activity of the flexor carpi radialis, brachioradialis, and extensor carpi radialis with surface electromyography during the daily work of dental hygienists and found that the average muscle

activity during dental scaling was 15 to 18 percent of the maximum voluntary contraction. Another study compared three categories of dental workers, including dentists, dental hygienists, and dental assistants, and found that dental hygienists were at the greatest risk for developing upper extremity symptoms and carpal tunnel syndrome, due to their higher number of hours performing dental scaling and root planing, as compared to the other two groups.<sup>10</sup>

Recently, there have been considerable technological advances in dental equipment that make dental practice easier. For example, using an ultrasonic dental scaler may reduce the pinch force required to perform scaling and root planing. There is some controversy about whether or not hand instruments are more efficient for scaling root surfaces and furcation areas.<sup>11-13</sup> However, it is not always appropriate or acceptable to the patients to use ultrasonic scalers, and potential occupational hazards, such as vibration, have yet to be investigated. In a review article,<sup>14</sup> Rucker concludes that the introduction of modern technology into dentistry has often been piecemeal and “rushed to market.” As a result, there has not been a systematic approach to evaluating the usability and ergonomics of new dental equipment and practices.

Since performing scaling and root planing with nonpowered hand instruments may involve high muscle loads, it is essential to develop techniques to prevent musculoskeletal injuries early in the career of the dental practitioner. During the past decade, dental schools have included some didactic training on biomechanics and occupational health.<sup>15</sup> However, data from an unpublished survey conducted by the American Dental Association revealed that 62 percent of the dentists in private practice considered the ergonomic training they had received in dental school to be inadequate.<sup>16</sup> Thornton et al. provided recommendations for developing an ergonomics awareness program in the dental school curriculum so that students would be able to apply biomechanical principles at the clinical level.<sup>17</sup>

One of the techniques taught in dental and dental hygiene programs is using finger rests to stabilize the instrument while performing dental scaling or other types of work. The purpose of this technique is to improve the precision of the work, to prevent sudden movements, and to reduce the muscle stress of the operator. However, no quantitative analysis has been performed to support the argument that this technique has a beneficial effect of reducing hand or

forearm muscle load during dental hygiene work. The purpose of this study was to compare the effects of three different finger rest positions on muscle load and pinch force during simulated dental hygiene work.

---

## Materials and Methods

### Subject Selection

Twelve subjects (five males and seven females) were recruited from among student volunteers at a community dental clinic. All the subjects were undergraduate students planning to apply to dental schools. The average age of the subjects was 23.2 ( $\pm 3.4$ ) years. The subjects had all been exposed to the concept and practice of dental hygiene work and dental ergonomics, but none had experience in performing dental scaling.

This sample size is based on previous studies of intensive hand tasks in which EMG measures were a primary outcome with a D of 10%MVC and an S of 5%MVC.<sup>18</sup> The sample size necessary for three conditions with a D/S ratio of 2, power of 90 percent and 95 percent confidence is twelve subjects.

Inexperienced subjects were selected because the concept and practice of using finger rests are normally taught early during the dental or dental hygiene curriculum, before students gain much clinical experience. The purpose was to assess how dental or dental hygiene students would benefit from ergonomic instructions at an early stage of clinical training.

Individuals with recent hand or wrist injuries, previous surgeries in the hand or wrist areas, or physician-diagnosed, upper-extremity musculoskeletal disorders were excluded from the study, as were those with a dominant left hand. The protocol for the study was reviewed and approved by the Committee of Human Research (CHR) at the University of California, San Francisco.

### Simulated Dental Hygiene Tasks

Simulated periodontal scaling procedures have been used for teaching and research purposes. Normally, extracted or artificial teeth are placed in a typodont, which is an artificial jaw fastened onto a manikin in order to simulate clinical situations. Plaque and calculus deposits are simulated by vari-

ous paints and mixtures.<sup>11,19-22</sup> The productivity of the scaling procedures can be measured by using a grading system with scores anchored by illustrated and described criteria<sup>19</sup> or by projecting the root surfaces with a video camera onto the monitor of an image analyzer and calculating the percentage of the paint area that has been instrumented during the scaling procedures.<sup>21,22</sup>

In this study, the subjects performed simulated periodontal scaling tasks on typodont teeth, using the instrument designed for the study. The typodont was fitted into a manikin head (both were made by Columbia Dental Corp., New York, NY, USA), which was positioned to simulate a real clinical situation (Figure 1).

