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The Impact of Ultrasonic Scalers on Musculoskeletal Disorder Risk During Dental Prophylaxis Among Dentists in the Philippines

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Abstract

Work-related musculoskeletal disorders (MSDs) are a common occupational concern among dentists due to repetitive movements, prolonged static postures, and the use of vibrating instruments such as ultrasonic scalers. This study investigated the ergonomic risks associated with ultrasonic scaler use during dental prophylaxis among licensed Filipino dentists by evaluating vibration exposure, muscle activity, postural risk, and perceived discomfort. Vibration was measured using a tri-axial accelerometer, muscle activity was recorded through electromyography (EMG), and posture was assessed using the Rapid Upper Limb Assessment (RULA). Subjective comfort and discomfort ratings were also collected before and after task performance. Twelve female dentists performed standardized scaling procedures on a simulated dental model representing anterior and posterior regions of the upper and lower jaw. Results showed that several participants exceeded recommended vibration exposure thresholds, indicating potential risk for hand–arm vibration syndrome. Muscle activity analysis revealed elevated activation levels in several upper limb muscles during scaling tasks, particularly in posterior regions of the mouth. Postural assessment further indicated moderate to high ergonomic risk during these procedures. Participants also reported increased discomfort after task completion, especially in the neck, shoulders, and hands. Overall, the findings demonstrate that dental prophylaxis using ultrasonic scalers presents notable ergonomic challenges due to the combined effects of vibration exposure, muscular workload, and non-neutral posture. These results highlight the need for improved ergonomic awareness and preventive measures to support the occupational health of dental professionals.

Keywords

Occupational ergonomics, Musculoskeletal disorders, Hand-arm vibration, Dentists, Ultrasonic scalers, Oral Prophylaxis, Electromyography, Postural assessment

1. Introduction

Musculoskeletal disorders (MSDs) are one of the major occupational health concerns worldwide, affecting approximately 1.71 billion people and representing a leading cause of disability across more than 160 countries (World Health Organization 2022). These disorders limit mobility, reduce functional capacity, and contribute to early retirement and decreased productivity. In occupational settings, MSDs are associated with substantial economic costs and long-term health consequences, particularly in professions that involve repetitive movements, sustained force, and awkward postures.

Healthcare professionals are among the most affected occupational groups, with high rates of MSDs reported among nurses, surgeons, and dentists. Studies indicate that MSD prevalence in healthcare workers ranges from 26.7% to

70.1%, with dentists reporting some of the highest rates of neck, shoulder, and back pain (Khan et al. 2013; Szeto et al. 2009). Dentists are particularly susceptible due to prolonged static postures, repetitive fine motor tasks, and the need to maintain precision in confined working spaces. Global studies report that 64% to 93% of dental professionals experience MSDs during their careers, commonly affecting the neck, shoulders, upper and lower back, and hands (Hayes et al. 2009; Dezfouli et al. 2021). Electromyographic studies have further shown sustained static loading of the trapezius muscles during dental procedures, indicating elevated risk of musculoskeletal strain (Milerad et al. 1991; Morse et al. 2017).

Despite the high prevalence of MSDs in dentistry, much of the existing literature relies on self-reported questionnaires and surveys, which provide limited insight into the biomechanical demands placed on dentists during clinical procedures. Objective methods such as electromyography (EMG) offer quantitative assessment of muscle activity and have demonstrated elevated activation in upper extremity muscles during dental work (Pope-Ford and Jiang 2015). These findings highlight the importance of objectively assessing muscle load and posture to better understand MSD risk in dental practice.

Dental tools are recognized as significant contributors to musculoskeletal strain. Dentists routinely use both manual instruments and powered devices, including ultrasonic scalers, particularly during dental prophylaxis. Ultrasonic scalers improve efficiency in plaque and calculus removal but emit high-frequency vibrations that are transmitted directly to the hands and arms. Prolonged exposure to such vibrations has been associated with neuromuscular disorders, including hand–arm vibration syndrome and carpal tunnel syndrome (Akesson et al. 2012; Chowdhry and Sethi 2017). These risks are aggravated by awkward working postures such as neck flexion, trunk bending, and shoulder elevation, which are commonly required during dental procedures (Katano et al. 2021; Lemaster et al. 2021). Both manual and ultrasonic scaling have been linked to high trapezius muscle loads and limited recovery time for the forearm muscles (Akesson et al. 2012).

Dental prophylaxis is one of the most frequently performed procedures in dental practice and typically lasts between 30 and 60 minutes. Although routine, this procedure requires prolonged static postures, repetitive hand movements, and sustained visual focus, placing considerable physical demands on dentists. Previous studies have reported increased musculoskeletal discomfort in the upper extremities during prophylaxis, which in turn highlights its ergonomic risks (Ohlendorf et al. 2020).

