Performance Enhancement and Oral Appliances

Mark Roettger, DDS*

Abstract: The use of some type of oral appliance to enhance human performance, decrease stress or improve strength, has occurred throughout human history, from ancient soldiers to modern athletes. To date, the science describing this phenomenon has been poorly understood, and the research has been limited. The goal of this paper is to review the efforts to improve human performance with oral appliances, and the research exploring the science behind these efforts.

For the past 40 years, it has been suggested that mandibular position could affect upper body strength and, hence, athletic performance. In the 1980s, this concept seemed to have little scientific support and was highly criticized.[1,2] More recently, research suggests mandibular position and oral appliances positively affect not only upper body strength, but also endurance, recovery after athletic competition, concentration, and stress response.[3] This information could revolutionize the practice of dentistry. This paper reviews the literature and details the early research regarding mandibular position, clenching, and oral appliances and their effects on physiology and human performance.

THE QUEST TO IMPROVE HUMAN PERFORMANCE

Legend and history provide a glimpse of the beginnings of performance enhancement and oral appliances. Roman soldiers were said to use leather straps between their teeth to improve their prowess in battle. Native American women would bite on sticks during childbirth to ease delivery. Perhaps the most dramatic example of this phenomenon is from the US Civil War. Surgical options for devastating wounds from heavy lead bullets were limited. As a result, the treatment of choice for many of these wounds in the extremities was amputation. At that time, general anesthesia was in its infancy (in 1844, Horace Wells, a dentist, was the first to use nitrous oxide to induce the loss of consciousness for surgery). Therefore, soldiers were given bullets to bite on during these procedures to help them endure the agony, and the phrase "bite the bullet" was born. What was it about the action of biting a bullet that could help these soldiers deal with the incredible stress created by these crude operations?

Although there were early forays into these concepts of occlusion, oral appliances, and human performance, the quest for optimal jaw position and its relationship to performance began in earnest in 1958 under Stenger et al at the University of Notre Dame.[4] A starter on the football team, Jim Schaaf, suffered a concussion and subsequently Ménière's disease, a recurrent prostrating vertigo associated with generalized dilation of the membranous labyrinth of the inner ear, was diagnosed. The serious nature of the disease prevented Schaaf from competing. The researchers believed he had a temporomandibular joint (TMJ) problem, contributing to his equilibrium issues, and received permission from the coaches to examine him. The researchers placed cotton rolls over the player's back teeth and instructed him to swallow; the patient stated that his ears had cleared for the first time in weeks. It was determined that a splint and special mouthguard would be made: the patient wore the splint continuously and used the mouthguard during practice. In 2 weeks, the patient's equilibrium returned to normal and he resumed his starting role

*Executive Director, Bite Tech Research Institute; Clinical Assistant Professor, Department of Primary Care Dentistry, University of Minnesota School of Dentistry, Minneapolis, Minnesota; Private Practice, Lake Elmo, Minnesota

with the football team. Stenger and his dental colleagues at Notre Dame documented other cases in which jaw position was able to enhance or enable football players' abilities. However, these case reports are anecdotal, rendering them scientifically suspect although the results appear impressive.

Approximately 10 years later, Stephen Smith performed a sample study of professional football players, examining jaw position and muscle strength.[5] Smith's test position was obtained by bringing the player's lower jaw from physiologic rest position toward the closest speaking space, with evenly aligned midlines. He measured the player's strength, using a Cybex II Dynamometer (Cybex International, Inc, Medway, MA). When he reviewed the data, Smith failed to use statistical analysis and was criticized for poor science, although he did observe improvement in strength when participants' jaws were placed into the test position.

In 1980, Kaufman[6] fabricated bite-altering splints for the US Olympic bobsled and luge teams. He discovered that a number of the luge athletes who had reported headaches during and after runs found relief by wearing the dental splints. Some athletes also perceived increased strength when pushing off at the start of their runs. Again, these results were discounted as unscientific and anecdotal.

Kaufman followed up his Olympics findings with a double blind study to observe the effects of a mandibular orthopedic repositioning appliance (MORA) on football players.[7] The overall results were positive: among players using the MORA, there were fewer severe injuries, such as knee injuries. The athletes reported greater strength.

In the early 1980s, a double blind study was conducted at the University of Illinois with 20 students who were randomly selected.[8] The participants were examined, and two appliances were fabricated for each person: a MORA, which repositioned the mandible as described by Gelb, and a placebo appliance that did not affect the occlusion. Three bite conditions were tested for each participant: centric occlusion, centric occlusion with the placebo splint in place, and the Gelb position using the active MORA appliance. Data were collected using a Cybex II Dynamometer. Statistically significant differences were recorded between the MORA and normal centric occlusion when measuring shoulder strength. No significant differences were noted between the placebo and centric occlusion.

