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Hand-Arm Vibration Syndrome in Dentistry: A Questionnaire Survey among Dentists and Review of Literature †

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Abstract: The use of dental handpieces and ultrasonic instruments expose dental professionals to high-frequency vibration, precise gripping, high pinch force, and repetitive bending movements of wrist during restorative procedures involving cutting dental material, periodontal scaling, and root planning. There is clear evidence of an association between the dentistry profession and work-related musculoskeletal disorders in the neck, upper back and upper extremities; however, the influence of high-frequency vibration on hand and fingers from dental handpieces is not well known. The objectives of the current paper are to present the results of a survey on hand-arm vibration syndrome (HAVS) among members of a professional dental society and to present a literature review on dental handpieces and ultrasonic scalers exposure assessment and occurrence of hand-arm vibration syndrome among dental professionals. There seems to be limited awareness of the occupational risk associated with hand-arm vibration from handpieces and ultrasonic devices. This study highlights the occurrence of vascular and neurological disorders of HAVS among dental professionals, as well as wrist/hand pain, osteoarthritis, diminished hand grip, and carpal tunnel syndrome. The assessment of high-frequency vibration and ultra-vibration from these vibrating tools and vibration-related injuries deserve special attention for future preventive measures.

Keywords: dentists; musculoskeletal disorders; dental handpieces; hand-arm vibration syndrome; white fingers; neuro-sensorineural injury; exposure; vibration; wrist/hand/fingers pain; carpal tunnel syndrome; osteoarthritis

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1. Introduction

Handpieces and ultrasonic scalers expose dental professionals, including dental specialists and dental hygienists, to high-frequency mechanical vibration, ranging from 0.5 kHz to 50 kHz. Air turbines and micromotor handpieces are used for tooth preparation, removal of decay, root canal treatments, restorations, implants surgery, bone cutting procedures, and various other procedures. Traditional handpieces are either air-driven or electrically driven, running with low or high speed. Each tool has specific purposes for dental procedures [1]. Dentists and dental hygienists use low-speed micromotor handpieces for polishing and removing decays, which are typically used between 20,000 rpm and 40,000 rpm. High-speed electric handpieces have typical speeds in the range of 200,000 rpm, while high speed air-driven handpieces operate at up to 400,000 rpm, but are typically and are usually used within the 180,000 to 330,000 rpm range. In addition to handpieces, sonic and ultrasonic scalers are frequently used by dentists, specialists, and dental hygienists for periodontal procedures [2]. The latter operate in a wide range of frequencies: around 3–8 kHz for sonic scalers, 18–45 kHz for piezoelectric ultrasonic scalers, and 25–50 kHz for magnetostrictive scalers [3]. Early studies have shown that dental professionals exposed to high-frequency dental tools have shown neurological and vascular symptoms, especially in the dominant hand, comparable to hand-arm vibration syndrome dating back to 1980 [4,5].

The pathological role of high-frequency vibration and potential risk for vibration-related disorders among dental professionals remains to be fully understood. Despite the fact that these excitations are much higher that the hand natural frequencies, it was postulated that injury to small nerve fibers and mecanoreceptors in the skin would be related to vibration neuropathic disorder. In addition, high-frequency vibration may contribute to decreased hand grip, pain, carpal tunnel syndrome, and osteoarthritis, although typically associated with working position, repetitive movements, and high biomechanical load. To date, no study on HAVS among dentists in Quebec has been undertaken. This study presents the results of a short questionnaire survey among dentists and a narrative review of literature to estimate the prevalence of HAVS and musculoskeletal wrist/hand pain, osteoarthritis, and carpal tunnel syndrome among dental professionals exposed to vibrating dental tools.

2. Methods

A preliminary survey was carried out on dentists from a dental association of Quebec city (Société Dentaire de Québec). A short self-administrated questionnaire was designed as a data collection instrument for dentist voluntarily responding to the invitation. Data collection was carried out from September 2016 to January 2017.

