Chapter 2

Ergonomics and Dentistry:

A Literature Review

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Abstract

This chapter provides a brief summary of selected literature on ergonomics and dentistry. It is organized into three main parts: musculoskeletal disorders and risk factors; psychosocial disorders and risk factors; and availability and effectiveness of current ergonomic interventions. The objective is to highlight selected works rather than to provide an exhaustive treatise of the literature in this area. Table 1 breaks the literature down by author, study design, sample size, instruments used (such as questionnaires), measures (from instruments used), and results and conclusions. Table 2 shows that dentists are more than twice as likely as dental assistants and dental hygienists are more than three times as likely to have repetitive musculoskeletal injuries and illnesses. Psychosocial-related musculoskeletal disorders appear to be connected with time pressures that may not allow dental personnel to fully recover between patients or tasks. These pressures may be driven by changes in the health care system that require extreme efficiency for a practice to be profitable. Finally, the availability of ergonomic interventions is limited because most solutions are reported anecdotally rather than studied systematically for effectiveness. However, recent advances in dental workplace layout, instruments, and operatory furniture show promise. Systematic, quantitative, epidemiologic evaluations of ergonomically designed dental furniture and instruments, as well as informative literature about good work practices and work postures in dentistry are needed to provide guidance in combating potentially career-ending musculoskeletal disorders such as carpal tunnel syndrome.

Introduction

The purpose of this chapter is to present a review of literature about ergonomics in dentistry. Ergonomics today requires the consideration and integration of both physical and psychosocial issues. Previous literature on ergonomics in dentistry may

be classified into three major categories: musculoskeletal disorders and associated risk factors, psychosocial disorders and associated risk factors, and the availability and effectiveness of current ergonomic interventions. Table 1 summarizes the literature under the classifications listed above.

Musculoskeletal Disorders and Risk Factors

Prevalence

Work-related musculoskeletal disorders in the service industry are common today, and their occurrence continues to proliferate globally. Statistics from 1995 (the latest available data at this writing) showed that "sprains" and "strains" accounted for 49.7% of all occupational injuries in service industries in the United States. Out of all musculoskeletal injuries, 2.1% were related to the neck, 31.4% were of the upper limbs, and 31.4% were of the back.[1]

Similarly, the prevalence of musculoskeletal injuries in the dental profession is high, showing significant differences among dentists, dental hygienists, and dental assistants. Table 2 lists the injury rates for the 1994 employed population (not including the self-employed) from the Bureau of Labor Statistics (BLS).

A number of studies have estimated the prevalence of work-related musculoskeletal disorders in dental work.[2–18] Most of the studies are cross-sectional, providing prevalence rates; because they lack comparisons with control groups they are unable to demonstrate true cause and effect. Many of these studies have not used statistical measures such as odds ratios, incidence rates, or risk ratios to analyze their results.

The most recent studies of the prevalence and incidence of work-related musculoskeletal disorders are briefly summarized below under the three major classifications of epidemiological studies: cross-sectional, case-control, and cohort studies.

Cross-Sectional

Auguston and Morken[2] administered a questionnaire to employees in the Public Dental Services of Hordaland County

Table 1.—A summary of Literature for Ergnomics in Dentistry

Musculoskeletal Disorders					
Authors	Study Design	Sample	Instruments Used	Measures	Results and Conclusions
Burke et al, 1997[6]	Retrospective analysis	393 dentists with premature retirement because of illness between 1981 and 1992	Records from one organization operating in the private medical sickness industry in the UK.	Causes of premature retirement	Premature retirements were due to musculoskeletal disorders (29.5%), cardiovascular disease (21.2%) and neurotic symptoms (16.5%). Eighty-two percent of cases examined were in the >50 years age group. Musculoskeletal disorders and stress related illnesses were the two most important groups of factors that influenced premature retirement.
Auguston and Morken, 1996[2]	Cross-sectional	329 employees in the public dental services of Hordaland (Norway)	Questionnaire	Musculoskeletal discomfort	Eighty-one percent experienced some sort of musculoskeletal discomfort in the last 12 months. Shoulder discomfort was experienced by 45%. Neck discomfort had been experienced by 47% and low back pain by 49%. Twenty-one percent hand/wrists and 20% upper back were reported. The dental personnel's experience of musculoskeletal discomfort did not differ from that found in the general Norwegian population. Neck discomfort increased with increasing age. Ergonomic equipment helped to alleviate discomfort in the shoulder. Perceived work load was positively associated with shoulder discomfort. Participation in sport activities showed negative association with discomfort in the lower back.

Table 1.—*Continued*

Authors	Study Design	Sample	Instruments Used	Measures	Results and Conclusions
Moen and Bjorvatn, 1996[8]	Cross-sectional	96 female dentists in a University (cases), 83 female dental auxiliaries and 25 female office workers	Questionnaire	Musculoskeletal symptoms	No significant differences in musculoskeletal symptoms between the female dentists and the other female employees were found. Female dentists reported more musculoskeletal symptoms than male. The study concluded that symptoms are not related to the work as dentists, but to female working conditions in general or to factors outside work. The dentists in this study treated patients only part of their working time and had varied types of work. The low occurrence of musculoskeletal symptoms may have been caused by less time spent in difficult positions and/or by the lack of stress factors such as time, economics, public attitudes, repetition, and professional isolation.
Jacobsen et al, 1996[9]	Case-control	489 male and 242 female dental laboratory technicians (cases) and 163 males and 160 females of other occupations (controls)	Questionnaire	Health complaints	Biannual prevalence comprising 68% of musculoskeletal complaints. Job-specific ergonomic and stress factors were responsible for musculoskeletal and neurological reactions. There were no age prevalence patterns. Female technicians consistently showed a larger prevalence of musculoskeletal complaints than their male counterparts. The prevalence of job-related health complaints was still higher among the technicians than in control groups. Only a few of the technicians had consulted medical personnel.

Table 1.—*Continued*

Authors	Study Design	Sample	Instruments Used	Measures	Results and Conclusions
Van Doorn, 1995[7]	a) Retrospective investigation b) intervention program	795 cases of self-employed dentists, veterinarians, physicians, and physical therapists.	Disability data from an insurance company in the Netherlands.	a) low back disability of 1987 and 1988 b) results after intervention program given in 1990	Among dentists over 44 years of age and veterinarians over 34 years of age had specific low back pain, nonspecific low back pain in combination with a deferred period of 14 days or more, low back problems before acceptance, and the presence of psychosocial problems at the start of the disability were significantly associated with the duration of low back disability. The same was not evident for physicians or physical therapists. After the introduction of an early intervention program the mean cumulative duration of low back disability decreased significantly. Standardized to 1990 (N=134), the number of claimants who reached a cumulative duration of 1 year was reduced by 56%. The early intervention program was cost-effective.
Kihara, 1995[23]	Cross-sectional	16 male dentists of an urban clinic in Japan	Questionnaire, time study of daily actions, electro-myography	Work-related complaints, daily action times	Most common posture was right-forward position. Neck and shoulder complaints were more than eyes, hands and arms and low back. The amplitude of electromyograms was increased by the extension of the muscles to lateral bending of 30 degrees and internal rotation of 15 degrees. It was concluded that body positions of daily dental practices cause an increase in work-related complaints.
Liss et al, 1995[12]	Cross-sectional	2,142 dental hygienists (DH) and 305 dental assistants (DA) (50% response rate)	Standardized Nordic Questionnaire	Musculo-skeletal symptoms	DHs compared to DAs (after adjusting for age) were 5.2 times (95% CI 0.9 - 32) more likely to have been told they had carpal tunnel syndrome, 3.7 times (95% CI 1.1 - 11.9) more likely to meet a carpal tunnel syndrome case definition. DHs more likely to have 2.5 times (95% CI 1.6 - 3.9) more hand/wrist, 2.8 times (95% CI 1.8 - 4.4) more shoulder and 1.8 times (95% CI 1.2 - 2.7) more neck problems than DAs. Less likely to complain of back problems.

Table 1.—*Continued*

Authors	Study Design	Sample	Instruments Used	Measures	Results and Conclusions
Jacobsen and Hensten-Petersen 1995[85]	Case-control	189 dental hygienists (cases) and 160 female and 163 male controls.	Questionnaire	General health problems	50% of industrial hygienists experienced occupationally related health problems. Most common health complaints were dermal reactions. Headache and dizziness were reported in about 25% of those surveyed. Headaches were associated with workload stress or musculoskeletal problems.
Milerad and Ericson, 1994[28]	Descriptive	12 healthy subjects	Electromyography	Electromyographic activities of six muscles during circular and eccentrically rotating track while holding a dental instrument with varying grip sizes and resistance against motion	The highest mean muscular activity was found in the dominant trapezius pars descends and supraspinatus/trapezius transversus muscles. Precision significantly affected the muscular load on extensor carpi radialis and infraspinatus muscles, while force had no impact on EMG activity in any of the muscles. Arm support during the task appeared to reduce the muscular load on the upper trapezius and supraspinatus.

Table 1.—*Continued*

Authors	Study Design	Sample	Instruments Used	Measures	Results and Conclusions
Stentz et al, 1994[39]	Cross-sectional	260 dental hygienists in the state of Nebraska (56.5% response rate)	Questionnaire	Subjective responses to questions on demography, working environment, workload, pain, discomfort, and numbness (altered sensation).	Sixty-one percent indicated that they experienced upper-extremity altered sensations related to physical stress. Pain, tingling, and numbness were most frequently reported. Sixteen percent had been previously diagnosed with an upper-extremity neuropathy. Ninety percent noticed altered sensations only after entering the profession.
Sinczuk-Walczak and Izycki, 1994[86]	Literature review	N/A	N/A	N/A	Aggregated data provide evidence that cervical and lumbosacral pains are the most common complaints as far as the locomotor system is concerned.
Polakowska, 1994[37]	Cross-sectional	31 dentists	Neurological examination, electroneurographic and radiological examinations	Condition of peripheral nervous system, particularly cervical roots and peripheral nerves of the upper limb	All subjects complained of lumbar pain. In 80.6% of subjects, these pains indicated radicular neuralgia. Lesion of ulna nerve was found in 22.6% and lesion of median nerve in 35.5% of dentists examined.

Table 1.—*Continued*

Authors	Study Design	Sample	Instruments Used	Measures	Results and Conclusions
Visser and Straker, 1994[20]	Cross-sectional	28 qualified dental therapists and 26 qualified dental assistants	Written questionnaire, anthropometer and weight scale	Level of discomfort (visual analog scale on general body discomfort diagram), anthropometric measures and weights.	Discussed that since the 1960s, the introduction of the sitting posture, which was recommended to decrease lower-extremity problems, has not eliminated musculoskeletal injuries. Loads on soft-tissue structures of the lumbar spine and discs are increased in seating. Dental therapists and assistants experienced discomfort associated with their work, localized mainly in the back, neck, and shoulder areas. Dental assistants were shown to experience significantly lower levels of discomfort than dental therapists. Discomfort experienced by dental workers at work was also shown to significantly increase across the working day.
Stockstill et al, 1993[5]	Cross-sectional	1016 dentists in Nebraska	Survey	Musculoskeletal complaints	Twenty-nine percent of Nebraska dentists surveyed said they felt pain, followed by numbness and tingling. Frequency of symptoms was not associated significantly with age, years in practice, type of practice, or patient position. More frequent symptoms were associated with "crown and bridge" work. The prevalence suggests the possibility of an occupational concern.
Jacobsen and Peterson 1993[10]	Cross-sectional	101 women, 100 men employed in dental technology	Survey	Occupation-related health complaints	Fifty percent experienced job-related health complaints. Thirty-nine percent of the complaints were musculoskeletal. In general the occupation-related health complaints were equally frequent among men and women. Self-reported occupational risk factors revealed that approximately one third of the musculoskeletal complaints were work related. Ergonomics and work-specific stress factors were important etiologic factors for the musculoskeletal reactions.