The teeth used in the study were plastic maxillary left second premolars (number 13), which were secured to the typodont with screws. The teeth were painted on the same area of the cervical portion with nail polish to simulate plaque and calculus deposits. The painted area included the surface between the facial midline and the distal contact, apical to the contact area and coronal to the gingiva. To standardize the painting process, a paint mask was placed over the tooth before it was painted. To simplify the scaling procedures, subgingival scaling was not considered in the study, and paint was not applied below the gingiva.

A posterior scaler (SN135, Hu-Friedy, Inc., USA) was used throughout the experiment. The instrument was sharpened with a sharpening stone before each scaling task and tested on the same type of plastic teeth used for data collection.

## Electromyography

Surface bipolar electromyography (EMG) recordings were used to measure muscle activity during the dental scaling tasks. EMG signals were obtained using circular Ag/AgCl electrodes with an active diameter of 8 mm and a center-to-center distance of 21 mm. The EMG signals were amplified with preamplifiers and an adjustable-gain amplifier. The amplifier produced the root mean square (RMS)



**Figure 1.** Typodont and manikin used to simulate dental scaling

of the EMG signal using a 55ms time constant (Therapeutics Unlimited, Iowa City, IA, USA). Data were collected at 100Hz using LabView software (National Instruments Corp., Austin, TX, USA) through a National Instruments data acquisition card on a Windows-based notebook computer.

Sites on the right forearm for the placement of the electrodes were localized using recommended anatomical placement.<sup>23</sup> Four extrinsic hand muscles that experience high loads during a sustained pinch were studied: the flexor digitorum superficialis (FDS), the flexor pollicis longus (FPL), the extensor digitorum communis (EDC), and extensor carpi radialis (ECR). A ground electrode was placed over the lateral epicondyle. The skin was shaved (if necessary), abraded, and cleaned with an alcohol pad prior to placement of the electrodes.

Prior to performing the dental scaling tasks, maximum voluntary contractions (MVCs) of the four muscles were recorded in two postures: 1) the typical pinch and wrist posture used during scaling, and 2) a wrist extension posture with all fingers, except the thumb, performing a maximum resisted finger extension. Subjects performed the contraction for three to five seconds and repeated each MVC maneuver three times. The MVCs for the muscles FDS and FPL were calculated from the EMG signals re-

corded in the pinch posture, while the MVCs for EDC and ECR were calculated from the wrist extension posture. The MVC was selected as the highest value of a one-second moving average of the RMS EMG signal across a trial. The average of three trials was used to represent the MVC of each muscle. Subsequently obtained EMG signals were normalized as a percentage of the MVCs.

## Thumb Pinch Force Measurement

In addition to EMG data collection, a ConTacts pressure sensor (Pressure Profile Systems, Inc., Los Angeles, CA, USA) was attached to the handle surface of the dental scaling instrument (Figure 2) to measure thumb pinch force. The thin sensor (0.58mm) covered approximately one-fourth of the circumference of the instrument and extended 29mm along the distal aspect of the instrument surface. The lead from the instrument to the amplifier was very thin and applied no significant torque to the tool. Subjects were instructed to place the thumb directly onto the sensor pad throughout the experiment. The sensor measures total integrated pressure, i.e., force generated within a surface. Using an independent, high accuracy six-axis load cell (resolution 0.1N; ATT Industrial Automaton, Apex, North Carolina, USA), a second-order calibration equation was developed to convert the sensor voltages into Newtons. The estimated pinch force error due to the regional sensitivity of the sensor was  $\pm 4.9$  percent.

