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The effects of periodontal curette handle weight and diameter on arm pain

A four–month randomized controlled trial

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ABSTRACT

Background. The design of periodontal curette handles may cause or aggravate arm pain in dental practitioners. The authors conducted a four-month randomized controlled trial to evaluate the effects of curette handle diameter and weight on arm pain among dental hygienists and dentists.

Methods. One hundred ten dental hygienists and dentists who performed scaling, root planing or dental prophylaxis procedures participated in this study. The authors assessed right wrist/hand, elbow/forearm and shoulder pain levels weekly. They randomized participants to receive either a set of light (14 grams) periodontal curettes with a large diameter (11 millimeters) or a set of heavy (34 g) periodontal curettes with a narrow diameter (8 mm). The authors compared changes in mean pain scores across the study period between intervention groups by using general linear models and controlling for covariates.

Results. The improvement in pain scores across the three body regions was greater for participants who used the lighter, wider-diameter curettes. In the final adjusted model, the differences were statistically significant only for the shoulder region ($P = .02$).

Conclusions. The study results show that dental instrument design has an effect on upper-extremity pain in dental practitioners. Using a lighter instrument with a wider diameter may be an easy and cost-effective intervention to reduce or prevent upper-extremity pain associated with dental hygiene procedures.

Clinical implications. To prevent or reduce arm pain, practitioners should consider using lightweight instruments with large diameters when performing scaling and root planing procedures.

Key Words. Musculoskeletal disorders; pain; ergonomics; shoulder; dental instrument design; occupational; intervention; periodontitis.

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Work disability and decreased productivity due to musculoskeletal disorders of the hands and arms are common problems among dentists and dental hygienists.[1-11] A survey conducted by the American Dental Association[12] showed that 9.2 percent of 2,983 responding dentists had received diagnoses of upper-extremity musculoskeletal disorders; of these, approximately 20 percent required surgery and more than 40 percent reduced their work hours. A survey of dentists in the United Kingdom found that 29.5 percent of premature retirements were the result of similar problems.[13]

Pain in the right wrist, elbow and shoulder appears to be the problem that most interferes with dental procedures. The prevalence of right arm symptoms among dentists and dental hygienists ranges from 19 to 61 percent.[9,14,15] Carpal tunnel syndrome, one of the more disabling disorders that affects the hand, is more common among dental practitioners than it is among people in most other occupations.[16]

Carpal tunnel syndrome and other hand and arm disorders are associated with factors both personal (for example, female sex, obesity, diabetes, age) and workplace-related (for example, repetitive forceful

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TABLE 1

Demographic and preintervention characteristics of study participants (N = 110).

CHARACTERISTIC	NO. OF PARTICIPANTS*	
	Heavy Instrument, Narrow Handle (n = 56)	Light Instrument, Wide Handle (n = 54)
Mean (SD†) Age, Years	42.9 (10.8)	46.6 (9.8)
Sex		
Female	49	51
Male	7	3
Occupation		
Dentist	6	7
Dental hygienist	50	47
Years in Practice		
1-5	16	7
> 5	40	47
Dental Scaling/Root Planing per Week, Hours		
< 20	14	14
20-30	19	20
> 30	23	20
Mean (SD) Percentage of Time Using Hand Scaler	62.5 (18.9)	65.7 (23.4)
Mean (SD) Percentage of Time Using Ultrasonic Scaler	39.8 (20.6)	37.5 (24.2)
Mean (SD) No. of Days per Week Performing Dental Procedures	3.7 (0.9)	3.6 (1.1)
Mean (SD) No. of Hours per Day Performing Dental Procedures	7.9 (0.7)	7.9 (0.8)
Mean (SD) No. of Patients Treated in Eight-Hour Period	7.8 (1.8)	8.3 (1.2)
Second Dental Job	12	14
Physician-Diagnosed Upper-Extremity Disorder‡	8	10

* Unless otherwise specified.
† SD: Standard deviation.
‡ Wrist tendonitis, carpal tunnel syndrome, Raynaud disease, epicondylitis, rotator cuff injury or cervical radiculopathy. Participants were not being treated for these conditions at the time of the study.
§ 0 indicates no pain and 10, unbearable pain.
¶ Calculated from reported hours performing scaling or root planing on a weekly questionnaire during the four-week preintervention period.