Table 1.—*Continued*

Authors	Study Design	Sample	Instruments Used	Measures	Results and Conclusions
Oberg and Oberg, 1993[11]	Cross- sectional	28 female dental hygienists, mean age of 40 years (most part-time workers)	Standard Nordic Questionnaire	Demographic data, presence and location of musculoskeletal complaints	Neck and shoulder complaints showed a clear predominance over other locations. Sixty-two percent of the subjects reported complaints of the neck and 81% reported complaints of one or both shoulders during the previous 12 months. The frequency of lower-extremity complaints was low. Most neck, shoulder, arm, and back complaints were considered work related by the dental hygienists themselves.
Izycki and Wagrowska-Koski, 1992[87]	Descriptive	Between 1984, and 1991, 188 dentists were referred for consultation with suspected occupational disease.	Assessed at the outpatient department of Occupational Diseases, Institute of Occupational Medicine, Poland	Musculoskeletal signs and symptoms were assessed for definite diagnosis.	In total, 122 (64.9%) of the cases referred were diagnosed with an occupational disease. Chronic inflammation of the humeral epicondyles (61.5%) and periarticular shoulder inflammation (25.4%) dominated the diagnoses. Low back disorders due to spondyloses or discopathies were rejected from the population because of high frequency in the general population and legal regulations that do not include them as an occupational disease in Poland.

Table 1.—*Continued*

Authors	Study Design	Sample	Instruments Used	Measures	Results and Conclusions
Rundcrantz 1991[86]	Cross-sectional	359 dentists	Questionnaire, ergonomic evaluation	Musculoskeletal complaints, ergonomic examination of 143 dentists' workplace	Seventy-two percent reported headache and pain and discomfort in the neck and shoulders. Female dentists had a higher prevalence of pain and discomfort. Younger dentists had pain and discomfort in the neck and shoulders as well as headaches, to a greater extent than older dentists. Male dentists, who positioned their patient carefully to gain a direct view suffered less from headache. Dentists who used the mirror reported less headache and pain and discomfort of the shoulders. Patient wedge cushions and intrinsic pauses in the work decreased the number of symptoms. Dentists having symptoms experienced unsatisfactory workload, were burdened by anxiety, and had poorer psychosomatic health and less confidence in the future. Regression analysis showed that personal harmony and age had the highest value for explaining the number of painful sites in the musculoskeletal system.
Kwahito et al, 1991[48]	Descriptive	5 instructors in the department of operative dentistry each preparing 5 cavities	Plastic-film-based stress-sensing element and a three-light emitted diode on the axis of a the bur	Measure finger stress and behavior of bur	Vibration emitted by the bur head is 500 000 rpm. The finger stress of forefingers had a tendency to be larger than the thumb. It appears that the middle finger controls the behavior of the hand-piece. The head end of the bur tended to incline into the buccal site.

Table 1.—*Continued*

Authors	Study Design	Sample	Instruments Used	Measures	Results and Conclusions
Rundcrantz et al, 1991a[14]	Cohort of 3 years	311 dentists (170 female) in 1987; 262 dentists (84%) reassessed in 1990.	Questionnaire	Information on pain experienced in the neck, shoulder, and low back areas and headache experienced during the past year and the past week and working postures.	Musculoskeletal pain symptoms increased in most body regions between 1987 and 1990 except low back. The incidence of musculoskeletal symptoms was greater in female dentists than in males. When stratified by age, the incidence of new cases of musculoskeletal problems was 0.2 case/person year for subjects 40 year old, 0.3 case/person years for subjects 40 to 49 years old, and 0.1 case/person year for subjects 50 to 65 years old. Attempts to relate working postures to development or resolution of symptoms between 1987 and 1990 surveys revealed no significant correlation. Ergonomic factors as indicated working postures have little predictive value for the recovery from or development of musculoskeletal problems.
Milerad et al, 1991[89]	Descriptive	12 dentists	Vocational electro-myography	Electro-myographic activity in different dental practice activities	Trapezius muscle showed similar activity between left and right. The right (dominant) extensor carpi radialis muscle had a significantly higher muscular load level than the left. The infraspinatus muscle had low activity levels on both sides.

Table 1.—*Continued*

Authors	Study Design	Sample	Instruments Used	Measures	Results and Conclusions
Lehto et al, 1991[3]	Cross-sectional	131 professionally active dentists	Questionnaire about health and general background; questionnaire on symptom checklist; Standard Clinical Examination; general fitness test (bicycle ergometer); hand grip force; radiographs of cervical spine and shoulder joint and lumbar spine (if over 40 years); psychological tests; and tempero-mandibular joint dysfunction test.	Multidisciplinary results-objective and subjective tests.	Forty-two percent had experienced pain and disability in the neck and shoulder in the preceding year (greater prevalence in salaried), and thirty-seven percent in the low back. Somatic symptoms or stress, perceiving dentistry as physically too heavy or mentally too straining, and a poorer general health status rating were all associated with greater than 1 year prevalence of neck-shoulder and lower back pain and disability and with poorer general physical fitness. The results provide evidence that physical exercise should be recommended to dentists and might also be applicable to subjects in other occupations with similar requirements.

Table 1.—*Continued*

Authors	Study Design	Sample	Instruments Used	Measures	Results and Conclusions
Lehto et al, 1990[40]	Case-control	136 dentists between ages 33 and 69 and 940 controls from general population of same age	X-rays of the hand	Prevalence of arthrosis in the hands and pinch power.	The prevalence of arthrosis was significantly higher in male than female dentists. Male dentists tended to have a higher and female dentists a similar prevalence of arthrosis as compared with the respective controls. The proportion of arthrotic distal interphalangeal joints (DIP) of all arthrotic joints of the hand was in both male and female dentists greater than that in controls, especially under the age of 50, suggesting earlier development in dentists. This might result from the extensive use of the precision grip in dentistry. Arthrosis of the DIP joint of the index finger was not associated with pinch power between the thumb and index finger, indicating good preservation of manual function in spite of increasing degeneration changes in hand joints with advancing age.
Milerad and Ekenvall 1990[4]	Case-control/ cross-sectional	99 dentists and 100 pharmacists	Telephone interview	Musculoskeletal symptoms	Forty-four percent of dentists and 26% pharmacists reported symptoms of the neck (RR = 2.1, 95% CI 1.4, 3.1). Symptoms of the shoulder were reported by 51% of the dentists and 23% pharmacists (RR = 2.2, 95% CI 1.5 , 3.3). Forearm symptoms were present almost exclusively in the dentists (12% versus 1%). Male dentists had increased prevalence of Raynaud phenomenon in the dominant hand, but the etiology was unclear. Numbness and paraesthesia were more common among the dentists than among pharmacists (RR= 4.2, 95% CI 2.3, 7.7). Symptoms of the dentists were probably related to their difficult work positions with arms abducted and elevated, cervical flexion and rotation, and repetitive precision-demanding hand grips.

Table 1.—*Continued*

Authors	Study Design	Sample	Instruments Used	Measures	Results and Conclusions
Ekenvall et al, 1990[49]	Case-control	26 dentists exposed to long-term, high-frequency vibration and 18 dentists with short- term exposure.	Survey	Differences between the dominant and non-dominant in the perception of vibration, temperature, heat and pain were compared between case and control groups.	Larger vibration thresholds were found in those with long-term exposure both for digit II (exposed to vibration) and digit V (unexposed). Temperature and pain thresholds were similar. The case group had neurological symptoms in the dominant hand more often than the controls. Vibration threshold (more advanced symptoms) differences were higher for the symptomatic dentists than for the symptom-free dentists. Since exposed and unexposed fingers were similarly affected, the neurological symptoms in the dominant hand of dentists with long-term exposure seem to have some other etiology than higher-frequency vibration.
Rundcrantz et al, 1990[13]	Cross-sectional	359 dentist (90.8% response rate)	Questionnaire	Musculoskeletal symptoms	Female dentists suffered more headaches (46% vs. 29%; $P < .001$), pain of the neck (61% vs. 46%; $P < .01$), and shoulder pain (62% vs. 43%; $P < 0.01$). Male dentists had pain and discomfort in neck, shoulders, and headaches to a greater extent in the younger sample. Younger female dentists had a significantly higher frequency of pain and discomfort in the neck and more headaches than older colleagues. If the patient was positioned carefully (direct view), significantly lower frequency of headaches was seen. Dentists who did not have discomfort in the upper locomotor system used the mirror (55% mostly used the mirror to facilitate a direct view).

Table 1.—*Continued*

Authors	Study Design	Sample	Instruments Used	Measures	Results and Conclusions
Persson and Brune, 1989[90]	Cross-sectional, descriptive		Survey, chemical air sampling, indoor air quality, observation.	Survey of health complaints and stress levels, exposure levels of methylmeth-acrylate, formal-dehyde and mercury vapor, dust exposure, ventilation system, observation of ergonomic status.	The potential hazards in the environment of the dental laboratory were related to ergonomics, chemicals (methylmethacrylate, formaldehyde, and mercury vapor), dust, noise, and light. Generally, headache was a common symptom among dental technicians and could be related to stress factors.
Hagberg and Hagberg, 1989[15]	Review	N/A	N/A	N/A	A review of literature was presented for posture; movement; and musculoskeletal load in dentistry, prevalence and risks of musculo-skeletal disorders, and prevention of musculo-skeletal disorders in dentistry.
Blewett and Hirsch, 1986[16]	Cross-sectional	168 dentists (out of 600)	Survey via professional newsletter	Demographic data, number of hours worked, type of seating, ratings of chair against certain criteria, musculoskeletal symptoms.	Eighty-eight percent reported pain, 54 reported no pain, and 24 were excluded from the study because they did not sit to work or the response did not have sufficient data.

Table 1.—*Continued*

Authors	Study Design	Sample	Instruments Used	Measures	Results and Conclusions
Shugars et al, 1984[18]	Cross-sectional	487 dentists of the South Carolina Dental Society (51% response)	Questionnaire	Prevalence and location of back pain, possible causative factors, (e.g., chair posture) and predisposing factors (e.g., age), years of practice, hours per week in practice, practice type, and percentage of time sitting.	Fifty-seven percent reported at least occasional general back pain. Twelve percent indicated they had sought professional treatment for back pain. Predisposing factors (26%) correlated more strongly with back pain than other factors. Good posture correlated negatively with back pain. Generally, dentists who sat 80 to 100 percent of the time reported more frequent low back pain.
Kajland et al, 1974[17]	Case-control	152 private and public health dentists 35-51 years old, majority of whom were females and 95 clerks (controls matched for age, sex and economic status).	Interview and questionnaire, kinocyclography motion analysis	Sociology background, professional environment, prevalence of medical conditions, equipment used, opinions on work positions, and observations of postures.	No significant differences were seen between dentists and comparisons with regard to reported absences from work because of sickness. Dentists suffered more musculoskeletal problems (shoulders and backs) than did comparisons. Those who reported musculoskeletal symptoms also reported lower work satisfaction or had a lower satisfaction index. Dentists with good working postures exhibited a lower frequency of absence because of illness.

Table 1.—*Continued*

Authors	Study Design	Sample	Instruments Used	Measures	Results and Conclusions
Powell and Smith, 1964[22]	Cross-sectional	49 dental operators	Visual and cinephotographic observations made during examinations, prosthetics, conservation and extraction operations.	Postures observed	For all operations, dentists spent most of their time either in a position of antero-posterior flexion, rotated counter-clockwise, or bent laterally to the right (in 70% of cases, all three at the same time). The cervical spine was involved to a greater degree. An outstanding problem is the provision of a satisfactory seat for the operator. The present dental stools tend to distort posture more than the equivalent standing attitudes, and to reduce mobility; some of this is due to the obstruction offered by the patient's chair.
Nystrom 1958[19]	N/A	N/A	N/A	N/A	Found that approximately 25% out of the 580 dentists surveyed reported backache and pains in the muscles and joints of the upper extremity. The clinical examination revealed that pains in the upper extremities were mainly located in the right hand and arm. Pains in muscles and ligaments were experienced, particularly from the flexors and extensors of the fingers, as well as from shoulders and neck. Joint symptoms were most pronounced in the index finger and thumb of the right hand.

