Mechanisms leading to musculoskeletal disorders in dentistry

BETHANY VALACHI, M.S., P.T., C.E.A.S.; KEITH VALACHI, D.D.S.

First in a two-part series on the musculoskeletal health of dental professionals

ABSTRACT

Background. The authors reviewed the implications of prolonged, seated working postures on dental operator health and the potential development of musculoskeletal disorders, or MSDs.

Types of Studies Reviewed. The authors reviewed studies to assess the mechanisms associated with the development of musculoskeletal pain and MSDs among dental operators. Some studies investigated work duration, operator positioning and the physiological effects of various static sitting postures. Others explored the relationships between prolonged muscle contraction and muscle imbalances, as related to the development of pain and MSDs.

Results. This review advances the idea that the causes of musculoskeletal pain and disorders common to dental operators are multifactorial. Physiological changes that accompany these disorders can be related to practices used by today's operators—primarily being seated for prolonged periods. Studies associated such postures with increased disk pressures and spinal hypomobility, which are factors that may lead to degenerative changes within the lumbar spine and low back pain or injury. There is a relationship shown between prolonged, static (motionless) muscle contractions and muscle ischemia or necrosis. Weak postural muscles of the trunk and shoulder may lead to poor operator posture. As muscles adapt by lengthening or shortening to accommodate these postures, a muscle imbalance may result, leading to structural damage and pain.

Clinical Implications. A significant number of today's dental operators experience musculoskeletal pain and are at risk of developing serious MSDs. A thorough understanding of the underlying physiological mechanisms leading to these problems is necessary to develop and implement a comprehensive approach to minimize the risks of a work-related injury.

Dental professionals commonly experience musculoskeletal pain during the course of their careers. While the occasional backache or neck ache is not a cause for alarm, if regularly occurring pain or discomfort is ignored, the cumulative physiological damage can lead to an injury or a career-ending disability. The musculoskeletal health of dental professionals has been the subject of numerous studies worldwide, and their focus has been on the pain experienced by the practitioner. In a 1946 study, Biller[1] found that 65 percent of dentists complained of back pain. Even after the evolution to seated four-handed dentistry and ergonomic equipment, studies [2-6] found back, neck, shoulder or arm pain present in up to 81 percent of dental operators. The table lists studies that investigated whether dental operators had experienced musculoskeletal pain in the past 12 months.

If regularly occurring pain or discomfort is ignored, the cumulative physiological damage can lead to an injury or a career-ending disability.

When we compared statistics on pain experienced by standing dentists in 1946 to those of seated dentists, we found that being seated has made little difference in how frequently operators experience pain. It did, however, change the part of the body in which operators experience pain. When operators sit, pain occurs not only in their backs, but also their necks, shoulders and arms. On the other hand, operators who primarily stood experienced low back pain (65.7 percent), as well as neurocirculatory disease including vari-

cose veins (66.7 percent), postural defects (77 percent) and flatfoot (60.1 percent).[1] We conducted a literature review to determine the core cause of musculosketetal pain in dentists who practice in standing or sitting postures.

A number of studies have found that the mechanisms leading to work-related musculoskeletal pain are multifactorial.[7-12] This pain can be attributed to numerous risk factors, including prolonged static postures, or PSPs; repetitive movements; suboptimal lighting; poor positioning; genetic predisposition; mental stress; physical conditioning; and age. Each dental team member is predisposed to pain or injury in slightly different areas of the body, depending on his or her tasks and positioning in relation to the patient. For example, hygienists and periodontists who are seated are predisposed to neck, shoulder and hand-wrist pain largely due to static postures combined with forceful, repetitive movements that are inherent in the job. On the other hand, general practitioners tend to be susceptible to lower back and neck injuries, due to PSPs, but have relatively fewer repetitive-motion injuries. We have chosen to focus on this latter group, since the most compelling evidence for detrimental physiological changes in the body resulting from both standing and seated postures in dentistry comes from research on the effects of PSPs.[13-16]

TABLE

DENTAL PROFESSIONALS REPORTING PAIN IN THE PAST YEAR.