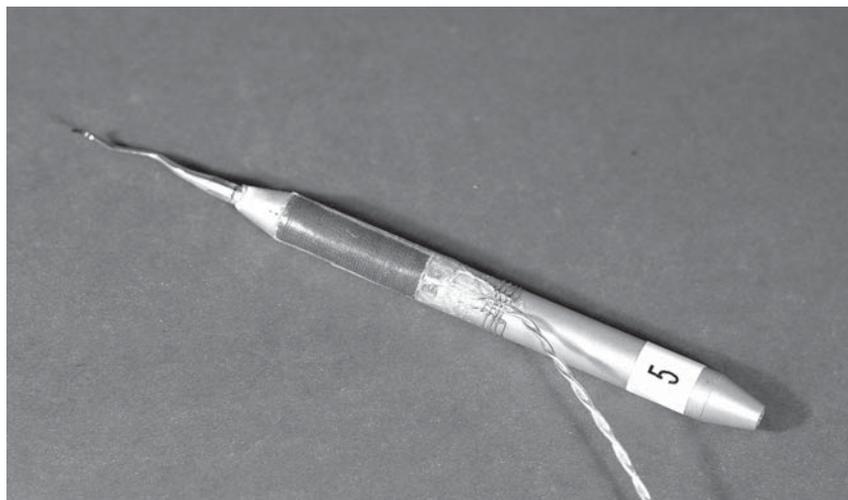


Figure 2. Pressure sensor attached to the surface of the tool handle

## Data Collection Sessions and Analysis

At the beginning of each experimental session, the subject was given brief instructions on dental scaling procedures. The instructions included patient positioning, orientation of the instrument, and motions of scaling/root planing. He or she was instructed to perform the scaling procedures as if working on a real patient (i.e., applying enough force to remove simulated plaque and calculus deposits without damaging the tooth structure), to adopt a consistent working pattern, and to make an effort to scale off all the nail polish in a timely manner. The subject was taught to use tripod grasp to hold the instrument, and the three types of finger rest positions (no finger rest, F0; one finger rest, F1; and two finger rests, F2; see Figure 3) were demonstrated. The subject practiced scaling with the finger rest positions for approximately fifteen minutes, until he or she was comfortable performing the scaling tasks.

The surface electrodes were then placed on the forearms of the subject, and MVCs were recorded. The order of the three finger rest positions was randomized to control for potential sequence effect. The subject was allowed two minutes to complete a scaling task with each type of finger rest position, and five minutes was allowed for rest between the tasks.

For each scaling task, a representative sixty-second window of data was used to calculate the amplitude probability distribution function (APDF) values of the EMG RMS signals for each muscle at the 10 percent, 50 percent, and 90 percent levels; these levels represent the static, median, and peak muscle activities, respectively.<sup>24</sup> The APDF values were also calculated for the pinch force data.

Statistical analysis was performed with SAS System for Windows V8 software (Cary, NC, USA). ANOVA with repeated measures was used to compare the EMG and pinch force values in the three different finger positions. If significant ( $p < 0.05$ ), a follow-up Tukey test was performed to evaluate pair-wise differences.

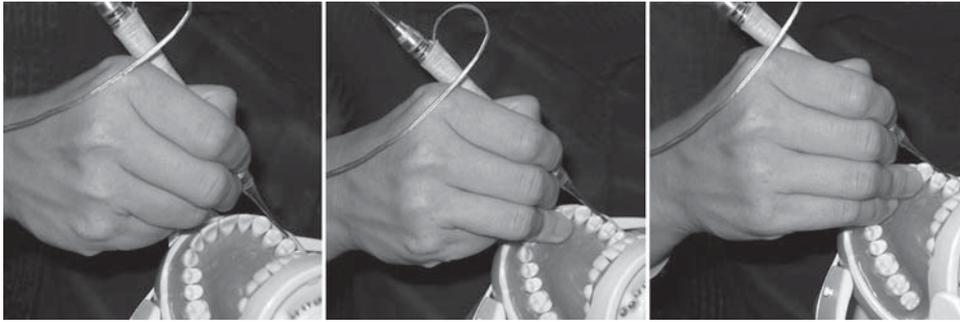


Figure 3. The three finger rest positions: no finger rest (F0, left); one finger rest (F1, middle); two finger rests (F2, right)

## Results

Figure 4 demonstrates typical EMG-RMS and force recordings while a subject performed a scaling task. In this subject, pinch force fluctuates between 5 and 18 N, and each fluctuation corresponds to a stroke of the scaling motion. The fluctuations in EMG also roughly correlate with the strokes of the scaling motion.