Table 1.—*Continued*

Psychosocial					
Authors	Study Design	Sample	Instruments Used	Measures	Results and Conclusions
Reitemer, 1996[65]	Cross-sectional (over 72 workdays)	24 dentists	Heart rate periods, Nitsch self-assessment scale.	Workplace design (conventional versus ergonomic), light, noise, air movement, electro-cardiogram epidemiological data of occupa-tional diseases (extracted from reports from various medical disciplines).	Analysis of the results revealed that dental work involves high psychic stress. Recommendations include the inclusion of dentists in occupational care, ergonomic design of working areas and their use, and coordinated advanced training in the field of dental work design. Dental extractions led to the highest working pulse in every proband, possibly being the procedure that causes the highest stress to the worker.
Newton and Gibbons, 1996[60]	Qualitative case comparisons	Two groups of dentists working under different systems of remuneration—NHS and independent capitation scheme	Questionnaire	Stress experienced	Both groups identified patient management, time pressures, and staff and practice management as sources of stress, although under the independent capitation scheme dentists felt that they were under less time pressure and faced considerably less paperwork. Results suggest that changing from a National Health System to an independent capitation scheme is of great benefit.

Table 1.—*Continued*

Authors	Study Design	Sample	Instruments Used	Measures	Results and Conclusions
Davidove, 1996[66]	Descriptive	Not specified	Ongoing discussions with dentists	Observation by Dr H. Adelson	Depression has a serious and adverse effect on the lives of many dentists today. Certain environmental demands, such as economy and constraints imposed by insurance companies, are accelerating and subjecting dentists to significant emotional pressures. Self-esteem may be compromised, and it has been recommended that self-criticism can help work as a prophylaxis against depression.
Joffe, 1996[67]	Descriptive	N/A	N/A	N/A	Written from a clinical psychologist's view point. Dentists have a number of common characteristics—hard-working and driven to achieve perfection at all costs. The critical inner voice can cause shame, anxiety, depression, exhaustion, and low self-esteem. It can lead to a compulsive lifestyle. Several studies suggest that the adult personality of dentists stem from patterns established in childhood and parental failure to provide adequate nurture. Dentists' cardiovascular systems have been shown to be stressed by difficult procedures. Burnout may result—a syndrome of physical and emotional fatigue.
Freeman et al, 1995[61]	Descriptive	N/A	N/A	N/A	Stressors that have been identified as being intrinsic to dentistry have included the heavy workload, the repetitive nature of the work, dealing with fears and anxieties of patients, and financial concerns. Time pressures have also been identified as stressors.

Table 1.—*Continued*

Authors	Study Design	Sample	Instruments Used	Measures	Results and Conclusions
Craven et al, 1995[62]	Cross-sectional	370 dental surgery assistants	Questionnaire	Psychological stress, job satisfaction, and organization	Results suggest that severe overall job stress and dissatisfaction were not prevalent but do present an important problem for the minority. The chief sources of stress were mainly time limitations, feeling undervalued, handling difficult patients, unclear job description, and annual salary review. Having a regular staff meeting, an annual salary review, and a clear job description were associated with significantly less job stress.
Osborne and Croucher, 1994[70]	Cross-sectional	340 dental practitioners	Questionnaire	Emotional exhaustion, depersonalization, personal accomplishment, demographic variables, frequency and type of practice.	Lower levels of emotional exhaustion were found in those working in practices containing four or more dentists and those working 3 days per week. Lower levels of depersonalization were found in married subjects and higher levels of personal accomplishment in those with postgraduate qualification.
Rundcrantz et al, 1991c[69]	Case-control	Case-96 dentists with cervico-brachial disorders and 47 controls are dentists without cervico-brachial disorders	Questionnaire	Psychosocial variables	Dentists with symptoms showed less satisfaction with work environment. Dentists with symptoms found (significant difference) work more unsatisfactory, were more burdened by anxiety, had poorer psychosomatic health, and less confidence in the future. Specialists were overall more satisfied (with or without symptoms). Specialists had more self-confidence and experienced less anxiety than general practitioners and head dentists.

Table 1.—*Continued*

Authors	Study Design	Sample	Instruments Used	Measures	Results and Conclusions
Katz, 1987[68]	Cross-sectional	291 members of the Texas Dental Association.	Survey	Predictor variables: hardiness (control, commitment, and challenge), dental attitude survey: situational predictors: outcome variables: dental stress (self-perception), career satisfaction, psychiatric symptoms.	Hardiness was found to be significantly related to lower levels of stress and psychiatric symptoms and higher levels of career satisfaction experienced. Dental attitude survey also was predictive of stress, symptoms, and career satisfaction. Income level and frequency of exercise were strongly related to dentists' career satisfaction. Specialization and number of weeks away from the office were significantly related to reduced stress.
Ergonomic Intervention					
Authors	Study Design	Sample	Instruments Used	Measures	Results and Conclusions
Pollack 1996[72]	Descriptive	N/A	N/A	N/A	In dentistry, poor working habits, along with repetitive tasks such as scaling and root planning, contribute greatly to musculoskeletal disorders, stress claims, and lost productivity. The key objective for clinicians is to find a position that allows them to achieve optimum access, visibility, comfort, and control at all times.

Table 1.—*Continued*

Authors	Study Design	Sample	Instruments Used	Measures	Results and Conclusions
Powell et al, 1994[77]	2x2 intervention trial	176 dental hygienists	The distance between the two points with the hand in the modified pen grasp was subtracted from the distance between the two points in the relaxed position for each glove (converted into force)	Differences of forces exerted by ambidextrous and fitted gloves	Fitted gloves (f=0.792 N, SD=0.199) exerted significantly less force on the hand compared to ambidextrous gloves (f = 0.597N, SD=0.297) ;t=9.06, df = 175, P < .0001.
Oberg 1993[74]	Case-study	One Swedish dental hygienist	Time distributions study, posture targeting diagrams, biomechanical computations, serial photography and video recording	Critical factors causing work-related pain in the neck and shoulders	Fixed working postures, sparse movement patterns, limited work space, and long standing static load on the neck and shoulder muscles were shown. Horseshoe-shaped support for the patient chair and a special armrest for the operator chair were designed to provide an ergonomically desirable environment of decreased load.
Bruder and Rohmert, 1991[91]	Cross-sectional, descriptive	466 dentists	Questionnaire	Information on working conditions, individual characteristics and health problems	One of the major areas of concern and change was in the position of the dentist and the assistant in relation to the patient. Changes were suggested in the design of the chair for the patient.

Table 1.—*Continued*

Authors	Study Design	Sample	Instruments Used	Measures	Results and Conclusions
Rundcrantz et al., 1991b[27]	Case-control	96 dentists (64 males) who experienced neck and shoulder pain (cases) and 47 dentists (31 males) who did not report neck or shoulder problems	Observation/ Questionnaire	Musculoskeletal complaints from previous questionnaire, sitting work postures, use of mirror, clock-related working posture relative to patient, use of wedge cushion, active neck and shoulder mobility, and static endurance of the shoulder muscles	Approximately 26% of the asymptomatic dentists and 11% of the dentists with symptoms used a wedge cushion. No significant differences were found with mirror use. Cervico-brachial complaints in dentists cannot completely be explained by deficiencies in the neck and shoulder mobility or ergonomic factors.
Rundcrantz et al, 1991d[84]	Intervention study	Group A - dentists with occupational cervico-brachial disorders receiving physiotherapy treatment and psychosomatic approach and individual ergonomic instruction; Group B - as above, only receiving ergonomic instruction.	Ergonomic intervention, psychosomatic physiotherapy techniques, questionnaire	Pain and discomfort levels, experience of well-being, self-confidence, control over work, confidence in the future.	Both groups showed decrease in cervico-brachial disorders. In Group A significant decrease of pain and discomfort in the neck ($P < 0.05$) and a significant improvement was found concerning the experience of well-being ($P < 0.05$). The feeling of self-confidence had increased significantly in five weeks for Group A ($P < 0.05$).

Table 1.—*Continued*

Authors	Study Design	Sample	Instruments Used	Measures	Results and Conclusions
Jamar and Sevais, 1990[92]	Review	N/A	N/A	N/A	Recommendations of dentists' chairs and cupboards' designs and contents. Fixed furniture with fixed dentist's chairs are advised not ergonomic.
Grace et al, 1990[75]	Intervention	50 freshman dental student volunteers	Patient dental chair angle chosen by the subject	Volunteers were asked if they were comfor-table and the chair was subsequently adjusted in 5-degree intervals with the patient being questioned at each interval.	The initial sitting position of the patient affects the selected preferred inclination of the dental chair by the patient. If the patient is initially seated in a dental chair that has been present in the horizontal or supine position, this study suggests that the patient would not experience discomfort and therefore would have no objections to this position.
Micholt, 1990[93]	Review	N/A	N/A	N/A	Several studies indicate that there is still a large gap between the theoretical knowledge of work organization, working postures, and health risks on the one hand and its application in the dental practice on the other hand. Therefore it is useful again to take a closer look at the preventive measures that can contribute to less physical and psychological strain in the daily practice.
Eccles, 1976[71]	Descriptive/ Review	N/A	N/A	N/A	Discusses changes of posture and ergonomic intervention in dentistry over the years. Discusses the applications of ergonomics research to dentistry by using observation, timing operations, surveys, quantity of work measurements, physiological data, and other health hazards in dentistry. Areas of future research are urged for equipment design, building design, cost effectiveness, and human factors.

Table 1.—*Continued*

Authors	Study Design	Sample	Instruments Used	Measures	Results and Conclusions
Kwasman et al, 1975[78]	Intervention	Five interns and four dental assistants of the Eastman Dental Center (paired as dental teams). 150 actual dental treatment sessions in two dental treatment rooms of identical construction	Video recording	Observed frequency and duration of instrument transfer, critical incidents that interfered with instrument movements, and subjective responses of the dental team members.	The handpiece transfers were faster and more frequent in the 12 o'clock location where they were done by the assistant. The reverse was true for the transfers of the three-way syringe. The subjective responses indicated that the assistant working with the 12 o'clock instrument location had many more tasks and must be more highly trained.
Eccles and Davies, 1972[76]	Intervention	15 (10 male, 5 female) students of the Cardiff Dental School.	Posture of operator assessed by one examiner using a four-point scale for back tilt and back rotation, arm and shoulder movement, and right wrist and hand movements. The degree of undesirable movement was scored.	Postural score comparisons were made for operating positions (9 o'clock and 12 o'clock), handpiece position (5 o'clock and various positions), handpiece angle (vertical head up, horizontal, vertical head down), and tooth position (upper or lower)	In low-line dentistry, handpieces positioned in the mid-line above the patient are most convenient for operators working either at the 9 or 12 o'clock position and give fewer postural problems. For lower teeth the handpiece is best placed horizontally, and for upper teeth it is best placed with the head down.

Table 1.—*Continued*

Authors	Study Design	Sample	Instruments Used	Measures	Results and Conclusions
Eccles and Davies, 1971[63]	Intervention	32 male and 6 female dental students from the Cardiff Dental School	Patient stimulator to carry out a series of timed precision-movement tests	Accurate measure of time required to gain access to a number of cavities using a series of set operating positions	It was better to have the patient chair in the horizontal position than at 30 degrees since better posture could be achieved. In general it was better to have the patient's head facing forward and not rotated left or right. Though for some individual cavities, rotation may be desirable. The operator should work in the 9 o'clock or 12 o'clock position and not in the 3 o'clock position.
Kilpatrick, 1971[60]	Intervention	6 dentists and 8 assistants	Time studies (observation and stop watches)	Time differences between independent work, assistant utilization, workplace layout variances, and preparation prior to various dental procedures	Factors affecting efficiency were psychological factors (preference for working alone, patient temperament), use of the assistant (level of assistants' training), case involvement (complexity level of procedure), and physical factors (workplace layout).
Eccles, 1970[58]	Case-control, descriptive	10 male dentists carrying out treatment on 50 patients in total (5 patients to each dentist)	Two-channel galvanic skin response (GSR) apparatus measuring skin conductance. Electrodes placed on the palmar surfaces of the wrists.	Using the principle that skin conductance increases with arousal (as a measure of stress).	There was no real evidence that stress occurred in dentists that could be directly attributed to reactions of their patients and in only a few cases did dentists believe themselves to be affected by patients.