In the Philippine context, these challenges may be intensified by high patient volumes and limited access to dental professionals. Although the dentist-to-population ratio has improved over time, it remains below the global average, resulting in heavier workloads for practicing dentists (World Health Organization n.d.). Local studies have reported ergonomic inefficiencies in dental clinics, including limited use of adjustable equipment and non-ergonomic instrument handles, contributing to upper extremity discomfort among Filipino dentists (Alcazaren and Carpio n.d.; Esporlas and Fabro-Esporlas 2020). However, there is a lack of objective, region-specific studies examining the impact of ultrasonic scaler vibrations on muscle activity, posture, and MSD risk during dental prophylaxis in the country.

This study addresses this gap by investigating the impact of ultrasonic scaler use on musculoskeletal disorder risk during dental prophylaxis among dentists in the Philippines. Specifically, the study evaluates hand–arm vibration exposure, analyzes muscle activation across key upper-body muscle groups using electromyography, assesses postural risk using the Rapid Upper Limb Assessment (RULA), and compares subjective discomfort before and after the procedure. The study tests the hypothesis that the use of ultrasonic scalers during dental prophylaxis increases ergonomic risk factors, including vibration exposure, muscle activity, and postural strain, which may contribute to a higher likelihood of musculoskeletal disorder risk among dentists. By focusing on a common dental task and applying objective ergonomic assessment tools, this study contributes evidence relevant to improving occupational health and ergonomic practices among Filipino dental professionals.

2. Problem Formulation

Musculoskeletal disorders (MSDs) are widely reported among dental professionals due to the physical demands of dental practice. Repetitive movements, prolonged static postures, and the frequent use of power tools contribute to strain in key muscle groups, particularly the neck, shoulders, back, arms, and hands. Ergonomics, which focuses on adapting work environments and tasks to workers' capabilities, plays a critical role in addressing these risks. Existing literature consistently identifies dentistry as a high-risk profession for the development of MSDs.

Studies conducted across various countries report that 64% to 93% of dental practitioners experience MSDs during their careers, with the neck, shoulders, upper back, lower back, and wrists being the most commonly affected regions (Hayes et al. 2009; Dezfouli et al. 2021). Research from Iran, Saudi Arabia, Germany, Sweden, and Australia demonstrates similar prevalence patterns, indicating that MSDs among dentists are a global occupational issue (Alghadir et al. 2015; Johansson et al., 2009; Ohlendorf et al. 2020). Scaling tasks, including manual and ultrasonic scaling, have repeatedly been identified as predictors of upper-body musculoskeletal discomfort (Hayes et al. 2012; Johansson et al. 2009). Workload-related factors further intensify these risks, as dentists working longer hours or more days per week report higher rates of shoulder pain and cumulative trauma disorders (Liss et al. 1995; Shenkar et al. 1998). These findings highlight the cumulative effects of repetitive dental tasks performed over extended periods.

Dental practice exposes practitioners to several ergonomic risk factors, including awkward postures, repetitive movements, limited rest periods, anthropometric mismatches, and handedness-related constraints. Dentists often maintain static postures to preserve a fixed line of sight during procedures, which increases muscle strain in the neck, shoulders, and back (Lazăr et al. 2024). Even minor deviations from neutral posture, such as 10° of neck or trunk flexion, significantly increase muscle workload and contribute to musculoskeletal discomfort over time (Lemaster et al., 2021). Repetitive tasks such as cleaning and scaling require sustained activation of upper-arm and hand muscles, leading to fatigue and overuse injuries (Morse et al. 2017). Limited opportunities for muscle recovery further elevate MSD risk, particularly in the shoulders and forearms (Åkesson et al. 2012; Katano et al. 2021).

Anthropometric factors also influence ergonomic outcomes in dentistry. Mismatches between tool handle dimensions and hand size can result in improper grip and awkward wrist positions, increasing strain on the upper extremities (Dong et al. 2007). Gender-related differences in hand size and grip strength further affect how dental tools are handled, potentially exacerbating musculoskeletal strain when tools are not ergonomically designed to accommodate variation among users (Saremi et al. 2021). Handedness has similarly been identified as a contributing factor to ergonomic risk. Studies report that left-handed dentists often lack access to appropriately designed tools and receive limited training tailored to their needs, resulting in higher reported injury rates and perceived performance limitations compared to right-handed dentists (Arora and Saiya 2018).

