International Journal of Occupational Safety and Ergonomics (*JOSE*) 2013, Vol. 19, No. 4, 561–571

Dental Ergonomics to Combat Musculoskeletal Disorders: A Review

Arpit Gupta
Anil V. Ankola
Mamata Hebbal

Department of Public Health Dentistry, KLE VK Institute of Dental Sciences, Belgaum, India

Musculoskeletal disorders (MSDs) are significant workplace problems affecting occupational health, productivity and the careers of dental professionals. The prevalence of MSDs is on the rise for all types of dental workers. In spite of different patterns of work culture, there are parallel levels of symptoms in dentists across nations. Risk factors for MSDs are multifactorial. Symptoms appear very early in careers, with higher prevalence of MSDs even during educational training. Ergonomics improvements, health promotion and organizational interventions are necessary to reduce the risk. An interdisciplinary approach with progressive efforts should be taken to address MSDs in dental professionals.

dentist occupational hazards prevalence disability risk factors psychosocial risk prevention

1. INTRODUCTION

Occupational health hazards are common in many sectors and are on a continuous rise. According to the U.S. Occupational Safety and Health Administration, work-related musculoskeletal disorders (MSDs) occur when there is a mismatch between the physical requirements of the job and the physical capacity of the human body [1]. MSDs are significant workplace problems affecting occupational health, productivity and the careers of the working population [2].

Ergonomics looks at what kind of work is done, what tools are used and the whole working environment. The aim of ergonomics is to find the best fit between workers and their working conditions. No matter what the job is, the goal is to make sure that workers are safe, comfortable and less prone to work-related injuries. Ergonomics, therefore, is the fitting of the job to the worker by designing the work and creating a working environment to prevent work-related MSDs and other health problems.

Dentistry poses a great challenge because the ergonomics of dental work is difficult. Ergonomics seeks to reduce cognitive and physical stress, prevent occupational diseases related to the practice of dentistry and to improve productivity, with better quality and greater comfort for both the professional and the patient [3].

There is no uniform medical information and or sufficient understanding of the nature of MSDs. Significant difficulties in diagnosis generate an ongoing debate on many aspects of these conditions. However, various risk factors have been identified and preventive measures are now available. To achieve a realistic target of safety and health at work, prevention is clearly the best approach; hence, preventive philosophy deserves considerable attention [3].

Therefore, this review paper aims primarily to provide background information on MSDs in dentistry and on the identified risk factors, but also to discuss the basic philosophy of prevention.

Correspondence should be sent to Arpit Gupta, Department of Public Health Dentistry, KLE VK Institute of Dental Sciences, Nehru Nagar, Belgaum (Karnataka) – 590010, India. E-mail: doc.arpit.gupta@gmail.com.

2. METHODS

Scientific articles or abstacts published in English in peer-reviewed journals were considered for this review. Letters to the editor and policy statements were excluded. No restrictions were placed on age, gender, race or socioeconomic status of the participants in the studies. Papers that studied the prevalence of MSDs and their risk factors were considered. MEDLINE, Scopus and Cochrane databases were searched for appropriate keywords. Moreover, reference lists of potentially relevant manuscripts were hand-searched to uncover further papers.

For all papers identified with those search strategies, the title, keywords and abstract (where available) were considered for possible relevance to this literature review. After excluding any duplicates, the complete text of all potentially relevant papers was obtained. All these papers were subject to critical analysis and data extraction. From these papers, after excluding some irrelevant ones, 39 manuscripts were finally considered suitable to be included in this review.

3. EPIDEMIOLOGY OF MSDs

The concept of ergonomics in dentistry dates back to the mid-20th century. In the late 1950s, Eccles and Powell (as cited in Murphy [4]) wrote one of the first journal articles on dental ergonomics. By the 1960s, Kilpatrick and others (as cited in Murphy [4]) began to identify postural and procedural rules for sit-down dentistry. Since the 1970s, ergonomic education in dental schools has included many concepts and practices, such as performance logic, four-handed dentistry, human factors engineering and dento-ergonomics [5].

In 1998, Mangharam and McGlothan reviewed nearly 60 papers. Their results support the relationship between working as a dental professional and the incidence of work-related MSDs and psychological stress [6].

The prevalence of low-back pain increased by 2700% from 1980 to 1993 [7]. Burke, Main and Freeman found that nearly one third of the dentists who retired early were forced to do so due to disability [8]. Numerous dental studies reported that, on average, 2 out of 3 dentists experienced musculoskeletal pain [4, 5, 9].

