LIVING WITH GRAVITY: POSTURE AND THE STOMATOGNATHIC SYSTEM

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Equine dental specialists have long been aware of the anecdotal connection between good dental care and athletic performance. In some cases of dental pathology, horses can show obvious signs of mouth discomfort while being ridden or driven, including head-tossing, bit avoidance, and teeth-grinding. These behaviors, often alleviated by the equine dentist, are assumed to be the cause of the horse's poor performance. Post-dentistry, the difficulty in picking up a right canter lead or taking a tricky line of fences magically disappears along with the head-tossing. The assumption has been that oral pain was such a distraction to the horse that it could not perform at its best. But that does not explain the horse that never gave any prior indication of mouth pain who shows remarkable improvement in athletic performance after dental correction. This scenario is common to any experienced dental practitioner. Successful dental corrections of this type are often the results of experience and medical intuition. This presentation will explain the mechanics, or the scientific basis of what the equine dentist often instinctively knows about their work.

First, we need to consider the workings of the neuro-musculoskeletal system (muscles, tendons, ligaments and nerves) as a complex interaction of many synergistic parts. Complexity science offers a new perspective in recognizing biological organisms as self-organizing, self-healing, complex systems made up of many interdependent parts: systems, organs, tissues, cells, molecules. The characteristics of a complex system are emergent properties, which is to say, they emerge from the interaction of the parts, not from the characteristics of individual components. Alteration of the individual components will change the interactions, which alters emergent properties such as posture locomotion, and performance.

All athletic endeavors—indeed, all activities of living—are governed by the fundamental laws of physics, most importantly, by gravity. Whether an animal is standing or moving, it continually expends energy against gravity. The musculoskeletal system of any living organism is specifically adapted to help it effectively resist gravity in its particular environment, so that it can accomplish the critical tasks of life: eating, sleeping, protection and reproduction. Since gravitational effects are mass dependent (remember-- weight = mass x gravity?), a large animal, such as the horse, has special musculoskeletal adaptations to resist gravity with optimal metabolic efficiency. We see these anatomic adaptations in the passive stay apparatus (the locking mechanism of the stifles), and the isolated tendons of the distal limbs, and the nuchal ligament (elastic connective tissue bands connecting and supporting the head, neck and withers) which allow the horse to stand with minimal expenditure of muscular energy. Equine stance must be held for long periods without fatigue—often for 20-22 hours a day. Except for brief periods of recumbent deep sleep, horses perform all their essential body functions standing.

A horse's standing posture, then, is a window into the overall integration of the complex neuro-musculoskeletal system. The standing posture that is observed in a normal, sound horse at rest is called neutral stance. Neutral stance balances and stabilizes the body's center of mass, allowing rapid, accurate mobilization when necessary. It defines the most prevalent orientation of the major muscle group's fascia (the connective tissue coating of muscles), which is critical for the effective transfer of force and stabilization of joints during locomotion. Maintaining static posture involves constant work against gravity, the integration of multiple neuro-musculoskeletal structures, and unconscious dynamic evaluation of balance and stability. While maintaining a neutral stance, the horse is able to prioritize and perform its essential functions of body maintenance: feeding, sleeping, and healing from injury. In neutral stance, all four legs are square and cannon bones are perpendicular to the ground. Any other posture is a compensatory stance, an abnormal posture resulting from external or internal alterations to the reflexive postural control mechanisms. The most common causes of compensatory stance are: structural damage (scars) to the musculoskeletal system, altered nerve signal transmission due to inflammation along the nerves or spinal cord, receptor damage or down regulation (number of receptors is decreased), or distortion of the normal structures of regions rich in postural signals, such as the upper cervical muscles, feet or temporo-mandibular and dento-aveolar joints. These distortions are often a by-product of living with people: training, dentistry, shoeing or environmental changes. In particular, the integrity of the stomatognathic system in domestic horses is commonly compromised by human intervention.

The head and neck of any vertebrate is critical to numerous survival functions. Protecting the brain is the highest priority for the nervous system, so the head needs to maintain positional stability with respect to the rest of the body and the ground. Sensory perception is located in the cranial region: vision (important for predator/prey detection and vestibulo-ocular reflexes), smell (environmental monitoring, food location), hearing (environmental monitoring, communication) and the inner ear structures that maintain posture and balance. All of these systems work optimally when the head is upright and balanced from side to side. Maintaining an upright posture is the second priority of the nervous system. With an intact brain and a head correctly positioned for optimal perception, an animal is able to respond to the third priority of the nervous system, which is external stimuli, such as food, predator threats or reproductive opportunities. Pain is the lowest priority, and is easily ignored if there is a threat to any higher priority.

