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Part 2: Ergonomic Principles in the Dental Setting

Achieving optimal ergonomics in the dental office involves modifications in instrument specifications, refinements in the layout of the operatory, and a systems-based delivery system for integrating all technologies.

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In Part I of this article (see related link), two aspects of the ergonomics of dental equipment design were discussed: the need to enable operators to perform dental procedures without compromising their preferred posture and the need to operate at a specific point in space where they feel they have the best control of their fingers. To provide optimal ergonomic conditions, repositioning and avoiding objects should be kept to a minimum while operating. Determined through masked-eye testing using the proprioceptive senses of the body, these conditions are used to derive the most ergonomic design of dental equipment and instruments.

Improving the ergonomics of dental delivery equipment requires changes in instrument design and the organization of the dental operatory. A change in the position of the patient and operator to provide better ergonomic conditions for dental care, as discussed in Part I, is supported and enhanced by refined specifications for dental instruments. The modification of angles, surface textures, and diameters of instruments will allow finger contacts and forces that are more appropriate for sensing, working, and positioning.

Dental ergonomics involves not only instrument design and operator skill, but also the integration of dental devices into the operatory. The number of instruments and devices available for dental treatment also is challenging to the organization of the operatory. Having multiple devices on wheels, slides, and hinged arms, each with their own tethers (power, air, water, light, and data cables) and foot controllers, cognitively challenges the operator to identify, locate, position, and activate each technology.

These distractions are major barriers to human-centered conditions in dentistry. Standards for integrating instruments and devices into dental delivery systems will provide a much-needed shift from product-oriented controls, monitors, and housings. The treatment area becomes more cognitively and physically ergonomic by having a single delivery system that controls and monitors devices and technologies. Further, the prevailing dual entry/power wall design is obsolete in the proprioceptively derived (PD) dental setting. This article illustrates several changes in instrument specifications, highlights ergonomic refinements in the layout of the dental operatory, and specifies a systems-based delivery system as a model for integrating all technologies.

Human-centered design

The study of ergonomics, which traditionally deals with applied forces, has been expanded to include the best use of the human body. This best use is termed "skill." Human-centered design analyzes body movement (and reach) paths, finger contacts, line-of-sight views, direction and amount of applied forces, and other elements that can be derived proprioceptively. Human-centered design depends upon proprioceptive feedback to reveal human standards for intraoral procedures, placement and design of equipment, and the configuration, size, weight, and surface texture of instruments. The ergonomic functions of hand instruments and handpieces are related to the operator's ability to see, sense resistance and textures, and position to gain access for finger contacts that support unstrained joint positions of the neck, shoulder, upper arm, and wrist.

Instrumentation

Ergonomics also is related to the ease and precision with which instruments can be positioned for control, direction, duration, and distance of applied force. The following examples of design changes will enhance ergonomics in the oral cavity:

Example 1: Dental Mirror - Increasing the angle of the prevailing dental mirror surface to its handle by 7° reduces the habit of laterally extending the elbow of the arm holding the mirror for intraoral viewing.

In addition, using a smaller No. 1 mirror and a lighter-weight handle creates more ergonomic contacts for holding and positioning the mirror. The prevailing dental mirror angle was designed for standup dentistry. The angle of the mirror surface to the mirror handle was set at approximately 38° to supply reflected vision for an operator's who stood behind, beside, or slightly behind the seated patient. Right-handed operators would extend their left arm around the left side of the patient's head for reflected viewing of mouth structures. When dentists sat down to work in the late 1960s, the same mirror configuration was used. Through masked-eye testing, it has been found that a loosely hanging upper arm is preferable for holding the mirror for long periods of time, a position not attainable with the traditional mirror.

To maintain preferred body conditions the mirror to handle angle is set at 45° and is held in a vertical manner and at the end of its handle (see Fig. 1). The PD mirror handle is made lighter, has a smaller diameter for finite rotational movement, and has slight ribbing parallel with the long axis of the handle to aid in rotary movements for viewing; it is held in a pendulum fashion to allow for access by the assistant. A No. 1-sized mirror is preferable as its reflected image includes one-half of a tooth on either side of the one being treated. The mirror surface-to-handle angle and smaller mirror size enables a more systematic way of integrating operating views with finger positions and movements during tooth preparations (see Fig. 2).