Summary measures of muscle activity for the three scaling tasks (F0, F1, and F2) are presented in

Figure 5; thumb pinch force values are presented in Figure 6. In both figures, the error bars represent the standard deviations among the twelve subjects.

Repeated measures ANOVA was used to test the effect of finger rest positions (F0, F1, and F2) on muscle activity and pinch force for each of the three methods of summarizing the data (APDF 10, 50, and 90 percent). All fifteen repeated measures ANOVA analyses were significant (Table 1); therefore, the Tukey follow-up test was performed. Significant pairwise comparisons are identified in Table 1 with a '+'. All differences between F0 and F2 were statisti-

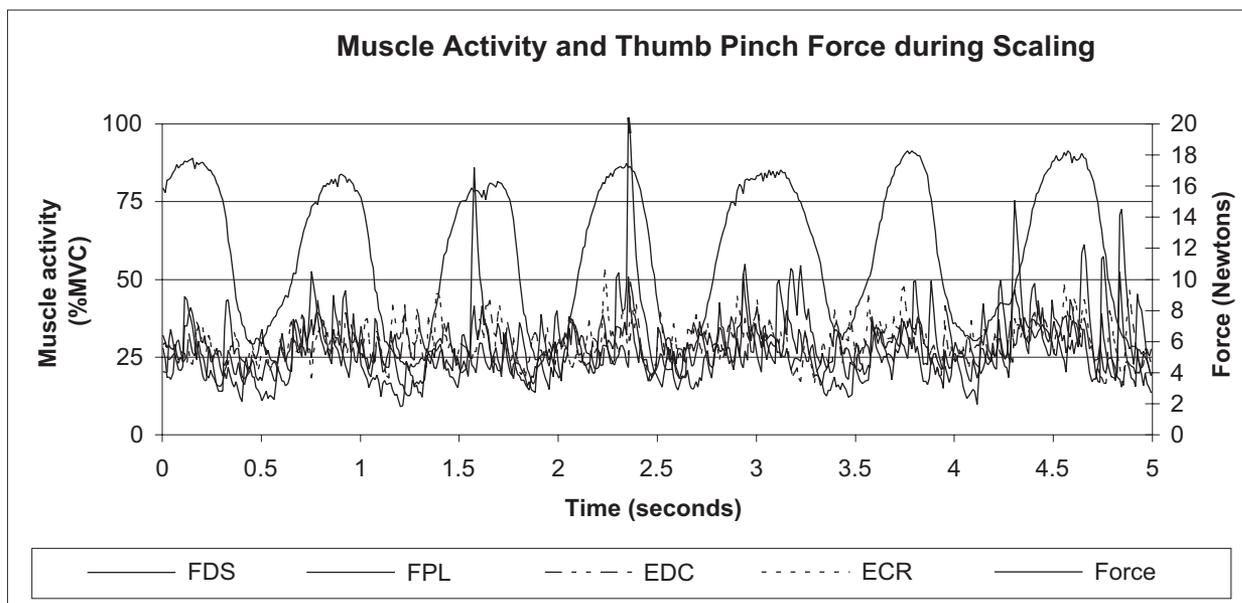


Figure 4. Typical muscle activity and thumb pinch force recorded while a subject performed a scaling task