The stomatognathic system is a complex kinematic chain that involves the teeth and dento-alveolar joints, temporo-mandibular joint (TMJ), the skull, jaw, hyoid apparatus (suspension of the larynx), sternum, and all of their muscular and ligamentous attachments. Functionally, the connections of the brain's tough coating (dura mater) to the skull, first two cervical vertebrae and associated structures (1,2,3), can mechanically engage the remainder of the spine through to the sacrum, which is the site of the most distal dural attachments. Therefore, abnormalities of skull and TMJ function can potentially have repercussions for locomotion and posture far beyond the direct inputs to the vestibular centers of the brain from the sensory nerves of the TMJ (4, 5, 6).

The TMJ is highly innervated, because of its dual function in mastication (an essential body process), and as a contributor of postural information. The highest concentration of mechanoreceptor (sensory nerves that report shape change) cells is found in the periphery of the disc and its attachments via the lateral ligaments to the joint capsule (7, 8). This proprioceptive (position signaling) array, similar to that found in the soles of the feet and upper cervical muscles, suggests that data about the position of the disc and forces acting upon its capsular suspension system are used by the central postural system to perform balance and righting tasks. The articular surface of the equine TMJ is functionally concentric with the curvature of Spee, which is the complex curvature of the occlusal surfaces (9, 10). The most profound implication of this relationship is that any change made in the curve of the occlusal surface through human intervention will result in neurologic adaptation, cartilage and bone remodeling in the TMJ and concurrent functional changes in the entire stomatognathic system (11, 12). These changes may affect head position, center of gravity and balance as receptors reset in response to changes in jaw movement.

The highest priority of the stomatognathic system is to protect the teeth. Mechanoreceptors innervating the TMJ and the dento-alveolar joints evaluate and neutralize prematurity of tooth strike or restrictions in TMJ movement by minutely altering muscle bundle contraction within the fan-like architecture of the masseter and medial pteregoid muscles, much like a bicycle wheel is balanced by tuning the spokes. However, avoiding prematurity of strike and asymmetric occlusion can distort information to the righting mechanisms (a complex interaction of signals and responses designed to keep the animal upright with respect to the ground). During neutral stance, as long as there is no pathologic muscle restriction on the TMJ, the weight of the mandible (responding to gravity) will drop the jaw. Once the mandible is freely moving, with respect to gravity alone (like a gyroscope) joint and capsular receptors can evaluate the jaw's movement and its connective tissue and neural attachments to the hyoid, skull and upper cervicals (11). In this way, the freely swinging mandible contributes important information about jaw position in relation to the skull to upper cervical righting mechanisms and the intrinsic righting reflexes of the postural system.

Recent research has shown that balance and posture are closely linked to TMJ function, with direct innervation from the trigeminal nerve afferents (sensory nerves) of the TMJ to the vestibular nuclei of the brain, where all postural information is processed (4, 5, 6). One of the important reasons for this connection is the need for postural adjustment during mastication, since the jaw movement of chewing changes the instantaneous center of mass of the head and neck, triggering coordinated neck position adjustment (13, 14).

The repercussions of this postural relationship, in cases of congenital malocclusions or TMJ pathology, have been noted anecdotally since the 1920s. In humans, the most common congenital malocclusion patterns are identified as Class II (overbites) and Class III (underbites) malocclusions. Overbites in humans have been shown to be associated with excessive extension, or arching of the cervical spine, and forward shifted posture. Underbites are seen with humping of the cervical spine and backwards shifted posture. (15, 16). Acquired TMJ disorders have also been shown to be associated with faulty body posture (17). In addition to the front to back malocclusions described above, there has been shown to be a high prevalence of lateral malocclusions in human patients with scoliotic (laterally distorted) spines (18). Along this vein of research, a recent experimental study showed that rat pups with a one-sided, experimentally induced lateral molar malocclusion exhibited scoliotic changes in their thoracic spines after one week (19). Most significantly, these changes were shown to be reversible within a week, by rebalancing the dental occlusion, in 84% of subjects.

The stomatognathic system and its neurologic connections have been shown, experimentally, to integrate stabilizing support actions and distal (foot) proprioceptors for gaze stabilization (i.e. the ability to hold the head steady to focus on a distant object) and visual acuity, essential functions for a prey animal (20, 21). Skilled marksmen, using occlusal splints that either centered or lateralized their molar occlusion, were found to have a variable level of performance in postural control and shooting tasks. The subjects' best performances were correlated with centered occlusion, next best when lateralized in their habitual orientation, and worst in opposite lateralization. Gaze stabilization and postural function, presumably, are dependent upon cortical integration of a wide range of sensory information. Impaired gaze stabilization from congenital malocclusion might prove to be a fatal disability for a prey animal, which would be selected against in wild horses. In domestic horses, however, survival is not dependent upon this degree of intact neurologic function.