3.1. MSDs and Disability

In 2010, Cherniack, Dussetschleger and Bjor highlighted differing national characteristics of the relationship between exposure, injury and retirement from the active work force [10]. They summarized some international supporting evidence for a high prevalence of MSDs leading to lost work time and chronic symptoms (Table 1).

Leggat and Smith surveyed 285 Australian dentists, 90% of whom practised general dentistry. Complaints in the neck, shoulder and back were most common. About 37.5% of the dentists required medical care for MSDs, whereas 25% suffered from disability and 9% required extended leave from their practice [11].

Reporting on the experience of Greek dentists, Alexopoulos, Stathi and Charizani also found a high prevalence of MSDs that required medical attention or leave [12]. Low-back problems were the most common (46%). As many as 30% of the subjects experienced disability due to MSDs. Alexopoulos et al. found that 19% of dentists had

TABLE 1. International Comparison of Musculoskeletal Disorders (MSDs) and Disability in Dentists

Country and Study	*N*	Male	Female	MSD Prevalence (%)	Chronicity (%)		Primary Site
					Disability	Lost Work Time	
Australia [11]	285	73	27	87	25	9	neck/shoulder
Denmark [22]	99	56	43	66	n.d.	n.d.	neck/shoulder
Greece [12]	430	55	45	62	30	16	low back
Poland [38]	268	29	239	91	n.d.	n.d.	thoraco-lumbar region and neck
Sweden [14]	391	50	50	86	n.d.	n.d.	shoulder and low back

Notes. n.d. = no data. Table modified from Cherniack, Dussetschleger and Bjor [10].

sought medical treatment for low-back problems and 13% for hand and wrist problems.

Sartorio, Vercelli, Ferriero, et al. reported high frequencies (54%–93%) for Italian dental personnel, with higher risk in elderly subjects and women [13]. The spine, shoulder, elbow and hand were most involved.

Rolander and Bellner, who surveyed Swedish dentists, showed that 86% of the respondents reported MSDs and 70% of that group attributed causation to the workplace [14]. Despite the very high level of physical symptoms, both male and female dentists differed from their co-workers, e.g., dental assistants and hygienists. While dentists reported higher levels of psychosocial and physical work demands than their co-workers, these factors were less associated with pain intensity or location than in other dental personnel. The overall patterns suggest somewhat parallel levels of symptoms in dentists across nations, but different patterns of work culture [10].

Hamann, Werner, Franzblau, et al.'s study on North American dentists supports evidence that symptoms may be congruent across national lines but that practice patterns and work culture affect reporting [15]. Their results are striking as 36% of the 2197 American dentists who completed the questionnaire reported hand paresthesia. About half of the group (1097) consented to nerve conduction tests. However, those declining testing were twice as likely to be symptomatic (45% versus 24%) than those submitting to testing. One implication is that symptomatic dentists were more likely to self-censor more serious evidence of disease, and that problems are more widespread among American dentists than reported data suggest [10].

3.2. Neck and Shoulder MSDs

Table 2 summarizes the prevalence of MSDs reported in studies conducted around the globe. Here, we focus on a major group of the disorders affecting dentists: neck and shoulder MSDs.

Morse, Bruneau and Dussetschleger reported that the rates of neck and shoulder MSDs were very high for all types of dental workers. They gave rough estimates for prevalence: on average, 41% of dentists, 66% of hygienists, 30% of assistants and 30% of students reported neck pain, whereas 30%, 53%, 24% and 11%, respectively, reported shoulder pain. While a number of these symptoms are not currently disabling, these studies also point to considerable impact on chronic health, missed days and reduced income, and a significant negative overall impact on daily life [9].

Similarly, in a Swedish study, Lindfors, von Thiele and Lundberg showed that 81% of 945 female dental health workers reported an upper-extremity MSD [16]. In a study of dental hygienists and dental hygiene students, Morse, Bruneau, Michalak-Turcotte, et al. found a high level of agreement between self-reported neck symptoms and physician-diagnosed findings. As many as 83% of the subjects who reported no symptoms had normal examination results, while 57% of the subjects who reported symptoms had physical examination abnormalities [17].

