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ERGONOMICS: A REVIEW

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ABSTRACT

The contemporary dental unit incorporates as many ergonomic features as possible to enable the operator, dental nurse and patient to experience the minimum of stress and fatigue. Dentists are at risk for work-related musculoskeletal disorders compared to the general population. The most common injuries occur in the spine (neck and back), shoulders, elbows and hands. Sitting in an appropriate chair, using magnification for visualization, and the selection of ergonomically-friendly equipment are essential for the health of dental clinicians. Posture varies depending on the dental stool selected. Depending on the type of magnification selected, the clinician can work with a head posture of up to 25 degrees forward. This is achieved with loupes by a set focal range. Working ergonomically helps prevent work-related injuries. Attention must be given to changing destructive postural habits and selecting equipment conducive to good posture.

KEYWORD: Ergonomic.

INTRODUCTION

"Ergo" means work; "Nomos" means natural laws or systems. Ergonomics is defined as 'the study of man in relation to his working environment: the adaptation of machines and general conditions to fit the individual so that he may work at maximum efficiency'.[1] Ergonomics draws on many disciplines in its study of humans and their environments, including anthropometry, biomechanics, mechanical engineering, industrial engineering, industrial design, kinesiology, physiology and psychology. The contemporary dental unit incorporates as many ergonomic features as possible to enable the operator, dental nurse and patient to experience the minimum of stress and fatigue. A healthy dentist is one of the most important components in a successful dental practice. With productivity goals and time management constraints looming, taking the time to properly position yourself and your patients is often overlooked and your body pays the price. There are growing evidences that suggest increased vulnerability with in profession to certain disorders and afflictions that can only be categorized as practice related.[2] It has been estimated that work-related musculoskeletal injuries occur in 54% to 93% of dental professionals, with the most frequent injuries occurring in the spine (neck and back), shoulders, elbows and hands.[3] One survey of dentists found that 62% complained of one or more musculoskeletal disorders[4], and a survey of dental hygienists found that the risk of finger disorders increased with the length of time the clinician practiced[5]. Acc. to Gorter[6] et al, 2000 one out of ten dentists reports having poor general health and three out of ten dentists reports having poor physical state. These problems can be avoided by increasing awareness of the postures used during work, redesigning the workstation to promote neutral positions, examining the impact of instrument use on upper extremity pain and following healthy practices to reduce the stress of dental work on practitioner's body. So, the goal of ergonomics is to help people stay healthy and at the same time perform their work more effectively by changing the design of the workplace, instruments, systems, products, training, or some combination of these elements. This paper attempts to provide both important background and practical advice to dentists interested in addressing ergonomic issues in the workplace.

Ergonomics elements: When analysing work and how it can be improved from an ergonomics point of view there are five elements that need to be addressed:

1. **The worker**: the human element of the workplace. Employees have a range of characteristics that need to be considered including physical and cognitive capacities; experience and skills; education and training; age; sex; personality; health; residual disabilities. An individual's personal needs and aspirations are also considered.
2. **Job/task design**: what the employee is required to do and what they actually do. It includes job content; work demands; restrictions and time requirements

such as deadlines; individual's control over workload including decision latitude, working with other employees; and responsibilities of the job.

3. **Work environment**: the buildings, work areas and spaces; lighting, noise, the thermal environment.
4. **Equipment design**: the hardware of the workplace. It is part of ergonomics that most people recognise and includes electronic and mobile equipment, protective clothing, furniture and tools.
5. **Work organisation**: the broader context of the organisation and the work and how this affects individuals. It includes patterns of work; peaks and troughs in workload, shift work; consultation; inefficiencies or organisational difficulties; rest and work breaks; teamwork; how the work is organised and why; the workplace culture; as well as the broader economic and social influences.[7]

Musculoskeletal disorders (MSDs): The musculoskeletal system includes muscles, tendons, tendon sheathes, nerves, bursa, blood vessels, joints/spinal discs, and ligaments. MSDs may be caused or aggravated by the presence of one or any combination of the following risk factors: repetition, awkward or static postures, high forces, and contact stress. When these factors exist simultaneously, the risk of developing a MSD is significantly increased.[8]

