AN INTRODUCTION TO ERGONOMICS:
Risk Factors, MSDs, Approaches and Interventions

A Report of the Ergonomics and Disability Support Advisory Committee (EDSAC) to
Council on Dental Practice (CDP)

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Recommendations in the report are based on suggestions and scientific evidence published in the literature. However, there are limitations regarding the current state of evidence in the field of ergonomics. There are no randomized controlled trials to test the efficacy of design recommendations on preventing ergonomic injuries. A number of the recommendations are based on experiential observations and on analysis of injury reports. While such reports are useful, they are not free from bias. Hence, the recommendation made in Section 4 (*Interventions*) should be considered as suggestions. The efficacy of these suggestions may not be validated by well-controlled scientific studies.

SECTION 1: INTRODUCTION

This paper attempts to provide both important background and practical advice to dentists interested in addressing ergonomic issues in the workplace. It is divided into sections, so readers looking for practical suggestions can go directly to the relevant section of the paper. Similarly, readers interested in citations to the literature need not review the entire document.

This paper focuses on ergonomic risk factors, the various types of musculoskeletal disorders (MSD), and practical approaches to ergonomic issues in the workplace. The scope of this paper is intentionally limited, for a variety of reasons. The study of ergonomics is exceedingly difficult because so many factors can contribute to any particular case of a MSD. One key area of uncertainty is often whether the MSD is work related or is attributable to non-work factors (or is attributable to some combination of both). To the extent a definite or even probable answer to that question is possible, it certainly can only be answered on a case-by-case basis. Such an inquiry is beyond the scope of this paper.

Rather, this paper sets forth broad important background information on ergonomics so that the dental practitioner can have a general awareness of ergonomic risk factors as well as some basis for understanding the on-going national dialogue about ergonomics, its diagnosis, treatment, and regulation. This paper does not try to identify any particular condition or factor as responsible for MSDs in dentistry. That too is beyond the scope of this paper.

Finally, and perhaps more importantly, this paper provides specific steps a dentist may wish to consider taking relative to ergonomic concerns. The proposals contained in this paper are designed to make the practitioner both more comfortable and more productive. These ideas may prove to be helpful regardless of whether the practitioner is experiencing an MSD or whether the MSD is work related.

This paper makes no recommendation for best practices relating to ergonomics and dentistry. Rather, it provides alternatives to be considered by the practitioner in light of the practitioner's own circumstances, experiences and goals. A practitioner wishing to improve his or her work environment, for whatever reason, may wish to follow an incremental approach to such efforts, as is briefly discussed in this paper.

SECTION 2: ERGONOMIC RISK FACTORS IN GENERAL

Although the causes of any particular case of a MSD are exceedingly difficult to identify with complete accuracy, certain risk factors are typically discussed in the field of ergonomic studies. The primary occupational risk factors for MSDs discussed in the literature [1,2,3,4,5] include:

- repetition
- force
- mechanical stresses
- posture
- vibration
- cold temperature
- extrinsic stress

It is essential to understand just what a risk factor is, or rather is not. A risk factor itself is not *necessarily* a causation factor for any particular MSD. Many times it is not simply the presence of a risk factor, but the degree to which the risk factor is expressed that may lead to MSDs. [6, 7] Similarly, to the extent a MSD case is attributable to a risk factor, often it will be a combination of multiple risk factors, rather than any single factor, which contributes to or causes an MSD.

It is also important to note, in evaluating any particular case of a MSD, that risk factors may be experienced by the affected individual during non-occupational activities. In addressing any ergonomic issue, it would be a mistake to focus solely on the workplace. Further, not every person exposed to any or all of these risk factors will develop a MSD. Nor, for that matter, will any two people who are exposed to the same combination of risk factors and in the same degree, respond to them in the same way. Nevertheless, because these are common factors that may give rise to a MSD in some combination and in some people, these seven risk factors are discussed in greater detail below.

Each of these work factors is discussed in more detail below.

Repetitions. Repetition rate is defined as the average number of movements or exertions performed by a joint or a body link within a unit of time. [5] Repeated identical or similar motions performed over a period of time could cause over-extension and overuse of certain muscle groups, which could lead to muscular fatigue. Interestingly, symptoms often relate not to the tendon and muscle groups involved in repetitive motions, but to the stabilizing or antagonistic tendon and muscle groups used to position and stabilize the extremity in space. [8] Sometimes, by varying tasks, muscle groups have periods of activity alternated with periods of rest, which may be beneficial in reducing the possibility of injury.[6]

Force. Force is the mechanical or physical effort to accomplish a specific movement or exertion.[5] For example, using the hands instead of a clamp to hold an object while performing a task such as placing an interproximal composite restoration. The amount of force required by an activity can sometimes be magnified causing even more muscular fatigue. If for example, in the just described dental procedure the arms are also elevated at the time.