3.2.1. Dentists

Marshall, Duncombe, Robinson, et al. found that 81% of 355 dentists in New South Wales, Australia, reported some musculoskeletal symptoms, headaches or both in the past month, primarily in the hands and wrists, with 32% reported neck symptoms [18]. Leggat and Smith found that 58% of 283 Australian dentists reported neck symptoms (with significantly higher rates for females), whereas 34% reported upper back symptoms (with higher rates for older and more experienced dentists). Symptoms were reported to interfere with daily activities in 25% of dentists with neck problems and 22% of dentists with shoulder problems [11]. In their survey of 421 dentists (43% response rate) in Canada, Rucker and Sunell found that 61% of them reported neck pain and discomfort, 44% reported shoulder pain and discomfort, while 19% reported decreased recreational activity because of MSDs [19]. In their survey of 60 male dentists in Israel, Ratzon, Yaros, Mizlik, et al. found that 38% reported neck symptoms in the past 12 months, 28% in the past 7 days and 8% were unable to do normal work due to their symptoms. The corresponding frequencies for shoulder symptoms were 25%, 15% and 7%, respectively [20].

TABLE 2. Specific Musculoskeletal Disorders (MSDs) in Dental Workers

	Dentists With MSD Symptoms in Past 12 Months (%)							Study		
Country and Study	in Neck	in Shoulder	in Neck or Shoulder	in Back	in Hands & Wrists	in Other Regions	Any	Type	Sample	Notes
Australia [18]	32	8	n.d.	n.d.	n.d.	n.d.	64	cross	community	in past month
Australia [11]	57	53	n.d.	54 (lower) 34 (upper)	34	13 (hips) 19 (knees) 12 (ankles/feet)	n.d.	cross	community	
Canada [19]	61	44	n.d.	n.d.	n.d.	n.d.	n.d.	cross	recent graduates	
Denmark [22]	54	40	60	60 (lower)	40	20 (hips & thighs)	n.d.	cross	community	also field study
Greece [12]	26	20	n.d.	46 (lower)	26	n.d.	n.d.	cross	community	
Israel [20]	38	25	n.d.	55 (lower) 20 (upper)	7	10 (knees) 5 (hips & thighs) 5 (ankles/ feet)	n.d.	cross	community	also field study, males only
Netherlands [38]	51	52	n.d.	45	21 (hands) 14 (wrists)	12 (pelvis) 2 (ankles) 7 (knees)	n.d.	intervention	community	
Poland [39]	56	37 (right) 14 (left)	n.d.	60 (thoraco-lumbar)	44	48 (lower extremities)	n.d.	cross	community	at Polish Stomatological Association meeting
Saudi Arabia [23]	54	n.d.	n.d.	74	n.d.	n.d.	n.d.	cross	community	dentists & dental assistants
Sweden [21]	54	53	n.d.	n.d.	n.d.	n.d.	n.d.	cross	community	
Sweden [31]	73	65	85	n.d.	54	23 (hips) 27 (elbows)	78	prospective	community	females only
USA [24]	46	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	cross	community	peripheral neuropathy only
USA [34]	28	21	n.d.	35	n.d.	9 (legs) 6 (arms)	n.d.	cross	army	frequent pain/score

Notes. n.d. = no data.

In Greece, Alexopoulos et al. found that 62% of dentists reported MSDs, 30% had chronic complaints, 16% experienced a spell of absence due to MSDs and 32% sought medical care [12]. According to Rundcrantz, Johnsson and Moritz's Swedish survey, 72% of dentists reported neck or shoulder pain or headaches. A follow-up visit in 143 dental offices found that 96 dentists (67%) had signs of cervico-brachial disorders and discomfort [21]. In Finsen, Christensen and Bakke's Danish study, just over half of surveyed dentists reported ache, pain and discomfort in the neck, and 40% in the shoulder over the past year, with ~20% reporting such pain in the past week. Younger dentists and those that worked longer hours tended to have more complaints [22]. Similarly, Al-Wazzan, Almas, Al Shethri, et al. found that 54% of 204 dental professionals in five dental offices in Saudi Arabia experienced neck pain. The frequency of neck pain was significantly higher ($p = .01$) in dentists than in other dental professionals [23].

The international studies summarized in section 3. show consistently high frequencies for neck and shoulder pain, which cause both discomfort and difficulty with functional daily activities. This indicates a high level of severity of neck and shoulder MSDs in dentists.

In survey of 1015 dentists in Nebraska, USA, (98% response rate), Stockstill, Harn, Strickland, et al. reported a lower prevalence. They recorded 294 dentists (29% of the total) with symptoms of peripheral neuropathy; 46% of that group located the problem in the neck. Overall, 16% of that group reported constant symptoms, and 41% had symptoms while working [24]. Neck pain, therefore, appears to be pervasive, and dentists are not taking activity breaks that could potentially reduce symptoms. Relatively low frequencies of neck and shoulder MSDs, of up to ~30%, were recorded also in Greece [12] and Australia [18] (Table 2).