The database used for interrogation were Medline and Embase, from inception to 2022 with the following search terms: ultrasonic scalers, dental handpieces, occupational exposure or vibration exposure, dent* or dental personnel or oral health or dental specialists, dental hygienist, and dental laboratory technicians, musculoskeletal pain or disorders, hand-arm vibration syndrome, neuropathy, sensorineural disorder, and carpal tunnel syndrome. The eligibility criteria were the following: inclusion of relevant health outcomes, be published in French or English, original data (except one abstract in English), and human studies. The exclusion criteria were: lack of mentioning the prevalence of wrist/hand/fingers pain, ergonomic assessment of dentistry, preventive measures, lack of relation with the subject of study, letter to the editor, treatment, rehabilitation, perception of risks or awareness, experts statements on ergonomics in dentistry, and general topics on MSK and CTS. A concurrent search on vibration assessment of dental tools was performed.

3. Results

In total, 71 dentists (n = 71) consented to participate (women: 37, men: 30). Four incomplete questionnaires were rejected. The response rate was low (67/350). Years of practice varied from 0–10 years (n = 19), 11–20 y (n = 11), 21–30 y (n = 26), to more than 30 y (n = 11). Overall, 85% declared having exposure to handpieces for more than 11 h/week. Among the respondents, 14 dentists (13 women, 1 man) declare Raynaud's episodes (1 declare Raynaud's disease) during the last year, aged 35–44 y (n = 6), 45–54 y (n = 4), 55–64 y (n = 3), 65 and + (n = 1), cumulating years of practice as follows: 0–10 years (n = 2), 11–20 y (n = 3), 21–30 y (n = 8), and 31 and more (n = 1). Among them, two have white fingers without other symptoms. Four dentists report having consulted a physician for white fingers. Thirteen did not recall any restrictions in their professional tasks while six declared restrictions in their leisure activities. Among the respondents with episodes of white fingers, six reported having tingling, numbness, or tingling in the fingers, and seven have pain or stiffness in the finger joints. Two dentists report white fingers, tingling, numbness or tingling in the fingers, and pain or stiffness in the finger joints. Intolerance to cold, which manifests as pain, numbness, discomfort, and oedema of the fingers, afflicted 64% of respondents who report episodes of white fingers in the past year. Four of them consulted a doctor for this problem. Fifteen (22%) dentists described experiencing often or sometimes tingling and numbness in their fingers lasting more than 20 min/day. In total, 22% report (often or sometimes) tingling, numbness that wakes them up during the night. Among them, six dentists report having consulted a doctor for these problems. Twenty-four dentists (36%) reported pain or stiffness in the joints of the fingers and among them, four dentists treatment for this problem. Among these 24 dentists, 8 reported experiencing often or sometimes tingling and numbness in the fingers. In summary, 53% report one of

the HAVS symptoms. Fourteen (14) of them (41.2%; 6 M, 8 F) report that their problems are work-related, of which nine dentists represent 21 years or more of experience, manipulating handpieces more than 10 h per week (n = 11).

3.1. Review of Literature

3.1.1. Vibration Assessment

Handpieces are mostly studied for their cutting and torque efficiency, noise [6–8], pinch force, or tool handle shape for non-vibrating curettes [9]. Information about vibration characteristics is sparse [10]. Five studies were retrieved. The assessment of vibration from dental tools dates back to 1979 [11]. Various methods of assessment of vibration have been described. Interpretation of results is controversial as low-frequency is known to be more important for adverse health effects according to frequency weighting of ISO 5349-1 standardized methods, despite generating high unweighted value [12]. Studies show that vibration spectra from handpieces and scalers is dominated by high-frequency component above 1000 Hz. Measurements during idling, normal work, or simulating drilling on plastic plate with air turbines or micromotor were performed with weighted vibration according to standard ISO-5349:1986, as well as the total acceleration of high-frequency unweighted. Weighted acceleration of 2–4 m/s^2 while grinding and from 3 to 500 m/s^2 above 1.2 kHz [13] or 0.01 to 0.2 m/s^2 during idling, values of 0.03 to 0.2 m/s^2 during drilling, while ultravibration during idling varied from 29 to 320 m/s^2 and during drilling from 120 to 640 m/s^2, old handpieces showing increased values [14]. During normal work, the weighted vibrations of air-turbine handpieces were 0.01–0.04 m/s^2 and for micromotor handpieces from 0.2 to 0.9 m/s^2. The range of ultravibration was 3–200 m/s^2 [15]. Using a laser vibrometer whilst idling, no single measurement for air turbines or micromotor exceeded 4 mm for the handpieces (in the range of 4–1607 m/s^2) [10]. A recent study measured the vibration amplitude of micromotor and air-turbine handpieces during idling although interpretation due to lack of methodology data is difficult [16]. In summary, vibration assessment of these tools is challenging due to their high frequency of oscillation and small associated displacement amplitude, technical problems relating to the adding mass of the accelerometer, replication of actual work during restorative procedures or periodontal work removing plaques, and frequency weighting [17].