Table 1.—*Continued*

Authors	Study Design	Sample	Instruments Used	Measures	Results and Conclusions
Eccles, 1969[57]	Case-control, Descriptive	10 male dentists between ages 23 and 40	Electrocardiograph	Heart rate continuously monitored while patient reads a book, during conservative treatment carried out on a phantom head and during similar treatment carried out on a patient on four separate occasions each.	There was a significantly fall in heart rate from the first to the fourth trial indicating a reaction and subsequent adaptation to the experimental environment. There was a highly significant difference between the heart rate of different dentists and between the heart rates while patient reads book and while dentist carried out treatment. The difference in heart rate between treating a patient and a phantom head was just significant ($P < 0.05$), but not enough to warrant the firm conclusion that the dentist's heart rate was influenced by working on a living patient.
Fox and Jones, 1967[79]	Descriptive	N/A	N/A	N/A	Common working postures of dentists were presented. The dental chair role and design were discussed in terms of design parameters (working heights, access to patient, comfort of the patient, articulation, the operator's stool). The need for postural education was emphasized.

Table 1.—*Continued*

Authors	Study Design	Sample	Instruments Used	Measures	Results and Conclusions
Eccles and Powell, 1967[55]	Cross-sectional	231 (88.5% response) in the1965 Dentists Register in the counties of Carmarthen, Glamorgan, and Monmouth, Wales.	Questionnaire	Personal, morbidity, attitudes about work, surgery equipment and organization.	For most part they found their work fatiguing and considered the pace high. Nearly all made use of chairside assistance and more than half worked standing up. Dentists' satisfaction was obtained principally from relationships with patients and from achievements. The main source of dissatisfaction was from work restrictions and the pace of work. The dentists believed that their work was fatiguing because of long hours and severe pace, stress, and inadequate working environment. Poor posture was believed to be a contributory cause. Younger dentists and older dentists were the least dissatisfied.
Green and Brown, 1963[24]	Descriptive	11 subjects covering 3628 frames of film (one frame per second), and 163 tracings were made directly from selected frames. The frames were chosen on the basis of visibility of the dentist.	Memo-motion pictures	Observations of various postures adopted by the dentist.	More subjects stood than sat and only one dentist divided time between sitting and standing. Ten out of the 11 dentists assumed the 11 o'clock position with the subject in a head extension position. Cervical flexion (head down) position was assumed most often during work (69% of time). In most of the illustrations the dentist has a flexed cervical spine and rounded shoulders, the elbow is elevated, and the left hand is flexed at the wrist. A variety of stools were used (extent of adjustability unknown). For each of these observed postures, recommendations to improve posture were made. Education about good body mechanics was encouraged.

Table 2.—Estimates of Injury Rates from the Bureau of Labor Statistics[1] for the Employed Population (Does Not Include Self-Employed)

	Dentists		Dental Hygienists		Dental Assistants	
Population employed in 1994 (excluding self-employed)	67 000		92 000		182 000	
	Rates	Total count	Rates	Total count	Rates	Total count
Sprains and Strains	Not available for 1994	Not available for 1994	8 per 10 000	67	12 per 10 000	214
Repetitive trauma	22 per 10 000	149	30 per 10 000	270	8 per 10 000	135

in Norway. The purpose of the questionnaire was to measure the prevalence of musculoskeletal symptoms in various parts of the body. They found that out of the 329 satisfactory responses (76%), 81% had experienced musculoskeletal discomfort in the last 12 months, and among these, shoulder discomfort had been experienced by 45%, neck discomfort by 47%, and low back pain by 49%. Twenty-one percent reported hand and wrist symptoms, and 20% reported upper back symptoms.

Case-Control

A case-control study carried out by Jacobsen et al,[9] which studied female dental laboratory technicians (n = 242), consistently showed a higher frequency of musculoskeletal complaints ($P < .005$) than 160 matched controls of other occupations. Male technicians, although they had a higher frequency of musculoskeletal complaints than their respective controls, did not show significant differences.

Cohort

Two studies[7,14] used a cohort design to determine the incidence rate and risk ratio of work-related musculoskeletal

disorders in the dental industry. Rundcrantz et al.[14] carried out a cohort study on 311 dentists in 1987, and 262 of them were followed up in 1990, in the Municipality of Malmo, Sweden. Results of a questionnaire showed that the incidence of new cases of work-related musculoskeletal disorders was greater among female dentists than male dentists. When stratified by age, the difference in reported symptoms (between the period of 1987 and 1990) among three age groups (< 40, 40–50, 50–65) was not significant. Van Doorn[7] used a combined case-control and retrospective method to study 795 self-employed dentists, veterinarians, physicians, and physical therapists. Compared with dentists, physical therapists (relative risk [RR] = 2.67; 95% CI 2.23, 3.19) and veterinarians (RR = 2.04; 95% CI 0.72, 2.43) had a significantly greater risk of lowback disability claims, while physicians had a significantly lower risk (RR = 0.87; 95% CI 0.72, 1.06) . For all four professions combined, the annual incidence rate of lowback disability per 1000 persons at risk, adjusted for profession, age and deferred period for claims increased from 3.5 per 1000 in 1977 to 7.4 per 1000 in 1989.

The body of literature that supports the association between dental work and work-related musculoskeletal disorders has steadily accumulated since the 1950s. Nystrom,[19] cited in Kajland et al,[17] carried out one of the earlier studies in the field. Approximately 25% of the 580 dentists surveyed reported backache and pains in the muscles and joints of the upper extremity. Clinical examinations revealed that most pain in the upper extremities was located in the right hand and arm. Such pains were experienced not only in the flexor and extensor muscles (tendons and ligaments of the fingers), but also in the shoulders and neck. Joint symptoms were most pronounced in the index finger and thumb of the right hand. This literature prompted researchers to study the associations of occupational risk factors, environmental factors outside of work, age, and gender with the various types of musculoskeletal disorders commonly seen in this occupation. More recently, methods of prevention and specific ergonomic interventions have been studied: these will be addressed later in this chapter.

The remainder of the chapter will detail the specific types of musculoskeletal injuries common to dental practice and the

risk factors associated with the profession for three major categories: neck and shoulder; hand and wrists; and low back.

Neck and Shoulder Disorders

Neck and shoulder symptoms among dentists, dental hygienists, and dental assistants have been commonly reported according to several researchers.[3, 4, 8, 11–14, 17, 20]

Types of Neck and Shoulder Disorders

Pain and discomfort are the major symptoms of neck and shoulder complaints. A case control study carried out by Milerad and Ekenvall found that a group of 99 dentists had a higher frequency of cervical symptoms than a group of 100 pharmacists (44% versus 26%; RR = 2.1; 95% CI 1.4, 3.1)[4]. Female dentists reported neck symptoms 1.4 times more often than male dentists (95% CI 1.0, 2.0). Among the female dentists, the frequency of symptoms increased with age (not observed in male dentists or in either gender among pharmacists). Dentists with neck symptoms also experienced shoulder and arm symptoms more often than pharmacists with neck symptoms (RR = 5.4; 95% CI 1.6, 17.9). The shoulder on the dominant side was affected as often as that on the nondominant side. The authors felt that the result might reflect the effects of a work position in which both arms were abducted.

Risk Factors for Neck and Shoulder Disorders

Epidemiological studies have been designed to determine if sufficient evidence implicates physical workplace factors in neck and shoulder musculoskeletal disorders.[21] There is supportive evidence for a causal relation between highly repetitive work and neck and shoulder musculoskeletal disorders. Repetitive neck movements and continuous arm and hand movements affecting the neck and shoulder demonstrate significant associations. According to the National Institute for Occupational Safety and Health (NIOSH) Executive Summary (p. xiii), there is also evidence for a causal relation between forceful exertion and the occurrence of neck musculoskeletal

disorders in epidemiological literature. However, there was insufficient evidence for positive association between force and shoulder musculoskeletal disorders.

There is a strong relationship between neck musculoskeletal disorders and high levels of static contraction, prolonged static loads, and extreme working postures involving neck and shoulder muscles.[21] There is also evidence for a relationship between shoulder musculoskeletal disorders and repeated or sustained shoulder postures involving greater than 60 degrees of shoulder flexion or abduction. However, there was insufficient evidence to provide support for the relationship of vibration and neck or shoulder musculoskeletal disorders, according to this investigation.[21]

Dentists and dental assistants are required to adopt nonneutral postures for much of the workday. The postures adopted usually require prolonged static contraction of the trunk and scapulothoracic and scapulohumeral musculature, combined with repetitive contraction of muscles in the wrist, hand, and fingers during fine hand motor control work. Dental workers usually assume awkward postures for several reasons:

- to obtain optimal view of teeth within the patient's mouth, often while maintaining a seated posture;
- to provide a comfortable position for the patient;
- to coordinate their positions relative to assistants, with whom they often share limited space; and
- to maneuver complex equipment and reach for instruments.

The posture and biomechanics of dental workers have been analyzed by several authors. Operating procedures can be identified in relation to a 12 o'clock position (Nield and Houseman cited in Liss et al[12] (see Figure 6 in Chapter 11, "Human-Centered Ergonomics: Proprioceptive Pathway to Occupational Health and Peak Performance in Dental Practice").

Operating positions are usually identified in relation to a 12-hour clock face:

1. the 8 o'clock position, to the front of the patient;
2. the 9 o'clock position, at the side of the patient;
3. the 10 o'clock position;
4. the 11 o'clock position; or
5. the 12 o'clock position, in back of the patient.

Powell and Smith[22] carried out visual and cinephotographic observations during dental examinations, prosthetics, conservation, and extraction operations. For all operations, the dentists spent most of their time either in a position of anteroposterior flexion, or rotated counterclockwise and bent laterally to the right (all three positions at the same time in 70% of cases).

Kihara[23] performed a cross-sectional study of 16 male dentists. Results from a questionnaire, time study of daily actions, and electromyography showed that the most common posture was the combination of the flexed and right side–flexion position of the neck. Similarly, Green and Brown[24] observed that dentists adopted a head-down position (45 to 90 degrees cervical flexion) for 58% to 83% of the studied period. The load upon the cervical muscles in such workers has been described as being 15% of maximal voluntary contraction at 30 degrees cervical flexion,[25] and it has been shown that significant muscular fatigue can occur within 2 hours in this position.[26]

To support the inference that awkward postures can lead to musculoskeletal symptoms, Rundcrantz et al.[27] found that dentists with cervico-brachial disorders adopted a posture of cervical flexion or rotation or a combination of the two more frequently than dentists without symptoms ($P < .01$).

Milerad and Ericson[28] carried out electromyographic (EMG) studies to identify the active musculature of dentists during dental procedures. The highest mean muscular activity was found in the dominant trapezius pars descends and supraspinatus/trapezius transversus muscles. High-precision work requiring dexterity significantly affected the muscular load on the extensor carpi radialis and infraspinatus muscles, but force had no impact on EMG activity in any of the muscles. Arm support during the task appeared to reduce the muscular load on the upper trapezius and supraspinatus muscles.

Prolonged static contraction of the upper trapezius may lead to fatigue, contributing to the high frequency of pain and discomfort in the neck and shoulder region.[29] The load of shoulder flexion and abduction may also lead to fatigue or irritation of the supraspinatus muscle.[30] According to Hagberg and Hagberg[15] the static elevation of the shoulders may cause chronic myalgia in the descending part of the trapezius muscle,

often referred to as "tension neck syndrome." Hagberg and Hagberg[15] also described how at 30 degrees of shoulder abduction, the perfusion of the supraspinatus muscle may decrease, since the intramuscular pressure increases. The static contraction of a muscle in an abducted position may also cause impairment of the blood flow to the muscle. Decreased blood flow in the suprapinatus muscle may cause degeneration of the tendon and rotator cuff tendonitis.[15]

Although epidemiological studies reviewed by the National Institute for Occupational Safety and Health[21] showed a positive relationship between repetition and shoulder and neck symptoms, no specific studies in dentistry have examined the effects of repetitive movement on neck or shoulder problems. Most studies of repetition of movement have studied the more distal aspects of the upper limb.