pinching or gripping, sustained nonneutral wrist positions and use of vibrating tools).[9,17-19] For dental practitioners, periodontal scaling and root planing may pose the most important risk.[20,21] The results of a study of pinch force in a clinical setting show that dentists applied repeated mean (standard deviation [SD]) peak pinch forces of 24.5 (4.1) newtons during periodontal scaling and root planing procedures.[22] This may be a primary cause of hand and arm disorders and pain. In studies of industrial workers, investigators have found that repeated pinch forces of more than 10 N (1 kilogram of force) were associated with an increased risk of experiencing wrist, elbow and shoulder disorders.[19,23-25]

Modifications to work practices that reduce the applied pinch force may play a role in preventing hand and arm disorders among dental practitioners. Researchers in a recent laboratory study found that using lighter (15 versus 24 grams) or larger-diameter (10 versus 7 millimeters) instruments reduced the peak pinch force applied during scaling on a typodont by 23 and 17 percent, respectively.[26] Ozawa and colleagues[27] found that the use of a larger-diameter endodontic instrument handle (6.0 mm versus 3.5 mm) was associated with decreased forearm muscle activity.

To our knowledge, no systematic workplace intervention studies have been conducted to identify work practices or dental instrument designs that may prevent musculoskeletal disorders or decrease arm pain among dental practitioners. The purpose of this randomized controlled trial (RCT) was to evaluate the effects of periodontal instrument handle diameter and weight on arm pain among dentists and dental

ABBREVIATION KEY. RCT: Randomized controlled trial.

TABLE 1 (CONTINUED)

CHARACTERISTIC	NO. OF PARTICIPANTS*	
	Heavy Instrument, Narrow Handle (n = 56)	Light Instrument, Wide Handle (n = 54)
Pain, Stiffness, Ache in Previous Month		
Right shoulder	5	10
Right elbow/forearm	7	9
Right hand/wrist	15	12
Any Difficulty in Previous Four Months Because of Upper-Extremity Problem		
Using usual technique for work	13	17
Doing usual work	9	19
Doing work as well as you would like	15	17
Spending usual amount of time doing work	11	15
Earning sufficient income	5	4
Always or Often Physically Exhausted After Work	16	23
General Health Very Good or Excellent	42	45
Race/Ethnicity		
Asian or Pacific Islander	8	15
African American, not of Hispanic origin	1	2
Hispanic	8	3
White, not of Hispanic origin	36	32
Other	3	2
Mean (SD) Preintervention Pain (0-10 Scale[§])		
Right shoulder	1.9 (1.3)	2.2 (1.5)
Right elbow/forearm	1.7 (1.3)	1.8 (1.3)
Right hand/wrist	1.9 (1.4)	2.3 (1.4)
Mean (SD) Hours per Week Performing Scaling or Root Planing[¶]	10.7 (8.2)	11.3 (6.7)

hygienists who perform scaling and root planing procedures. Our hypothesis was that a lighter, larger-diameter periodontal instrument would result in less arm pain than that resulting from use of the more traditional heavier instrument with a small diameter.

METHODS

We conducted a four-month cluster RCT with randomization at the level of the dental office. We recruited dentists and dental hygienists from the greater San Francisco Bay Area to participate in the study. The University of California, San Francisco, Committee on Human Research approved the study design, and all participants signed consent forms. The study took place between April 2009 and February 2011.

Dentists and dental hygienists were eligible to participate if they performed scaling and root planing or teeth cleaning for more than 10 hours per week and had been doing this work for more than one year. They were not eligible if they were receiving care from a physician for treatment of an upper-extremity disorder. We recruited participants at local dental professional meetings.

Participants completed an online baseline questionnaire from which we collected demographic data and work history information. They then completed an online questionnaire at the end of every workweek (Thursday or Friday) for the next five months. The weekly questionnaire assessed the participant's maximum pain level (on a 0- to 10-point scale, with anchors at 0 ["no pain"] and 10 ["unbearable pain"]) for the right wrist and hand, right elbow and forearm, and right shoulder. The questionnaire also assessed the number of hours during the week that the participant performed different dental tasks; the number of nights during which he or she awakened with numbness in the right thumb, index finger or middle finger; and the number of days during which the participant used pain medication for right–upper-extremity symptoms.