3.1.2. Hand-Arm Vibration Syndrome and Related Disorders

A total of 891 articles were retrieved, of which 879 were kept, excluding duplicates. A total of 5 articles were rejected for plagiarism or error from the publisher. Sixteen references were added to make a total of 890 articles. Out of these, 535 were excluded and 355 were assessed according to pre-established criteria. There were a total of 36 literature reviews dealing with MSK disorders among dental professionals out of which international reviews and meta-analysis were retrieved [18–27]. One literature review on HAVS among dentists was found, as well as another review relating to neuropathy and high frequency vibration, and one on occupational hazards related to ultrasonic scalers [3,28–30]. Unfortunately, the review on HAVS retrieved six articles, of which one does not relate to dentistry.

The prevalence of musculoskeletal disorders is high among all dental professionals and has been studied worldwide, leading to serious impact on quality of life [22,26]. Females show a higher prevalence than males in some studies [18]. Use of dental tools are related to repetitive movements of the hand and fingers, pinch force, static and asymmetrical posture, precise hand movements, awkward postures of the wrist, high-frequency vibration, as well as other factors, such as poor visibility, lack of breaks between patients, and high job demand [31,32]. Despite the high prevalence of MSK among dental professionals, HAVS has been far less studied (Table A1). Studies with estimation of vibration exposure or risk assessment of vibration exposure according to ISO-5349-1 are sparse, as well as assessment of high-frequency vibration exposure among studies on hand/fingers pain.

For the outcome of Raynaud's phenomenon, 11 studies were included. White fingers have been described among dental hygienists, dentists, and dental technicians, with a

prevalence varying ranged from 1.9% to 80%. Some studies present a positive association with daily use of high-frequency hand tools, lifetime exposure to vibration, total time dental filling, and root canal, while one found a negative association between Raynaud's phenomenon and a control group. Low cumulative exposure to vibration estimated at 1 m/s^2 during 8 h/day for 200 days/yr. or below the action value of 2.5 m/s^2 of the Vibration Directive of the European Union was described in two studies.

For the outcome neurosensory injury, 20 studies were included. Neurosensory injury has been described by questionnaire or objective neurophysiological tests. Significant impairments of vibrotactile sensibility, strength, and motor performance and more frequent sensorineural symptoms in the dominant hands of exposed dentists than controls were found. Injury to small nerve fibers and mechanoreceptors are suspected to affect tactile function. A high frequency of neurological symptoms among dentists with long-term experience especially in the dominant hand both in exposed and nonexposed fingers was found, suggesting other occupational risks than vibration. A positive association with years of experience and hours of using vibrating tools was described. The absence of a dental assistant and use of manually endodontic instruments were significantly related to a high prevalence of hand senso-neural disorders in root canal procedures compare to the use of low-speed dental handpieces, putting strain on the wrist due to pulling and pushing movements with the small handle of the instruments. Contrary these results, among dental hygienists and dental students, the vibration perception threshold in the 125 Hz (FAII receptors) indicate a fundamental difference between vibration exposure and the other biomechanical risk factors.

For the outcome of wrist/hand/fingers pain, 161 studies were included. The prevalence varied from 17% to 75% in the past 12 months among all dental professionals. In 18 studies, a positive association with vibrating tools or dental work was found, such as number of hours using vibrating tool, procedures such as scaling, inability to select the size of dental tools, or time spent forcefully gripping a tool with each patient or time. High job demand and stress was associated with symptoms in wrist/hand in three studies.