Ergonomic risk factors in general: With over 11,000 registered dental hygienists in Canada and about 100,000 in the United States, the American Dental Hygienists' Association predicted a 41% growth rate in new jobs between 1992 and 2005 (Smith, 2002). Researchers have found symptoms of discomfort for dental workers occurred in the wrists/hands (69.5%), neck (68.5%), upper back (67.4%), low back (56.8%) and shoulders (60.0%). They also found that 93% of those surveyed stated that they had at least one job-related ache, pain, or discomfort in the 12 months prior to the survey (Anton, 2002). With respect to dental hygienists, Atwood and Michalak (1992) reported that the prevalence of musculoskeletal pain ranged from 63 to 93%, with the low back, neck, shoulder, and hand being the most frequent sites. According to an evaluation from the Bureau of Labor Statistics (2002), dental hygienists ranked first above all occupations in the proportion of cases of carpal tunnel syndrome per 1,000 employees (Anton, 2002). Conditions can vary from mild recurrent symptoms to severe and incapacitating. Early symptoms of MSDs include pain, swelling, tenderness, numbness, tingling sensation, and loss of strength.[8] Lake in 1995 implicates several mechanisms in the generation of pains and soreness in dentists, such as:

a) Elevated work area with permanent static positions of more than 30 degrees, which would produce a reduction of blood flow in the supra spine tendon and would also originate high muscle tension on the trapezoids.
b) Lack of support of the forearms during repetitive holding of instruments which would compromise different body segments such as spine, shoulder, and wrists.
c) The handling of vibrating instruments is associated with specific lesions such as nerve trapping, early arthrosis and even, with Raynaud syndrome.
d) Forced cervical static postures.
e) Poor posture when seating. The flexion of the lumbar spine, when seating forward, produces marked pressure increments between the interdiscal spaces.
f) Lighting at the work place: the lack or excess of light can generate myopia and irreversible retinal lesions, among others.
g) Temperature, ventilation and humidity at the work place. If the temperature is high and the air is saturated with humidity, there is exhaustion, increased body temperature and, respiratory and circulatory disorders.
h) Intermittent and continuous noise produced by high and low speed instruments
i) Present dental chairs allow adaptation of the patient´s position in height, inclination of the torso, flexion or hyper extension of the head of the patient.[9]

Ergonomics in dentistry

Ergonomic improvements in seating, instrumentation, magnification, lighting, and glove use have offered a proactive measure for ensuring a proper balance between job requirements and worker capabilities. Although the causes of MSDs are varied and dependant to some extent 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.

a) 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[10].

b) 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.

c) *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.

d) *Other Interventions for Consideration:* *In the Dental Practice.* In addition to widely recognized general interventions, consider the following interventions as well[9]:

1. **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.
2. **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.
3. **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. 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.[7]

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 fewer errors. Bad posture results in pain, fatigue, poor work quality, negative attitudes, and aging.[5]

4. ***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.[11]

5. **Hand instruments:** Various features of dental instruments may have an effect on ergonomic issues[12]. 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.
- Manoeuvrability 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.[13]

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.[14]

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.[15] 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.[15,16]

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.[15] Sharp instruments are keys for reducing excessive force during instrumentation.

6. **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-condensers 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.[17]

7. ***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.[18]

8. **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.[19,20]
9. **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.[21] 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.
10. **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.[22]

Four-handed dentistry is based on a set of principles that define the conditions under which efficiency can be attained. The principles[23] of four-handed dentistry 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.

11. **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.

12. **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.[20]
13. **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.[23]
14. **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.[16] 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.

CONCLUSION

Development of dental ergonomics must take place on the basis of coherent vision of the future. Right ergonomics along with regular exercises, relaxation techniques (meditation, biofeedback and yoga) should be practised. Proper nutrition help in combat stress, thus conserving the productive energy, thereby increasing comfort, involving the quality of life and ultimately to extend careers.

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