AUTHORS	COUNTRY	STUDY YEAR	PERCENTAGE REPORTING PAIN
Shugars and colleagues[2]	United States	1987	60
Rundcrantz and colleagues[3]	Sweden	1990	72
Auguston and Morken[4]	Norway	1996	81
Finsen and colleagues[5]	Denmark	1997	65
Chowanadisai and colleagues[6]	Thailand	2000	78

Each dental team member is predisposed to pain or injury in slightly different areas of the body, depending on his or her tasks and positioning in relation to the patient.

The negative physiological effects of using static seated postures in dentistry may be exacerbated by four-handed dentistry, which was introduced in the 1960s to decrease operator stress and fatigue while achieving maximum efficiency. Although allowing the operator to remain stationary for longer periods was seen as a benefit, studies suggest that the PSPs also may contribute to operator pain.[13-16] One showed that operators who practiced four-handed dentistry tended to work for longer periods without taking a break and reported significantly higher frequencies of pain than did those not practicing four-handed dentistry.[17]

In this article, we focus on the biomechanical and physiological changes imposed on the body due to PSPs and how these changes can progress to a musculoskeletal disorder, or MSD.

PROLONGED STATIC POSTURES

The human body was designed for movement. Over thousands of years, the human body has depended on movement for its survival; for example, if early humans did not hunt and gather food, they died. Human physiology has evolved around movement for thousands of years. In the last 250 years, with the onset of the Industrial Revolution, increasing numbers of workers have performed stationary tasks. More recently, with the advent of computers and as the number of sedentary jobs have increased, the number of MSDs has risen dramatically. This has, in part, resulted in the formation of such organizations as the Occupational Safety and Health Administration and National Institute of Safety and Health in 1970. One study showed that the prevalence of low back pain increased by 2,700 percent from 1980 to 1993.[18]

Dentists frequently assume static postures, which require more than 50 percent of the body's muscles to contract to hold the body motionless