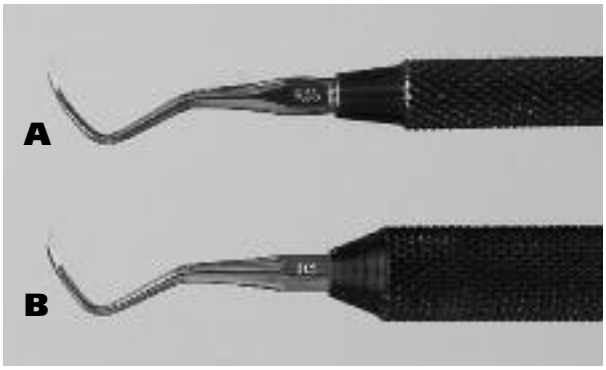

Figure 1. The two periodontal instruments evaluated in the study. **A.** Instrument 2 (weighing 34 grams with an 8-millimeter–diameter handle). **B.** Instrument 1 (weighing 14 g with an 11-mm–diameter handle).

One month after the start of the study, we randomly assigned participants to one of two types of periodontal instruments for the remaining four months of the study. Randomization was at the level of the dental office. If two or more participants worked in the same office, we assigned the same instrument to them to minimize contamination bias. A postdoctoral fellow made computer-generated random assignments. We concealed intervention allocation from the researchers who recruited participants (K.D., P.L.). The one-month run-in period before the intervention allowed participants to become accustomed to the questionnaire and provided us with baseline arm pain data. We instructed participants not to discuss the study or their impressions of the assigned instruments with dental personnel inside or outside of their office.

Instruments. Instrument 1 weighed 14 g (with curette tips) and had an 11-mm–diameter handle; instrument 2 weighed 34 g and had an 8-mm–diameter handle (Figure 1). We selected the instrument diameters and weights on the basis of previous laboratory study results[26] to provide a practical range that would have an effect on pinch force. The instruments were custom manufactured and surfaced with a medium diamond texture. Instrument 1 was made from black plastic (acetal resin, Delrin, DuPont, Wilmington, Del.), and instrument 2 was made from steel plated with black coating. All instruments were fitted with an R3S and an R4S tip (Ratcliff stainless steel universal scalers, G. Hartzell & Son, Concord, Calif.).

We informed participants that the study involved evaluation of a new periodontal instrument, but they did not know what design elements were being compared. Therefore, participants were effectively masked to the intervention. The cluster randomization, at the level of the dental office, also helped maintain masking and minimized contamination. Participants received as many of the instruments as they needed for their practice; the typical number requested ranged from four to eight. We instructed participants to sterilize and sharpen the assigned instruments as they did for their own instruments. At the end of the study, participants completed an online exit survey, the results of which enabled us to assess their opinions about the instrument to which they were assigned.

Primary and secondary outcomes. The primary outcomes tested were change in mean pain score, in the right wrist, elbow and shoulder, from the month before the intervention to the last month of the study after we adjusted for important covariates. We compared differences in pain score changes between the two intervention groups by using general linear models (SAS version 10, SAS, Cary, N.C.) and by controlling for age, sex, occupation and hours of instrument use per week. The analyses followed an intent-to-treat approach. We tested the effect of interaction between instrument and sex, instrument and age, and instrument and occupation. We based sample size calculations on an estimated mean (SD) shoulder pain score of 2.9 (1.6) (obtained from preliminary studies). For a type I error of 5 percent, a total of 82 participants (41 in each group) would be needed to have 80 percent power to detect a difference of 1.0 point (33 percent) between groups in the mean pain score change. To account for covariates and dropouts, we increased the recruitment goal to 120. Ultimately, we recruited 120 participants, but only 110 met the inclusion criteria. We used the *t* test to compare secondary outcomes (that is, nights awakened by finger numbness, days of medication use for pain) for the subset of participants who reported these outcomes.

RESULTS

The 110 participants (13 dentists and 97 dental hygienists) worked at 90 dental offices. The greatest number of participants in any one dental office was three. The mean (SD) age of participants was 44.7 (10.4) years and 100 participants (91 percent) were female. The similar distribution of demographic and other characteristics between the two intervention groups demonstrates baseline comparability (Table 1, pages 1106-1107).