For the outcome of decreased grip strength, six studies were included. For the outcome of osteoarthritis (OA) of the fingers, six studies were included. OA in the distal interphalangeal joints among dentists without statistical difference between the drill and mirror hand contrary to another study showing more severe OA in the right-hand thumb and the index and middle fingers and among dentists with a low task variation was found. Arthrosis of the upper extremities without significant difference among dentists and dental assistants was reported. The results from the questionnaire showed thumb disability among female dentists aged 50 years and over. Upon physical exam, in one study, Heberden's arthrosis among dentists, dental hygienists, and assistants (n = 15) was compared to referents (n = 6). For the outcome of carpal tunnel syndrome, 41 studies were included. The prevalence varies from 3.8% to 86% by questionnaire and a lower prevalence was shown with nerve conduction studies. The prevalence in the dominant hand is not always reported. The prevalence seems higher among dental hygienists. The assessment of high-frequency vibration as an occupational risk is seldom reported. Significant risk factors of CTS were found: (1) vibration exposure greater than two hours per day, a wrist diameter ratio of greater than 0.7, and female sex; (2) an association of vibration exposure and two different pathologies associated with paresthesia, such as CTS and weak pinch grip associated with raised vibration perception threshold; and (3) specific dental procedures due to repetitive movements performed during scaling or to vibration of the handpieces and scalers during shaping of the root canal, polishing, or removing heavy calculus.

4. Discussion and Conclusions

Dental professionals are exposed to a vast array of occupational risks while exposed to vibrating handpieces. Neurosensory injury is more frequently described than Raynaud's phenomenon, documented with neurophysiologic tests among studies. Only one study reported results of the cold provocation test. The estimates of prevalence of Raynaud's,

according to the daily equivalent vibration expressed as A(8), are missing. Diminished grip, osteoarthritis, carpal tunnel, and hand/finger pain have been described, but there is a lack of information on dental procedures among dental professionals to fully understand the association between all occupational risks and diseases. Vibration assessment of high-frequency handpieces is mainly reported from old studies, relying on metrics giving more importance to low-frequency vibration. Measurement of daily vibration exposure constructed with the frequency weighting Wp (Ap(8) and Ep,d), giving more importance to intermediate and high-frequency vibration, would provide better assessment of occurrence of Raynaud's phenomenon than the metric derived from the conventional ISO frequency weighting Wh (Ah(8)) [33]. Our questionnaire survey shows that HAVS may be present among dentists in accordance with our literature review. A more in-depth evaluation would rule out other probable causes of paresthesia or Raynaud's phenomenon. The consultation of four respondents' dentists with a physician deserves attention. Future studies need to be performed with a protocol well designed for HAVS research among dental workers. High-frequency vibration from handpieces and scalers is absorbed by superficial tissues and tissue structures affecting mechanoreceptors sensitive to mechanical skin displacement (Pacinian responding to 5–800 Hz, less likely Meisner corpuscules 1–300 Hz, Merkel cells 100 Hz), as well as small nerve fibers [34–37]. Lundstrom suspected that if the signals from these receptors are disturbed, a reduction in tactile sensitivity would be detectable at lower frequencies, as shown in [11]. Surprisingly, these high frequencies fall out of the resonant frequency of the human hand (100–300 Hz), which generate an increased biodynamic response in the exposed tissue [38]. Hand intensive work, local stress, and high pinch force can also constitute contributory factors for the occurrence of vascular and nerve damage and osteoarthritis [39]. Repetitive movements and awkward and static posture could cause nerve compression at the wrist and increase the risk for CTS. Our results suggest that the usage of high- and low-speed type dental handpieces represent an occupational risk among dental professionals deserving further study.

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Data Availability Statement: The survey's data are available on request from the corresponding author, the data are not publicly available due to preliminary step of the study.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. HAVS and Dentists.