3.2.2. Dental students

Available data on MSDs in dental and dental hygiene students are sparse in comparison to data on dental professionals. However, more recently, attention has been given to students, either as a control group or as a newly exposed group [9]. Werner, Franzblau, Gell, et al. found very low rates of MSDs in dental and dental hygiene students (compared to a control group of clerical workers): 6% with elbow complaints and 16% with shoulder or neck complaints, but only 1.7% of dental students and 3.6% of dental hygiene students had physician-diagnosed shoulder tendonitis [25]. Morse et al. found self-reported neck symptoms in 37% of dental hygiene students, in 43% of dental hygiene students who had previously been dental assistants and in 72% of experienced dental hygienists. The corresponding frequencies for physician-confirmed neck findings were 22%, 38% and 47%, respectively. Shoulder pain in the past 12 months was reported by 26.9% of respondents overall [17]. According to Rising, Bennett, Hursh, et al., female dental students in California, USA, reported the neck and shoulders as the most affected regions (they also reported higher levels of pain than males), while back complaints were more common in male students [26]. Rising et al. also found that 46%–50% of female students had neck or shoulder pain, compared to 29%–58% of males. As many as 65–85% of dental students who had previously worked in the dental field reported some type of MSD pain, and pain was related both to fatigue and to stress [26]. In a survey of 590 U.S. dental students, Thornton, Barr, Stuart-Buttle, et al. found similar results, with 48% reporting neck symptoms and 31% reporting shoulder symptoms, with the highest rates in the third year [27].

Collectively, these studies indicate that dental students are not unexposed or symptom-free. These studies suggest that prevention programmes should be introduced into dental education to prevent musculoskeletal discomfort during educational and professional years [9].

4. RISK FACTORS FOR MSDs IN DENTAL PROFESSIONALS

To identify and develop intervention strategies to minimize risks, in addition to epidemiology, the risk factors for MSDs have been investigated. Many authors have concluded that MSD risk factors are multifactorial, including static and

awkward postures (particularly in relation to neck and shoulder conditions); repetition and force (more commonly related to hand and arm conditions); poor lighting (both intensity and positioning); improper positioning of both patient and dental worker; individual characteristics (physical conditioning, height, weight, general health, gender, age) and stress [9]. Figure 1 summarizes how prolonged, static postures can progress to a cumulative trauma.

In an extensive review of risk factors affecting dental workers, Yamalik listed specific dental tasks as risks: limited range of motion (constrained postures) resulting in isometric muscle contractions; difficulties in direct visualization, which causes awkward posture; visual demands requiring static postures; prolonged, repetitive tasks (including scaling and endodontic procedures); long surgical procedures; forceful clinical tasks (e.g., scaling); and high precision and flexion for instrumentation [29].

In dentists, head rotation, neck flexion and necessary upper arm abduction for mirror use are common risk factors for upper extremity disorders. For example, risk for trapezius pain may be heightened by holding the arm elevated for long periods [30]. A Swedish study of 143 site observations found that dentists with cervicobrachial disorders keep their head bent to the side and rotated to a greater extent than dentists without symptoms [21]. Marshall found that 87% of New South Wales dentists sit when treating patients, and 65% practise four-handed dentistry, i.e., they work with an assistant [18]. Valachi and Valachi concluded that general practitioners tend to be susceptible to lower back and neck injuries due to prolonged, static postures, but have relatively fewer repetitive-motion injuries [30]. Those authors also noted that dentists often rotate their necks to the left with side bending to the right for better visibility and this is likely to strengthen the muscles on one side, while weakening the opposing muscles, thus resulting in the inability to rotate the neck to the right with side bending to the left [21]. Similarly, the forward viewing posture, frequently used by dental workers, can lead to weakening of the stabilizer muscles of the shoulder blades, leading to rounded shoulder