Five participants dropped out of the study between two and 12 weeks after receiving the

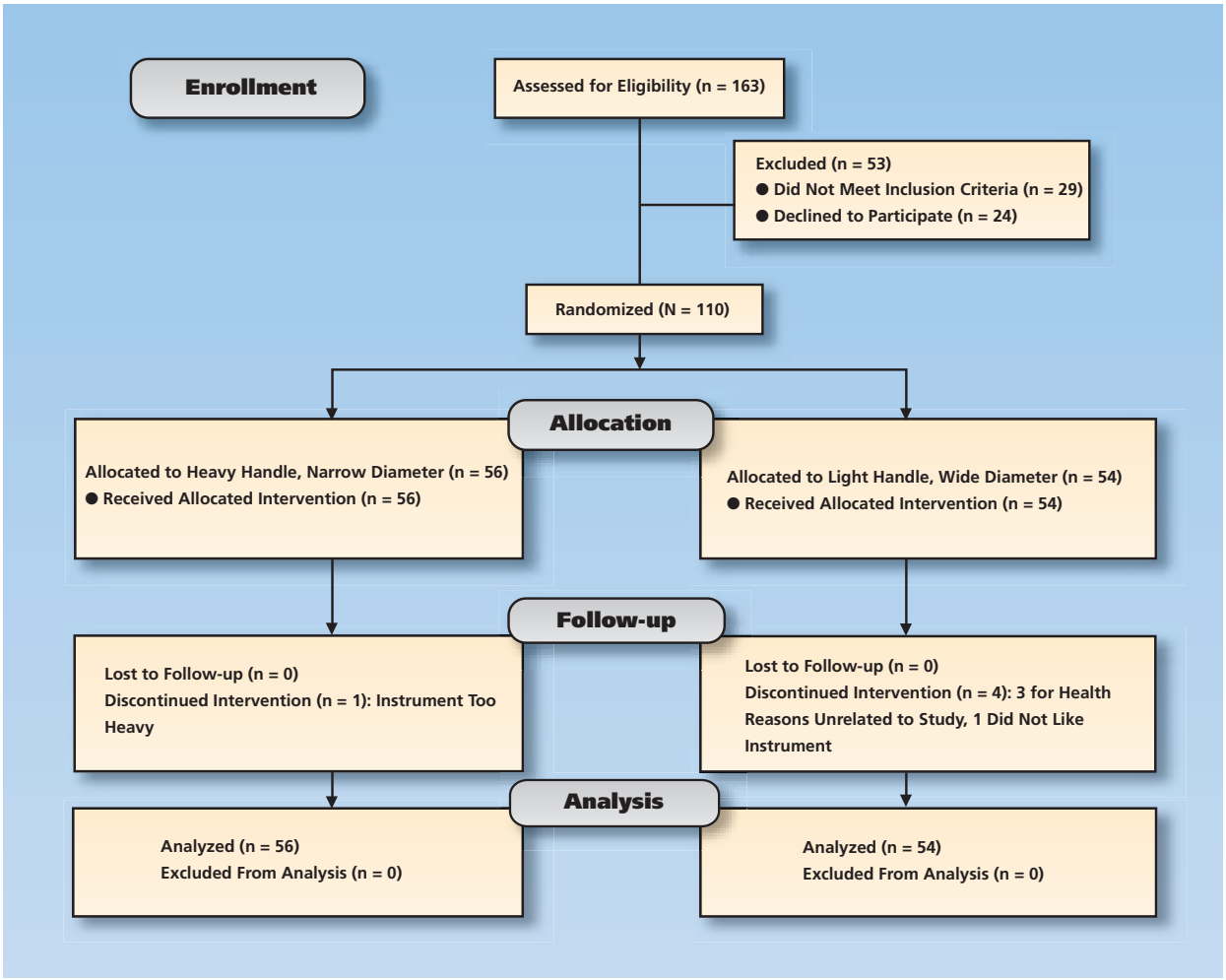

Figure 2. Flowchart of the randomized controlled trial of the effect of curette handle design on upper-extremity pain.

allocated intervention (Figure 2). We included their data in the analysis following intent-to-treat methods (that is, the last observation was carried forward to the 16th week). One participant who was assigned to the heavy instrument with the narrow-diameter handle dropped out because the instrument was too heavy. The other four participants who dropped out had been assigned to the lighter instrument with the larger diameter; one of these participants dropped out because the instrument was not as effective as her usual instruments, and the other three stopped working because of personal health issues unrelated to the study. During the intervention period, the weekly reported mean hours of dental procedures, hours of scaling or root planing, and hours of use of the assigned instrument were similar between the two intervention groups (Tables 1 and 2).