Power tools are essential in modern dental practice, offering improved efficiency and procedural effectiveness, but they also introduce additional ergonomic risks. High-speed handpieces require sustained grip strength and precise control, which contributes to repetitive strain in the hands and wrists (Bhandary et al. 2014), while air polishers demand fine motor stability that can further increase hand strain (Hongsathavij et al. 2017). Among these tools, ultrasonic scalers are of particular concern due to the high-frequency vibrations they emit, typically ranging from 25 to 30 kHz (Lea et al. 2004). Although effective in plaque and calculus removal, prolonged exposure to these vibrations has been associated with neuromuscular fatigue, hand–arm vibration syndrome, and increased risk of carpal tunnel syndrome (Åkesson et al. 2012; Chowdhry and Sethi 2017; Ohlendorf et al. 2020). These risks are compounded by static postures and repetitive movements during dental procedures, which emphasizes the need for ergonomic considerations when using vibrating tools.

As aforementioned, in the Philippine context, dentists may face additional ergonomic challenges due to high patient volumes, limited resources, and reduced access to ergonomic equipment. Although the dentist-to-population ratio has improved over time, it remains below global averages, contributing to heavier workloads and longer working hours. In contrast, higher dentistry personnel densities in countries such as Sweden, Australia, and Canada allow for better workload distribution and reduced physical strain on practitioners. Economic constraints in the Philippines often limit access to ergonomic interventions such as adjustable dental chairs, ergonomic stools, and magnification devices (Lietz et al. 2020). Local studies have reported that the non-use of adjustable chairs and non-ergonomic tool handles contributes to upper back, wrist, and hand discomfort among Filipino dentists (Alcazaren and Carpio n.d.). Despite these challenges, research specifically addressing ergonomic risks in this population remains limited.

Electromyography (EMG) has been widely used to objectively assess muscle activation during dental procedures. Studies consistently report high activation levels in the upper trapezius, anterior deltoid, biceps brachii, flexor carpi radialis, and abductor pollicis brevis during dental work (Milerad et al. 1991; Pope-Ford and Jiang 2015). The trapezius muscles, in particular, demonstrate sustained static loading, which indicates elevated risk for neck and shoulder MSDs. Standardized EMG methodologies enhance the reliability of these assessments and allow for real-

time measurement of muscle strain (Hermens et al. 2000). Compared with subjective tools, EMG provides a more precise evaluation of physical demands during dental procedures.

Postural assessment tools such as the Rapid Upper Limb Assessment (RULA) have also been widely applied in dental ergonomics. Studies report that a large proportion of dentists fall into high-risk categories, particularly due to neck and shoulder postures (Rafie et al. 2015; Blume et al. 2021). While other tools such as the Rapid Entire Body Assessment and the Nordic Musculoskeletal Questionnaire have been used to evaluate ergonomic risk and MSD prevalence, they rely primarily on observational or self-reported data. Integrating objective methods such as EMG and vibration analysis addresses limitations associated with subjective assessments and allows for a more comprehensive evaluation of ergonomic risk.

Despite the extensive literature on MSDs in dentistry, several gaps remain. The specific impact of ultrasonic scaler vibrations on musculoskeletal risk among Filipino dentists is underexplored, and region-specific ergonomic challenges in developing countries remain insufficiently addressed. Furthermore, much of the existing research relies heavily on subjective measures, underscoring the need for objective assessments that integrate muscle activation, posture, and vibration exposure. Addressing these gaps is essential for improving understanding of ergonomic risks associated with dental prophylaxis and for developing targeted interventions to reduce MSD risk among dental professionals.

3. Methods

A quantitative research design was employed to assess the impact of ultrasonic scaler vibration on musculoskeletal disorder (MSD) risk among dentists during dental prophylaxis. The study involved a purposive sample of 12 licensed female dentists practicing in Laguna, Philippines, specifically in towns of Los Baños and Bay. Participants were required to have at least one year of experience performing dental prophylaxis and to regularly use ultrasonic scalers at least three times per week for a minimum of 10 minutes per procedure. Dentists with unresolved or currently diagnosed musculoskeletal disorders were excluded, while those with previous MSDs were included if fully healed and asymptomatic at the time of the study. Written informed consent was obtained prior to participation.

Demographic and professional information was collected using a basic information sheet, including years of practice, average number of patients treated per day, ultrasonic scaler brand or model, frequency of scaler use, handedness, use of ergonomic tools, and history of musculoskeletal discomfort. These data provided contextual variables relevant to ergonomic risk.