As with repetition, no studies could be found that questioned the effects of forceful exertion in dentistry on the neck and shoulder problems.

Literature on neck and shoulder disorders has provided evidence that the prevalence of the disorders is high and that several risk factors are associated with dental work. Prolonged static neck flexion and shoulder abduction or flexion, lack of upper-extremity support, and inadequate work breaks seem to be major risk factors for neck and shoulder symptoms. A factor that has not been discussed is psychological stress and how it may increase tension in the neck and upper extremity musculature, possibly leading to overall musculoskeletal strain of this body region. The issue of stress is discussed in more detail in the section on psychosocial issues.

Wrist and Hand Disorders

Types of wrist and hand disorders

In addition to neck and shoulder problems, dental work has been associated with hand and wrist problems such as carpal tunnel syndrome and Raynaud's phenomenon (white finger).

Carpal tunnel syndrome is simply defined as symptomatic compression of the median nerve within the carpal tunnel.[31] The carpal tunnel is a space between the transverse carpal liga-

ment on the palmar aspect of the wrist and the carpal bones on the dorsal aspect of the wrist. Through this tunnel pass the median nerve, the finger flexor tendons, and blood vessels. Swelling of the tendon sheaths, for example, can reduce the size of the tunnel, compressing its other contents.[32] Symptoms of carpal tunnel compression are reproduced by any activity causing prolonged increased (passive or active) pressure in the carpal canal. The condition appears to be primarily a compression neuropathy although some cases may involve an element of traction (symptoms reproduced by stretch). Acute neuropraxia occurs at greater than 30 mm mercury of compression upon the median nerve. The acute compression causes local interruption of function of the nodes of Ranvier (nodes on peripheral nerves between myelin-producing Schwann cells—their primary function is to increase nerve conduction rate). Chronic nerve compression leads to segmental demyelination and Wallerian degeneration (late stages). Chronic ischemia due to blood vessel compression is another factor that can lead to demyelination.[33]

Liss et al.[12] used a standardized questionnaire to measure the prevalence of musculoskeletal complaints in 2142 dental hygienists and 305 dental assistants. They found that after they had adjusted for age, dental hygienists were 5.2 times (95% CI 0.9, 3.2) more likely to have been told that they had carpal tunnel syndrome and 3.7 times more likely to meet a case definition of carpal tunnel syndrome than were dental assistants. However, these diagnoses were not confirmed by objective tests.

A cross-sectional study by Osborn et al,[34] used a questionnaire to survey 444 Minnesota dental hygienists. The results showed that 7% had been previously diagnosed with carpal tunnel syndrome and that 63% of the sample reported one or more symptomes of carpal tunnel syndrome. Similarly, a previous survey of 2400 California dental hygienists reported that 6.4% had been diagnosed with carpal tunnel syndrome and that up to 32% had reported symptoms common to carpal tunnel syndrome.[35]

Conrad et al.[36] used vibrometry testing of 58 practicing Minnesota dental hygienists to show that 12% of the nonrandom sample had mild carpal tunnel syndrome. Objective tests

carried out by Polakowska et al,[37] used electroneurography and showed that lesions of the median nerve were found in 35.5% and lesions of the ulnar nerve in 22.6% of 31 dentists. No control groups, however, were used for comparisons in this study.

The condition termed secondary Raynaud's phenomenon, also known as vibration-induced white finger and constitutional white finger, is characterized by blanching (often painful) of the fingers. Initial signs and symptoms usually include numbness, tingling, and cyanosis (bluish discoloration). Exposure to vibration is required for a significant number of years before blanching occurs. Secondary Raynaud's phenomenon has been associated with changes that occur in the local vascular and neurological system as a result of exposure to long-term vibration. In contrast to carpal tunnel syndrome, numbness and tingling of the hands are not limited to the median nerve distribution. Temperature has more of an effect on the symptoms resulting from vascular involvement. Dose-effect guidelines and action levels have been proposed by several professional bodies, giving rise to International Standards, British Standards, and American National Standards. Various physical parameters, such as vibration magnitude, vibration frequencies, vibration directions, exposure durations, and grip forces, may play a role in the pathogenesis of secondary Raynaud's phenomenon, making it difficult to standardize guidelines for hand-tool vibration.[38]

Stentz et al,[39] carried out a cross-sectional study on 260 dental hygienists in Nebraska. Sixty-one percent indicated that they experienced altered sensations in the upper extremity related to physical stress. Pain, tingling, and numbness were the most frequently reported symptoms. Sixteen percent of the dental hygienists had been previously diagnosed with upper-extremity neuropathy, and 90% of those who complained of altered sensation stated that they only noticed the symptoms after entering the profession. In support of this finding, Milerad and Ekenvall[4] demonstrated in a case-control study that numbness and paresthesia were more common among dentists (99) than among pharmacists (100) (as described previously in this chapter). Because of the similar symptoms presented by carpal tunnel syndrome and Raynaud's (white finger) phenomena, these studies did not provide definite diagnoses of the conditions.

Looking at ailments related to the dental occupation, Lehto et al,[40] found that the distal interphalangeal joints had more degenerative changes in both male and female dentists than in controls. The difference was more predominant for those younger than 50 years of age, suggesting earlier development of joint degeneration in dentists.

Risk Factors for Wrist and Hand Disorders

There is evidence of an association between carpal tunnel syndrome and highly repetitive work alone or in combination with other factors. Evidence also indicates an association between forceful work and carpal tunnel syndrome. There is insufficient evidence, however, for an association between carpal tunnel syndrome and extreme postures. There is evidence of a positive association between work involving hand/wrist vibration and carpal tunnel syndrome. Strong evidence indicates a positive relationship between high levels of hand-arm vibration and secondary Raynaud's phenomenon.[21]

The amount and type of repetitive movement performed during dental work has not been accurately quantified by previous studies. Liss et al,[12] however, highlighted that one of the predictors for high prevalence of carpal tunnel syndrome among dental hygienists was their longer clinical period of repetitive movements when work was done on parts of the mouth that were difficult to access.

It has been suggested that synovial tissue irritation results from repetitive movement. Repetitive movements within the enclosed sheath cause irritation and subsequently inflammation of the synovium lining, resulting in tenosynovitis. This may be the primary cause for increased pressure within the carpal tunnel. Treatment by removal of compression (carpal tunnel release surgery) has demonstrated partial subsequent relief from decreased constriction of the flexor tendons.[41]

A study by Neal et al,[42] found in fact that histopathological examination of the tenosynovium removed during surgery for carpal tunnel syndrome has shown a striking absence of inflammation. Barton et al,[43] feel that tenosynovitis is a distinct entity, in which the synovium around the tendon actually becomes inflamed. The term, according to Barton et al, is often

applied inappropriately to conditions that do not involve inflammation of the synovium

Skie et al,[44] reasoned that flexed wrist postures may reduce the volume of the carpal tunnel, thus increasing the intracanal pressure and subsequently compressing the median nerve. Szabo and Chidgey[45] showed that repetitive flexion and extension of the wrist created pressures in the carpal tunnel, that were more elevated in those who had reported symptoms than in normal subjects, and that the symptoms took longer to dissipate. Laboratory studies support these findings, demonstrating that carpal tunnel pressure is increased from less than 5 mm mercury to more than 30 mm mercury during wrist flexion and extension.[46]

Milerad and Ericson[28] found that precision work by dentists significantly affected the muscular load on extensor carpi radialis and infraspinatus muscles, while force had no impact on EMG activity in any of the muscles. In another study, it was suggested that chronic disorders of the fingers resulting in arthritic joints may be caused by extensive use of the precision grip in dentistry.[40] Increasing degenerative changes in the joint, however, did not hinder manual function. Within dentistry, Liss et al,[12] presented the predictors of wrist/hand disorders in the past 12 months. The duration of work, the percentage of time that the trunk was in a rotated position relative to the lower body when operating, and instrument types were found to be predictors of work-related musculoskeletal disorders. The impact of instrument type was less clear than that of other predictors because of possibly a greater mix of instruments and longer clinical periods of repetitive movements when work was done on patients with inaccessible calculus.

Because of the high precision required by much dental work, the muscles used in sustaining such activity are at risk of becoming fatigued and causing discomfort. Stability maintained through static muscle loading in the shoulder and elbow areas for prolonged periods can lead to fatigue and discomfort.[20] Grandjean[47] suggested that with prolonged contraction of upper trapezius during upper extremity stabilization, adjacent blood vessels and nerves may be compressed, making the upper extremity susceptible to temporary ischemia and neuropraxia.

Kwahito et al,[48] carried out finger stress measurements during various "burr head" operations. It was found that

vibration emitted by the burr head was about 500,000 rpm and finger stress had a tendency to be greater than thumb stress, particularly for the middle finger, which controlled the behavior of the handpiece. Milerad and Ekenvall[4] found that male dentists had an increased prevalence of Raynaud's phenomenon in the dominant hand. Ekenvall et al,[49] found sensory-perceptions differences in the hands of dentists. In their research findings, they stated that "dentists with long term exposure had larger vibration threshold differences than those with short-term exposure, both for the digit II (exposed to high frequency vibration) and for digit V (unexposed), whereas the temperature and pain thresholds were similar." The former group had neurological symptoms in the dominant hand more often than the latter. Vibration threshold differences of exposed digit II and unexposed digit V were higher for the symptomatic dentists than for the symptom-free dentists. Since the exposed and unexposed fingers were similarly affected, the neurological symptoms in the dominant hand of dentists with long-term exposure seem to have some other etiology than high-frequency vibration.

Low Back Disorders

Types of Low Back Disorder

Low-back discomfort is a problem associated with dental work in numerous studies.[2, 3, 7, 10, 11, 17, 18, 20, 37]

Van Doorn[7] carried out a retrospective study of 795 cases of self-employed dentists, veterinarians, physicians, and physical therapists. His study showed that dentists over 44 years of age had significantly longer duration of low back disability if they had

1. specific low back pain,
2. nonspecific low back pain in combination with a deferred period of 14 days or more,
3. low back disorders before acceptance of the disorder, and
4. psychosocial problems at the start of the disability.

Polakowska et al,[37] carried out a study using electromyography and radiological examination of 31 dentists. All subjects

complained of lumbar pain. In 80.6% of the subjects, the pains were associated with objective signs of radicular neuralgia.

Risk Factors for Low Back Disorders

The NIOSH literature review[21] showed evidence indicated a positive relationship between lowback disorder and heavy physical work, work-related lifting, forceful movements, and work-related awkward postures. There was strong evidence also for a positive relationship between whole body vibration and low back disorders. The only risk factor that pertains to dental work is work-related awkward posture.

Changes in operating methods in dentistry, which have occurred since the late 1950s, have altered the occupation from a standing to a sitting profession. Shugars et al, [18] found that good (neutral) posture correlated negatively with back pain and, generally, dentists who sat 80% to 100% of the day reported more frequent lower-back pain. Static work in the sitting posture requiring spinal flexion and rotation has been associated with increased risk of low back pain.[20, 50–52] According to Visser and Straker,[20] since the introduction of the sitting posture, lower-extremity problems of the worker have decreased, but musculoskeletal injuries of upper extremities and the low back have not been eliminated. Loads on soft-tissue structures of the lumbar spine and discs are increased by sitting. Additionally, extensor muscle activity in the lumbar spine area in the unsupported sitting posture is greater than in standing. Discomfort experienced by dental workers was shown to increase over the working day.