(Table 3, page 1111) shows a comparison of differences in pain score changes between the two intervention groups from the month before the intervention began to the last month of the intervention. The unadjusted pain scores improved more for participants who used instrument 1 (light handle with wide diameter) than for those who used instrument 2 (heavy handle with narrow diameter) for the three right–upper-extremity regions. After adjusting for age, sex, occupation and hours of instrument use per week, we found that the only significant difference between the two groups was for shoulder pain. The interaction terms between instrument and sex, instrument and age, and instrument and occupation were not significant and, therefore, we did not include them in the final models.

Secondary outcomes. For the secondary outcomes, both the number of nights awakened with finger numbness and the number of days of pain medication use improved more for participants assigned to the lightweight instrument

TABLE 2

Participants' work pattern during intervention period and exit survey results.

VARIABLE	HEAVY INSTRUMENT, NARROW HANDLE (n = 56)	LIGHT INSTRUMENT, WIDE HANDLE (n = 54)
Mean (SD*) No. of Hours per Week†		
Dental procedure	25.3 (7.3)	25.3 (7.6)
Scaling or root planing	12.4 (7.8)	11.9 (6.4)
Use of assigned instrument	9.8 (4.8)	10.2 (6.4)
Mean (SD) Exit Survey Rating of Assigned Instrument (0 = Worst; 5 = Best)		
Compared with usual instrument	2.6 (1.3)	3.6 (1.4)
Diameter	2.4 (1.2)	3.9 (1.1)
Weight	2.3 (1.5)	4.3 (1.1)
Shape	2.8 (1.2)	3.9 (1.0)
Productivity	2.7 (1.1)	3.6 (1.3)
Positive Features of Assigned Instrument According to Exit Survey Rating,‡ No. of Participants		
Weight	10	38
Diameter	9	19
Surface texture	13	9
Negative Features of Assigned Instrument According to Exit Survey Rating,‡ No. of Participants		
Weight	28	4
Diameter	22	1
Surface texture	4	3
Tips too loose	3	16

* SD: Standard deviation.
† Calculated from the weekly questionnaire completed during the intervention period.
‡ Cumulative responses from open-ended questions on the exit survey. Not all participants answered the question.

with the wide diameter than they did for those assigned to the heavy instrument with the narrow diameter (Table 4, page 1112). The mean difference between the groups with regard to the change in number of nights that participants were awakened with numbness in the right thumb or index or middle finger was 1.6 (95 percent confidence interval [CI], 0.13 to 2.92; $P = .04$). The mean difference between the groups with regard to the change in days of pain medication use was 0.7 (95 percent CI, 0.03 to 1.50; $P = .07$).

Exit survey. The online exit survey ratings for instrument diameter, weight, shape and productivity were more positive for participants who used the lightweight instrument with the wide diameter than they were for those who used the heavy instrument with the narrow diameter (Table 2). We noted similar findings in participants' responses to the open-ended questions regarding the positive and negative features of the assigned instrument. Participants reported that they used the assigned instrument approximately 82 percent of the time during scaling and root planing procedures (Table 2). One indication of successful masking in this study was that participants' positive and negative comments about the handle texture, which was the same for the two instruments, were distributed similarly between the two intervention groups. Sixteen participants who used the larger-diameter instrument reported that the tips were loosened easily and were not stiff enough. These instruments were made from acetal resin, which did not maintain a stiff thread. Consequently, we had to replace several of these handles during the study.