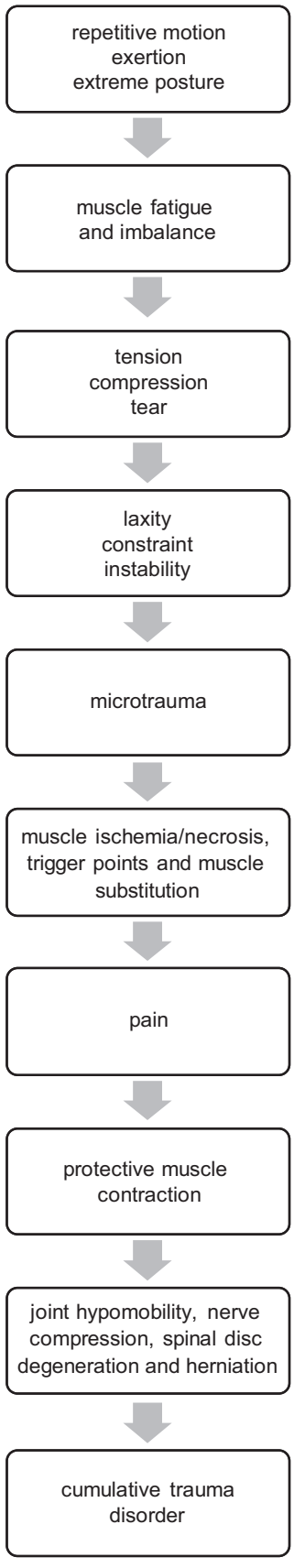

Figure 1. Flowchart showing how repetitive motion and extreme postures can progress to pain and cumulative trauma disorders.

posture [30]. Several studies noted an association of headaches with neck and shoulder pain [9].

Valachi and Valachi suggested that the historic change in dental workers from standing posture to typically seated posture has not reduced the rate of MSDs, but that the part of the body affected has moved from the back to the neck, shoulders, and arms, largely due to static postures combined with forceful, repetitive movements [30]. Considering that most dental care is provided while the team is seated, seated postures play a key part to spinal balance. Rucker noted that dentists experience less varicosities of the legs, but more problems with the upper back and extremities [5].

Students work alone, without assistants, so they may be at a particular risk as they move into clinical practice, which appears to increase postural risks. Moreover, left-handed students have been shown to have a higher risk of MSDs. Therefore, postural risk factors appear to be widely present in all dental occupations and to be related to MSD symptoms. The symptoms appear to increase cumulatively as students move into practice. These are likely aggravated by repetition and force, in all types of dental practice [9].

Biomechanical risk factors are not the only risk factors that must be considered when examining MSDs in the dental population; psychosocial factors have been studied both singly and in combination with biomechanical risks. Psychosocial factors include issues like organization of the job, job demands (number of workers seen, the hours worked), job control, style of supervision, support amongst co-workers and others. Work–home conflicts have also been studied in relation to stress and related musculoskeletal pain [9].

Murphy correlated the common risk factors in the general public to the practice of dentistry. These included a constrained and fixed posture (sitting), awkward postures (of neck/shoulder/wrist), exertion of force (extraction of teeth), repetitive motions (scaling), and duration of force (injection of anaesthetic/scaling). He also related these risk factors to "ergonomic causes": work station design (operatory), tool design, work object (or patient), work techniques, work organization (case load), and work environment (lighting) [4].

Historic trends towards higher efficiency (such as increased number of patient visits) may have also increased MSD risk. In addition, there may also be relationships to personal characteristics (such as body height), high visual demands, workplace organization, and lack of recovery time, which add to the risk of developing a MSD [9]. In a Swedish survey, Ylipää, Arnetz and Preber found that active leisure decreased the odds for upper extremity MSDs, while work duration (including the hours worked) and family overload increased the odds [32].

5. PREVENTION OF MSDs IN DENTAL PROFESSIONALS

Several papers have presented numerous recommendations for preventing MSDs in dental workers, but there have been essentially no controlled intervention studies. Therefore, these recommendations primarily tend to reduce the associated risk factors based on cross-sectional epidemiological studies or small, lab-based assessments of risk factor levels. Linton and Tulder noted this lack of randomized controlled intervention trials as a severe problem more generally (not just with respect to dental workers) in interventions on neck and back pain, including ergonomics interventions [33], with only exercise programmes having sufficient support for clear recommendations.

Following a large U.S. Army symptom survey and literature review, Lalumandier, McPhee, Parrott, et al. suggested that MSDs can be reduced through proper positioning of the dental worker and patient, regular rest breaks, general good health and exercises designed to counteract the particular risk factors for the dental occupation. Postures to avoid include head leaning forward, rounded shoulders and bent back. Recommendations include (a) an adjustable ergonomic stool with lumbar support and capability to rotate; (b) dentists sitting with feet flat on the floor and thighs parallel to the floor, while dental assistants sitting 10–15 cm (4–6 in.) higher and using a footrest with the stool; (c) patient fully reclined, with the mouth at the dentist's elbow height for maxillary arch tasks, and lowered with a 20°

incline (still with the mouth at the dentist's elbow height) for mandibular arch tasks; (d) proper lighting and indirect mirror viewing; (e) regular resting from static postures, particularly for the trapezius and forearm muscles, and from repetitive motions of the forearm and hand (minimum of 6 min/h and 10–15 min every 2–3 h); (f) exercises during those breaks, such as relaxing the arms at the side and shaking, or moving limbs and muscles in the opposite direction of repetitive or static postures between patient visits (e.g., bending the neck backwards after a prolonged forward tilt); (g) observing recommended practices for nutrition and regular leisure exercise; and (h) using shoulder blade repositioning and chin tuck exercises for neck pain [34].