Psychosocial Disorders Related to Dentistry

Types of Psychosocial Disorders

Studies of psychosocial stress levels experienced by dentists are numerous.[53–55] Litchfield[53] commented that a high level of stress is associated with dentistry because it involves fine, meticulous surgery and little or no rest or diversion. The stresses experienced may be internally or externally provoked.[54]

Risk Factors for Psychosocial Disorders

Eccles and Powell[55] surveyed 358 male dentists in South Wales to determine the health of dentists, as defined by the World Health Organization: *"Health is a state of complete mental, physical and social well-being and not merely the absence of disease or disability."* The questionnaire found that 60% liked their work. Younger dentists (between 23 and 34 years of age) were more satisfied than older dentists, and the 45 to 54 age group was the most dissatisfied. These findings occurred possibly because the younger dentists worked shorter hours and had less responsibility (being assisted), while those over 65 years of age had adapted by reducing their work load. It seemed that the greatest sources of dissatisfaction lay in the external limitations (e.g., finance constraints, fearful patients, time pressures, length of working day, and health care system) imposed on the dentist and the pace at which the work was carried out.

According to Diakow and Cassidy[59] financial obligations of dentists may promote longer and harder working hours, placing more stress on the worker psychologically and physically. Basset[56] reasoned that dentists kept working despite physical discomfort because, like many others who are self-employed, dentists suffer direct loss of income if they are unable to work.

Basset[56] found that one psychosocial stress factor that may increase low back pain is the constant coping with fearful patients. Eccles[57] studied whether the presence or absence of a patient affects the degree of stress experienced by dentists carrying out conservation work. It was found that precision activities or activities requiring high levels of concentration, such as reading, giving injections, cavity preparation, and insertion of a lining, were associated with short, low-amplitude electrocardiogram waves, preceded by a cardio-decelerator reflex. According to the researchers, the short, low-amplitude waves may be significant of an increased respiratory rate. The researchers felt it could not be concluded from the study that dentists were influenced strongly by the presence of a living patient as compared with a mannequin head.

Eccles[58] used skin conductance to assess the level of arousal of dentists during practice. An elevated skin conductance is believed to be associated with increased arousal. It was shown

that a rise in skin conductance before treatment events indicates some apprehension. Specific behaviors of patients, however, did not influence the skin conductance of dentists. Eccles reported that "it seems likely that dentists have learned to adapt successfully to reactions of their patients which might otherwise be stressful but that they sometimes show apprehension before certain phases of treatment, such as injection of local anesthetic and cavity preparation."

Time pressures have been found to be one of the major sources of extrinsic stress for the dentist.[60–62] Freeman et al,[61] reported that dentists had to schedule more work in less time to stay profitable. There was a perception among dentists, especially the National Health System (NHS) dentists, that they were constantly running late, and it was found that this perception itself was stressful.[60] In two studies that investigated potential dentist stresses, it was found that running behind schedule and constant time pressures ranked high. In the first study, Cecchini[63] found that dentists from the United Kingdom reported that running behind schedule and constant time pressures ranked third and fourth, respectively, among 20 other stresses reported in the survey. In the second study, Cooper et al,[64] reported that running behind schedule and constant time pressures ranked seventh and third, respectively, among the other 20 stresses.

Reitemeier[65] found that the length of the working day can affect the motivation and social qualities of a dentist. When working long hours, practitioners tend to decrease their manual contacts and efforts later in the day. Decline in sociability is evident in the younger dentists, while senior professionals tend to have significant decline in the ability to relax. For experienced workers, symptoms of general physical fatigue were significantly higher, but the trade-off was greater emotional stability at the end of the working day.

The organization of the health care system has been shown to influence the stress levels of the dentist. Newton and Gibbons of Guy's Hospital, London,[60] showed that changing from a National Health System to an independent capitation scheme is of great benefit. In the independent capitation scheme, dentists felt that they were under less time pressure and faced considerably less paperwork, although both groups still identified patient management, time pressures, and staff and prac-

tice management as sources of stress. Davidove[66] found that environmental demands, such as economy and constraints imposed by insurance companies, were accelerating and subjecting dentists to significant pressures. Although both systems are very different, it is evident that dentists in both countries face stress from the different health system changes imposed upon them.

Joffe[67] pointed out that there was a basic personality profile for dentists: hard-working, dedicated, altruistic, empathic, humble, well-balanced, and selfless. Many use their inner voice to criticize themselves in a negative manner, causing shame, anxiety, depression, exhaustion, and low self-esteem. Burnout may result from the combination of physical and emotional fatigue.

Katz[68] surveyed 291 members of the Texas Dental Association. From this survey, it was concluded that higher levels of control (belief that they have control over their life); commitment (ability to feel deeply involved or committed to the activities, people, or institutions in their lives); and challenge (anticipation of change as an exciting challenge) were found to be significantly related to lower levels of stress and psychiatric symptoms and higher levels of career satisfaction.

It was found that specialized dentists were overall more satisfied, having more self-confidence and less anxiety than general practitioners.[68–70]

Stress and Work-Related Musculoskeletal dDsorders

There has been speculation that work-related musculoskeletal disorders may be associated not only with the physical stresses imposed on the dental professional but also the psychological stresses.[20] Rundcrantz et al,[69] carried out a case control study of 96 dentists with cervico-brachial disorders and 47 dentists without cervico-brachial disorders (controls). Dentists with symptoms showed a significant tendency to be more dissatisfied at work and to be more burdened by anxiety, experiencing poorer psychosomatic health and feeling less confident in their future.

Lehto et al,[3] found that dentists who perceived dentistry as physically too heavy had a greater 1-year prevalence of neck,

shoulder, and low back pain than those who perceived dentistry as physically light or optimal (odd ratio (OR) = 4.0 [CI 1.3, 12.2] for neck and shoulder pain; (OR = 5.4 [CI 1.7, 17.2] for low back pain). Dentists who perceived dentistry as mentally too straining had a greater 1-year prevalence of neck, shoulder, and low back pain than those who perceived dentistry as mentally too undemanding or optimal (OR = 2.5 [CI 0.9, 0.2] for neck and shoulder pain; (OR = 4.6 [CI 1.5, 14.2] for low back pain). Dentists who perceived their work as fast paced had a greater 1-year prevalence of neck, shoulder, and low back pain than those who did not perceive dentistry as fast paced (OR = 6.8 [CI 1.5, 30.1] for neck and shoulder pain; (OR = 3.4 [CI 0.8, 13.8] for low back pain).

To reduce stress, the dentist can make efforts initially by recognizing or unmasking it.[54] Exercising and taking a greater number of weeks away from the office,[68] employing healthy and useful self-criticism,[66] and paying attention to ergonomic design[65] have decreased stress in dental practice.

The Availability and Effectiveness of Current Ergonomic Intervention

Eccles[71] discussed the changes of ergonomics in dentistry. Modification of the patient dental chair did not occur until the 19th century. Mechanisms for elevating and tilting the chair slightly backwards so that it could be adapted to operators of different heights and operations in different parts of the mouth were the first modifications. The modern dentist works seated on a low stool, and the assistant, also seated, provides continuous chairside assistance: this is commonly called four-handed low-seated dentistry. Instruments and equipment are placed within close reach of the dentist and the assistant. The patterns of floor area design have evolved on an empirical basis for each functional area and for flow in occupants' movements.

Aims of Ergonomic Principles

According to Pollack[72] the aim of ergonomic intervention should be to achieve optimum access, visibility, comfort, and

control at all times of treatment. Many ergonomists have urged an evaluation of the dental work space and process to improve not only health, but also productivity.

Equipment Design

Hardage et al,[73] used electromyography to study 20 dental students and faculty members to evaluate the effects of stool height and lumbar support. They found that lumbar support reduced muscle activity in the upper and lower spine and that the stool height had no significant influence on the muscle activity of the back. They suggested, however, that knee angles of 90 and 75 degrees were more desirable than 105 degrees as the back was more supported in this position.

Oberg[74] considered the working postures, sparse movement patterns, limited workspace, and long standing static load on the neck and shoulder musculature in designing a reference workplace to provide an ergonomically desirable dental practice environment for a single dental hygienist. A horseshoe-shaped support for the patient chair and a special armrest for the operator chair were designed to alleviate the static load on the neck and shoulders. The dental hygienist experienced fewer complaints in her shoulder region. These prototypes are now available commercially. No other study, however, was found to support this design.

Grace et al,[75] found that the position in which the patient is placed in when first seated in the dental chair significantly determines the patient's final chosen position for optimum comfort. Patients who are first placed in an upright position will choose a position that is closer to upright. Similarly, patients who are first placed in a supine position choose a final position that is close to supine. If the patient is initially seated in a dental chair that has been preset in the horizontal or supine position, the study suggests that the patient will not experience discomfort sitting up and therefore will have no objections to this position.

Eccles and Davies[76] found that in low-line dentistry, handpieces positioned in the mid-line above the patients are most convenient for operators working at the 9 and 12 o'clock positions, thus decreasing postural problems. However,

mid-line position may not be accepted well by all patients. The position on the right side is not at all convenient for the surgery assistant, but may be less threatening to the patient. The best handpiece angle would seem to be somewhere between horizontal and head down. A hand piece placed head up, which is common practice in dental equipment, was less favored by dentists.

Accessories

Rundcrantz et al,[27] carried out an ergonomic analysis and locomotor function analysis on 96 dentists who experienced neck and shoulder pain and 47 dentists who did not report neck or shoulder problems. They found that approximately 26% of the asymptomatic dentists and 11% of the symptomatic dentists used a wedge cushion under the upper part of the back of the patient to get an optimal view ($P < .05$).

Rundcrantz et al,[13] found that if the dentist worked with a direct view, it was probably appropriate for the dentist to sit in the 9 o'clock position when working in the upper jaw to reduce stress in the neck. Dentists who sat in the 11 or 10 o'clock position ought to use the mirror to reduce the load to the neck. Dentists without pain who worked in this position used the mirror to a greater extent. However, no significant differences in neck stress were seen with the use of a mirror by or Rundcrantz et al,.[14]

Powell et al,[77] found that fitted gloves exerted significantly less force on the hand compared with ambidextrous gloves (i.e., one size fits all). The findings from this study and further research in this area may provide some guidance toward decreasing prolonged high-forced static gripping during dental practice.

Kwasman et al,[78] showed that rather than elect to retract the instrument back into the cabinet, some dentists or assistants had the option of placing the instrument on the holding pad on top of the cabinet while working. This practice made it easier to access the instrument when it was used often during a procedure. Although both the 8 and 12 o'clock positions showed that the dynamic instruments were stored in the cabinet more than on the holding pad, the holding pad was used

three times more frequently in the 8 o'clock location, where the dentist transferred the handpiece, than in the 12 o'clock location, where the assistant transferred the handpiece.

Recovery Period

A study by Hellerstein (1959, cited in Fox and Jones,[79]) showed that dentists had a low calorie output during hours of practice, but that they nevertheless felt fatigued at the end of the workday. It appears that the dental operator averages 1.2 calories per minute during a working day (walking burns approximately 4 to 5 calories per minute). The fatigue that is felt by the dental professional may result from the static muscular contraction required in prolonged postures. Muscular imbalance may result from certain muscles remaining in prolonged contraction while the relaxed muscles remain in neutral or lengthened positions.

Rundcrantz et al,[27] found that significantly more dentists without pain and discomfort took advantage of the intermittent interruptions provided in their work (e.g., when the assistant was preparing the amalgam), using them for a rest or taking the chance to raise and lower their shoulders.

Workplace Layout

The arrangement of the equipment can affect efficiency and whether the operator works alone or with assistants.[80] According to Kilpatrick, dynamic instruments, such as turbines, multiplex syringe, and suction lines, should be accessible.[80] Medications, linings, cements, amalgam and plastic fillings, impression trays and materials, instruments, and other essentials should be arranged in such a way that the operating team does not have to leave the seated position at the chair to retrieve them.

Rundcrantz et al,[27] pointed out that in restricted working spaces, the dentist may have more difficulty when assisted by a nurse. The dentist's working position is influenced not only by the limited work but also by the dentist's position relative to the dental assistant when instruments are being handed over or when reach is required, in using dynamic equipment.

Green and Lynam,[81] used motion film analysis to carry out "work simplification" principles during dental operations. The analysis resulted in recommendations that considered the layout of the workspace. All of the equipment could be recessed in a cabinet such that pressure on various buttons would allow necessary pieces of equipment to glide out and the spotlight to be foot controlled. Green and Lyman stressed that objective time studies and motion analysis were necessary to work out ideal patient flow patterns; working arrangements for multiple workers in a room; and workspace layout for equipment (cabinets, trays, spotlight, hand instruments) and personnel.

