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Brain Injury in Sports Related to Trauma to the Lower Jaw

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CE Test 36.3

Recent media attention to traumatic brain injuries (TBIs) in sports is primarily due to the occurrence of these injuries in high-profile professional athletes. In professional hockey, Paul Kariya missed the last 28 games of the 1998 season after his fourth concussion as a result of an impact to the lower jaw. Eric Lindros finished the 2000 season as a six-time all-star and six-time concussion victim. Victims of career ending concussions include Roger Staubach and Al Toon in football, Bobby Allison and Ernie Irvan in auto racing, and Dave Taylor and Jeff Cournall in hockey. The devastating effect of TBIs on our younger athletes has become an issue of increasing concern.

Concussions and traumatic brain injuries in sports are the consequence of transfer of the energy of an impact, including impact to the lower jaw, to the brain.1-4 As intraoral appliance design evolves beyond the role of protecting only the teeth and periodontal tissues to assume a role of risk reduction for brain and TMJ injury in sports, the dental professional must have a thorough understanding of the nature and consequences of lower jaw impacts.

UNDERSTANDING TRAUMATIC BRAIN INJURIES AND CONCUSSIONS

Brain injury from trauma in sports can be broadly classified into two categories:

•Diffuse brain injury—including concussions

•Focal brain injury—including hematoma, edema, and hemorrhage.5-7

Figure 6. Test results compare the relative effectiveness of various mouthguards placed in an articulated headform subjected to the 60” standard NOCSAE drop test. The helmet with articulated headform is dropped on the faceguard at an angle off of center to produce a difference between right and left TMJ/basal skull surface forces. The articulated headform was utilized in order to study the effectiveness of various mouthguards and intraoral appliances during standard NOCSAE 60” drop test studies. The 60” drop height generates a force equivalent to an abrupt stop from approximately 18 ft/sec impact velocity during sports. This acceleration is sufficient to cause bone fractures, TMJ pathology, and TBI. The single-arch custom-fabricated mouthguard (Custom) protected only slightly better than the over-the-counter product. In both cases, energy transfer to the jaw joint and base of skull

sensors exceeded impact forces proscribed by the helmet standards by 40%. The jaw joint protector (Brain-Pad; WIPSS) redistributed those forces of head impact to the appliance and the mandibular and maxillary dental structures, resulting in a significant decrease (within proscribed standards) in the load force arriving at the TMJ and skull base sensors.

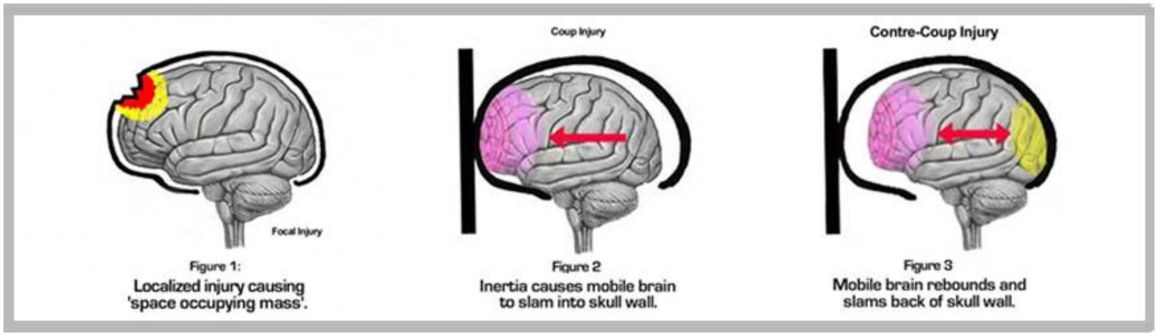

Figure 1: Localized injury causing 'space occupying mass'.

Figure 2 Inertia causes mobile brain to slam into skull wall.

Figure 3 Mobile brain rebounds and slams back of skull wall.