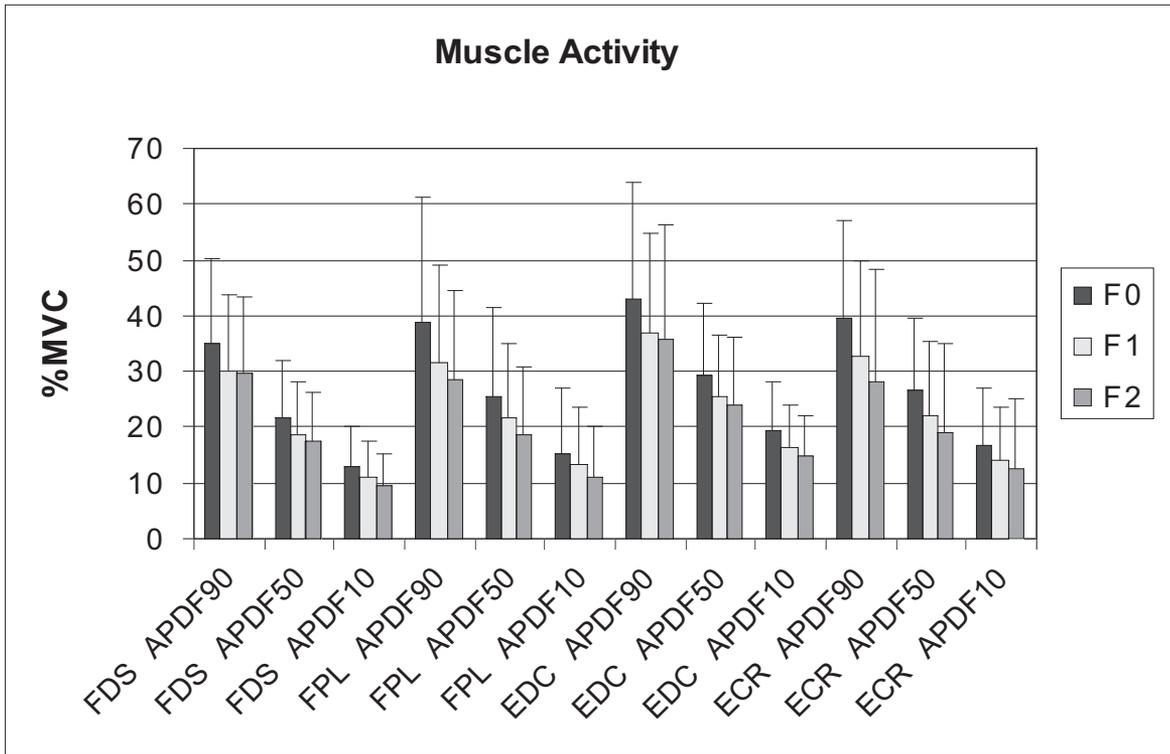


Figure 5. Summary measures of EMG values across the three scaling tasks (F0=no finger rest; F1=one finger rest, and F2=two finger rests). Mean  $\pm$ SD values of APDF 10, 50, and 90 percent are presented for the four muscles: FDS, FPL, EDC, and ECR (N=12).

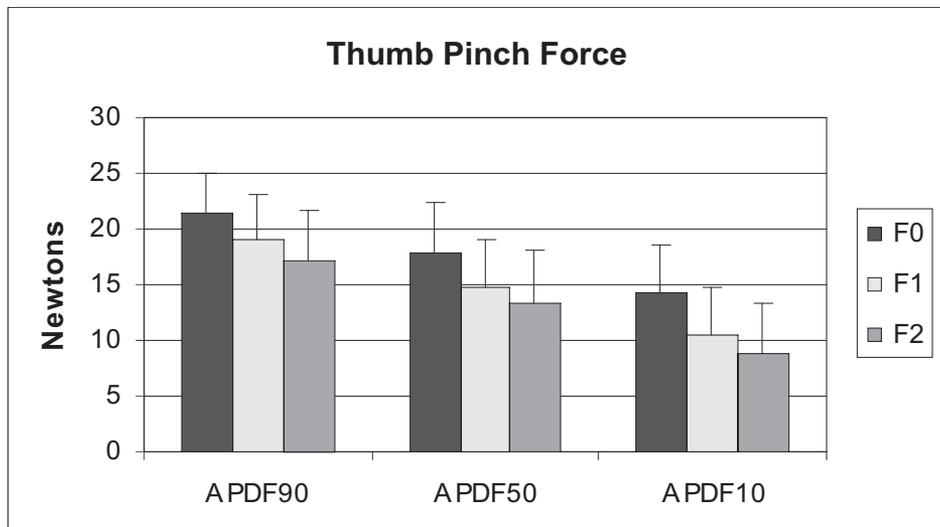


Figure 6. Mean thumb pinch force ( $\pm$ SD) across the three finger rest positions (F0, F1, and F2). Peak forces are represented as APDF 90 percent, while median forces are APDF 50 percent, and static forces are APDF 10 percent (N=9).

cally significant. Differences between F1 and F2 were not statistically significant. Differences between F0 and F1 were statistically significant in most cases.