Mechanical Stresses. Mechanical stresses are defined as impingement or injury by hard, sharp objects, equipment or instruments when grasping, balancing or manipulating. Mechanical stresses are encountered when working with forearms or wrists against the edge of a desk or work counter. The muscles and tendons are impinged when pressed into the sharp edge. Using the hand as a hammer to close a lid securely also creates mechanical stresses, especially if the lid has raised surfaces or sharp edges.

Posture. Posture is the position of a part of the body relative to an adjacent part as measured by the angle of the joint connecting them. Postural stress is assuming an extreme posture at or near the normal range of motion.[5] Posture is one of the most frequently cited occupational risk factors. [1,2, 9, 10,11]

There is a neutral zone of movement for every articulating joint in the body. For each joint the range of motion is defined by movements that do not require high muscular force or cause undue discomfort. Injury risks increase whenever work requires a person to perform tasks with body segments outside their neutral range in a deviated posture.

For the upper arm and shoulder area neutral posture is relaxed with the shoulders down and on the same plane, with arms at the side. Working with the arms abducted away from the body, overextended and shoulders hunched places these joints at the end of their normal range of motion, requires higher muscular force and greatly increases the risk for injury.

Strained sitting positions, such as tilting sideways, twisting the vertebral column, bending forward or slumping begin in response to compensation for specific work relationships but can become habit over time. Posture and positioning profile factors such as torso twist, tipped shoulders, head tilt/rotation, raised elbows (either dominant , non-dominant, or both) and operating with hands close to the face are associated with increased risk of musculoskeletal symptoms. [10]

Vibration. Vibration has been found to be an etiological factor in work environments utilizing tools vibrating in the frequency band of 20 to 80 hz.[1] Dental handpieces and powered automatic instruments operate at higher frequencies in the 5000 to 10,000 hz range, and duration of exposure to vibratory force during dental procedures is relatively short. Thus, it would appear that the exposure to this risk factor in dentistry is relatively small. The vibratory peaks experienced using dental handpieces is in the frequency range similar to driving a car.[12]

However, certain non-occupational activities of a practitioner may involve this risk factor. For example, use of a chain saw or powered wood working tools for extended periods of time.

Cold Temperature. Low temperatures reduce manual dexterity and accentuate the symptoms of nerve-end impairment.[1]

Extrinsic Stress. Extrinsic stress, or sometimes called organizational factors, can be defined as the way in which work is structured, supervised and processed. [4] Extrinsic stress reflects the objective nature of the work process. It may include such variables as job variety, job control, workload, time pressure, and financial constraints. In general manufacturing, some studies show a relationship between extrinsic stress factors and a higher incidence of MSDs. [13]

Of course, risk factors are only part of the story. As was noted above, two individuals exposed to the same combination of risk factors and to the same degree will respond differently. One worker may not experience any discomfort, while another might develop a MSD. Why this is so is not fully understood. Nevertheless, studies have identified some "worker predisposing factors". Those factors might increase a person's probability of developing an MSD.

Some predisposing factors (i.e., age, rheumatoid arthritis, renal disease, hormonal imbalances, diabetes, hypothyroidism) are biological mechanisms that could account for an increased occurrence of tissue damage and MSDs. For other factors (i.e., weight, wrist dimension) there is epidemiological evidence but the mechanism is less clear. Still other factors are even less well established (i.e. genetics, general conditioning). In addition, there are a host of non-work risk factors inherent to the hobbies and other activities a person engages in when away from work (i.e., knitting, crocheting, bowling, computer use, excessive driving). [13]

<u>Suggestion:</u> A life-long priority for susceptible individuals should be learning to control, wherever possible, many of these risk factors and planning non-work related activities that include physical rest and conditioning needed to balance the stresses of practicing dentistry. [14]

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SECTION 3: TYPES OF MSDs

Risk factors may lead to MSDs, at least in some people some of the time. Background on risk factors has already been given in this paper. But MSDs themselves also need to be explained before any realistic discussion of ergonomic solutions. MSDs come in a variety of forms. Indeed, lumping them all together suggests a greater uniformity in condition than what actually exists. The purpose of this section of the paper is to provide the reader with general information about the primary types of MSDs. Both back problems, and hand and wrist conditions will be discussed.

Back Problems

Lower back pain. Ninety per cent of people will have back pain at some point in their lives.[2] Low back pain is second only to the common cold as the main reason for seeking medical attention.[3] Low back pain (LBP) has been, and continues to be, an epidemic in the United States. It has been estimated that the annual incidence (number of persons who will have back pain this year) is 5% of the population.[1]

Understanding the natural history of LBP can be confusing as one looks at the medical literature. Reports show that 90% of back pain resolves within 6-12 weeks.[4] The problem most people have is that there is a high rate of recidivism. Between 70% and 90% of people have recurrent episodes of pain, and one third of patients continue to have persistent, recurrent or intermittent pain after their first episode.[5,6] In addition to the difficulty with healing certain tissue types (such as with spondylolisthesis), the degenerative process is ongoing with age, and many patients do not minimize potential risk factors. All of this can contribute to continued episodes of LBP.