Muscle activity was assessed using wireless electromyography (EMG) sensors with a sampling rate of 1,000 Hz. Maximum Voluntary Contraction (MVC) measurements were obtained for the upper trapezius, anterior deltoid, biceps brachii, flexor carpi radialis, and abductor pollicis brevis muscles following Surface Electromyography for the Non-Invasive Assessment of Muscles (SENIAM) electrode placement guidelines. MVC trials lasted five seconds and were repeated three times per muscle, with the middle one-second segment of each trial processed using root mean square analysis to determine mean MVC values. EMG data collected during the task were normalized as a percentage of MVC (%MVC), with muscle activation levels exceeding 15% MVC identified as indicative of increased musculoskeletal risk during static or repetitive work.

Hand–arm vibration exposure was measured using a tri-axial accelerometer mounted on the ultrasonic scaler handle, recording acceleration along the X, Y, and Z axes at a sampling rate of 3,000 samples per minute. Data collection adhered to ISO 5349-1:2001 guidelines for hand-transmitted vibration. Time-domain signals were processed using Fast Fourier Transform and one-third octave band analysis to compute frequency-weighted root mean square acceleration values. Total vibration exposure was calculated by combining weighted accelerations across all three axes and compared with ISO action and exposure limits of 2.5 m/s^2 A(8) and 5.0 m/s^2 A(8), respectively.

Postural risk was evaluated using the Rapid Upper Limb Assessment (RULA). Video recordings of participants during the procedure were used to score posture based on joint angles, muscle use, and exerted force. Scores were averaged to determine overall postural risk. Subjective discomfort was assessed using the Wong–Baker FACES Pain Rating Scale, and overall comfort was rated using a 10-point subjective comfort scale.

Statistical analyses were conducted using IBM SPSS Statistics version 30. Data normality was assessed using the Shapiro–Wilk test at a significance level of 0.05. Depending on data distribution, repeated measures analysis of

variance or Friedman tests were used to examine differences in muscle activity, vibration exposure, and RULA scores. Wilcoxon Signed-Rank tests were applied to analyze pre- and post-task differences in subjective discomfort and comfort ratings. Spearman's rank correlation was used to examine relationships among muscle activity, vibration exposure, postural risk, and subjective ratings, while the Mann–Whitney U test assessed differences associated with handedness.

4. Data Collection

Data collection was conducted in the participants' clinical environments to reflect actual working conditions. Prior to the experimental task, participants were provided with a rest period of 30 to 60 minutes to minimize residual muscle fatigue from earlier clinical activities. Dental prophylaxis was performed on a dental manikin phantom head mounted on an adjustable dental chair to simulate clinical positioning while maintaining consistency across trials.

To standardize the working surface, a mixture of dental plaster, water, and black manicure was applied to the manikin teeth and allowed to set overnight to simulate calculus with uniform texture and visibility. Participants used their own ultrasonic scalers at medium power settings (levels 3 to 5) and performed scaling using their dominant hand. The dental chair was positioned in a semi-reclined orientation of approximately 30 degrees throughout the procedure.

The dental prophylaxis task was divided into four stages: upper jaw anterior, upper jaw posterior, lower jaw anterior, and lower jaw posterior. Electromyography and vibration data were recorded continuously across all stages. Video recordings were captured simultaneously to support postural assessment.

Baseline discomfort and comfort ratings were collected immediately prior to the procedure using the Wong–Baker FACES Pain Rating Scale and a 10-point subjective comfort scale, respectively. These assessments were repeated immediately after completion of the dental prophylaxis task to evaluate changes associated with the procedure.

5. Results and Discussion

5.1 Numerical Results

The study involved 12 licensed female dentists with a mean age of 37.17 years (SD = 9.62) and an average of 12.83 years of professional practice. Table 1 summarizes the socio-demographic profile of the participants.

Table 1. Socio-demographic profile of participants.

VARIABLE	CATEGORY	FREQUENCY (N)	PERCENTAGE (%)
Age Group	20 - 29	5	41.67
	30 - 39	1	8.33
	40 - 49	4	33.33
	50 - 59	2	16.67
Sex	Female	12	100.00
	Male	0	0.00
Handedness	Right-handed	10	83.33
	Left-handed	2	16.67
Years of Practice	1 - 10	5	41.67
	10 - 20	3	25.00
	20 - 30	4	33.33
Specialization	General Dentistry	2	12.50
	Orthodontics	5	31.25
	Surgery	3	18.75
	Endodontics	1	6.25
	Esthetics	1	6.25
	N/A	4	25.00

Eight dentists reported musculoskeletal pain or discomfort during procedures, primarily in the hands, back, wrists, shoulders, and flank, which indicates an already vulnerable population for ergonomic risk. Two had prior diagnoses of scoliosis and carpal tunnel syndrome (resolved since 2012). None used ergonomic tools or interventions.