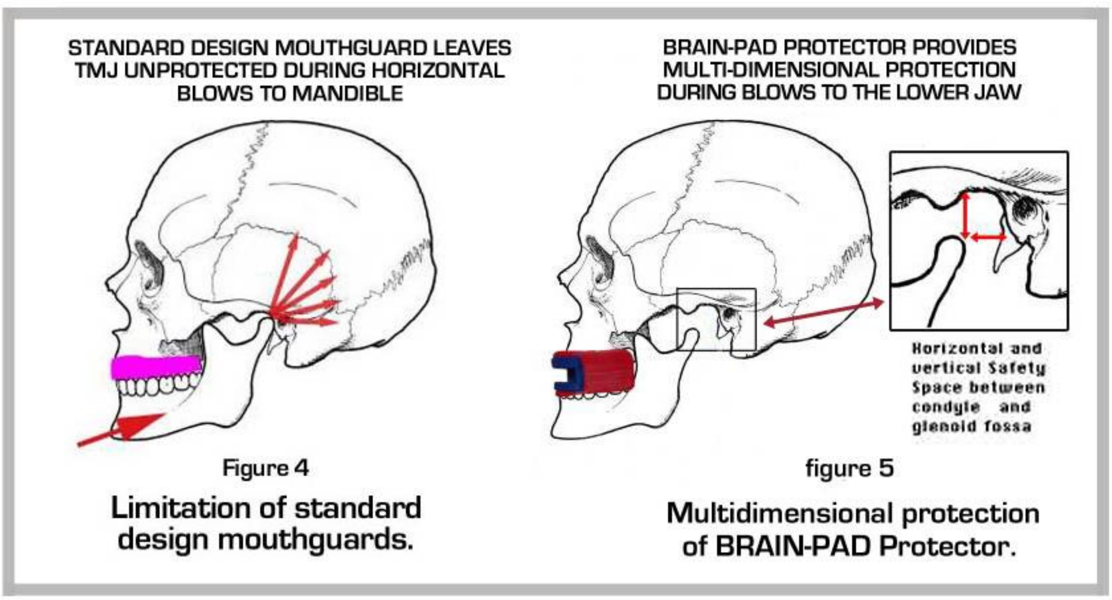

Figure 4 Limitation of standard design mouthguards.

figure 5 Multidimensional protection of BRAIN-PAD Protector.

Diffuse Brain Injury and Concussions

A concussion (mild traumatic brain injury or mTBI)8 is a diffuse (widespread) injury of the brain resulting from the shaking effect of the brain within the skull as a result of trauma. Shear strain from rotational forces can cause stretching of the axons with subsequent loss of function. The cellular injury may be a mechanical disruption of the axons, or a functional disruption resulting from the effects of inflammation, pressure changes, and neurotoxin accumulation within surrounding tissue.7 Diffuse brain injury is not visible with computerized tomography (CT) or magnetic resonance imaging (MRI). Diagnosis is based on assessment of brain function by neuropsychological testing.6,7,9,10

Focal Brain Injury

Focal brain injuries are usually a result of direct trauma or blows to the skull, producing localized space occupying lesions (contusions, hematomas, hemorrhage, edema) (Figure 1). Focal injuries can be visualized with CT or by MRI.5,6 Neurological problems are a result of local cellular damage and shifting and compression of brain tissue due to the effects of a space occupying mass within the confines of the skull.11 The effects of focal injuries are often reversible with surgery, but can be lethal.5,6

PHYSIOLOGY OF TRAUMATIC BRAIN INJURY

The American Orthopedic Society for Sports Medicine states that following brain injury there is a general metabolic dysfunction within the brain, a decrease in the ability of the brain to regulate its blood flow, and an overall inability of the brain to re-establish a normal physiologic balance.11 Death of a neuron may result from lack of oxygen or glucose, or from the shearing forces or pressure effects of trauma. Following an injury to the brain, many cells may be functionally disrupted but mechanically intact. If the surrounding environment is favorable there is possibility of cell recovery; however, if it is unfavorable then cells may die.11 Trauma to the brain is therefore capable of bringing about serious and permanent brain injury.1,11

MECHANISMS OF ENERGY TRANSFER IN BRAIN INJURY

Mechanisms of brain injury
involve a transfer of energy to the brain by various means6,7,9,12:

(1) Direct transfer of energy
can be a result of impact forces to the head. With sufficient force, skull fracture with underlying focal injuries can occur (coup injury) (Figure 2). Differential acceleration of the brain and skull can result in a delayed and second collision of the brain (which is still in motion) with the inner table of the opposite side of the skull (contre-coup injury) (Figure 3). Often, these result in focal injuries including contusions, lacerations, and hematomas.