Based on a nonsystematic literature review and biomechanical and physical therapy principles, Valachi and Valachi gave multiple specific recommendations for dental workers, e.g., relaxing and stretching neck muscles, exercising, using 2× magnification, proper positioning of the chair and patient, alternating sitting and standing, and using properly adjusted armrests to reduce shoulder fatigue and allow reduced force due to more stable positioning of instruments [35].

Yamalik also performed a nonsystematic but comprehensive literature review to produce a set of specific recommendations, including choosing lighter ergonomic dental instruments to reduce shoulder and neck fatigue and effects from holding static postures [29]. Better sizes and shapes of dental instrument handles have been shown to reduce hand force in laboratory experiments, although it is unclear if this would have effects on the neck and shoulders [36].

Based on a biomechanical and survey study of 590 dental students (and observation of practice areas for the four participating schools), Thornton et al. recommended an adjustable stool with integrated lumbar and arm support, proper lighting (e.g., for maxillary treatment, having the overhead light close to the operator's line of vision), and having the patient reclining [27]. Such approaches can be developed for individual situations by evaluating individual characteristics and symptoms, postures, instrumentation, and environmental and organizational factors in relation to workplace improvements [9]. Qualitative responses suggest ergonomic design characteristics, including patient chairs able to go down sufficiently (particularly for dentists of smaller stature), adequate space in the room for moving the stool around easily, dental instruments that are sized properly for smaller hands and are lightweight, sufficient lighting, magnifying loupes available, and addressing psychosocial issues, e.g., control over scheduling, social isolation (hygienists tend to work alone, in contrast to dental assistants), work–family conflicts, inadequate recognition and professional satisfaction [37]. Properly selected and positioned magnification systems can help reduce forward posture, including keeping forward flexion of the neck under 20°.

6. RECOMMENDATIONS

There have been general alarms that the practice of dentistry carries high risks of disabling disease and injury and hence potential premature career loss. MSDs have significant social and economic consequences, including quitting the profession or significantly reducing working hours. Ergonomics improvements in the dental setting have reduced risk factors; however, those risk factors may be exacerbated by higher productivity demands in the profession generally as well as psychosocial considerations including social isolation and work–family conflicts. Symptoms appear to begin very early in careers, with higher prevalence of MSDs even during educational training as clinical hours increase. Therefore, the students are more at risk as they practice dentistry without assistants.

The evidence reviewed indicates that most studies on dental ergonomics and MSDs have been conducted in developed countries. In developing countries, like India, there is hardly any published report on this vital subject. As there is national variation in the prevalence data, based on differing work culture and other factors, there is an urgent need to promote research on such neglected subjects also in developing countries.

Moreover, to elucidate the potential risk factors and to formulate effective prevention programmes, several approaches are suggested:

- designing large-scale studies to assess the prevalence of various MSDs and also to identify the risk factors associated with them; such studies should be promoted across the globe;
- designing an intervention study to identify the various risk factors, to evaluate the efficacy of various preventive measures and to discover various innovative prevention strategies;
- combining the efforts of professionals from various disciplines (dentistry, medicine, physiotherapy, biomechanics, instrument industries, etc.) to promote dental ergonomics and to prevent MSDs.

According to the available reviewed data, a few recommendations are made:

- promoting training on both ergonomics (biomechanics) and stress reduction (psychosocial and physical) in dental schools as a prevention strategy;
- including a separate course on ergonomics in the dentistry curriculum and periodical evaluating the ergonomics practices of students;
- promoting continuing dental education programs on dental ergonomics for clinicians;
- formulating global guidelines for developing ergonomic dental equipment;
- setting up an international monitoring agency to prevent manufacturing and sale of nonergonomic dental equipment;
- periodical screening of dental professionals for MSD-related symptoms to diagnose them early and treat promptly;
- promoting worldwide research on this subject;
- welcoming collaborations among all health-care professionals to prevent MSDs with focus upon examining the broad social and cultural contexts of disability for dental professionals, the prevalence and risk factors for MSDs and unique solutions for MSD prevention.