DISCUSSION

The mean pain scores for the three regions (wrist/hand, elbow/forearm and shoulder) improved in both intervention groups during the four-month study. However, the improvements were greater among those who were assigned to the lighter instrument with the larger-diameter handle. The differences between groups were statistically significant for change in shoulder pain but not for change in wrist or elbow pain. The lack of interaction between the instrument and the covariates (sex, age and occupation) indicates that the reported changes in pain scores are relatively homogeneous across the range of covariates and that stratification on the covariates would not have altered our findings.

The reported difference between groups in change in right shoulder pain from preintervention to postintervention was modest (0.33) and represents a 16 percent decline from the mean baseline shoulder pain score of 2.1. Although the effect is relatively small, it is similar to that observed in other workplace intervention studies. Rempel and colleagues[28] found that a new task chair design tested among garment

TABLE 3

Unadjusted and adjusted* regression models comparing effects of periodontal curette instrument on change in pain scores in right–upper-extremity regions.

BODY REGION	HEAVY INSTRUMENT, NARROW HANDLE (n = 56)		LIGHT INSTRUMENT, WIDE HANDLE (n = 54)		BETA† (95% CI‡)	P VALUE
	MEAN PAIN SCORE CHANGE§	SEM¶	MEAN PAIN SCORE CHANGE	SEM		
Wrist/Hand						
Unadjusted	0.14	0.11	0.40	0.11	0.13	.10
Adjusted	0.14	0.17	0.40	0.18	0.11 (–0.04-0.28)	.15
Elbow/Forearm						
Unadjusted	0.06	0.09	0.20	0.09	0.07	.27
Adjusted	0.06	0.14	0.20	0.15	0.07 (–0.06-0.21)	.29
Shoulder						
Unadjusted	0.19	0.15	0.51	0.16	0.17	.03
Adjusted	0.19	0.16	0.52	0.17	0.18 (0.02-0.324)	.02

* Adjusted models include covariates age, sex, occupation and mean hours of instrument use per week.
† The beta coefficient for instrument in the general linear model.
‡ CI: Confidence interval.
§ A positive value is a reduction in the pain score across the intervention period.
¶ SEM: Standard error of the mean.

workers reduced shoulder and neck pain by 0.28 point on a 0- to 10-point scale. Rempel and colleagues[29] reported that use of a forearm support board resulted in reduced shoulder and neck pain among computer users by 0.48 point on the same 0- to 10-point scale. On the basis of the results of our previous laboratory studies, we expected the reduction in pinch force to be greater than 33 percent when participants used the lighter, larger-diameter instrument compared with the heavier, smaller-diameter instrument.

In a recent prospective study of blue-collar workers, Harris and colleagues[19] found that the duration of work during which pinch force was greater than 10 N was a strong predictor of upper-extremity musculoskeletal disorders. The smaller effect size in our RCT may be due to the fact that participants used more instruments than the ones provided to them for dental hygiene procedures. We might have observed a larger effect if all of the instruments used had been replaced with the instrument to which participants had been assigned.

The effect of the instrument and differences in pinch force on the shoulder may be due to an increase in shoulder muscle co-contraction when the dental professional increases the hand grip force.[30] During dental hygiene procedures, the high-force fine motor work of the hand requires shoulder stabilization, which is achieved by increased shoulder muscle activity. Investigators conducting epidemiologic studies have identified forceful pinch as a risk factor for shoulder disorders.[24,25]

Our study findings show that secondary outcome measures also improved more among participants assigned to the lightweight wide-diameter curettes than they did among those assigned to the heavy, narrow-diameter curettes. At baseline, 20 participants reported experiencing symptoms, which may be associated with carpal tunnel syndrome (that is, numbness or tingling in the thumb or index or middle finger) and they reported waking an average of two nights per week because of these symptoms. Among those assigned to the lightweight, wide-diameter curette, this number declined to 0.7 night per week, whereas in the other group, it increased to 2.1 nights per week ($P = .04$). Given the small number of participants, we did not adjust for covariates in our analysis. The results showed no significant difference between the intervention groups with regard to change in medication use from baseline to postintervention.

Study strengths and limitations. The strengths of this study were the randomized intervention design, with randomization at the level of the dental office (to minimize contami-

TABLE 4

Summary measures for participants who reported right-finger numbness or use of medications for right–upper-extremity pain.