Modern helmet design in contact sports such as hockey and football has been extremely successful in reducing the incidence of skull fracture and focal brain injury during head impacts when a properly fitted and properly worn helmet is used.12,13 The dental professional has a role in promoting the use of approved and tested helmets in all sports in which head impact is a risk. Dentists should also be aware of the limitations of helmets as a means of protecting the player during impact to the mobile lower jaw. This will be discussed in more detail.

Direct transfer of energy can also be reduced by modifying the playing environment to decrease the risk and severity of head impacts with playing surfaces or field objects. Dentists can provide support to local and regional efforts to assure modifications such as the introduction of plexiglass in arenas and padding on goalposts.

(2) Indirect transfer of energy can result from sudden acceleration or deceleration of the head, such as during player collisions or impacts with playing surfaces. The rotational forces that are generated cause shear strains as the brain attempts to glide against the irregular inner skull surface.2,6,7,9,11,14,15 Shearing injury to the nerve fibers and neurons, in proportion to the degree that the

head is accelerated, results in diffuse injuries to the brain.[2,6,7,11]

Reduction of risk from indirect transfers of energy is more dependent on the rules governing the sport in question.[16] In contact sports involving high-speed collisions, deceleration injuries are inevitable.

(3) Lower jaw impacts represent a unique mechanism of focal brain injury, diffuse brain injury, and jaw joint injury.[4,17,18] This article will examine this common but poorly understood mechanism of injury in detail.

UNDERSTANDING THE PROBLEMS
THAT RESULT FROM LOWER JAW IMPACTS

Since the lower jaw forms
a bilateral joint with the base of the skull at the glenoid fossa, blows to this mobile jaw may drive the jaw up and back, creating a transfer of energy from the lower jaw to the temporomandibular joint (TMJ) and base of the skull. Dr. Robert Cantu stated that blows to the chin, which acts as a lever, produce maximal forces. This fact has long been known in boxing, where the prime target for the opposing combatants has always been the chin. Stewart and Witzig[19] have estimated that in athletes, over 90% of concussions resulting in unconsciousness are the result of blows to the lower jaw.

Although boxing serves as
a prime example of the effects of direct blows to the lower jaw, even athletes wearing face shields and helmets are at risk of TMJ and traumatic brain injury from lower jaw impacts. Tim Walilko at the Wayne State School of Medicine demonstrated that the impact of a hockey puck traveling at 64 mph into a face shield is capable of creating enough energy transfer (shield - chin rest - lower jaw - TMJ - basal skull) to create a 20% likelihood of mTBI.[20]

Standard National Operating
Committee on Standards in Athletic Equipment (NOCSAE) football helmet drop test studies[21] have shown that impact to the football helmet faceguard can displace the helmet and pull on the chin strap, causing a similar transfer of energy exceeding the pass/fail criteria set for helmets themselves.[21,22] The ability of standard design mouthguards to protect against concussion has long been an area of debate. Barth has pointed out the theoretical and mathematical basis for a role of mouthguards in protecting the brain during lower jaw impacts if the mouthguard is fitted to provide vertical separation between the condyle and glenoid fossa. He also pointed out that the protective effect is limited to blows of a vertical nature only.[23] Blows with a horizontal component are still capable of driving the lower jaw posteriorly, imparting impact energy at the TMJ area.[17]

Unfortunately, most blows
to the lower jaw in sports arrive from the front and side,[24-26] and carry a significant component of horizontal force. Additionally, little protection is available if the jaw is open during impact.[27] Without the ability to lock the lower jaw into position, standard design mouthguards are capable of providing only unidimensional protection (Figure 4).

A prime determinant of the
effectiveness of an appliance in reducing the risk of brain injury is the ability of the appliance to prevent displacement of the lower jaw during lower jaw impacts

from any direction. When considering risk reduction for TMJ and brain injury in sports, we must begin to distinguish between the uni-dimensional protection afforded by standard design mouthguards and the multidimensional support provided by a new class of intraoral guard known as jaw joint protectors (Figure 5).

INTRAORAL GUARDS TO REDUCE LOWER JAW IMPACT TRAUMA

Classification of Mouthguards in Sports

Types of athletic mouthguards have traditionally been classified based on fabrication or design, as follows[27]:

(1) Classification by fabrication.

•Stock mouthguard—cannot be custom sized and should not be used

•Boil and bite—can be custom sized by molding when soft after boiling

•Custom made—dentist prescribed and laboratory fabricated mouthguards.

(2) Classification by design.