The cause of LBP is often multifactorial. While a full description of the anatomy of the lumbosacral spine is beyond the scope of this paper, any tissue or structure innervated with afferent nerve fibers has the potential to be a pain generator. That includes muscles, ligaments, facet and sacroiliac joints, intervertebral discs, nerve roots, and bony periosteum. However, this only addresses the "end organ" cause of pain. There can be many other biomechanical and functional deficits that might lead to tissue pain. In addition, the degenerative cascade affects multiple areas of the lumbar spine, including potentially, all of the pain generators.[7]

A separate but related issue with regard to back pain is back injury. These are usually acute, sudden episodes of back pain or "sciatica" related to a specific event. (Such injuries are typically not considered to be MSDs attributed to repetitive motions. Nevertheless, such injuries may render certain repetitive motions painful.) A fall, sudden jarring, or lifting incident can initiate the onset of pain in all of the tissues previously listed. However, certain persons are at increased risk of injury. Disc herniation occurs more frequently in middle age, usually due to early effects of degeneration of the outer disc annulus, combined with increased disc swelling pressure of the inner nucleus[8].

It has also been described that combined motions of lumbar flexion with rotation increase risk to the lumbar disc. This is further exacerbated by inflexibilities around the hips and pelvis, as well as relative weakness of the stabilizers of the lumbar spine including the abdominal and gluteal muscles. Furthermore, back pain can exist due to underlying normal age related processes, become exacerbated by abnormal postures, relative weakness and decreased endurance, and then exacerbated by a "specific" injury.

The treatment of low back pain has to be individualized for each patient. While there is little hard scientific evidence to support one specific intervention over all others, postural correction, proper patient positioning, general exercise, and possibly specific physical therapy techniques and/or manipulation may be beneficial.[9]

Upper back pain. While not as common as lower back pain, some individuals report extensive pain in the mid and upper back (thoracic area). The thoracic spine is designed for support in standing and for caging the vital organs, and is quite strong. It only rarely experiences symptoms of degeneration since there is little movement and great stability. Of course trauma or injury from strain could cause pain. Although the spinal structures (bones, discs, nerves) are less commonly injured, some conditions such as osteoporosis can predispose one to specific conditions such as compression fractures. Also, the thoracic spine is frequently involved in idiopathic scoliosis (side to side curve) or kyphosis (excessive forward curve). These can later develop into painful conditions, although the exact source and cause is often unclear.

Probably a more frequent cause of mid back pain, but again difficult to precisely diagnose, is muscular pain from the postural muscles and scapular muscles. The contributions of abnormal posture, static postures, poor strength and endurance, and overall individual conditioning need to be taken into account. Some rehabilitation efforts, because of the large muscles involved, include stretching, strengthening exercises, which mimic functional activities, and attention to posture [10]

<u>Hand and Wrist Problems</u>

MSDs of the hand and wrist can take a variety of forms, such as, cumulative trauma disorder, repetitive strain injury, occupational repetitive micro-trauma, repetitive motion injury, overuse syndrome, carpal tunnel syndrome and repetitive stress disorder.[1] A predominant cause of repetitive motion hand disorders is constant flexion and extension motions of the wrist and fingers. Chronic, repetitive movements of the hand and wrist, especially with the hand in "pinch" position, seem to be the most detrimental.[2] Other common contributing factors to hand and wrist injuries include movements in which the wrist is deviated from neutral posture into an abnormal or awkward position; working for too long a period without allowing rest or alternation of hand and forearm muscles; mechanical stresses to digital nerves from sustained grasps to sharp edges on instrument handles; forceful work; and extended use of vibratory instruments.

Some of the specific hand and wrist conditions are discussed below.

Tendinitis/Tenosynovitis. Tendinitis and tenosynovitis refers to inflammation of the tendon and tendon sheath, respectively. Both are associated with the occurrence of pain during physical movement that places the tendons in tension. Inflammation can occur in any of the tendons of muscles that control the movement of the fingers, wrist and forearm.

The most common types of tenosynovitis of the hand and wrist are those involved with the muscles of the thumb and index finger.

DeQuervain's Disease. DeQuervain's disease is an inflammation of the common tendon sheath of two muscles to the thumb – abductor pollicis longus and extensor pollicis brevis. Predisposing activities include postures that maintain the thumb in abduction and extension, forceful gripping, and thumb flexion combined with wrist ulnar deviation.[10] Symptoms include sharp pain and swelling over the radial sytloid process of the wrist, the bony prominence just proximal to the wrist joint. The pain may radiate up the forearm or down into the thumb. Muscle weakness and decreased ability to grip with the thumb will result.