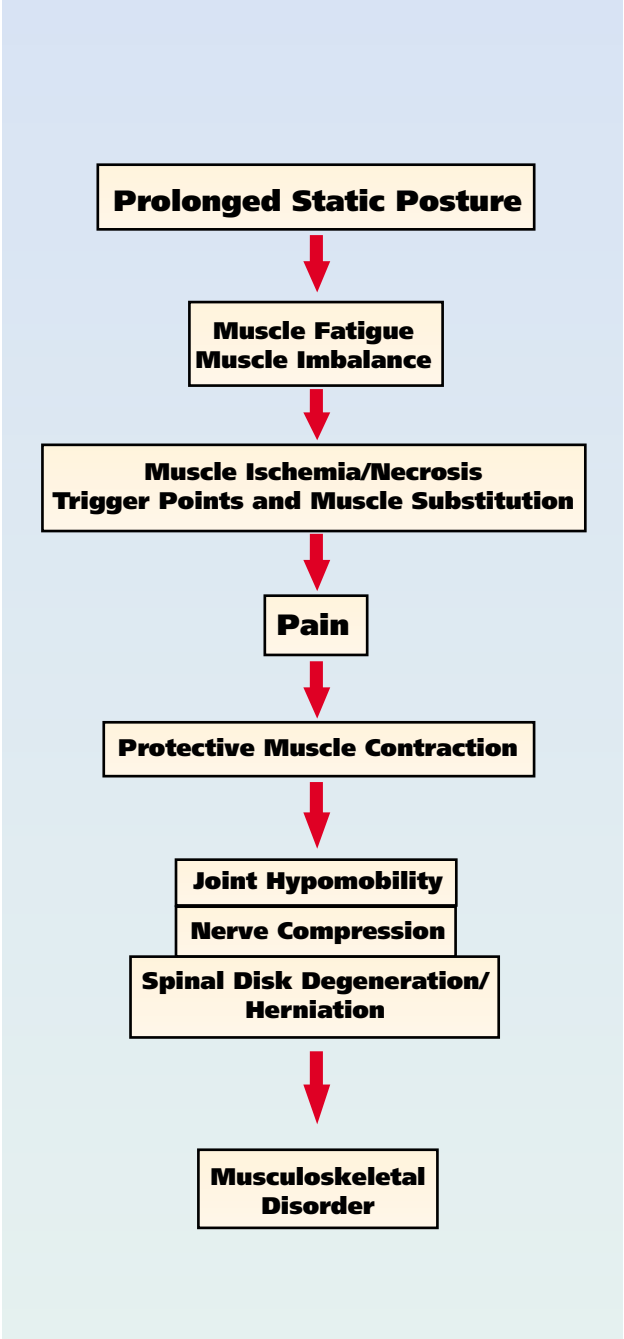

Figure 1. Flowchart showing how prolonged static postures can progress to pain or a musculosketetal disorder.

while resisting gravity. The static forces resulting from these postures have been shown to be much more taxing than dynamic (moving) forces.[19]

When the human body is subjected repeatedly to PSPs, it can initiate a series of events that may result in pain, injury or a career-ending MSD (Figure 1). Muscle imbalances, ischemia, trigger points, joint hypomobility and spinal disk degeneration are some of the physiological consequences of PSPs.

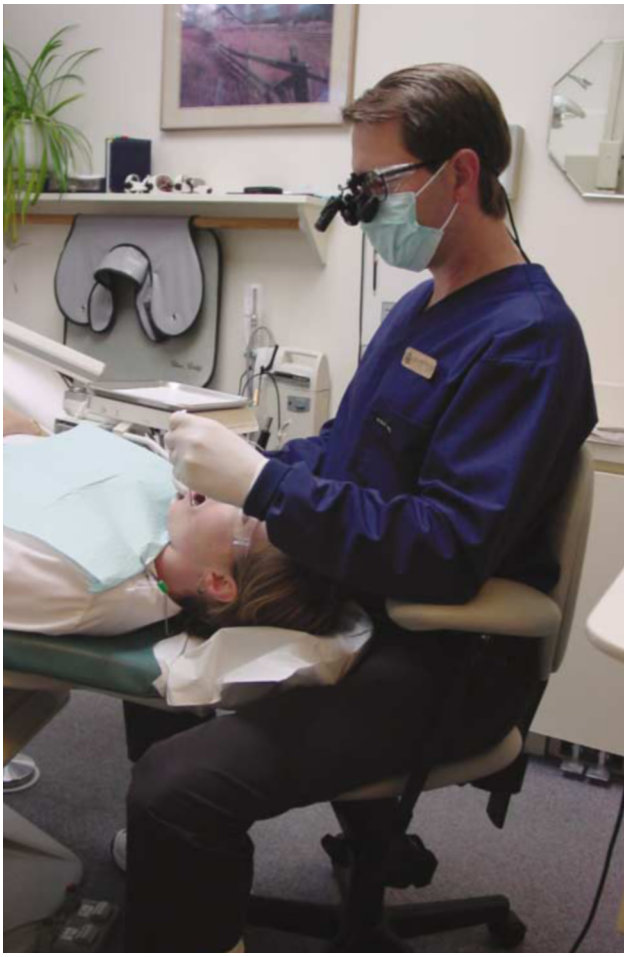

Figure 2. Example of an optimal working posture that should be maintained to reduces stress on muscles, ligaments, tendons, spinal disks and surrounding tissue.

Just as dentists need to be knowledgeable about the mechanisms contributing to oral pathology so they can effectively treat and prevent the progression of symptoms, they also must understand the mechanisms that contribute to MSDs so they can make informed choices regarding ergonomic equipment, exercise and lifestyle. Having this knowledge is key in preventing and managing work-related musculoskeletal problems in clinical dentistry.

MUSCLE IMBALANCES

The delivery of modern clinical dentistry means that practitioners regularly maintain static postures. During treatment, however, operators should strive to maintain a neutral, balanced posture (Figure 2). Even with the best ergonomic equipment, operators can find themselves in sus-

tained awkward postures. These postures often consist of forward bending and repeated rotation of the head, neck and trunk to one side (Figure 3). Over time, the muscles responsible for rotating the body to one side can become stronger and shorter, while the opposing muscles become weaker and elongated. The stressed shortened muscles can become ischemic and painful, exerting asymmetrical forces on the spine that can cause misalignment of the spinal column and decreased range of motion in one direction over the other. One study, for example, showed that for a majority of dentists, neck rotation to the right with side bending to the left is a difficult movement to perform.[20] Most right-handed dentists repeatedly assume just the opposite position—rotating the neck to the left with side-bending to the right to gain better visibility.