SECONDARY OUTCOME	MEAN (STANDARD DEVIATION)		*P* VALUE
	Heavy Instrument, Narrow Handle	Light Instrument, Wide Handle	
Mean No. of Nights per Week Awakened Because of Numbness in Fingers	(n = 9)	(n = 11)	
Preintervention*	1.9 (2.1)	2.0 (2.3)	
Postintervention*	2.1 (2.7)	0.7 (1.1)	
Preintervention minus postintervention†	–0.3 (1.0)	1.3 (1.9)	.04
Mean No. of Days of Medication Use for Upper-Extremity Pain	(n = 13)	(n = 15)	
Preintervention*	1.5 (2.2)	1.1 (1.4)	
Postintervention*	1.7 (2.7)	0.6 (1.0)	
Preintervention minus postintervention†	–0.2 (1.3)	0.5 (0.7)	.07

* Calculated from weekly questionnaire during the four-week preintervention period.
† Mean preintervention value minus mean postintervention value. Positive values indicate a reduction in finger numbness or medication use after the intervention.

nation bias and maintain masking); participant masking with regard to the specific features of the instrument being evaluated; the concealment of instrument allocation from study investigators; the effective randomization of participants whose demographic characteristics were similar; the low dropout rate; the similar number of hours per week that participants in both groups performed dental procedures and their exposure to the intervention instruments; and the intention-to-treat approach to analysis. One limitation of the study was in restricting the intervention to only one type of instrument for each participant. Another limitation was the lack of objective clinical outcome measures, such as results of physical examinations or of nerve conduction studies in participants. However, adding clinical outcomes would have substantially increased the expenses associated with the study, and the more complex logistics may have reduced the number of participants.

CONCLUSION

The results of our study show that replacing periodontal instruments with handles that are lighter and wider in diameter (11 mm) than a typical handle is a low-cost intervention that resulted in a modest reduction in arm pain among dental practitioners who performed dental hygiene procedures. Other workplace changes also are likely to lead to reduced arm pain, but these interventions have not been evaluated in RCTs, to our knowledge. These changes include maintaining sharp scaling tips to reduce the applied pinch force; scheduling patients with heavy calculus on different days; and reducing the time during which the practitioner applies a high pinch force during the workday (allowing adequate recovery time from the pinch). Other handle designs, such as a tapered grip or high friction surface, may reduce applied pinch force during dental hygiene procedures, but, to our knowledge, these also have not been tested in field studies. ■

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1. Milerad E, Ekenvall L. Symptoms of the neck and upper extremities in dentists. Scand J Work Environ Health 1990;16(2):129-134.
2. Osborn JB, Newell KJ, Rudney JD, Stoltenberg JL. Musculoskeletal pain among Minnesota dental hygienists. J Dent Hyg 1990; 64(3):132-138.
3. Oberg T, Oberg U. Musculoskeletal complaints in dental hygiene: a survey study from a Swedish county (published correction appears in J Dent Hyg 1993;67[6]:288). J Dent Hyg 1993;67(5):257-261.
4. Liss GM, Jesin E, Kusiak RA, White P. Musculoskeletal problems among Ontario dental hygienists. Am J Ind Med 1998;28(4): 521-540.
5. Finsen L, Christensen H, Bakke M. Musculoskeletal disorders among dentists and variation in dental work. Appl Ergon 1998;29(2):119-125.
6. Akesson I, Johnsson B, Rylander L, Moritz U, Skerfving S. Musculoskeletal disorders among female dental personnel: clinical examination and a 5-year follow-up study of symptoms. Int Arch Occup Environ Health 1999;72(6):395-403.
7. Lalumandier JA, McPhee SD. Prevalence and risk factors of hand problems and carpal tunnel syndrome among dental hygienists. J Dent Hyg 2001;75(2):130-134.
8. Werner RA, Hamann C, Franzblau A, Rodgers PA. Prevalence of carpal tunnel syndrome and upper extremity tendinitis among dental hygienists. J Dent Hyg 2002;76(2):126-132.
9. Crawford L, Gutierrez G, Harber P. Work environment and occupational health of dental hygienists: a qualitative assessment. J Occup Environ Med 2005;47(6):623-632.
10. Ayers KM, Thomson WM, Newton JT, Morgaine KC, Rich AM. Self-reported occupational health of general dental practitioners (published online ahead of print Feb. 17, 2009). Occup Med (Lond) 2009;59(3):142-148. doi:10.1093/occmed/kqp004.
11. Morse T, Bruneau H, Dussetschleger J. Musculoskeletal disorders of the neck and shoulder in the dental professions. Work 2010; 35(4):419-429.
12. American Dental Association. 1997 Survey of Current Issues in Dentistry: Repetitive Motion Injuries. Chicago: American Dental