Trigger Finger. Tenosynovitis can progress causing a narrowing of the inflamed tendon sheath preventing the smooth movement of the tendon through the digital pulley system. A nodule will form on the tendon creating a "clicking" or "triggering" movement. Tenosynovitis of the finger is due to sustained, forceful power grip and/or repetitive motion. Symptoms include pain during physical movements that place the tendons in tension; and the presence of warmth, swelling and tenderness of the tendon on palpation.[1]

Carpal Tunnel Syndrome. Cumulative trauma disorder, repetitive strain injury and repetitive stress disorder are terms often used to describe the condition when the nerves innervating the hands are compressed. Any of the three nerves of the hand – medial, radial, or ulnar – may be affected.[3] The most common of these nerve compressions for dentistry, as well as for the general population, is carpal tunnel syndrome. There has been a tremendous increase during the last 20 years in the number of reported cases of carpal tunnel syndrome.[3]

Carpal tunnel syndrome is difficult to deal with in the occupational setting because so many non-work factors may be involved. Numerous studies confirm that patients diagnosed with work-related carpal tunnel syndrome have a high prevalence of concurrent medical conditions that are capable of causing carpal tunnel syndrome without respect to any particular occupation.[5-8] These medical factors include a genetic predisposition; obesity; metabolic or inflammatory diseases (i.e., arthritis, diabetes, hypothyroidism, neoplasms, gout, myxedema, amyloidosis, multiple myeloma); and hormonal factors (i.e., pregnancy, oral contraceptives, hormone replacement, menopause). Statistics reveal that carpal tunnel syndrome is at least three times more common in women than in men.[6] Typically, carpal tunnel syndrome manifests during middle age.

Carpel tunnel syndrome is a peripheral neuropathy caused by compression of the median nerve as it passes through the bony landmark in the wrist known as the carpal tunnel. The

carpal tunnel is bordered on three sides by carpal bones. The fourth side is formed by the transverse carpal ligament; a thick, dense, fibrous band. The carpal tunnel is a rigid structure through which nine flexor tendons, blood vessels, and the median nerve pass. Tenosynovitis, an inflammation or swelling of the synovium around the tendons, may occur with repetitive, forceful exertion of the fingers, particularly with the wrist in a deviated position. The increased swelling cannot be accommodated in the limited space of the carpel tunnel, resulting in compression of the median nerve and its blood supply. It is either the compression of the median nerve, or the metabolic dysfunction of the median nerve due to obstruction of its vascular supply, or both, that results in a myriad of symptoms.[2]

Symptoms of carpal tunnel syndrome include:

- Tingling or numbness in the hand
- Shooting pain from the hand up the arm
- A swollen feeling in the hand without visible swelling
- Hand weakness and clumsiness of the hands especially in the morning
- Stiffness and numbness in the thumb, index finger, middle finger and radial side of the ring finger
- Difficulty grasping and pinching
- Frequently dropping objects due to reduced sensation to touch
- Symptoms are worse at night
- Occurs most often in the dominant hand but is frequently bilateral

Carpel tunnel syndrome is accurately diagnosed by the presence of any two of three criteria:
1) clinical symptoms; 2) physical tests (i.e., Phalen's test, Tindel's sign); and 3) electro-diagnostic studies.[4]

Guyon's Syndrome. Guyon's syndrome, or ulnar neuropathy most commonly occurs secondary to compression or injury at the elbow as the ulnar nerve passes through the cubital tunnel. In addition to compression at the elbow, the ulnar nerve can also be compressed at the base of the palm as it passes through Guyon's Canal. The contents of Guyon's Canal are the ulnar nerve and artery and fatty tissue. No flexor tendons pass through the canal. Compression of the ulnar nerve can occur just proximal to Guyon's canal or at the distal end where the motor branch of the ulnar nerve enters an arcade of ligaments and tendons.[9]

Symptoms of ulnar neuropathy generally include pain, numbness and/or tingling in the distribution of the ulnar nerve in the ring finger and the small finger; and a shooting electrical sensation down the ulnar aspect of the arm. Motor symptoms are less common, but may include loss of control of the small finger, weakness and clumsiness of the hand.[9]

Diagnosis of Guyon's syndrome is accomplished using clinical symptoms, physical examination and electro-diagnostic studies.[4]

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SECTION 4: INTERVENTIONS

Although the causes of MSDs are varied and dependant to some extant on worker predisposing factors, anyone who is experiencing a MSD, wishes to minimize the risk of developing a MSD or who simply wants to improve comfort and efficiency may wish to consider the suggestions set forth in this section of the paper. Interventions or prevention strategies require an awareness of how to fit the job to the worker and not the worker to the job. Applying ergonomics to the practice of dentistry not only could provide safety benefits but a practice might also improve performance objectives through greater productivity. One of the main goals of ergonomics in dentistry is to minimize the amount of physical and mental stress that sometimes occurs day to day in a dental practice.