Fig. 1 An ergonomic grasp on the mirror handle minimizes hand strain.

Fig. 2 Placing the mirror vertically enhances auxiliary access to the mouth.

Example 2: Dental Handpiece - A smooth surface, a 15° angle of the shaft to the working end, and a distance of approximately 26 mm from the working end to the angle facilitate transitions between finger contacts on dental handpieces. This allows for a stable unstrained wrist and upper arm during procedures that require finite control.

In addition, using a third-digit rest is more ergonomic than using a fourth-digit rest because it does not engage the wrist as much while guiding and positioning the handpiece. Keeping the wrist straight and relaxed improves control. When the wrist is flexed backward or forward to position an instrument, tension increases in the tendons controlling the fingers, resulting in fatigue, which in turn decreases control and sensation. Finite control requires a stabilizing influence as close as possible to the instrument working point (see Fig. 3).

Fig. 3 A third-finger rest provides sensitivity for improved control and ergonomic positioning.

Because the second digit (index finger) can detect very fine movements with great accuracy, it should be placed as close to the operating point as possible. Eliminating the fourth digit as a both a stabilizer of the handpiece and a rest reduces the number of fingers in the oral cavity, increases one’s ability to position instruments, and involves as few joint segments as possible. When fewer joint segments are involved in any movement, the degree of control is greater, providing enhanced tactile sense potential. Specialized skill training is needed to prepare students and practitioners for more ergonomic work habits, routes, and routines. Although there is not a major difference in prevailing handpiece design, the subtle differences are apparent once recommended contacts on the instrument are applied (see Fig. 4).

Fig. 4 Four popular dental handpieces, the farthest left being the benchmark.

Proprioceptive analysis of paths and distances of movement relative to the operating point and preferred pick-up contacts on instruments has resulted in specifications for positions of associated hardware in the operatory. The specifications for the treatment area and method of treatment are identified in open space with only human beings and data recordings; they relate the dentist, dental assistant, and patient to one other. When individuals approach what they want as dental care providers with no preconceptions of operatory hardware and no defenses concerning past habits, the relationships of patient station, operator’s stations, assistant station, and preparation station become evident (see Fig. 5).

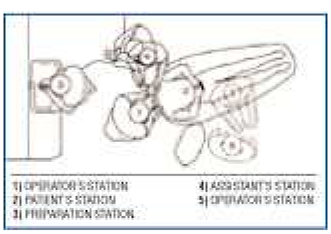

Fig. 5 Treatment area specifications must provide five distinct stations.

Operatory layout

The prevailing dual-entry space favors rear delivery of tubings and cables and forces the operator to work more from the 9 o’clock position. The rear "power wall" design does not provide individuals operating at stations with necessary equipment, instruments, and supplies within an arm’s reach from the preferred operating positions as discussed in Part I. In the more ergonomic relationship, patient, auxiliaries, and operator share a single entry point and walkway and are able to access instrumentation in stable positions within a comfortable arm’s reach. The common walkways offer the most efficient use of space. Derivation exercises in open space have not supported the need for dual access and/or separate operator and assistant walkways. Positioning requirements for monitors that need to be viewed by both the assistant and the dentist have further justified the single entry design. In the prevailing dual-entry design (power-wall concept), the monitor, when positioned for viewing by both operator and assistant, ends up obstructing the assistant’s doorway.

The new treatment space is defined by a skill axis: a vertical axis centered on the reposed patient’s "zero point," which is the intersection of the patient’s midline and maxillary occlusal plane. The best finger control for the dental operator is located along this axis. As with design of the patient support, the design of a dental operatory is determined from this axis outward. Everything in the operating space relates to this primary axis of the dental operation. The treatment area can further be defined into a three-dimensional area of function related to the skill axis: High Skill Space, Free Act Space, Full Rest Space, Balanced Rest Space, and Cleaning-Prep Space. (see Fig 6).