Association; 1997:2-8.
13. Burke FJ, Main JR, Freeman R. The practice of dentistry: an assessment of reasons for premature retirement. Br Dent J 1997;182(7):250-254.
14. Hamann C, Werner RA, Franzblau A, Rodgers PA, Siew C, Gruninger S. Prevalence of carpal tunnel syndrome and median mononeuropathy among dentists. JADA 2001;132(2):163-170.
15. Anton D, Rosecrance J, Merlino L, Cook T. Prevalence of musculoskeletal symptoms and carpal tunnel syndrome among dental hygienists. Am J Ind Med 2002;42(3):248-257.
16. Leigh JP, Miller TR. Occupational illnesses within two national data sets. Int J Occup Environ Health 1998;4(2):99-113.
17. Geoghegan JM, Clark DI, Bainbridge LC, Smith C, Hubbard R. Risk factors in carpal tunnel syndrome. J Hand Surg Br 2004;29(4): 315-320.
18. Bernard BP, Putz-Anderson V. Musculoskeletal Disorders and Workplace Factors: A Critical Review of Epidemiologic Evidence for Work-related Musculoskeletal Disorders of the Neck, Upper Extremity, and Low Back. Atlanta: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health; 1997. DHHS publication (NIOSH) 97-141.
19. Harris C, Eisen E, Goldberg R, et al. 1st place, PREMUS best paper competition: workplace and individual factors in wrist tendinosis among blue-collar workers—the San Francisco study (published online ahead of print Feb. 6, 2011). Scand J Work Environ Health 2011;37(2):86-98. doi:10.5271/sjweh.3147.
20. 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):218-233.
21. Bramson JB, Smith S, Romagnoli G. Evaluating dental office ergonomic risk factors and hazards. JADA 1998;129(2):174-183.
22. Dong H, Loomer P, Villanueva A, Rempel D. Pinch forces and instrument tip forces during periodontal scaling. J Periodontol 2007;78(1):97-103.
23. Roquelaure Y, Mechali S, Dano C, et al. Occupational and personal risk factors for carpal tunnel syndrome in industrial workers. Scand J Work Environ Health 1997;23(5):364-369.
24. Silverstein BA, Bao SS, Fan ZJ, et al. Rotator cuff syndrome: personal, work-related psychosocial and physical load factors. J Occup Environ Med 2008;50(9):1062-1076.
25. van Rijn RM, Huisstede BM, Koes BW, Burdorf A. Associations between work-related factors and specific disorders of the shoulder: a systematic review of the literature (published online ahead of print Jan. 22, 2010). Scand J Work Environ Health 2010;36(3):189-201. doi:10.5271/sjweh.2895.
26. Dong H, Barr A, Loomer P, Laroche C, Young E, Rempel D. The effects of periodontal instrument handle design on hand muscle load and pinch force. JADA 2006;137(8):1123-1130.
27. Ozawa T, Nakano M, Sugimura H, et al. Effects of endodontic instrument handle diameter on electromyographic activity of forearm and hand muscles. Int Endod J 2001;34(2):100-106.
28. Rempel DM, Wang PC, Janowitz I, Harrison RJ, Yu F, Ritz BR. A randomized controlled trial evaluating the effects of new task chairs on shoulder and neck pain among sewing machine operators: the Los Angeles garment study. Spine 2007;32(9):931-938.
29. Rempel DM, Krause N, Goldberg R, Benner D, Hudes M, Goldner GU. A randomized controlled trial evaluating the effects of two workstation interventions on upper body pain and incident musculoskeletal disorders among computer operators. Occup Environ Med 2006;63(5):300-306.
30. Sporrong H, Palmerud G, Herberts P. Hand grip increases shoulder muscle activity: an EMG analysis with static hand contractions in 9 subjects. Acta Orthop Scand 1996;67(5):485-490.