Of course, the effectiveness of any given intervention will depend on individual circumstances. Thus, this paper does not intend to establish a standard of care for treating MSDs or even establish particular interventions as the norm for improving comfort or productivity. Rather, the following interventions should be considered by the practitioner in light of his or her own experience and needs.

Process and Measurements of Success

First, however, anyone wishing to implement a program of ergonomic improvements should consider the process to be followed in doing so. A haphazard or shotgun approach to the problem would likely result in wasted and ineffective measures. Instead, interested persons should develop a plan of attack. Ergonomic improvements should be implemented incrementally, according to a plan, progressing from the simpler to the more complex, while assessing the impact of each step before implementing the next. If the problem being addressed seems to be resolved through the first or second improvement, there would be no need to proceed to the next. Because the initial steps should generally be simpler to implement and likely the least expensive, this incremental approach should permit many ergonomic situations to be resolved relatively easily. In this way, the effectiveness of each change can be better assessed and with real gains accrued in comfort and productivity at the lowest cost and with little inconvenience.

Following an incremental approach requires a way in which to assess the effectiveness of each change that is undertaken. Performance measures insure that the ergonomic process is on track. Long-term measures such as injury reduction, lost workdays, restricted workdays, and medical costs are typically used in industry to demonstrate that a program is successful. However, they may not be so easily adapted to the smaller setting of a dental office. Another challenge with these measures is that they are for the most part, reactive. That is, that they reflect progress in relation to the symptoms and not necessarily to the problem. Such measures also fail to account for stress factors from outside the workforce that may, in fact, be the cause of a MSD.

Adopting shorter-term measures, like the number of operations reduced to a low or no-risk level can be measured within hours or days. A more subjective measure may also be considered: Does the dentist or dental worker feel better performing the functions of the job? Is there more comfort? Greater productivity? The best measurement may well depend on the extent of the perceived problem, the number of persons affected by it and the type and extent of intervention.

Suggested Interventions For Consideration

Maintaining a healthy, comfortable and productive work environment for the dental team takes an awareness of the ergonomic risk factors. Often, the best intervention is the simplest. For example, something as simple as choosing alternate instrument grips; body, arm or finger positions; treatment sequencing; or instrumentation techniques can improve the work environment.

Some Interventions of Universal Applicability. According to the International Standards Organization (ISO #6385) ,[1] there are some core interventions applicable to every workplace:

- Adapt workspace and equipment to account for operator and work being performed with preferred body postures.
- Provide sufficient space for body movements.
- Provide variety in tasks and movements to avoid static muscle tension caused by postural constraints.
- Design work to allow machinery to do/assist highly repetitive tasks
- Avoid extreme posture when exerting high force

These general interventions should be considered in any case of an MSD, or even during remodeling or when purchasing new equipment.

Other Interventions For Consideration In The Dental Practice. In addition to widely recognized general interventions, consider the following interventions as well:

- Exercise caution in purchasing equipment
- Early Treatment of MSDs
- Posture and stools
- Patient positioning
- Hand instruments
- Automatic instruments
- Delivery systems
- Lighting and magnification
- Gloves
- Four-handed dentistry
- Supervised exercise/stretching
- Proper temperatures
- Procedures and administration

Each will be discussed in turn.

Exercise caution in purchasing equipment. When purchasing new equipment, dentists should consider the ergonomic ramifications of the purchase and be aware that the term "ergonomically designed" could simply be a marketing ploy. There are, unfortunately, no industry standards. Consequently, dentists should develop an understanding of ergonomic risk factors and the concept behind ergonomic interventions to help them make more knowledgeable decisions about instrument and equipment purchases.

Early Treatment of MSDs. Early intervention is of the utmost importance. Early symptoms in the wrist and hand respond to conservative medical management that includes rest, icing, non-steroidal anti-inflammatory drugs and splints. Early intervention could be important in order to achieve a better result at less cost and inconvenience.

Posture and stools. The posture adopted during the practice of operative dentistry has changed over the years. Originally, dentists commonly stood to provide treatment. With the introduction of four-handed dentistry in the 1960's, sitting became the preferred position. The sitting position was also an attempt to reduce the fatigue and discomfort sometimes associated with dental practice. Unfortunately, the seated working position has not eliminated the potential for discomfort or injury in dentistry. In many cases, dental care providers adopt whatever position is necessary to access the oral cavity.