Muscle imbalances also can develop between the muscles that stabilize and those that move. In dentistry, for example, continual work in front of and below the operator's eye level leads to a forward head and rounded shoulder posture. This can cause weakening and elongation of the "stabilizer" muscles of the shoulder blades (middle and lower trapezius, rhomboid and serratus anterior muscles). As a result, the shoulder blades tend to move away from the spine, leading to rounded shoulder posture. Meanwhile, anterior "mover" muscles (scalene, sternocleidomastoid and pectoralis) become short and tight, pulling the head forward. Ligaments and muscles then adapt to this new position, making it uncomfortable to assume correct posture. The cycle of muscle imbalance perpetuates as tighter muscles become tighter and weaker muscles become weaker. In addition, major nerves to the arm run behind certain tight muscles, and nerve entrapment syndromes may occur as a result of pressure on these nerves. The forward-head-and-rounded-shoulder posture also increases forces on the upper neck muscles (upper trapezius and levator scapulae) and spinal vertebral disks. This stress can result in ischemia and pain in the overworked muscles.[21] Within the cervical vertebral disk, increased pressure leads to degenerative changes, putting the disk at risk of injury.

The muscle imbalance that tends to develop between the abdominal and low back muscles is especially problematic in seated-posture dentistry. Repeatedly leaning toward a patient can cause strain and overexertion in the low back extensors, while the deep stabilizing abdominal muscle (transversus abdominus) tends to become weaker. The importance of the transversus abdominus muscle in preventing low back pain was the subject of two 1996 studies.[22,23] Another study showed that only 10 percent of patients with a history of low back pain could effectively contract the transversus abdominus muscle, compared with 82 percent of nonsymptomatic subjects.[24] The ability to effectively contract the transversus abdominus muscle was linked closely to patients' reports of decreased pain levels and expressions that their backs felt safer and to their ability to control back pain.[25]

Over months or years, the body will adapt to the abnormal posture caused by these muscle imbalances and maintain this unbalanced posture not only at work, but in leisure activities as well.

Figure 3. Example of an awkward posture that frequently is repeated in the same direction. It can lead to muscle imbalances.

This abnormal posture can lead to muscle necrosis, pain and protective muscle contractions that immobilize or "splint" the affected area, facilitating the development of an MSD (Figure 1, page 1346).

MUSCLE ISCHEMIA AND NECROSIS

Low back strain is a common diagnosis among workers who must sit in a slightly flexed forward position. One study showed that static prolonged contractions of the low back extensor muscles (lumbar erector spinae), which occur while sitting, significantly decreased oxygenation levels in the muscle.[26] This occurred while people performed as little as 2 percent of the maximum voluntary contraction of the muscle. In dentistry, these muscles must maintain eccentric contractions (lengthening while under tension), which increases the susceptibility to tearing of muscle tissue.[11]

Even when using the best working postures, dental operators still maintain static contractions of the trunk muscles. As their postures deviate from neutral, their muscles must contract harder to maintain a working posture. As muscles become fatigued, this prolonged contraction can cause muscle ischemia.[11]

Low back strain is a common diagnosis among workers who must sit in a slightly flexed forward position.

Ischemic areas are especially susceptible to the development of trigger points, which are groups of muscle fibers that are in a constant state of contraction inside a tight band of muscle. They feel like a knot or small pea. These points may be active (painful) or latent (causing stiffness and restricting range of motion). When pressed on, trigger points may be painful locally or refer pain to a distant part of the body.[27]

Human muscles are not adapted for continuous long-lasting contractions and require rest periods to recover from even very low-level exertion.[28] During a sustained, static muscle contraction, the tendon stretches and compresses the vascular supply to the muscle and surrounding tissues, thereby depleting nutrient and oxygen supply. Lactic acid and other metabolites accumulate in the muscle tissues.[13] This process can result in damaged muscle tissue and a painful sensation.