Based on theoretical models, general physical therapy and ergonomics principles, so-called active ergonomics, and health promotion concepts combined with ergonomics are gaining widespread support [9]. Both these approaches suggest regular movement as important in reducing the negative impact of dental work, particularly of static postures. This includes regular movement and changing postures over the work day, as well as integrating exercise, stretching (particularly in the opposite direction of static and repetitive workplace postures), yoga and relaxation exercises. Exercise and stretching also make sense from a biomechanical standpoint, but studies have not found any strong association with lower MSD rates. Therefore, intervention studies appear to be an important current research need.

7. CONCLUSIONS

Dentistry carries a high risk of physical injury and entails exposure to physical and organizational risk factors that require ergonomics intervention. An interdisciplinary approach is necessary to address the concern, and progressive efforts should be taken to prevent MSDs in dental professionals. There is a need for continuing efforts to discover innovative prevention strategies, understand the larger system issues, and appreciate the very damaging nature of MSDs on the lives of dental practitioners.

Outcome of intervention studies will be important for examining the efficacy of proposed interventions. Combining ergonomics interventions (chair redesigns, magnification and lighting, activity breaks, organizational changes, creative use of part-time or rotating work) with health promotion activities (stretching that targets the underused muscles, leisure exercise, preventing work–family conflicts) need to be designed and evaluated.

Since the evidence indicates that problems begin to occur at the start of clinical training, such interventions should be introduced at the training level, to reduce risks during training and also to get new practitioners to adopt the ergonomics culture.

REFERENCES

1. Occupational Safety and Health Administration. U.S. Department of Labor. Preventing work-related musculoskeletal disorders. 1999. Retrieved July 4, 2013, from: http://lobby.la.psu.edu/062_Ergonomics_Standards/Agency_Activities/OSHA/OSHA_Preventing_Work_Related_MSD.htm.
2. Nermin Y. Musculoskeletal disorders (MSDs) and dental practice. Part 1. General information—terminology, aetiology, work-relatedness, magnitude of the problem, and prevention. Int Dent J. 2006; 56(6):359–66.
3. Castro SL, Figlioli MD. Ergonomia aplicada à dentística: avaliação da postura e posições de trabalho do cirurgiãodentista destro e da auxiliar odontológica em procedimentos restauradores [Ergonomics applied to dentistry: evaluation of posture and work positions of the dentist and the assistant handed dentistry in restorative procedures]. JBC: jornal brasileiro de clinica & estetica em odontologia. 1999: 3(14):56–62.
4. Murphy DC. Ergonomics and dentistry. N Y State Dent J. 1997;63(7):30–4.
5. Rucker LM. Technology meets ergonomics in the dental clinic: new toys for old games? J Am Coll Dent. 2000;67(2):26–9.
6. Mangharam J, McGlothan JD. Ergonomics and dentistry: a literature review. In: Murphy DC, editor. Ergonomics and the dental care worker. Washington, DC, USA: American Public Health Association; 1998, p. 25–75.
7. Pope M. Muybridge lecture. In: Proceedings of the International Society of Biomechanics XIVth Congress. Paris, France: International Society of Biomechanics; 1993. p. 10–3.
8. Burke FJ, Main JR, Freeman R. The practice of dentistry: an assessment of reasons for premature retirement. Br Dent J. 1997;182(7): 250–4.
9. Morse T, Bruneau H, Dussetschleger J. Musculoskeletal disorders of the neck and shoulder in the dental professions. Work. 2010;35(4):419–29.
10. Cherniack MG, Dussetschleger J, Bjor B. Musculoskeletal disease and disability in dentists. Work. 2010;35(4):411–8.
11. Leggat PA, Smith DR. Musculoskeletal disorders self reported by dentists in Queensland, Australia. Aust Dent J. 2006; 51(4):324–7.
12. Alexopoulos EC, Stathi IC, Charizani F. Prevalence of musculoskeletal disorders in dentists. BMC Musculoskelet Disord. 2004;5:16. Retrieved July 4, 2013, from: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC441388/.
13. Sartorio F, Vercelli S, Ferriero G, D'Angelo F, Migliario M, Franchignoni M. Work-related musculoskeletal diseases in dental professionals. 1. Prevalence and risk factors. G Ital Med Lav Ergon. 2005;27(2): 165–9. In Italian, with an abstract in English.
14. Rolander B, Bellner AL. Experience of musculo-skeletal disorders, intensity of pain, and general conditions in work—the case of employees in non-private dental clinics in a county in southern Sweden. Work. 2001;17(1): 65–73.
15. Hamann C, Werner RA, Franzblau A, Rodgers PA, Siew C, Gruninger S. Prevalence of carpal tunnel syndrome and median mononeuropathy among dentists. J Am Dent Assoc. 2001;132(2):163–70.
16. Lindfors P, von Thiele U, Lundberg U. Work characteristics and upper extremity disorders in female dental health workers. J Occup Health. 2006;48(3):192–7.
17. Morse T, Bruneau H, Michalak-Turcotte C, Sanders M, Warren N, Dussetschleger J, et al. Musculoskeletal disorders of the neck and shoulder in dental hygienists and dental hygiene students. J Dent Hyg. 2007;81(1):10.
18. Marshall ED, Duncombe LM, Robinson RQ, Kilbreath SL. Musculoskeletal symptoms in New South Wales dentists. Aust Dent J. 1997;42(4):240–6.
19. Rucker LM, Sunell S. Ergonomic risk factors associated with clinical dentistry. J Calif Dent Assoc. 2002;30(2):139–48.
20. Ratzon NZ, Yaros T, Mizlik A, Kanner T. Musculoskeletal symptoms among dentists in relation to work posture. Work. 2000; 15(3):153–8.