The key objective for the dental care provider is to adopt a position that allows him or her to achieve optimal access, visibility, comfort and control at all times. Ideally, when providing patient care, muscles should be in a relaxed and well-balanced position with the exception, of course, of those muscles performing the actual task.

The operator's stool should support every operator in neutral posture; therefore it should be fully adjustable. When looking in profile at a human body, there are four curves in the spine. The first curve is the backward curve at the tailbone. This is followed by a forward curve at the lower spine, a backward curve at the upper spine and ends with a forward curve at the neck. The two forward curves counterbalance the two backward curves. These curves allow the entire trunk to remain balanced over the center of gravity. Since the operator is most commonly in a seated position while working, the design and use of the stool becomes a critical part of the balance. [6]

The operator's stool should have a broad base pan to support the buttocks and thighs, including a slight forward tilt with a "waterfall-tapered" edge. The seat should be adjusted so the operator's knees are slightly below the hip level so the thighs are 100° – 110° to the trunk with the feet resting flat on the floor.[3] Variations in footwear such as high-heeled shoes or thick soles could demand a higher seating base.

The backrest or lumbar support should be adjusted to fit in the center of the operator's lower back where the forward curve of the lower back meets the backward curve of the middle back. The operator should sit back as far as possible to take maximum advantage of the lumbar support. [3] If the operator uses a chair with arm rests, the arm rests should be fully adjustable to allow an operator full access to the patient while keeping elbows at their side.

The assistant's stool should have a broad base pan, square or rectangular, with a tilt to support the buttocks and thighs including a "waterfall-tapered" edge and anti-slip vinyl covering. Ideally, the assistant's stool should have a lumbar support adjusted to fit the assistant's lower back. The belly bar on the assistant's stool may encourage the assistant to lean forward causing an awkward or unbalanced posture. Many times the assistant is struggling with blocked vision and the only way to see is to lean forward. Without the belly bar to lean on, the assistant would probably come out of their seat. A simple readjustment of the operator's mirror hand oftentimes can give the assistant visual access to the operation field. With the increased visibility the assistant could simply pivot the belly rest around to the back of the chair and use it as a lumbar support.[3]

When seated, the assistant generally should maintain neutral posture with feet flat on the foot rest. In addition, the assistant's stool should be height adjustable to allow the assistant to maintain neutral posture when elevated above the operator.

At times it may be necessary to work in a standing position for a short period of time. A change in position, or periodic stretching provides necessary muscle relaxation to promote good posture.[4] Good posture promotes more energy, less stress and strain, less distraction from pain, and less errors. Bad posture results in pain, fatigue, poor work quality, negative attitudes, and aging.[5]

Patient positioning. While the patient's chair should provide support and comfort for the patient, it should also be adjustable to allow the operator to maintain neutral posture while working. Supine positioning of the patient in the chair is usually the most effective way to help maintain neutral posture. One result is that the maxillary occlusal plane of the patient is then perpendicular to the floor, creating the greatest access and the most effective visual line to the oral cavity.

The chair should be raised so the operator's thighs can freely turn beneath the patient's chair. Clearance around the patient's head should at least allow unimpeded operator access from the 7:00 to the 12:30 position, for right-handed operators.

The headrest should stabilize the patient's head, while allowing enough movement to position the patient and maximize access. A fully adjustable headrest will allow support for the cervical curvature and permit tilting of the patient's head. Rather than adjust the operator's position, re-position the patient's head whenever possible. For most intraoral access sites, the maxillary plane should be extended 7 degrees beyond the vertical. For treating the maxillary second and third molars, the maxillary plane should be 25 degrees beyond the vertical. For the mandibular anterior teeth, bring the patients chin down so the maxillary plane is 8 degrees ahead of the vertical. [6]

Hand instruments. Various features of dental instruments may have an affect on ergonomic issues.[7] These include:

- size and shape of the entire instrument
- diameter of the instrument handle
- surface configuration where the instrument contacts the fingers
- weight of the instrument including attachments
- balance and alignment of the instrument
- maneuverability of the instrument in space
- how well the moving parts can be manipulated
- maintenance of the cutting edge

As was noted, no industry standard for an "ergonomic" instrument currently exists. Most instruments approximate the size and shape of a No. 2 pencil. When gripping a small diameter handle (1/4 inch or less) the operator often grips the instrument with the very tips of the fingers. During movements requiring force this manner of grasping concentrates most of the strain within a very small set of hand muscles. Larger diameter instrument handles allow the operator to grip the instruments with the pads of the fingers and consequently distribute the strain through a larger group of muscles.[2]

Because of this, manufacturers are developing a greater variety of handle sizes, shapes materials and textures which reduce the pinching effect and distribute forces over the pads of the fingers. [8]

It is helpful to introduce variation, and balance of activities and instruments to shift the work to different muscle groups. For example, even the subtle variation between instruments of various handle size can distribute muscles activity among hand and finger muscle groups, reducing fatigue. [9]

A round handle, as opposed to a hexagonal handle, with hard edges will reduce muscular stress and digital nerve compression. However, a smooth, round handled instrument requires more pinching force to keep the handle from spinning in the hand. Handles with shallow, circumferential grooves or with knurling (texturing) allow better friction with the fingers so that a secure grasp requires less force. Small diameter, hexagonal shaped instrument handles produce a mechanical stress that may cause digital nerve compression. Resistance from retractable or coiled hoses on dental units could result in extra mechanical stress to maintain a precision grip.[10] Unbalanced instruments, such as slow speed motors, feel heavier at one end causing the operator to compensate in their grip by increasing the mechanical stress to the fingers and hand.