## Discussion

Although the primary purpose of finger stabilization during scaling is to improve the precision of scaling, this study demonstrates that finger stabilization also reduces hand muscle activity and pinch force. The results show that using two finger rests (F2) was always associated with reduced thumb pinch force and muscle activity, as compared to not using finger rests (F0). Using one finger rest (F1) reduced thumb pinch force and muscle activity in most cases. Interestingly, there were no differences in pinch force or muscle loading between using one finger rest and two finger rests.

Inexperienced subjects were selected because the concept and practice of using finger rests are normally taught early during the dental or dental hygiene curriculum before students gain much clinical experience. It takes time and practice to master this technique and incorporate it into daily work. The results show that subjects who had no previous experience in dental scaling benefited from a one-time instruction on finger rest techniques. Hence, dental or dental hygiene students would benefit ergonomically from the instructions at an early stage of clinical training. It is likely that experienced practitioners would similarly benefit from the use of finger rests, but that was not specifically tested in this study.

In practice, tripod grasp is commonly used by dentists and dental hygienists to handle instruments, although some practitioners may prefer other grasping techniques on certain occasions. Sometimes finger rests have to be placed in alternative locations, cross arch or in the opposite arch, depending on the oral conditions of the patient (e.g., missing teeth or inability to open very far). Although we specified tripod grasp to be used in the study and selected sites for finger rests on the same arch, it is likely that the results can be generalized

to include other grasping techniques and finger rest locations.

An easily accessible site in the mouth was selected for the subjects to perform the scaling tasks. Scaling on the distal-facial surface of tooth number 13 does not generally involve excessive bending of the wrist. In addition, subgingival scaling was not considered in the study; therefore, the motions did not involve deflection of the gingiva.

A potential limitation of using surface EMG to represent muscle activity is crosstalk. Because the muscles in the forearm are small and in close proximity to each other, it is difficult to isolate the activity of a single muscle using surface EMG. The extensors EDC and ECR are next to each other, and their activities can not be separated distinctly with surface EMG. Inter-muscle comparisons were not considered in the study because of crosstalk and because the EMG signals depend on the placement of the electrodes and the depths of the muscles, which vary from muscle to muscle.

Another limitation of the study was that productivity was not assessed. The subjects were instructed to make an effort to scale off all the nail polish in a timely manner and were given a time limit of two minutes, which would be sufficient for most inexperienced practitioners to complete each task. However, whether the subjects actually scaled off all the nail polish was not measured. In addition, some subjects used excessive forces that might have dam-

**Table 1. Results of significance testing of the effect of finger rest positions on each outcome measure. The second column is the repeated measures ANOVA, which was significant for all outcome measures. Columns 3, 4, and 5 present the pairwise comparisons using the Tukey method (“+” if  $p < 0.05$ , “-” if  $p > 0.05$ ).**

	APDF	RMANOVA	F0 vs F1	F0 vs F2	F1 vs F2
FDS	APDF90	+	+	+	-
	APDF50	+	+	+	-
	APDF10	+	-	+	-
FPL	APDF90	+	+	+	-
	APDF50	+	-	+	-
	APDF10	+	-	+	-
EDC	APDF90	+	+	+	-
	APDF50	+	+	+	-
	APDF10	+	+	+	-
ECR	APDF90	+	-	+	-
	APDF50	+	-	+	-
	APDF10	+	-	+	-
Thumb pinch force	APDF90	+	+	+	-
	APDF50	+	+	+	-
	APDF10	+	+	+	-

aged the tooth structure, despite the warning that they should perform the scaling procedures as if working on a real patient. These limitations were related to using inexperienced operators as subjects.

---

## Conclusions

Finger rests can play an important role in reducing pinch force and hand and forearm muscle activity during dental hygiene work. Dental and dental hygiene students may benefit from instructions on using finger rests at an early stage of training. Including biomechanical and ergonomic principles in dental and dental hygiene curricula will raise awareness of ergonomic principles among dental practitioners and help them incorporate these principles into daily practice.