Kwasman et al,[78] found that the high-speed handpiece transfers were faster and more frequent in the 12 o'clock location when carried out by an assistant. The dentist was able to make the transfer without moving his body or refocusing his eyes from the mouth to the unit. However, the passing of three-way syringes was less efficient in the 12 o'clock position by an assistant, compared with an 8 o'clock position without use of an assistant. In the transfer of the three-way syringe, additional time was required by the dentist and the dental assistant using the 12 o'clock position. Hand positions of the dentist and dental assistants needed to be changed from a pen to a palm grasp and vice versa. If the dentist was positioned in the 8 o'clock position, directly picking up the instrument with a palmar grasp increased efficiency.

Job Design

Kilpatrick[80] argued that if chairside assistants were trained and permitted, under supervision, to do more of the simple, time-consuming intraoral duties that are required of the dentist, more people could be served with quality dentistry. Subsequently, this would decrease the external (time-pressures) and internal (self-esteem, job satisfaction), stresses on dentists. The studies were designed to determine efficiency of patient service by a dentist working without a chairside assistant, with one assistant, and with two assistants. Significant amounts of time were saved by preplanning procedures and the use of assistants.

Factors that affected efficiency were psychological (dentist's comfort working with an assistant and patient's temperament controlled by conditioning education, proper anesthetic, and medication); use of a trained assistant; level of case complexity; and physical factors such as workplace layout.

Training

The working positions of dental professionals vary depending on where in the mouth the dentist is working and on which surface of the tooth procedures are required. Rundcrantz et al,[27] found that most (82%) dentists sat in the traditional way with a 90- degree hip angle when working on the 26d tooth (the distal surface of tooth 6 in the left upper jaw). Among dentists with seats that could be tilted, very few used this feature of the chair. Hence, training is required for the profession, as Bruder and Rohmert[91] also pointed out; they showed that ergonomic faults in positioning the patient lead to unfavorable postures for the dental professional.

A study by Davies and Eccles[82] showed that patients tend to prefer being in the 30-degree cervical flexion position while the operator prefers the patient to be in a nearly horizontal position of 15 degrees for clearer viewing without neck flexion. From this study, a list of requirements for the design of dental chairs was derived, pertaining to adjustability of the seat pan and back rest.

Eccles and Davies[83] carried out postural studies using a phantom head. Each operator was asked to carry out a cavity correction procedure on six standard teeth—both upper first molar teeth, both lower second molar teeth, and labial cervical cavities in the upper left canine and lower right canine. They recommended that the operator work in a 9 o'clock or 12 o'clock position relative to the patient and not in a 3 o'clock position. They also found that it was better to have the chair in the horizontal position than at 30 degrees to achieve a posture of less stress for the dentist, and that in general the patient's head should face forwards and not be rotated, except for certain tooth cavities.

Training on using as much support as possible for the upper limbs during precision work has been recommended.

Rundcrantz et al,[27] found that among dentists without pain and discomfort more worked with the left arm resting than those with pain. They noticed that dentists were able to decrease the load of the nondominant arm by resting it against the head of the patient, against the patient's chair, or against the instrument tray. Most dentists worked with the right arm abducted less than 40 degrees, resting their hand or wrist against the patient. Resting the dominant arm has to be intermittent and may be made dependent on the shoulder or thorax of the patient.

Exercise and Stress Reduction

Van Doorn[7] showed that an early intervention program (consisting of education on back care and body mechanics, early return to work, exercises to increase mobility and strength, and professional psychological advice) was cost-effective, significantly decreasing the mean cumulative duration of low back disability. Auguston and Morken[2] also showed that participation in sport activities was negatively associated with discomfort in the lower back.

Shugars et al,[18] conducted a survey of 1057 American Dental Association (ADA) members and showed that out of the 746 who reported musculoskeletal pain, 523 used exercise to alleviate pain with the result that 16% received complete relief and 16% received permanent relief. Two-hundred and thirty-four ADA members changed position relative to the patient; 9% received complete relief and 12% received permanent relief.

Rundcrantz et al,[84] carried out an intervention study on a group of dentists with occupational cervico-brachial disorders. Group A received physiotherapy, psychosomatic approach treatment, and ergonomic instruction. Group B only received ergonomic instruction. Both groups showed a decrease in cervico-brachial disorders. Group A showed significant improvement in pain and discomfort of the neck and increased self-confidence within a five-week period. The concentration required for the psychosomatic approach and the stretches and strengthening exercises provided by the physiotherapy program require dentists to take responsibility for the musculoskeletal conditions that they have acquired.

Lehto et al, [3] found that general physical fitness as measured by total work index was associated with a lower-stress symptoms score, lower score on somatic aspects of depression more favorable health status rating, and perception of dentistry as physically optimal or too light and as mentally optimal or without strain. Lehto et al, concluded that physical exercise can act as a prophylaxis against musculoskeletal illness and stress for dentists of a wide range of ages.

Conclusion

Ergonomics requires understanding of both the physical and the psychological aspects of the workplace. From the review of literature, it is evident that ergonomics plays a significant role in the health of dental professionals, but only after the dentist has recognized and integrated both physical and psychological systems. The musculoskeletal and stress-related disorders associated with dentistry seem to be interrelated. Literature about work-related musculoskeletal disorders and psychosocial disorders associated with dentistry is plentiful. However, ergonomic solutions for dental practitioners are under-reported in the literature. Furthermore, the few ergonomic solutions that have been provided have not been adequately evaluated or validated.

References

1. Bureau of Labor Statistics. 1995. Statistics of injuries categorized by industry, ftp://stats.bls.goc/pub/special.requests/ocwc/osh/cftb0067.txt.
2. Auguston TE, Morken T. Musculoskeletal problems among dental health personnel. A survey of the public dental health services in Hordaland (Norwegien). *Tidsskrift for Den Norske Laegeforening*. 1996;116(23):2776–2780.
3. Lehto TU, Helenius HY, Alaranta HT. Musculoskeletal symptoms of dentists assessed by a multidisciplinary approach. *Community Dentistry and Oral Epidemiology*. 1991;19(1):38–44.
4. Milerad E, Ekenvall L. Symptoms of the neck and upper extremities in dentists. *Scandinavian Journal of Work, Environment and Health*. 1990;16(2):129–134.

5. Stockstill JW, Harn SD, Strickland D, Hruska R. Prevalence of upper extremity neuropthy in a clinical dentist population. *Journal of the American Dental Association.* 1993;124(8):67–72.
6. Burke FJ, Main JR, Freeman R. The practice of dentistry: an assessment of reasons for premature retirement. *British Dental Journal.* 1997;182(7):250–254.
7. Van Doorn JW. Low back disability among self-employed dentists, veterinarians, physicians and physical therapists in the Netherlands. A retrospective study over a 13-year period (N=1,119) and an early intervention program with 1 year follow-up (N=134). *Acta Orthopaedica Scandinavica. Supplementum.* 1995;263:1–64.
8. Moen BE, Bjorvatn K. Musculoskeletal symptoms among dentists in a dental school. *Occupational Medicine.* 1996;46(1):65–68.
9. Jacobsen N, Derand T, Hensten-Pettersen A. Profile of work-related health complaints among Swedish dental laboratory technicians. *Community Dentistry and Oral Epidemiology.* 1996; 24(2):138–144.
10. Jacobsen N, Peterson AH. Self-reported occupation-related health complaints among dental laboratory technicians. *Quintessence International.* 1993; 24(6):409–415.
11. Oberg T, Oberg U. Musculoskeletal complaints in dental hygiene: a survey study from Swedish county. *Journal of Dental Hygiene.* 1993;67(5):257–261.
12. Liss GM, Jesin E, Kusiak RA, White P. Musculoskeletal problems among Ontario dental hygienists. *American Journal of Industrial Medicine.* 1995;28(4):521–540.
13. Rundcrantz BL, Johnsson B, and Moritz U. Cervical pain and discomfort among dentists. *Swedish Dental Journal.* 1990;14(2):71–80.
14. Rundcrantz BL, Johnsson B, Moritz U. Pain and discomfort in the musculoskeletal system among dentists—a prospective study. *Swedish Dental Journal.* 1991a;15(5):219–228.
15. Hagberg M, Hagberg C. Risks and prevention of musculokeletal disorders among dentists. In: Brune DK, Edling C, eds. *Occupational Hazards in the Health Professions.* Boca Raton, Florida: CRC Press;1989:323–332.
16. Blewett V, Hirsch R. Seating for dentists: ergonomic requirements and assessment of available chairs. In: Morrison D, Hartley L, Kemp D, eds. *Trends in the Ergonomics of Work, Proceedings of the 23rd Annual Conference of the Ergonomics Society of Australia and New Zealand.* 1986:219–221.
17. Kajland A, Lindvall T, Nilsson T. Occupational medical aspects of the dental profession. *Work, Environment Health.* 1974:11(2);100–107.

18. Shugars DA, Williams D, Cline SJ, Fishburne C. Musculoskeletal back pain among dentists. *General Dentistry.* 1984;32:481–485.
19. Nystrom A. Yrkesbetingade sjukdomstillstand bland tandlakare. Sverig. *Tanlakarforbunds tidning.* 1958;21(1).
20. Visser JL, Straker LM. An investigation of discomfort experienced by dental therapists and assistants at work. *Australian Dental Journal.* 1994;39(1):39–44.
21. NIOSH [Second Printing, 1997.] *Musculoskeletal Disorders and Workplace Factors: A Critical Review of Epidemiologic Evidence for Work-Related Musculoskeletal Disorders of the Neck, Upper Extremity, and Low Back.* Cincinnati, OH: US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. DHHS (NIOSH) Publication No. 97–141.
22. Powell M, Smith JW. Occupational stress in dentistry: the postural component. *Ergonomics, Supplement, Proceedings of the Second International Congress on Ergonomics.* Dortmund, West Germany: International Congress of Ergonomics;1964:337–340.
23. Kihara T. Dental care works and work-related complaints of dentists. *Kurume Medical Journal.* 1995;42(4):251–257.
24. Green EJ, Brown ME. An aid to the elimination of tension and fatigue: body mechanics applied to the practice of dentistry. *Journal of the American Dental Association.* 1963;67:679.
25. Chaffin DB, Andersson GBJ. *Occupational Biomechanics.* New York: John Wiley and Sons; 1984.
26. Chaffin DB. Localized muscle fatigue—definition and measurement. *Journal of Occupational Medicine.* 1973;15:346.
27. Rundcrantz BL, Johnsson B, Moritz U. Occupational cervicobrachial disorders among dentists—analysis of ergonomics and locomotor functions. *Swedish Dental Journal.* 1991b;15(3):105–115.
28. Milerad E, Ericson MO. Effects of precision and force demands, grip diameter and arm support during manual work. *Ergonomics.* 1994;37(2):255–264.
29. Jonsson B, Rugan P. Besvar fran rorelseorganen bland tandhygienister. Arbetatarskyddstyrelsen. *Undersokningsrapport.* 1982.
30. Hagberg M. Electromyographic signs of shoulder muscular fatigue in two elevated arm positions. *American Journal of Physical Medicine.* 1981;60:111–121
31. Nathan PA. Cumulative trauma disorders of the upper extremity: II. *American Association for Hand Surgeons Conference Proceedings.* August 1995, Cincinnati, OH.
32. Williams R, Westmorland M. Occupational cumulative trauma disorders of the extremity. *The American Journal of Occupational Therapy.* 1994;48(5):411–420.