When instruments are wet and slippery or handles have smooth round surfaces force is increased to maintain a secure grip on the instrument. Force can also be affected by posture. When the hand and wrist are moved out of neutral posture into a deviated or awkward posture, the effort exerted should increase to accomplish the same work. [10]

Finally keeping the working edges sharp is key to decreasing stress. When working edges are sharp, the instrument performs more of the work; when the edges are dulled, additional operator force is required to achieve the same result. [10] Sharp instruments are key for reducing excessive force during instrumentation.

Automatic instruments. Practitioners should consider use of automatic instruments instead of manual hand instruments. This could include:

- high-speed hand-piece
- slow-speed hand-piece
- belt driven drills
- lasers
- ultrasonic scalers
- endodontic hand-pieces
- auto-condensors for amalgam placement
- electro-surgical units

Hand-pieces should be as light as possible and well balanced. Hose length should be as short as possible; extra hose length adds weight. Avoid retractable or coiled hoses. The tension in the hose is transferred to the wrist and arm as the hose is stretched. Ideally, use a pliable hose with a swivel mechanism in the barrel of the hand-piece so that it can rotate with minimal effort. [11]

Delivery systems. Historically, we have assumed that there are three delivery styles:

- Rear delivery delivers at 12:00
- Over-the-patient delivery delivers at 5:00
- Side delivery delivers at 8-9:00

But over the past two decades, there have evolved a large number of delivery systems – primarily in the United States – with units that deliver from the 2:00 position. Unlike rear delivery, the hand-pieces are accessible by both the operator and the assistant. The term to describe this type of delivery system is over-the-head.[12]

Various delivery systems have advantages and disadvantages. When working in four-handed dentistry the dentist maintains a position around the operating field with limited hand, arm and body movement, and should best confine eye focus to the working field. Additionally, the dental equipment and instruments should be centered around the dental assistant. From an ergonomic viewpoint, over-the-head and over-the-patient delivery systems better allow the dental assistant to access the hand-pieces for bur changes or other operations.

Lighting and magnification. When properly selected and adjusted, lighting and surgical magnification can support balanced musculoskeletal ergonomics. Conversely, of course, improperly selected or poorly adjusted systems can contribute to, or may even create, unacceptable working postures. [13]

The goal of overhead lighting is to produce even, shadow-free, color-corrected illumination that is concentrated on the operating field. In general, the intensity ratio between task lighting (the dental operating light) and ambient room lighting should be no greater than 3 to 1.[6] Furthermore, the light source should be in the patient's mid-sagittal plane; directly above and slightly behind the patient's oral cavity; and 5° toward the head of the operator in the 12 o'clock position. [6]

Once the patient and operator are properly positioned, the light source can be left far above the heads of both the operator and assistant because the correct position will require no adjustment during the procedure.

It is important for the operator to keep his or her eyes on the oral cavity as much as possible and within the bright spot. Vision will stay sharp if the iris is not continually exercised by looking from the bright spot to dark places. With four-handed dentistry, instruments are delivered to the operator without need for them to move their eyes from the field of vision.

Fiber-optics adds concentrated lighting to the operating field. To minimize eyestrain, the light from the fiber-optic hand-piece should be only slightly greater in intensity than that of the overhead task light, but not greatly so.

It is important to make certain that the surgical magnification system fits the specific balanced neutral position of the operator using it. Magnification loops or microscopes predetermine working distance. Maintaining a properly established working distance helps prevent the operator from assuming an awkward posture. With the requirement of keeping proper positioning using magnification the operator stays focused and relies on the assistant to anticipate and facilitate each step in the procedure. Considerations are magnification power, depth of field, declination angle, weight and convergence.

Gloves. Universal precautions mandate the routine use of gloves. Each dental healthcare worker must have gloves of proper size and fit. Although the influence of gloves on hand discomfort has yet to be explored, they have been cited indirectly as a potential contributor to carpel tunnel syndrome. [14-16] Through self-reported surveys and anecdotal accounts, some operators attribute pain and discomfort at the base of the thumb to prolonged wearing of gloves. To date, however, no data has been published to support this contention.