Why do domestic horses have such a high prevalence of dental abnormalities? In a natural environment, the structures directly involved in chewing, especially the occlusal surfaces and the TMJ articulation, are adapted for use in a grazing stance, with head and neck lowered and fully stretched out. By contrast, most horses living in domestication have several profound differences from wild horses: they commonly prehend and chew their food with raised heads, they eat concentrated, partially digested carbohydrates (grain pellets and sweet feeds), and they acquire only a small part of their overall nutrition from traditional grazing. In traditional grazing, horses shear more abrasive material with the premolars (i.e. plant roots with accompanying soil), keeping the front cheek teeth more evenly worn with the back molars. The rostral cheek teeth, along with the tongue and cheek, also act as an auger, spirally propelling the foodstuffs from the front of the mouth to the back of the mouth for chewing (22). When a domesticated horse eats only precut forage (hay) or concentrated grains, the back molars, which now perform the grinding, are preferentially worn. The fiber content and dryness of the food material has a significant affect on the size of the lateral excursions during the power stroke, as observed in video and EMG studies (23). It can be surmised that in a natural environment—to which the horse has adapted over the past 50 million years—there would be seasonal changes in the fiber and water content of the available food, balancing the wear patterns in the mouth over the course of a year. Loss of this natural cycle of varying foodstuffs and the evolutionarily programmed head position has resulted in a broad range of dental problems in the modern horse, including molar waves, ramps, shears, incisor imbalances, excessive transverse ridging (ETR), and prematurity of strike (9, 24). Dietary changes can also affect the programmatic shedding of deciduous teeth, creating an initiating factor for steps, waves and ETR.

While horses certainly *can* chew in a raised head position, observation of the natural ecology of horses suggests that this is not the predominant posture for mastication for a horse in a herd setting (25). The bony TMJ joint, with its complex surfaces and movements, is not inherently stable. It relies upon an intra-articular disc, much like the meniscus of the knee, to compensate for the lack of congruence between articular surfaces (26, 27). In other words, without the disc, the TMJ joint would be very loose and unstable. The tissue of the disc adapts to “fill up” the space in the joint. With the head in a normal grazing position, the weight of the mandible (via gravity) will induce a specific spatial relationship of the bones within the joint, to which the disc will model. Mastication with a raised head will create a different spatial relationship, with its own adaptations. It would be difficult to argue that raised head mastication, so unlike that observed in nature, could be more beneficial to the horse. The raised, alert head position is also neurologically associated with sympathetic fight or flight responses, which conflicts with the parasympathetic autonomic dominance appropriate for feeding and digestion.

Horses subject to human management (diet, environment, dentistry), commonly sustain oral pathology that is incompatible with neutral posture and balanced locomotion. The nervous system will do its best to stay upright and balanced, but there are limits in its ability to compensate for distorted neural input, especially when bad information comes from a variety of sources, like malocclusion coupled with poor hoof balance. Structural distortion of these critical regions, like feet and teeth, results in chronic alterations in standing weight-bearing and joint stabilization. This can also be the primary initiating cause of many limb problems seen in horses. For example, an overbite is known to cause spinal lordosis, which pitches the overall center of mass to the rear. If a horse carries too much of its body weight on its hind limbs while standing 20 hours a day, it will sustain overload injuries to the weight-bearing cartilage of its distal joints, causing hock or stifle osteoarthritis and OCD--conditions seen commonly in performance horses. Abnormalities in standing weight-bearing often are accompanied by abnormalities in gait timing, joint stabilization and foot placement, leading to a high prevalence of traumatic injuries during athletic performance. This happens because abnormal balance in stance, such as rear pitch or diagonal tilt, changes how quickly the feet can leave the ground in the gait pattern. When structural abnormalities are corrected, the horse can reprogram its standing posture and gait patterning to achieve a neutral posture and properly stabilized stance phase of gait. Changing the horse's neurologically programmed abnormal pitch and tilt from malocclusion is the reason for improved locomotion performance after competent dental equilibration of trapezoidal distortions of the mouth, such as diagonal (wedge) incisors and the accompanying cheek teeth malocclusions. Accurate manipulative therapy aimed at recalibrating the proprioceptors of the upper cervical muscles can also be an important part of rehabilitation from postural abnormality.

Equine dentistry is a field undergoing enormous transition. The last ten years have seen incredible changes in knowledge and technology. We need, however, to clearly differentiate between a practitioner who rasps pre-molar points in an unsedated horse without a speculum, and someone with the education to evaluate and treat abnormalities of occlusion which are interfering with the horse's most basic interpretation of gravity. It is critical for veterinary dentists to evaluate and treat all the teeth in the mouth, not just the ones that are easy to reach. A dentist who removes hooks on the sixes and elevens but ignores whole mouth balance and occlusion in the name of being "conservative" is leaving a job half done. All dental specialists should learn how to equilibrate the horse's mouth, and be able to critically evaluate their final occlusion so that the horse can live up to its true performance potential.

Acknowledgments: This presentation was developed in conjunction with Dr. Judith Shoemaker, who originated the clinical concepts.

CITATIONS

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