In 1996, Dr. Harold Gelb retrospectively reviewed many of the claims and counterclaims published in the area of jaw posture and strength throughout the decades of the 1970s though the 1990s.[1] Gelb noted not only that many of the studies that found improved performance while using oral appliances were flawed, but that those studies refuting claims of improved performance were also flawed. In some of the older studies, he observed that if proper statistical analysis were applied, there were actual statistical improvements in performance within the studies. Gelb's explanation of the critical charges and countercharges during this controversial period was based on the training of researchers: clinical scientists spend most of their training in patient care, while basic scientists spend much of their training learning experimental design. He called on the two sides to work more closely together for the sake of science and the benefit of the patients. Afterwards, research in the area of jaw position and strength proceeded in a positive direction. The next few years produced some particularly strong work in this area from Tufts University College of Dental Medicine in Boston. A series of well-designed, well-controlled studies examining jaw position and strength under a number of different conditions were published; these studies showed significant improvements in strength while using well-designed oral appliances.[9-12]

Efforts have been made throughout the years to improve the science in designing studies to collect data on the correlation between jaw position and strength. Historically, opinion among dentists is divided as to whether jaw position positively affects athletic performance. Research will remove opinion and anecdote from evaluation of this phenomenon, and provide clinicians with important knowledge for prescribing effective appliances. The quest continues, using technology and advances in biology to help evaluate how oral appliances may enhance human performance.

CNS EFFECTS OF CLENCHING AND MANDIBULAR POSITION

Brain mapping using functional magnetic resonance imaging (fMRI) has offered an opportunity to study neurobiology safely and noninvasively and has presented an unprecedented view of the brain's inner workings. Blood oxygenation level-dependent (BOLD) fMRI is the most popular form of functional brain imaging. BOLD fMRI contrast arises from the consequence of a higher ratio of oxyhemoglobin to deoxyhemoglobin that accompanies neuronal activation.[13] Areas of brain activation during a task or procedure actually "light up" when imaged by fMRI.

Researchers have begun mapping brain activity during clenching and chewing. These early studies indicate jaw activity in the form of clenching or chewing stimulates not only the sensorimotor cortex of the brain but also results in activation of the brain's autonomic area, such as the insula and hypothalamus.[14] Further research needs to be performed to determine which areas are involved in clenching and if the mandibular position affects the neurophysiology of clenching. Stimulation of the hypothalamus would indicate a connection between clenching and the masticatory and autonomic nervous systems (ANS). The hypothalamus is considered to be the "master control" of the ANS, mediating a variety of functions, such as fluid and electrolyte balance, temperature regulation, stress regulation, and energy metabolism. The insula is considered to be the "coordinator" of the ANS.[14]

Additional evidence that the masticatory system is intimately related to the autonomic nervous system has been published in several journals. Gomez[15] in 1999 showed a possible attenuation of stress-induced dopamine metabolism by nonfunctional masticatory activity. The conclusion of this study was that this activity decreased the effects of stress on central cholinergic neurotransmission.

A 2004 study by Hori et al[16] clearly showed that nonfunctional biting could suppress stress-induced activation of the hypothalamic-pituitary-adrenal (HPA) axis and consequently the expression of corticotropin-releasing factor (CRF) in the rat hypothalamus. Corticotropin-releasing factor is a 41 amino acid hypophysiotropic peptide secreted from neurons in the paraventricular nucleus (PVN) of the hypothalamus. CRF activates the anterior lobe of the pituitary gland, releasing adrenocorticotropic hormone (ACTH), which in turn stimulates release of cortisol from the adrenal gland into the plasma. Cortisol is a steroidal hormone that helps the body cope with stress by increasing gluconeogenesis, providing antiinflammatory effects, and by influencing many other bodily functions responsible for homeostasis. Acute stress also activates noradrenergic neurons in the locus ceruleus, confirming involvement of the sympathetic nervous system as well as the HPA-axis in the stress-induced physiologic responses. This study showed that rats who were allowed to bite on a wooden stick during stress exhibited a significant reduction in CRF in the paraventricular nucleus (PVN) of the hypothalamus compared with rats that were not allowed to bite a stick. These observations suggest a possible antistress effect of biting and an important role of nonfunctional masticatory activity in coping. Attenuation of stress by stick-biting in rats suggests oral appliances may help control stress in humans and thereby improve performance.

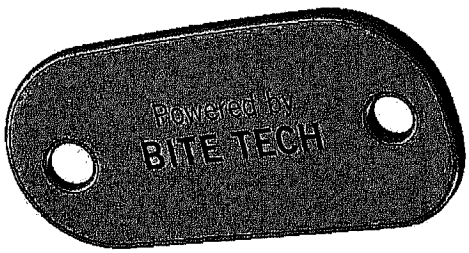

Figure 1 Schematic drawing of the Bite Tech wedge used in appliances to reposition the mandible, designed to help decrease stress and improve human performance when worn in a properly designed oral appliance.