21. Rundcrantz BL, Johnsson B, Moritz U. Occupational cervico-brachial disorders among dentists. Analysis of ergonomics and locomotor functions. Swed Dent J. 1991;15(3):105–15.
22. Finsen L, Christensen H, Bakke M. Musculoskeletal disorders among dentists and variation in dental work. Appl Ergon. 1998;29(2):119–25.
23. Al Wazzan KA, Almas K, Al Shethri SE, Al-Qahtani MQ. Back & neck problems among dentists and dental auxiliaries. J Contemp Dent Pract. 2001;2(3):17–30.
24. Stockstill JW, Harn SD, Strickland D, Hruska R. Prevalence of upper extremity neuropathy in a clinical dentist population. J Am Dent Assoc. 1993 Aug;124(8):67–72.
25. Werner RA, Franzblau A, Gell N, Hamann C, Rodgers PA, Caruso TJ, et al. Prevalence of upper extremity symptoms and disorders among dental and dental hygiene students. J Calif Dent Assoc. 2005;33(2):123–31.
26. Rising DW, Bennett BC, Hursh K, Plesh O. Reports of body pain in a dental student population. J Am Dent Assoc. 2005;136(1): 81–6.
27. Thornton LJ, Barr AE, Stuart-Buttle C, Gaughan JP, Wilson ER, Jackson AD, et al. Perceived musculoskeletal symptoms among dental students in the clinic work environment. Ergonomics. 2008;51(4):573–86.
28. Valachi B. Move to improve your health: the research behind static postures. Dentistry Today. 2011. Retrieved July 4, 2013, from: http://www.dentistrytoday.com/ergonomics/5361-move-to-improve-your-health-the-research-behind-static-postures.
29. Yamalik N. Musculoskeletal disorders (MSDs) and dental practice. Part 2. Risk factors for dentistry, magnitude of the problem, prevention, and dental ergonomics. Int Dent J. 2007;57(1):45–54.
30. Valachi B, Valachi K. Mechanisms leading to musculoskeletal disorders in dentistry. J Am Dent Assoc. 2003;134(10):1344–50.
31. 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 Sep;72(6): 395–403.
32. Ylipää V, Arnetz BB, Preber H. Predictors of good general health, well-being, and musculoskeletal disorders in Swedish dental hygienists. Acta Odontol Scand. 1999;57(5):277–82.
33. Linton SJ, van Tulder MW. Preventive interventions for back and neck pain problems: what is the evidence? Spine (Phila Pa 1976). 2001;26(7):778–87.
34. Lalumandier JA, McPhee SD, Parrott CB, Vendemia M. Musculoskeletal pain: prevalence, prevention, and differences among dental office personnel. Gen Dent. 2001;49(2):160–6.
35. Valachi B, Valachi K. Preventing musculoskeletal disorders in clinical dentistry: strategies to address the mechanisms leading to musculoskeletal disorders. J Am Dent Assoc. 2003;134(12):1604–12.
36. Dong H, Loomer P, Barr A, Laroche C, Young E, Rempel D. The effect of tool handle shape on hand muscle load and pinch force in a simulated dental scaling task. Appl Ergon. 2007;38(5):525–31.
37. Crawford L, Gutierrez G, Harber P. Work environment and occupational health of dental hygienists: a qualitative assessment. J Occup Environ Med. 2005 Jun;47(6): 623–32.
38. Droeze EH, Jonsson H. Evaluation of ergonomic interventions to reduce musculoskeletal disorders of dentists in the Netherlands. Work. 2005;25(3):211–20.
39. Szymańska J. Disorders of the musculoskeletal system among dentists from the aspect of ergonomics and prophylaxis. Ann Agric Environ Med. 2002;9(2):169–73.