Vibration exposure analysis showed total vibration acceleration values ranging from 1.33 to 9.21 m/s², with a mean value of 3.98 m/s². The X-axis consistently recorded the highest vibration magnitudes across participants, reflecting dominant vibration transmission along the primary gripping and operating direction of the scaler. Five participants exceeded the ISO exposure action value of 2.5 m/s², while two exceeded the exposure limit value of 5.0 m/s². These results imply that a substantial proportion of dentists may be exposed to vibration levels requiring preventive action, particularly during prolonged or repetitive procedures. The summary of frequency-weighted and total vibration acceleration values per participant is shown on Table 2.

Table 2. Frequency-weighted and total vibration acceleration values per participant.

DENTIST NO.	FREQUENCY-WEIGHTED VIBRATION (m/s^2)			TOTAL VIBRATION ACCELERATION VALUE (m/s^2)
	X-axis	Y-axis	Z-axis	
1	1.75	0.78	0.80	2.08
2	4.64	0.84	0.85	4.79
3	4.12	0.56	0.47	4.18
4	1.00	0.85	0.95	1.62
5	9.10	1.09	0.94	9.21
6	4.32	0.76	0.86	4.47
7	2.19	0.77	1.79	2.93
8	1.91	0.86	1.15	2.39
9	0.77	0.74	0.80	1.33
10	0.97	1.09	1.61	2.17
11	3.97	0.63	0.85	4.11
12	5.31	6.63	0.53	8.51

Based on the data summarized on Table 3, task-based vibration analysis indicated that scaling of the upper posterior teeth produced the highest average vibration exposure (3.21 m/s²), while lower anterior scaling showed the lowest exposure (2.34 m/s²). This suggests that posterior dental regions impose greater mechanical demands, likely due to reduced visibility, increased grip force, and constrained wrist posture, which increases hand–arm vibration exposure.

Table 3. Frequency-weighted and total vibration acceleration values per task.

SCALING TASK	FREQUENCY-WEIGHTED VIBRATION (m/s^2)			TOTAL VIBRATION ACCELERATION VALUE (m/s^2)
	X-axis	Y-axis	Z-axis	
1: Upper Jaw (Anterior)	1.89	1.38	0.54	2.40
2: Upper Jaw (Posterior)	2.77	1.50	0.64	3.21
3: Lower Jaw (Anterior)	1.96	1.16	0.55	2.34
4: Lower Jaw (Posterior)	2.66	0.54	0.62	2.79
Average	2.32	1.15	0.59	2.69

From the calculated mean and standard deviation in terms of %MVC for each task per muscle group shown in Table 4, muscle activity results showed that the Abductor Pollicis Brevis consistently exhibited the highest normalized muscle activation (%MVC), ranging from 62.23% to 71.50% across all tasks. The Upper Trapezius and Biceps Brachii also demonstrated elevated %MVC values, particularly during posterior scaling. All muscles except the Anterior Deltoid exceeded the 15% MVC threshold associated with increased fatigue risk. These findings imply sustained muscular loading of the thumb, shoulder, and arm muscles during dental prophylaxis, which may contribute to cumulative fatigue and long-term MSD risk.

Table 4. Mean and standard deviation (in %MVC) for each task per muscle group.

MUSCLE GROUP	MEAN & STANDARD DEVIATION	%MVC			
		Task 1: Scaling Upper Jaw (Anterior)	Task 2: Scaling Upper Jaw (Posterior)	Task 3: Scaling Lower Jaw (Anterior)	Task 4: Scaling Lower Jaw (Posterior)
Upper Trapezius	Mean	35.96	40.74	35.48	49.82
	STDev	11.67	14.08	9.76	17.34
Anterior Deltoid	Mean	13.80	19.48	11.67	15.10
	STDev	15.27	19.75	14.68	13.15
Biceps Brachii	Mean	37.30	36.44	29.99	36.01
	STDev	22.25	18.53	15.52	18.81
Flexor Carpi Radialis	Mean	29.96	29.12	25.56	27.52
	STDev	14.39	10.55	11.01	10.43
Abductor Pollicis Brevis	Mean	66.87	71.50	62.23	69.07
	STDev	25.98	27.08	20.87	23.65

The RULA scores per task is summarized on Table 5, where the said postural assessment showed moderate to high ergonomic risk. Anterior scaling tasks produced a mean score of 3.92, while posterior tasks yielded higher scores ranging from 5.75 to 5.92. These results indicate that posterior scaling requires more awkward and sustained postures, necessitating ergonomic intervention according to RULA action levels.

Table 5. RULA scores per task.