Under normal conditions, damaged tissue is repaired during rest periods. In dentistry, however, the damage often exceeds the rate of repair due to insufficient rest periods. Muscle necrosis then can occur. To protect the stressed area from further injury, the body uses another part of the damaged muscle to maintain the body position. Over long periods, entire muscles become compromised, so the body recruits different muscle groups to perform the needed task. This is known as muscle substitution, and muscles are required to perform a task for which they are not ideally designed. An abnormal "compensatory" motion then develops and predisposes the person to joint hypomobility (stiffness), nerve compression or spinal disk disorders.

HYPOMOBILE JOINTS

Each time a joint moves, a viscous liquid called synovial fluid is produced; it is a lubricant that is essential for optimal joint functioning. During periods of PSPs or when joints are restricted due to muscle contractions, synovial fluid production is reduced dramatically, and joint hypomobility may result. Operators who continually lean forward toward patients may have excellent or excessive spinal flexion, but over time, the ability of the spine to extend is diminished. The loss of mobility can lead to early degenerative changes in the joint and put the operator at risk of experiencing further injury.[29] Furthermore, flexed seated posture may cause increased forces in the lumbar facet joints, leading to degenerative changes in those joints. This can contribute to low back pain syndrome.[15]

SPINAL DISK HERNIATION AND DEGENERATION

Spinal disks provide movement between the vertebrae for spinal flexibility and sustain and transmit pressure between them. Disks are composed of a tough, outer layer (the annulus fibrosus) and a gellike mass in the center (the nucleus pulposus). When weight is applied to the disk, the nucleus pulposus acts similar to a water balloon and expands outward, exerting pressure on the annulus fibrosus. In unsupported sitting, pressure in the lumbar spinal disks increases 40 percent over pressure from standing. During forward flexion and rotation—a position often assumed by dental operators—the pressure increases 400 percent,[30] making the structure vulnerable to injury. The posterior aspect of the annulus fibrosus is the thinnest, and repeated

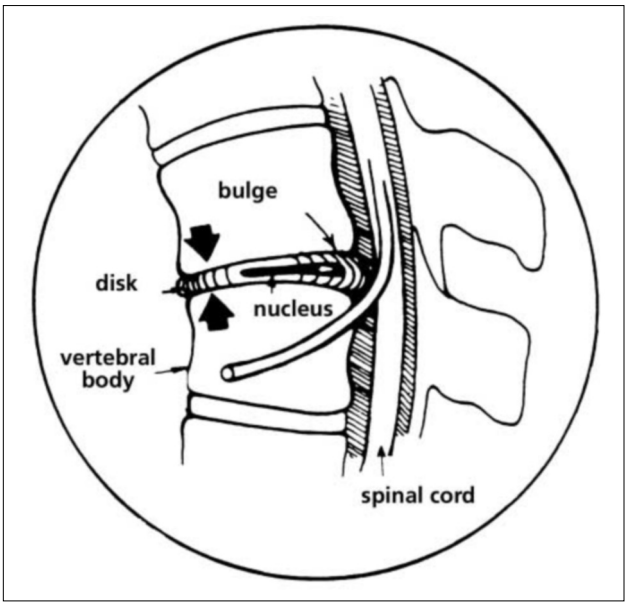

Figure 4. Rounded back postures can cause the nucleus to wear away layers of the annulus fibrosus, leading to disk bulge or herniation. Adapted with permission of the publisher from Saunders and Saunders.[29]

forward flexion causes the nucleus pulposus to push against the posterior annulus, tearing away its layers. Eventually the annulus fibrosus can "give way", resulting in a bulging, or herniated, disk (Figure 4), which can press on the spinal cord or peripheral nerves, causing low back, hip or leg pain.

Compounding the problem is the fact that only the outer one-third of the annulus fibrosus is innervated. Two-thirds of the spinal disk can be damaged or worn away before the operator ever feels pain. This is why many patients report episodes of herniated disks as happening "suddenly."