Corticotropin-releasing factor (CRF) is the subject of intense research as it becomes clear that it is involved in many physiologic processes in the nervous system and beyond. Research is identifying CRF receptors not only in additional areas of the brain but also in smooth, skeletal, and cardiac muscles.[17] This would indicate that CRF is active in many areas of human physiology. Considerable evidence suggests excessive activity in CRF systems is associated with depressive illness and anxiety disorders.[18] Overproduction of CRF and the resultant anxiety has been implicated in diminished performance in animal models.[18] CRF is also implicated in pregnancy and postpartum morbidity and physiology.[19] There is high-level neuropharmacologic research to find antagonists to CRF to be used as orally active agents against a number of neurologic disorders. Oral appliances that could help control the CRF production could be extremely important both in dentistry and medicine.

The link between teeth, clenching, oral appliances, and the autonomic nervous system is poorly understood and deserves thorough study to fully describe the connection. Basic science has suggested a relationship between the masticatory system, hypothalamus, and autonomic nervous system, which may explain how "biting the bullet" could positively affect those under intense stress. Can this basic research be translated into clinical studies to understand more completely the influence of oral appliances on human performance?

CLINICAL RESEARCH: EFFECTS OF SPECIALIZED ORAL APPLIANCES ON HUMAN PERFORMANCE

A wedge-shaped component (Figure 1) has been designed to reposition the human mandible (simulating the use of bullet, sticks, and leather straps) to improve human performance. This wedge can be imported into numerous oral appliances (Figure 2), making them useful in athletic sports and in many other applications. The wedge has spawned experiments designed to test its effectiveness in enhancing human performance.

The first test was conducted at the University of Tennessee in 1999.[20] This study examined how the wedge affects strength and endurance, measuring grip strength as well as heart rate and blood pressure during aerobic exercise. The grip strength portion of the study involved 123 males and females. Results indicated 93% of the women and 67% of the men displayed increased grip strength when wearing an oral appliance with the wedge. Data from these individuals indicate a 96% confidence level that appliances containing the wedge would increase strength as compared with a placebo. The aerobic endurance section was smaller, with 17 participants. Fifty percent of the participants wearing the wedge appliances showed an increase in endurance as evidenced by lower heart rates. This study raised the question as to how an oral appliance could affect strength and endurance.

Previously cited research has indicated that physical stress increases blood pressure and activates the HPA axis as indicated by hormonal changes with the ultimate production of cortisol.[18] There are also indications that a modest increase in cortisol during exercise is beneficial, while extreme elevations have been associated with suppressing testosterone and increasing anxiety,[21] thereby adversely affecting performance and endurance. Animal models, such as those done by Hori, studied the CRF levels in the rat as a result of stress, which required sacrifice of the animal and immunohistochemical analysis of neural tissue to measure CRF. Human studies required a new design to safely measure the stress response: measuring cortisol levels to see if specially designed oral appliances could have similar anti-stress effects in humans as stick biting did in rats. Cortisol can be easily and safely measured by salivary assay. Using salivary assay analysis, Garner and McDivitt[3] investigated the correlation between cortisol levels when wearing and not wearing an oral appliance with the Bite Tech wedge

Figure 2 Some of the Bite Tech oral appliances that incorporate the wedge to improve human performance, different designs are used for different sports and other applications

(Bite Tech, Minneapolis, MN) during exercise protocols. A definite trend for lowered cortisol levels was noted with use of the wedge appliance (mean value with appliance .2921 mgs/dL vs mean value without appliance .3229 mgs/dL, $P = .389$. In fact, cortisol levels were lower in 11 of 18 participants. Those who were helped by the appliance had a 49% decrease in cortisol.

Muscular activity is an integral part of the "fight or flight" response. The HPA axis and its hormones play a leading role in the preservation of homeostasis during intense exercise. Physical training and conditioning appears to lead to a reduction in the stress response to a given workload[22] just as the EDGE appliance did in many of the test participants. The fact that more than half of the participants experienced a significant decrease in cortisol is quite promising and justifies further research to clarify results and to examine the relationship of stress, performance, and oral appliances. The function of this modulation of the stress response in the improved performance of athletes is intriguing and will continue to be studied.

A link between cortisol and lactic acid has been described by Luger.[22] Because the EDGE appliance had some effect on cortisol levels, researchers studied the relationship of the EDGE appliance and lactic acid levels during exercise. Significant reductions in lactic acid were found in those wearing the EDGE appliance (see Garner page 9). This is another promising finding that could help explain the ability of oral appliances to affect human performance during exercise and stressful conditions.

CONCLUSION

The concept of oral appliances affecting human performance is not new. Crude appliances have been used for hundreds of years to help humans cope with difficult times and procedures. The mechanisms of this performance enhancement are complex and have been poorly understood. Recently, science has begun to explain more thoroughly the links between oral appliances and enhancement of human performance. Eventually, dentistry, medicine, the military, industry, athletics, and education may be positively impacted by this knowledge.

DISCLOSURE

The author is Executive Director of the Bite Tech Research Institute and a consultant for Bite Tech, Inc.

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