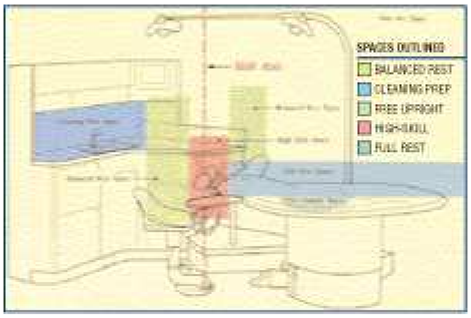

Fig. 6 The treatment area is a 3-D area of function related to the skill axis.

The operator’s support orbits around the skill axis while maintaining the optimal distance between operating point and operator for an erect vertebral column with normal physiologic curves. This radial distance is adjusted for the unique anatomic requirements of each operator. The layout of the room should be familiar to permit natural movements and self-positioning. That is, the patient is not passively manipulated into a tilted position. Because the stable position of the patient’s mouth is more conducive to proper positioning, the tilting function of the dental chair back is both undesired and unnecessary.

Efficiency and asepsis are related to the number of surface contacts necessary to accomplish a task. Efficiency and asepsis, along with safety and psychological factors due to clutter, are improved when three conditions exist: the setting is stabilized (needing fewer adjustments), instruments are manipulated with minimal contacts, and devices are integrated into the delivery system.

Ergonomic hazards

The "ergonomic hazards" of common dental care settings are primarily due to 1) the patient support and headrest design interfering with preferred operator positions, 2) the delivery system requiring the positioning of objects, including tilting of the patient back support, and 3) instrument designs that are inappropriate for enhanced performance skills. Objects on hinged arms or wheels that require positioning, such as lights, trays, instrument delivery units, carts, and seats, are major barriers to human-centered conditions in dentistry. Clutter also threatens the safety and cleanliness of the dental operatory. Designing the delivery system to house, monitor, and control devices is the foundation for integrating technology into the dental setting. This is best accomplished by providing multiple ports with standardized connectors for the different technologies (see Figs. 7 and 8).

Fig. 7 Ports should be located near the head of the patient.

Fig. 8 A device can be plugged in and activated with a single foot control.

Practice benefits

The working environment is a critical factor in recruiting and retaining qualified individuals. Work is best accomplished over time when the least sustained muscle contractions to accomplish a task and resist gravity are engaged. It is not unreasonable to expect that, over time, an investment in an ergonomic environment is dwarfed by what we estimate to be the average cost of $200,000-$250,000 to replace (train) a single dentist.

Although the cost of resetting the dental operatory is not insignificant, it is important to calculate the cost of dental errors, sick leave, treatments for work-related injuries, disability, forced early retirement, shortened work weeks, malpractice suits, and staff turnover. The current clinical environment poses a risk factor in all cases, with each incident levying a monetary expense, as well as an expense in quality of life and reputation. Thus, a human-centered environment by its very nature can have real sustained bottom-line benefits.

Ergonomic specifications for dental equipment and instruments are frequently reversed, forcing receivers of care and care providers to accommodate to settings or setting components; prevailing engineering design has relied on modifications of past designs and past work habits of dentists. In human-centered derivations for design of the ergonomic dental treatment setting, there are no references to objects or past habits. Instead, PD exercises have created principles for the functional design of ergonomic dental settings. The most compelling truth that these exercises have revealed is that the core of ergonomics is based upon proprioceptive feedback. Proprioception relates the healthcare provider to the task, the patient, and then to a preferred environment. This design concept relies on the premise that all humans who are not physically or mentally handicapped prefer to work and move in a similar manner, hence, in a similar environment based upon anthropometric measures. This new foundation for design via masked-eye testing is varied to accommodate differences in individual anatomy and acquired performance skills. Because sight and the preconceptions of what we have seen and used in the past dominate our thinking, removing visual cues and thoughts of past habits is important in order to concentrate on proprioceptive feedback. Using proprioception as an initial determiner of process enables environmental components to be designed so they conform to the best use of the body. Applying PD design criteria and following a decision hierarchy, using a concept of least intrusions into physical and mental performance, will create more ergonomic settings, devices, and instruments for the health and happiness of dental professionals. nDPR

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