33. Armadio PC. Cumulative trauma disorders of the upper extremity: II. *American Association for Hand Surgeons Conference Proceedings*, August 1995, Cincinnati, OH.
34. Osborn JB, Newell KJ, Rudney JD, Stoltenberg JL. Carpal tunnel syndrome among Minnesota dental hygienists. *Journal of Dental Hygienists*. 1990;Feb:79–85.
35. McDonald G, Robertson MM, Erikson JA. Carpal tunnel syndrome among California dental hygienists. *Dental Hygiene*. 1988;July/Aug:322–327.
36. Conrad JC, Osborn JB, Conrad KJ, Jetzer TC. Peripheral nerve dysfunction in practicing dental hygienists. *Journal of Dental Hygiene*. 1990;Oct:382–320.
37. Polakowska B, Gluszcz-Zielinska A. Neurological assessment of health status in dentists [Polish]. *Medycyna Pracy*. 1994; 45(3):221–225.
38. Griffin MJ. Occupational human vibration. In: Bhattacharya A, McGlothlin JD, eds. *Occupational Ergonomics*. New York: Marcel Dekker;1996:605–626.
39. Stentz TL, Riley MW, Harn SD, Sposato RC, Stockstill JM, Harn JA. Upper extremity altered sensations in dental hygienists. *International Journal of Industrial Ergonomics*. 1994;13(2):107–112.
40. Lehto TU, Ronnemaa TE, Aalto TV, Helenius HY. Roentgenological arthrosis of the hand in dentists with reference to manual function. *Community Dentistry and Oral Epidemiology*. 1990; 18(1):37–41.
41. Beckenbaugh RD. Cumulative trauma disorders of the upper extremity: ii. In: *American Association for Hand Surgeons Conference Proceedings*. August 1995; Cincinnati, Ohio.
42. Neal NC, McManners J, Stirling GA. Pathology of the flexor tendon sheath in spontaneous carpal tunnel syndrome. *Journal of Hand Surgery (Br.)*. 1987;12B:229–232.
43. Barton NJ, Hooper G, Noble J, Steel WM. Occupational causes of disorders in the upper limb. *British Medical Journal*. 1992; 304:309–311.
44. Skie M, Zeiss J, Ebraheim NA, Jackson WT. Carpal tunnel changes and median nerve compression during wrist flexion and extension seen by magnetic resonance imaging. *Journal of Hand Surgery (Am)*. 1990;15A(6):939.
45. Szabo RM, Chidgey LK. Stress carpal tunnel pressures in patients with carpal tunnel syndrome and normal patients. *Journal of Hand Surgery (Am)*. 1989;14A:624–627.
46. Gelberman RH, Herginroeder PT, Hargens AR, Lundborg GN, Akeson WH. The carpal tunnel syndrome: a study of carpal tunnel pressures. *Journal of Bone and Joint Surgery*. 1981; 63A(3): 380–383

47. Grandjean E. *Fitting the Task to the Man.* London: Taylor and Francis; 1981.
48. Kwahito T, Onchi Y, Inowe M, Fujii B. Three dimensional finger control on cavity preparation especially on hand-piece control and finger stress. In: Queinnec Y, Daniellou F, eds. *Designing for Everyone, Proceedings of the 11th Congress of the International Ergonomic Association.* London: Taylor and Francis;1991:170–172.
49. Ekenvall L, Nilsson BY, Flaconer C. Sensory perception in the hands of dentists. *Scandinavian Journal of Work, Environment and Health.* 1990;16(5):334–339.
50. Bergquist-Ullman M, Larsson U. Acute low back pain in industry. A controlled prospective study with special reference to therapy and confounding factors. *Acta Ortopaedica Scandinavia (Supplement 170).* 1977:1–117.
51. Brown JR. Factors contributing to the development of low back pain in industrial workers. *American Industrial Hygiene Association Journal.* 1975;36:26–31.
52. Damkot DK, Pope MH, Lord J, Frymoyer JW. The relationship between work history, work environment and low back pain in men. *Spine.* 1984;9:395–399.
53. Litchfield NB. Stress-related problems of dentists. *International Journal of Psychosomatics.* 1989;36(1–4):41–44.
54. Domeyer N. Stress as a synonym for marriage. *Florida Dental Journal.* 1988;59(1):27–28.
55. Eccles JD, Powell M. The health of dentists: a survey on South Wales 1965/1966. *British Dental Journal.* 1967;123:379–387.
56. Basset S. Back problems among dentists. *Journal of Canadian Dental Association.* 1983;49:251–256.
57. Eccles JD. The heart rate of dentists at work. *British Dental Journal.* 1969;126:216–220.
58. Eccles JD. Skin conductance changes in dentists and patients during conservation treatment. *Dental Practitioner and Dental Record.* 1970;21:43–48.
59. Diakow PRP, Cassidy J. Back pain in dentists. *Journal of Manipulative Physiological Therapy.* 1984;7:85–88.
60. Newton JT, Gibbons DE. Stress in dental practice: a qualitative comparison of dentists working within the NHS and those working within an independent capitation scheme. *British Dental J.* 1996;180(9):329–334.
61. Freeman R, Main JR, Burke FJ. Occupational stress and dentistry: theory and practice part II assessment and control. *British Dental Journal.* 1995;178(6):218–222.
62. Craven RC, Blinkhom AS, Roberts CA. Survey of job satisfaction among DSAs in the North-West of England. *British Dental Journal.* 1995;178(3):101–104.

63. Cecchini JG. Differences of anxiety and dental stresses between dental students and dentists. *International Journal of Psychosomatics.* 1985;32:6–11.
64. Cooper CL, Watts J, Kelly M. Job satisfaction, mental health and job stressors among general dental practitioners in the UK. *British Dental Journal.* 1987;162:77–81.
65. Reitemeier B. Psychophysiological and epidemiological investigations on the dentist. *Reviews on Environmental Health.* 1996;11(1–2):57–63.
66. Davidove DM. Dentistry, self-esteem and criticism. *New York State Dental Journal.* 1996;62(4):43–45.
67. Joffe H. Dentistry on the couch. *Australian Dental Journal.* 1996;41(3):206–210.
68. Katz CA. Are you a hardy dentist? The relationship between personality and stress. *Journal of Dental Practice Administration.* 1987;4(3):100–107.
69. Rundcrantz BL, Johnsson B, Moritz U, Roxendal G. Occupational cervico-brachial disorders among dentists. Psychosocial work environment, personal harmony and life-satisfaction. *Scandinavian Journal of Rehabilitation Medicine.* 1991c;19(3):174–180.
70. Osborne D, Croucher R. Levels of burnout in general dental practitioners in the south-east of England. *British Dental Journal.* 1994;177(10):372–277.
71. Eccles JD. Dental practice—a field for ergonomics research. *Applied Ergonomics.* 1976;7(3):151–155.
72. Pollack R. Dental office ergonomics: how to reduce stress factors and increase efficiency. *Journal de l'Association Dentaire Canadienne.* 1996;62(6):508–510.
73. Hardage JL, Gildersleeve JR, Rugh JD. Clinical work posture for the dentist: an electromyographic study. *Journal of the American Dental Association.* 1983;107:937.
74. Oberg T. Ergonomic evaluation and construction of a reference workplace in dental hygiene: a case study. *Journal of Dental Hygiene.* 1993;67(5):262–267.
75. Grace EG, Schoen DH, Cohen LA. Chair inclination and patient comfort. *Behavioral Science.* 1990;7(2):76–78.
76. Eccles JD, Davies MH. Hand piece positions in low-line dentistry. *The Dental Practitioner.* 1972;22:308–310.
77. Powell BJ, Winkley GP, Brown JO, Etersque S. Evaluating the fit of ambidextrous and fitted gloves. *Journal of the American Dental Association.* 1994;125(9):1235–1242.
78. Kwasman R, Handelman SL, McIntyre B, Barret G. Comparison of the effects of two hand-piece locations on dental team performance. *Journal of the American Dental Association.* 1975; 91:1203–1209.

79. Fox JG, Jones JM. Occupational stress in dental practice. *British Dental Journal.* 1967;123(10):465–473.
80. Kilpatrick HC. Production increases due to chairside assistance. *Journal of American Dental Association.* 1971;82:1367–1971.
81. Green ES, Lyman WA. Work simplification: an application to dentistry. *Journal of the American Dental Association.* 1958;57:242–252.
82. Davies MH, Eccles JD. Attitudes of dental patients to conservation treatment in different chair positions. *Journal of Dentistry.* 1978;6:294.
83. Eccles JD, Davies MH. A study of operating positions in conservative dentistry. *Dental Practitioner.* 1971;21:221.
84. Rundcrantz BL, Johnsson B, Moritz U, Roxendal G. Cervico-brachial disorders in dentists. A comparison between two kinds of physiotherapeutic interventions. *Scandinavian Journal of Rehabilitation Medicine.* 1991d;23(1):11–17.
85. Jacobsen N, Hensten-Petersen A. Occupational health problems among dental hygienists. *Community Dentistry and Oral Epidemiology.* 1995;23(3):177–181.
86. Sinczuk-Walczak H, Izycki J. Back pain syndromes in dentists. Diagnosis and differential diagnosis [Polish]. *Medycyna Pracy.* 1994;45 (1):71–74.
87. Izycki J, Wagrowska-Koski E. Musculoskeletal system diseases in dentists—an analysis of consultation cases referred to outpatient department of occupational disease [Polish]. *Medycyna Pracy.* 1992;43(6):525–529.
88. Rundcrantz BL. Pain and discomfort in the musculoskeletal system among dentists. *Swedish Dental Journal—Supplement.* 1991;76:1–102.
89. Milerad E, Ericson MO, Nisell R, Kilbom A. An electromyographic study of dental work. *Ergonomics.* 1991;34(7):953–962.
90. Persson B, Brune D. Dental laboratories. In: Brune DK. Edling C, eds. *Occupational Hazards in the Health Professions.* Boca Raton, Florida: CRC Press;1989:333–345.
91. Bruder R, Rohmert W. Ergonomic research of dentists—an example of a co-operation between industrial and university research departments. In: Queinnec Y, Daniellou F, eds. *Designing for Everyone, Proceedings of the 11th Congress of the International Ergonomic Association.* London: Taylor and Francis;1991:1159–1161.
92. Jamar P, Servais J. Choosing one's furniture, one's dental chair in a more ergonomic style [French]. *Revue Belge de Medecine Dentaire.* 1990;45(2):9–16.
93. Micholt F. Ergonomics and health risks for the dentists: overview [French]. *Revue Belge de Medecine Dentaire.* 1990;45(2):17–33.

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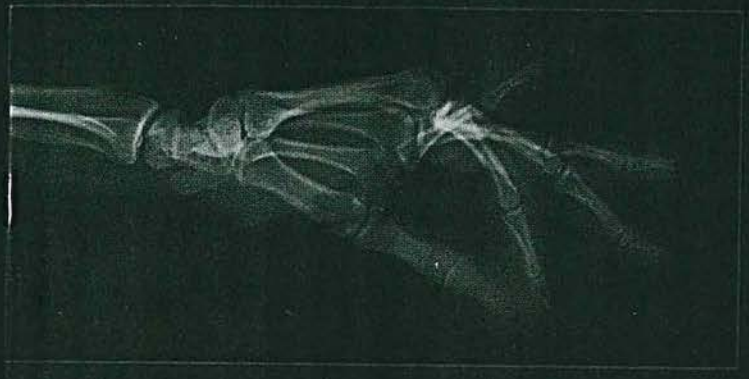

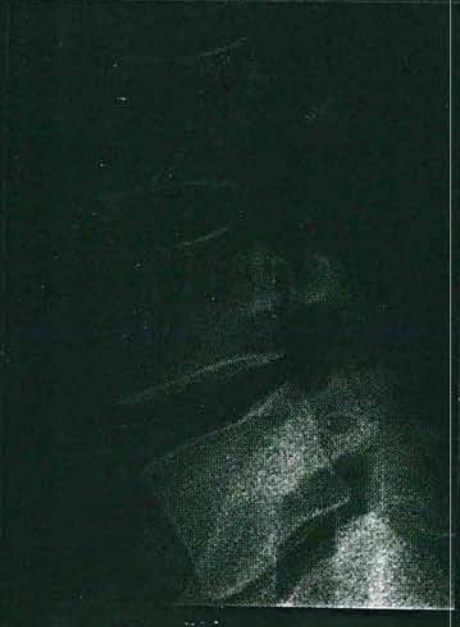

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