Four-handed dentistry. Dental assistants create a more efficient environment for the operator by eliminating unnecessary motion; decreasing twisting and turning movement; decreasing long reaches and unbalanced posture.

Four-handed dentistry is based on a set of principles that define the conditions under which efficiency can be attained. The principles of four-handed dentistry [17] are:

- Patient treatment is planned in advance in a logical sequence.
- Instruments and equipment used are based on ergonomic principles.
- Pre-planned instrument setups in cassette, tray or pre-bagged format
- All instruments, equipment and materials for the patient's appointment are in the operatory and readily accessible by the assistant before the team is seated.
- The operator, assistant, and patient are comfortably seated in balanced posture.
- Motion economy is practiced
- Equipment and instruments should be centered around the assistant.
- Instruments and materials should be delivered and retrieved by the assistant without the operator having to shift focal length or leave the finger rest.
- Instruments and materials are transferred in the transfer zone only.
- The operator assigns all legally delegable duties to qualified assistants based on the state's guidelines.

Four-handed dentistry not only can increase productivity and efficiency it also might decrease stress and strain from awkward posture, twisting and turning, and frequent movement away from the operating field.

Supervised exercise/stretching. Because dental work has become more sedentary, larger muscle groups, responsible for cardio-respiratory health and overall endurance, are relatively inactive. Extreme metabolic and functional demands are placed on the smaller muscle groups of the arms and hands. It is important to balance the sedentary with activities that promote conditioning and physical fitness.

While there is evidence in the literature that poor physical conditioning may increase the risk of musculoskeletal injury, there is no empirical support for the success of using stretching or exercise techniques in the prevention of MSDs. Exercise and stretching for the treatment of an MSD should be under the supervision of a physician or physical therapist. Injury could incur or a previous injury might be exacerbated by improperly performed exercises.

Proper temperatures: Within the work environment, low room temperatures, manipulation of cold materials or instruments and exposure to cold air exhaust can contribute to low finger temperatures. There are no standards for finger temperatures, but it is recommended that hands and fingers be kept above 25° C or 77° F to avoid detrimental effects on dexterity and grip strength.[19]

Procedures and administration. The appointment schedule can be used to reduce stress and strain. Alternate easy with difficult cases throughout the day and provide buffer periods that accommodate emergency patients or extra time for difficult procedures or patients. With difficult patients and procedures, alter the sequence of the tasks to be performed, whenever possible. For example, in order to increase task rotation, instead of scaling the entire mouth, then polishing all the teeth followed by flossing, consider doing these tasks a quadrant at a time.

Task rotation is a frequent recommendation to mitigate an injury or to prevent one, however, in general dentistry it can be very difficult or impossible to do. However, dentists should still be encouraged to implement task rotation throughout the day to whatever extent is possible. This could reduce the stress from repetitive procedures.

Workstation. Ergonomic principles also extend to the staff involved in the administrative, non-clinical areas of the dental office. Clerical office workers have been widely studied, so there are well-established ergonomic principles that can be followed[18].

For example, the business office staff should use a chair with a seat that is comfortable and capable of supporting a balanced posture, and yet permits occasional variation in the sitting position. The backrest should be easily adjusted to support the lower back. The chair height should be adjusted so that the thighs are horizontal to the feet flat on the floor. If using a keyboard, the chair should be adjusted such that the keyboard and a footrest keep the thighs parallel to the floor.

When using a keyboard, wrists should be extended straight in neutral posture. The wrist/palm rest is not to be used while actually keying but in periods of rest. The forearm should be horizontal and at right angles to the upper arm, keeping elbows close to the side. Shoulders should be in a relaxed position, not hunched up. Place the mouse close to the keyboard so that it can be used without stretching. A keyboard shelf under the counter or workstation places the keyboard at the correct height.

The top of the computer screen should be at eye level with the top line of print slightly lower. The screen and document holder should be at the same distance from the eye yet close together enough so that the operator can look from one to the other without excessive movement of the neck and back. A screen that swivels horizontally and tilts vertically enables the operator to select the optimal viewing angle. Position the screen to minimize glare or use an anti-glare filter on the front of the screen. Maintain a comfortable viewing distance of 20 to 24 inches from the screen.

The workstation desk or counter should suit the kind of task being performed and be large enough to accommodate the other essential office supplies. It should provide for sufficient legroom to accommodate a comfortable seated position and the ability to swing from one work area to another without physical barriers or obstructions. Normal room lighting should be supplemented by task lighting. Task lighting should not shine into the operator's eyes or cause reflections on the computer screen.

It should be clear that not all of the interventions discussed above apply to all ergonomic situations. Rather, the purpose of including the foregoing discussion is to provide ideas and alternatives to those attempting to address an MSD or to simply make a workplace more comfortable and productive.

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