Author	Population Study	Findings	Tests/Questionnaire
Lundström and Lindmark [11]	Dentists (n = 10), controls (n = 10)	Neuropathy	Vibrogram: reduction of vibration perception
Hjortsberg [13]	Dental technicians (n = 10), controls (n = 10)	HAVS: SV Stockholm: n = 4 SN Stockholm: n = 8	Questionnaire, sensory nerve conduction, abnormal vibrogram, warming & cold thresholds
Ekenvall [4]	Dentists: long term (n = 26), short term (n = 18)	Neuropathy, other causes suspected	Vibrogram, temperature & pain threshold, daily exposure to dental tools difficult to estimate
Milerad and Ekenvall [5]	Dentists: (n = 99), controls (n = 100)	Vascular symptoms RR:1.2 (CI 95%: 0.7–49.5) & neurological symptoms: RR:4.2 (CI 95%: 2.3–7.7)	Questionnaire, women had higher Raynaud's phenomenon, unilateral Raynaud's in dentist in the dominant hand of dentists
Yoshida [40]	Dental technicians (n = 164)	HAVS: 5.5% vascular symptoms & 18.5%: numbness	Symptoms related to the working posture and used of dental vibrating tools
Stockhill [41]	Dentists (n = 1016 respondents)	Neurological symptoms: 15% numbness,17% tingling, 25% pain	Questionnaire
Stentz [42]	Dental hygiene (n = 260)	Neurological symptoms: 61% (pain, tingling, numbness)	Questionnaire
Akesson [43]	Females dentists & dental hygienists; dental assistants & controls (n = 30 in each group)	HAVS: Neurological symptoms (n = 18/90) and vascular symptoms (n = 16/90), decreased hand grip, no increase of vascular symptoms in the groups exposed to vibration. Abnormal neurological tests	Neurological tests (vibrogram, sensibility index, two point discrimination, tactile identification test, grip strength)
Nakladalova [44]	Dental technicians (n = 120)	HAVS: numbness: 52.5%, white fingers: 0.03%, abnormal plethysmographic curves & abnormal EMG: n = 13/54 subjects tested	Questionnaire. Cold water test, plethysmographic investigation, EMG, X-ray, neurological and orthopaedic exam
Keruoso [45]	Dentists (n = 147), orthodentists (n = 81), controls (n = 99)	HAVS neurological symptoms (10.6%) & vascular symptoms (1.9%)	Questionnaire
Alnaser [46]	Dentists (n = 89)	Wrist pain, 1 case of HAVS/89 respondents	Questionnaire
Bylund [47]	Females dental hygienists (n = 21), dentists (n = 26), technicians (n = 31)	HAVS vascular symptoms: respectively (38%), (60%), (60%) & neurological symptoms (94%), (79%), (92%), decreased hand grip	Questionnaire
Morse [48]	Dental hygiene students (n = 82)	HAVS numbness (13%) & white fingers or painful fingers in cold (13%)	Numbness & tingling increase with each hour per week vibrating tools OR:1.10 (CI 95%: 1.01-1.19)
Cherniak [49]	Dental hygienists (n = 94) & students (n = 66)	HAVS: sensorineural (Stockholm SK): 45% hygienists, dental hygiene students: 9%, vascular symptoms:12% among both groups	Questionnaire, vibrogram, nerve conduction study, pinch & grip force, neither manual or vibratory accounted for VPT thresholds
Gijbels [36]	Dentists (n = 20 randomly selected /500)	HAVS Neurological symptoms (6%) decreasing discrimination with years of practice	Questionnaire, two points discrimination, thermal sensory test, light touch
Rytkönen [15]	Dentists (n = 295 females)	Fingers symptoms related with total time dental filling &root canal OR:.1.9 (CI 95%: 1.03–3.6)	Questionnaire & pinch strength, symptoms not specified, grip strength inversely related to finger symptoms
Morse [50]	Dental hygienists (n=27) & dental hygiene students (n = 39)	Physical exam: no HAVS found	-
Shabazian [37]	Dentists (n = 50) & controls (n = 20)	Neuropathy: diminished tactile sensibility in dentist with >25 years of practice	Light touch, two points discrimination, thermal sensation of both hand: reduction of tactile sensibility
Bjorkman [51]	Dental technicians (n = 10) & controls (n = 10)	Cortical reorganization in dental technician's group with neuropathy than in controls	Functional magnetic resonance

Table A1. *Cont.*

Author	Population Study	Findings	Tests/Questionnaire
Warren [52]	Dental hygienists (n = 94) & dental Hygiene students (n = 66)	Neuropathy and Carpal tunnel syndrome	Vibrogram & nerve conduction studies, role of vibrating tools
Ancuta [53]	Dentists (n = 30)	Neurological symptoms: paresthesias and thenar amyotrophy (n = 3/30)	Cornell musculoskeletal discomfort Questionnaire & exam
Zoidaki [54]	Dentists (n = 80)	Neurological symptoms, women reported more sensorineural disorders OR: 2.6 (CI 95%: 1.06–6.7)	Nordic Musculoskeletal questionnaire, Sensorineural symptoms in root canal (manual vs. rotor) - OR: 3.4 (CI 95%: 1.08–10.9)
Jaque and Burke [55]	Dentists (n = 6/10)	HAVS vascular 80%, numbness 80%, tingling 10% & pain 60%	Questionnaire

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