DENTIST NO.	SIDE	TASK 1: Scaling Upper Jaw (Anterior)	TASK 2: Scaling Upper Jaw (Posterior)	TASK 3: Scaling Lower Jaw (Anterior)	TASK 4: Scaling Lower Jaw (Posterior)
1	Right	4	6	4	6
2	Left	3	6	3	5
3	Right	4	4	4	7
4	Left	5	7	5	4
5	Right	3	6	4	5
6	Right	3	6	4	7
7	Right	5	6	4	7
8	Right	4	5	4	5
9	Right	4	6	4	7
10	Right	5	6	4	6
11	Right	3	6	3	6
12	Right	4	5	4	6
Average		3.92	5.75	3.92	5.92

Subjective discomfort ratings increased after task completion, with statistically significant increases observed in the upper arm, forearm, and hand regions ($p < 0.05$). This aligns with the objective muscle activation data and implies that perceived discomfort corresponds with measured physical workload during the procedure.

5.2 Graphical Results

Figure 1 compares vibration exposure across task stages, which shows that higher vibration levels occur during posterior scaling compared to anterior scaling. This visually confirms task-specific differences and implies that posterior regions represent higher ergonomic risk zones during dental prophylaxis.

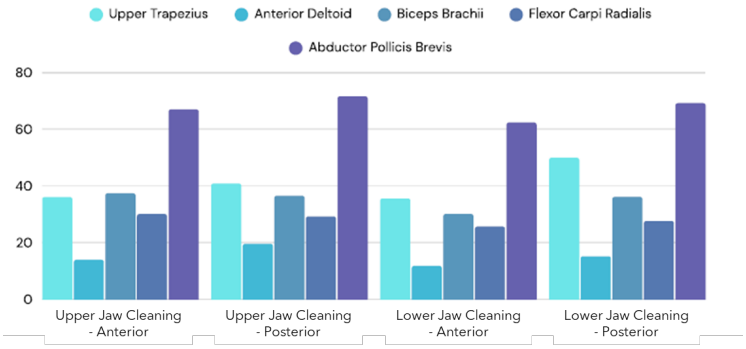

Figure 1. Muscle Workloads for various tasks.

Statistical analysis of the graphical data, summarized on Figure 2, revealed significant differences in muscle activation across task stages for most muscle groups using Friedman tests ($p < 0.05$), confirming that observed variations were not due to random fluctuation. In contrast, vibration exposure comparisons between baseline and task conditions did not reach statistical significance ($p = 0.875$), suggesting relatively consistent vibration output during scaler operation regardless of task stage.

Upper Trapezius

Ranks

	Mean Rank
Task1_UT	1.92
Task2_UT	2.71
Task3_UT	1.71
Task4_UT	3.67

Test Statistics[a]

N	12
Chi-Square	17.513
df	3
Asymp. Sig.	<.001

a. Friedman Test

Biceps Brachii

Ranks

	Mean Rank
Task1_BB	2.63
Task2_BB	3.08
Task3_BB	1.54
Task4_BB	2.75

Test Statistics[a]

N	12
Chi-Square	10.221
df	3
Asymp. Sig.	.017

a. Friedman Test

Anterior Deltoid

Ranks

	Mean Rank
Task1_AD	2.00
Task2_AD	3.17
Task3_AD	1.63
Task4_AD	3.21

Test Statistics[a]

N	12
Chi-Square	14.739
df	3
Asymp. Sig.	.002

a. Friedman Test

Abductor Pollicis Brevis

Ranks

	Mean Rank
Task1_APB	2.38
Task2_APB	3.25
Task3_APB	1.63
Task4_APB	2.75

Test Statistics[a]

N	12
Chi-Square	10.210
df	3
Asymp. Sig.	.017

a. Friedman Test

Figure 2. Friedman Test results for Muscle Activation

5.3 Validation

Validation of the findings was performed using nonparametric statistical testing. Friedman tests confirmed significant differences in %MVC across task stages for the Upper Trapezius, Anterior Deltoid, Biceps Brachii, and Abductor Pollicis Brevis ($p < 0.05$), validating task-dependent variations in muscle workload. Post hoc analysis indicated significantly higher Upper Trapezius activity during posterior scaling tasks.

RULA scores across task stages were also validated using a Friedman test, which showed statistically significant differences between anterior and posterior tasks ($p < 0.01$), supporting the consistency of observed postural risk patterns. Correlation analyses showed no statistically significant relationships between vibration exposure, muscle activation, postural scores, and discomfort ratings ($p > 0.05$), implying that MSD risk during dental prophylaxis arises from the combined influence of multiple ergonomic factors rather than a single isolated variable.