Movement is required to nourish the nucleus pulposus.[14] Under static, sustained pressure, nutrition to the disk is diminished and degenerative changes occur, placing the disk at an increased risk for injury.[26] If these physiological changes are allowed to persist over time without intervention, they can lead to significant structural damage and an MSD.

MUSCULOSKELETAL DISORDERS

The World Health Organization defines an MSD as "a disorder of the muscles, tendons, peripheral nerves or vascular system not directly resulting from an acute or instantaneous event (e.g., slips or falls). These disorders are considered to be work-related when the work environment and the performance of work contribute significantly, but are only one of a number of factors contributing to the causation of a multifactorial disease."[31]

Ms. Valachi is a physical therapist, a certified ergonomic assessment specialist, and co-founder of Posturedontics, Portland, Ore.

Dr. Valachi is in private family practice, St. Helens, Ore., and is co-founder of Posturedontics, Portland, Ore. Address reprint requests to Dr. Valachi at 2225 S.W .Scenic Drive, Portland, Ore. 97225, e-mail "stretchit@posturedontics.com".

The most common MSDs that result from PSPs in dentistry include the following:

- chronic low back pain: pain in the low back, often referring into the hip, buttock or one leg. The cause may be muscle strains or trigger points, instability due to weak postural muscles, hypomobile spinal facet joints, or degeneration or herniation of spinal disks.
- tension neck syndrome: pain, stiffness and muscle spasms in the cervical musculature, often referring pain between shoulder blades or the occiput, and sometimes numbness or tingling into one arm or hand. Forward head posture may precede this syndrome, precipitating muscle imbalances, ischemia, trigger points, or cervical disk degeneration or herniation.
- trapezius myalgia: pain, tenderness and muscle spasms in the upper trapezius muscle. Operating with the arm elevated can predispose the operator to this syndrome, which often is seen in the trapezius muscle on the side on which the dentist holds the mirror.
- rotator cuff impingement: pain in the shoulder on overhead reaching, sustained arm elevation or sleeping on the affected arm. Incorrect body mechanics and rounded shoulder posture in the operatory can lead to the impingement.

MSDs in dentistry may result in lowered productivity due to missed work or in a career-ending injury.

CONCLUSIONS

PSPs are inherent in dentistry. Serious detrimental physiological changes in the body can result from these abnormal postures, including muscle imbalances, muscle necrosis, trigger points, hypomobile joints, nerve compression, and spinal disk herniation or degeneration. These changes often result in pain, injury or MSDs.

Preventing chronic pain in dentistry may

require a paradigm shift within the profession regarding clinical work habits, including proper use of ergonomic equipment, frequent short stretch breaks and regular strengthening exercise. The second article in this series will discuss various effective prevention strategies that dental operators can use to manage discomfort and prevent MSDs. ■