---

## REFERENCES

1. Corks I. Occupational health hazards in dentistry: musculoskeletal disorders. *Ont Dent* 1997;74(6):27-30.
2. Fish DR, Morris-Allen DM. Musculoskeletal disorders in dentists. *N Y State Dent J* 1998;64(4):44-8.
3. Guay AH. Commentary: ergonomically related disorders in dental practice. *J Am Dent Assoc* 1998;129(2):184-6.
4. 1997 survey of current issues in dentistry: repetitive motion injuries. Chicago: American Dental Association, 1997:2-8.
5. Burke FJ, Main JR, Freeman R. The practice of dentistry: an assessment of reasons for premature retirement. *Br Dent J* 1997;182(7):250-4.
6. Hamann C, Werner RA, Franzblau A, Rodgers PA, Siew C, Gruninger S. Prevalence of carpal tunnel syndrome and median mononeuropathy among dentists. *J Am Dent Assoc* 2001;132(2):163-70; quiz 223-4.
7. Atroshi I, Gummesson C, Johnsson R, Ornstein E, Ranstam J, Rosen I. Prevalence of carpal tunnel syndrome in a general population. *JAMA* 1999;282(2):153-8.
8. Bernard BP. Musculoskeletal disorders and workplace factors. Cincinnati, OH: National Institute for Occupational Safety and Health, 1997.
9. Bramson JB, Smith S, Romagnoli G. Evaluating dental office ergonomic: risk factors and hazards. *J Am Dent Assoc* 1998;129(2):174-83.
10. Rice VJ, Nindl B, Pentikis JS. Dental workers, musculoskeletal cumulative trauma, and carpal tunnel syndrome: who is at risk? a pilot study. *Int J Occup Saf Ergon* 1996;2(3):218-33.
11. Kocher T, Ruhling A, Momsen H, Plagmann HC. Effectiveness of subgingival instrumentation with power-driven instruments in the hands of experienced and inexperienced operators: a study on manikins. *J Clin Periodontol* 1997;24(7):498-504.
12. Otero-Cagide FJ, Long BA. Comparative in vitro effectiveness of closed root debridement with fine instruments on specific areas of mandibular first molar furcations. I. Root trunk and furcation entrance. *J Periodontol* 1997;68(11):1093-7.
13. Drisko CL, Cochran DL, Blieden T, et al. Position paper: sonic and ultrasonic scalers in periodontics. Research, Science, and Therapy Committee of the American Academy of Periodontology. *J Periodontol* 2000;71(11):1792-801.
14. Rucker LM. Technology meets ergonomics in the dental clinic: new toys for old games? *J Am Coll Dent* 2000;67(2):26-9.
15. Sturdevant CM, Roberson TM, Hermann HO, Sturdevant JR. Preliminary considerations for operative dentistry: the art and science of operative dentistry. St. Louis, MO: Mosby, 1995.
16. Murphy DC, Guay AH. The American Dental Association and dental ergonomics: research, observations and activities. In: Murphy DC, ed. *Ergonomics and the dental care worker*. Washington, DC: United Book Press, 1998.
17. Thornton LJ, Stuart-Buttle C, Wyszynski TC, Wilson ER. Physical and psychosocial stress exposures in US dental schools: the need for expanded ergonomics training. *Appl Ergon* 2004;35(2):153-7.
18. Martin BJ, et al. Keyboard reaction force and finger flexor electromyograms during computer keyboard work. *Hum Factors* 1996;38(4):654-64.
19. Lie T, Hoff I, Gjerdet NR. Computerized evaluation of the effectiveness of subgingival scaling in jaw models: an introduction to the program developed at the School of Dentistry, University of Bergen. *J Clin Periodontol* 1987;14(3):149-55.
20. Takacs VJ, Lie T, Perala DG, Adams DF. Efficacy of five machining instruments in scaling of molar furcations. *J Periodontol* 1993;64(3):228-36.
21. Kocher T, Gutsche C, Plagmann HC. Instrumentation of furcation with modified sonic scaler inserts: study on manikins, part I. *J Clin Periodontol* 1998;25(5):388-93.
22. Kocher T, Tersic-Orth B, Plagmann HC. Instrumentation of furcation with modified sonic scaler inserts: a study on manikins (II). *J Clin Periodontol* 1998;25(6):451-6.
23. Delagi EF, Perotto A, Iazzetti J, Morrison D. *Anatomic guide for the electromyographer*. 2nd ed. Springfield, IL: Charles C. Thomas, 1981.
24. Jonsson B. Measurement and evaluation of local muscular strain in the shoulder during constrained work. *J Hum Ergol (Tokyo)* 1982;11(1):73-88.