6. Conclusion

This study evaluated ergonomic risks associated with dental prophylaxis using ultrasonic scalers among 12 licensed Filipino female dentists by examining vibration exposure, muscle activity, posture, and subjective discomfort across four standardized anterior and posterior scaling tasks. The findings demonstrate that dental prophylaxis, particularly during posterior scaling, poses considerable musculoskeletal disorder (MSD) risk due to task-specific physical demands.

Hand-transmitted vibration exposure was substantial, with several participants exceeding ISO 5349-1:2001 exposure thresholds. The highest vibration levels were consistently recorded along the X-axis, and posterior upper jaw scaling produced the greatest total vibration acceleration. Participants who exceeded exposure limits operated the ultrasonic scaler at higher power settings, suggesting increased risk associated with sustained high-power use. These results indicate potential long-term risk for vibration-related musculoskeletal conditions.

Electromyography results revealed high muscle workload, particularly in the Abductor Pollicis Brevis and Upper Trapezius muscles, with most monitored muscles exceeding the 15% MVC fatigue threshold. Posterior tasks generated the highest muscle activation, reflecting increased physical demand during these procedures. Postural assessment using RULA further confirmed elevated ergonomic risk, with posterior tasks classified as high-risk requiring intervention due to sustained awkward and static postures.

Subjective discomfort ratings increased following task completion, especially in the neck, shoulders, and hands, and posterior lower jaw scaling was consistently perceived as the most uncomfortable. These perceptions aligned with objective measurements and were associated with sustained posture, grip difficulty, tool weight, vibration exposure, and lack of posture adjustment during procedures.

Overall, the study confirms that dental prophylaxis using ultrasonic scalers presents significant ergonomic risks, particularly during posterior scaling tasks. These risks arise from the combined effects of vibration exposure, high muscle activity, non-neutral posture, and perceived discomfort. While ultrasonic scalers remain essential clinical tools, prolonged use without ergonomic consideration may contribute to cumulative musculoskeletal strain. The findings underscore the importance of ergonomic awareness and practical measures to mitigate occupational risk among dental professionals, particularly in resource-limited settings such as the Philippines.

References

Åkesson, I., Balogh, I. and Hansson, G. Å., Physical workload in neck, shoulders, and wrists/hands in dental hygienists during a workday, *Applied Ergonomics*, vol. 43, no. 4, pp. 803-811, 2012.

Alcazaren, J. F. and Carpio, C. M., Work related musculoskeletal disorders, ergonomics risk factors, and prevention strategies among Filipino dentists, *Manila Central University Research Journal*, vol. 2, pp. 1-7, n.d.

Alghadir, A., Zafar, H. and Iqbal, Z. A., Work-related musculoskeletal disorders among dental professionals in Saudi Arabia, *Journal of Physical Therapy Science*, vol. 27, no. 4, pp. 1107-1112, 2015.

Arora, A. and Saiya, P., Effect of handedness in professional dentists, *Journal of Dental and Allied Sciences*, vol. 7, no. 1, 2018.

Bhandary, N., Desai, A. and Shetty, Y. B., High-speed handpieces, *Journal of International Oral Health*, vol. 6, no. 1, pp. 130-132, 2014.

Blume, K. S., Holzgreve, F., Fraeulin, L., Erbe, C., Betz, W., Wanke, E. M., Brueggmann, D., Nienhaus, A., Maurer-Grubinger, C., Groneberg, D. A. and Ohlendorf, D., Ergonomic risk assessment of dental students—RULA applied to objective kinematic data, *International Journal of Environmental Research and Public Health*, vol. 18, no. 19, 10550, 2021.

Chowdhry, R. and Sethi, V., Hand arm vibration syndrome in dentistry: A review, *Current Medicine Research and Practice*, vol. 7, no. 6, pp. 235-239, 2017.

Dezfouli, M. K., Bagheri, B., Yazdani Charati, J. and Zamanzadeh, M., Prevalence of musculoskeletal disorders and related risk factors among general dentists in Sari in 2019, *Journal of Mashhad Dental School*, vol. 45, no. 4, pp. 395-404, 2021.

Dong, H., Loomer, P., Barr, A., Laroche, C., Young, E. and Rempel, D., The effect of tool handle shape on hand muscle load and pinch force in a simulated dental scaling task, *Applied Ergonomics*, vol. 38, no. 5, pp. 525-531, 2007.

Hayes, M. J., Cockrell, D. and Smith, D. R., A systematic review of musculoskeletal disorders among dental professionals, *International Journal of Dental Hygiene*, vol. 7, no. 3, pp. 159-165, 2009.

Hayes, M. J., Taylor, J. A. and Smith, D. R., Predictors of work-related musculoskeletal disorders among dental hygienists, *International Journal of Dental Hygiene*, vol. 10, no. 4, pp. 265-269, 2012.