1. Biller FE. Occupational hazards in dental practice. Oral Hyg 1946;36:1994.
2. Shugars DA, Miller D, Williams D, Fishburne C, Strickland D. Musculoskeletal pain among general dentists. Gen Dent 1987;35: 272-6.
3. Rundcrantz B, Johnsson B, Moritz U. Cervical pain and discomfort among dentists: epidemiological, clinical and therapeutic aspects. Part 1—a survey of pain and discomfort. Swed Dent J 1990;14:71-80.
4. Auguston TE, Morken T. Musculoskeletal problems among dental health personnel: a survey of the public dental health services in Hordaland (in Norwegian). Tidsskr Nor Laegeforen. 1996;116:2776-80.
5. Finsen L, Christensen H, Bakke M. Musculoskeletal disorders among dentists and variation in dental work. Appl Ergon 1998;29(2): 119-25.
6. Chowanadisai S, Kukiattrakoon B, Yapong B, Kedjarune U, Leggat PA. Occupational health problems of dentists in Southern Thailand. Int Dent J 2000;50:36-40.
7. Rundcrantz BL, Johnsson B, Moritz U, Roxendal G. Occupational cervico-brachial disorders among dentists: psychosocial work environment, personal harmony and life-satisfaction. Scand J Soc Med 1991; 19(3):174-80.
8. Westgaard RH. Effects of physical and mental stressors on muscle pain. Scand J Work Environ Health 1999;25(supplement 4):19-24.
9. Lehto TU, Helenius HY, Alaranta HT. Musculoskeletal symptoms of dentists assessed by a multidisciplinary approach. Community Dent Oral Epidemiol 1991;19:38-44.
10. Karwowski W, Marras WS. The occupational ergonomics handbook. Boca Raton, Fla.: CRC Press; 1999:69-170, 175, 285, 585–600, 1134.
11. Cailliet R. Soft tissue pain and disability. 3rd ed. Philadelphia: F.A. Davis; 1996:1-12, 35, 71, 124, 489-501.
12. Murphy DC. Ergonomics and the dental care worker. Washington: American Public Health Association; 1998:113-128, 191, 344, 350.
13. Kumar S. Biomechanics in ergonomics. Philadelphia: Taylor & Francis; 1999:12-5, 250-4.
14. Callaghan JP, McGill SM. Low back joint loading and kinematics during standing and unsupported sitting. Ergonomics 2001;44(3): 280-94.
15. Hedman TP, Fernie GR. Mechanical response of the lumbar spine to seated postural loads. Spine 1997;22:734-43.
16. Novak CB, Mackinnon SE. Repetitive use and static postures: a source of compression and pain. J Hand Ther 1997;10(2):151-9.
17. Marshall ED, Duncombe LM, Robinson RQ, Kilreath SL. Musculoskeletal symptoms in New South Wales dentists. Aust Dent J 1997; 42:240-6.
18. Pope M. Muybridge lecture. In: Proceedings of XIVth Congress International Society of Biomechanics, July 1993. Paris: International Society of Biomechanics; 1993.
19. Ratzon NH, Yaros T, Mizlik A, Kanner T. Musculoskeletal symptoms among dentists in relation to work posture. Work 2000;15(3): 153-8.
20. Rundcrantz BL, Johnsson B, Moritz U. Occupational cervicobrachial disorders among dentists: analysis of ergonomics and locomotor functions. Swed Dent J 1991;15:105-15.
21. Langford ML. Poor posture subjects a worker's body to muscle imbalance, nerve compression. Occup Health Saf 1994;63(9):38-42
22. Hodges PW, Richardson CA. Inefficient muscular stabilization of the lumbar spine associated with low back pain: a motor control evaluation of transverses abdominis. Spine 1996;21:2640-50.
23. Hides JA, Richardson CA, Jull GA. Multifidus muscle recovery is not automatic after resolution of acute, first-episode low back pain. Spine 1996;21:2763-9.
24. Richardson C, Jull G, Richardson B. A dysfunction of the deep abdominal muscles exists in low back pain patients. In: Proceedings of the International Congress: World Confederation of Physical Therapy. Washington: World Confederation of Physical Therapy; 1995:932.
25. Richardson C, Jull G, Hodges P, Hides J. Therapeutic exercise for spinal segmental stabilization in low back pain: Scientific basis and clinical approach. London: Churchill Livingstone; 1999:4-5.
26. McGill SM, Hughson RL, Parks K. Lumbar erector spinae oxygenation during prolonged contractions: implications for prolonged work. Ergonomics 2000;43(4):486-93.
27. Travell JG, Simons DG, Simons LS. Myofascial pain and dysfunction: The trigger point manual. Vol. 1. Baltimore: Lippincott Williams & Wilkins; 1999:4, 12, 19, 35.
28. Sjogaard G. Intramuscular changes during long-term contraction. In: The ergonomics of working postures: Models, methods and cases—The Proceedings of the First International Occupational Ergonomics Symposium, Zadar, Yugoslavia, 15-17 April, 1985. Philadelphia: Taylor & Francis; 1986:136-43.
29. Saunders HD, Saunders R. Evaluations, treatment and prevention of musculoskeletal disorders. Vol. 1: Spine, 3rd ed. Chaska, Minn. Educational Opportunities; 1995:106.
30. Nachemson AL. Disc pressure measurements. Spine 1981;6(1): 93-7.
31. Identification and control of work-related diseases: report of a WHO expert committee. World Health Organ Tech Rep Ser 1985;174: 7-11.