•Single-arch design—covers only one arch of teeth (usually the maxillary)

•Dual-arch design—covers both the maxillary and mandibular arches.

A NEW CLASSIFICATION FOR INTRAORAL SPORTS APPLIANCES

If we are to consider an expanded role of intraoral appliances in reducing the risk of concussion, traumatic brain injury, and jaw joint injury, we need to begin considering appliances based on classification by function, as follows:

(1) Mouthguard—an intraoral appliance designed to protect the teeth and the oral tissues.

(2) Jaw joint protector (or brain injury risk-reducing appliance)—an intraoral appliance designed to protect the teeth and oral tissues and the jaw joint and associated basal skull surface and brain during lower jaw impacts.

APPLIANCE DESIGN rEQUIREMENTS FOR MINIMIZATION OF CONCUSSION RISK

An intraoral appliance designed to protect the brain and jaw joint should have the following features:

(1) It must prevent posterior and superior displacement of the lower jaw during impact, by fixing the mandible into position. This can only be accomplished by a dual-arch appliance.[17]

(2) The appliance must exhibit rigidity and resistance to deformation during lower jaw impact and during clenching (a normal and beneficial physiological response of athletes during maximal performance).[27]

(3) An appliance must fit properly. Compliance of wear is dependent on comfort,

and comfort is dependent on fit. Proper fit is also required in order to provide retention. Only a properly retained mouthguard can be relied upon to be properly positioned at the time of impact.27,28

(4) The appliance must provide for adequate breathing during clenching.28,29 Prevention of lower jaw displacement during impacts is possible only when the mandibular dentition is firmly seated within the appliance. Therefore, an airway opening is of the utmost importance in order to allow both mouth and nasal breathing.

AN INTRAORAL APPLIANCE TO REDUCE THE RISK OF CONCUSSION

The limitations of single-arch appliances during lower jaw impact have also been recognized by athletes and dental professionals. Boxers have utilized numerous dual-arch dentist-fabricated appliances in the past, and various manufacturers (Everlast, Shock Doc) have had versions of dual-arch appliances meant to address lower jaw impact. Control of anteroposterior positioning of the mandible to create a horizontal separation of the TMJ and skull was not specifically addressed by these appliances. Compliance of wear by athletes is limited when breathing is compromised28,29 or when an airway breathing space is not incorporated or inadequate.

Dr. E. Williams designed an appliance to address the issue of lower jaw impacts and repetitive trauma in boxers. The appliance was designed to overcome previous limitations of dual-arch appliances, and is now utilized and endorsed by most major boxing, martial arts, and contact sport organizations. It is marketed as a jaw joint protector (Brain-Pad, WIPSS Products Inc). The appliance can be boil- and bite-fitted by dentists, athletes, or parents for general application, although custom fit by dental professionals may be recommended in cases of malocclusion, orthodontic therapy, or other special circumstances.

The Brain-Pad is fabricated with the following features to address the specific problem of energy transfer to the basal skull area during lower jaw impact:

(1) Dual-arch design with upper and lower bite channels to lock and hold the lower jaw into a down and forward position, creating a multidimensional safety space in the jaw joint area.

(2) Frontal airway space allows mouth breathing and speech while clenching the teeth. Dual material design allows for thermoplastic fitting as well as rigidity to maintain the airway space.

(3) A protective lower lingual flange guard minimizes posterior displacement of the mandible during impact.

(4) Down and forward mandibular positioning increases the airway space to optimize breathing during maximal exertion.

Impact to the lower jaw is transmitted to the appliance, which locks the lower jaw in position, and thus the forces are dissipated through the appliance into the maxillary arch. The risk reduction capacity of the Brain-Pad was evaluated by Voigt Hodgson at the Wayne State School of Medicine.22 In standard NOSCAE drop tests, the Brain-Pad design provided significant protection in the TMJ

basal skull area, while standard design custom or boil and bite mouthguards did not meet the pass/fail criteria (Figure 6).

The increase in bulk of a dual-arch appliance may be an initial concern for athletes accustomed to standard single-arch designs, but even younger athletes quickly adapt to the appliance. The Brain-Pad is not recommended for patients with class III malocclusion.

CONCLUSION

Dentists must increase public awareness that without locking the lower jaw into position, the brain and TMJ are at risk during lower jaw impacts.F

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Disclosure: Dr. Gusenbauer is a stockholder in WIPSS Products Inc and a medical consultant to the company.