Hermens, H. J., Freriks, B., Disselhorst-Klug, C. and Rau, G., Development of recommendations for SEMG sensors and sensor placement procedures, *Journal of Electromyography and Kinesiology*, vol. 10, no. 5, pp. 361-374, 2000.

Hongsathavij, R., Kuphasuk, Y. and Rattanasuwan, K., Clinical comparison of the stain removal efficacy of two air polishing powders, *European Journal of Dentistry*, vol. 11, no. 3, pp. 370-375, 2017.

Johansson, A. M. and Follin, M. E., Evaluation of the dental health component of the index of orthodontic treatment need by Swedish orthodontists, *European Journal of Orthodontics*, vol. 31, no. 2, pp. 184-188, 2009.

Katano, K., Nakajima, K., Saito, M., Kawano, Y., Takeda, T. and Fukuda, K., Effects of line of vision on posture, muscle activity, and sitting balance during tooth preparation, *International Dental Journal*, vol. 71, no. 5, pp. 399-406, 2021.

Lea, S., Landini, G. and Walmsley, A., Assessing the vibrations of dental ultrasonic scalers, *Journal of Sound and Vibration*, vol. 271, no. 3-5, pp. 1113-1120, 2003.

Lemaster, M. F., Kelleran, K. J., Moeini, M. and Russell, D. M., Electromyographical assessments of recommended neck and trunk positions for dental hygienists, *Journal of Dental Hygiene*, vol. 95, no. 5, pp. 6-13, 2021.

Lietz, J., Ulusoy, N. and Nienhaus, A., Prevention of musculoskeletal diseases and pain among dental professionals through ergonomic interventions: A systematic literature review, *International Journal of Environmental Research and Public Health*, vol. 17, no. 10, 3482, 2020.

Liss, G. M., Jesin, E., Kusiak, R. A. and White, P., Musculoskeletal problems among Ontario dental hygienists, *American Journal of Industrial Medicine*, vol. 28, no. 4, pp. 521-540, 1995.

Lazăr, A. M., Repanovici, A., Baritz, M. I., Scutariu, M. M., Tătaru, A. I. and Pantea, I., Postural risks in dental practice: An assessment of musculoskeletal health, *Sensors*, vol. 24, no. 19, 6240, 2024.

Milerad, E., Ericson, M. O., Nisell, R. and Kilbom, A., An electromyographic study of dental work, *Ergonomics*, vol. 34, no. 7, pp. 953-962, 1991.

Morse, T., Bruneau, H., Michalak-Turcotte, C., Sanders, M., Warren, N., Dussetschleger, J., Diva, U., Croteau, M. and Cherniack, M., Musculoskeletal disorders of the neck and shoulder in dental hygienists and dental hygiene students, *American Dental Hygienists' Association*, vol. 81, no. 1, pp. 10-10, 2017.

Ohlendorf, D., Naser, A., Haas, Y., Haenel, J., Fraeulin, L., Holzgreve, F., Erbe, C., Betz, W., Wanke, E. M., Brueggmann, D., Nienhaus, A. and Groneberg, D. A., Prevalence of musculoskeletal disorders among dentists and dental students in Germany, *International Journal of Environmental Research and Public Health*, vol. 17, no. 23, 8740, 2020.

Pope-Ford, R. and Jiang, Z., Neck and shoulder muscle activation patterns among dentists during common dental procedures, *Work*, vol. 51, no. 3, pp. 391-399, 2015.

Rafie, F., Zamani Jam, A., Shahravan, A., Raoof, M. and Eskandarizadeh, A., Prevalence of upper extremity musculoskeletal disorders in dentists: symptoms and risk factors, *Journal of Environmental and Public Health*, vol. 2015, no. 1, 517346, 2015.

Saremi, M., Rostamzadeh, S. and Nasr Esfahani, M., Hand functionality in dentists: the effect of anthropometric dimensions and specialty, *International Journal of Occupational Safety and Ergonomics*, vol. 28, no. 3, pp. 1473-1481, 2021.

Shenkar, O., Mann, J., Shevach, A., Ever-Hadani, P. and Weiss, P. L., Prevalence and risk factors of upper extremity cumulative trauma disorder in dental hygienists, *Work*, vol. 11, no. 3, pp. 263-275, 1998.

World Health Organization, Density of dentistry personnel (per 10 000 population), Available: https://data.who.int/indicators/i/C25EFD6/9F88C44, n.d.

World Health Organization, Musculoskeletal health, Available: https://www.who.int/news-room/fact-sheets/detail/musculoskeletal-conditions, July 14, 2022.

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