

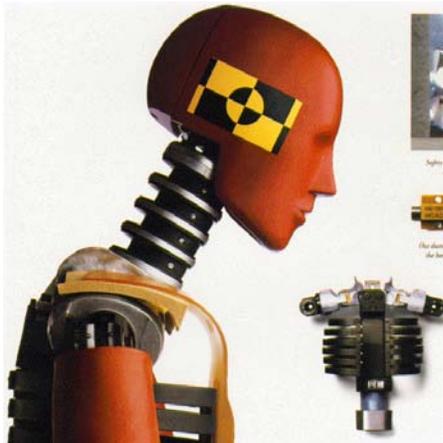
Concussions in Sports, and a Preventable Mechanism of Injury

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ABSTRACT: High velocity cranial injuries are the basis of some of the most frequent and most serious pathoneurologic disorders in sports. These injury manifestations are classified by the vague non-descript term *concussion*. The concussion syndrome encompasses a constellation of symptoms stemming from the violent shaking or the agitation of the brain mass. These activities are alleged to produce physical changes in the nerve cell axon, or myelin sheaths, lesions at the surface, bruising of the brain beneath the point of impact (coup injury) and the more extensive lacerations and contusions on the opposite side of the brain (contrecoup injuries), and others. The actual cranial impact producing these closed head injuries may be mild to moderate or caused by forces of considerable magnitude to the head. This non-descript term implies or manifests itself as

transient functional impairment, neurocognitive abnormalities, consciousness and unconsciousness, sleep apnea, headache, neck and shoulder pains, myofascial pain, TMJ disorders, and others. This syndrome is interchangeable with the term *knock-out*, employed in boxing. To deal effectively with the concussion syndrome and reduce its incidence in sports, demands a knowledge of jaw joint function and physiology, anatomy and landmarks, injury manifestations, physiologic mechanisms, and clinical evaluations. It is imperative that sports medicine and science recognize the existence of the jaw joint and appreciate its importance. In the absence of this knowledge sports medicine and science sanctions a mechanism of injury for concussions and develops injury prone athletes. To better understand and support this premise, review the enclosed document.

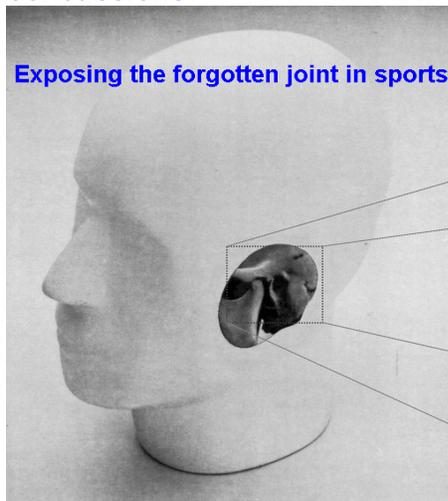
The relationship of internal head injuries and the concussion syndrome to the jaw joint complex has been ignored, underestimated and disassociated by many sports and health care providers. This may be due in fact to the difficulty of jaw-joint injury assessment by the conventional radiographs and the general acceptance of solid headform robots used for head and helmet impact testing in sports and the automotive industry. This is verified by the familiar automobile hybrid test dummy seen in this picture. Clinicians and engineers have recognized and created



the function of every joint of the body with the exception of the vital jaw joint at the base of the brain. These impact headforms and crash dummies used in head impact and crash testing, though conforming to the shape and form of the human head, are anatomically incorrect and misleading in that they lack an articulating jaw joint. Imagine the erroneous testing data that would be received from tests on the impact that sports or an auto accident would have on a leg that had no knee. To reduce the escalating incidence of concussions, the jaw joint must be considered and protected. The *following page* of this document has been specially formatted to better

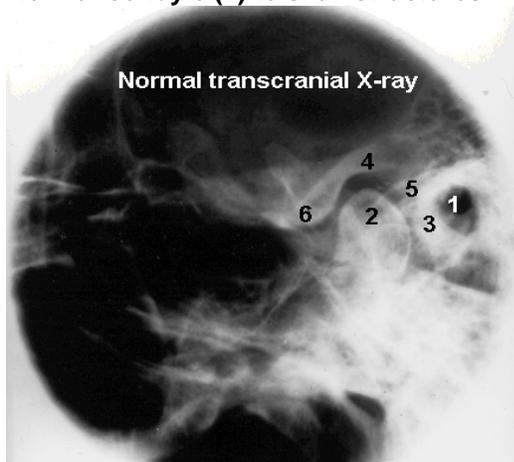
visualize structural anatomy and differentiate the injuries of the jaw joint complex. This is facilitated by reading the figures from left to right as opposed to reading down the left column then the right column. It is of interest to note number (2), **the condyle**, will be the reference point in all figures in this document.

Physical assault to the basal skull, a mechanism of injury in sports for many concussions



Picture 1. The forgotten joint
This vital joint supports the brain and is surrounded by some of the most delicate structures of the body.

Normal-condyle (2) to skull structures:



Picture 3. Normal union of front or anterior wall of tympanic temporal(3) and post glenoid process (5);

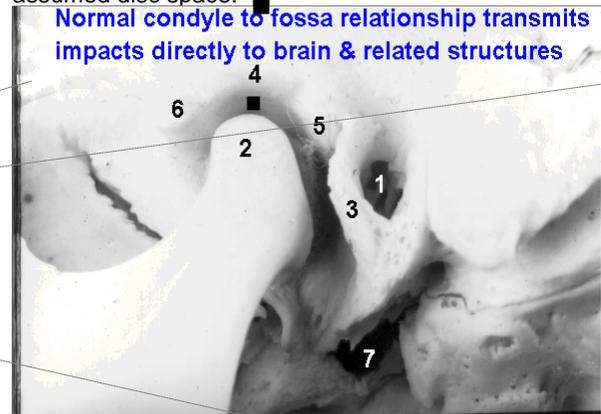
Normal: The radiographic findings reveal:

- A) Bone continuity or union between the post glenoid process (5) and the anterior wall of the ear canal temporal tympanic bone (3);
- B) rounded and well defined ear canal-external auditory meatus (1);
- C) congruent surfaces between condyle (2) and the glenoid fossa (4) creating a ball and socket joint relationship.

The injury patterns of the jaw joint will be a function of the speed of acceleration, size and mass of the athlete, the repetition and angle of impact.

Comparing jaw joint structures and determining the landmarks of injury

Legend: 1) ear canal-external auditory meatus; 2) condyle; 3) anterior wall of tympanic temporal bone; 4) glenoid fossa; 5) post glenoid process; 6) articular eminence; 7) internal carotid canal; assumed disc space.



Picture 2. With head and facial impact the normal condyle to fossa relationship allows the condyle to club the structures at the base of the skull.

The football player:



Picture 4. Green stick fracture of Tympanic temporal bone (3).

Pathology: The structural injuries of this football player are as follows picture 4:

- A) Loss of continuity between the post glenoid process (5) and front wall of ear canal (3) produces:
 - a) traumatic green stick fracture of the anterior wall temporal tympanic bone, and
 - b) creates atresia of the ear canal and will affect the hearing of the athlete,
 - c) this injury is common to football and hockey players.

This tympanic bone injury is caused by the explosive speed of acceleration seen in football and hockey with the impact terminating on the chin or faceguard, driving the condyle (2) onto the ear bone (3).

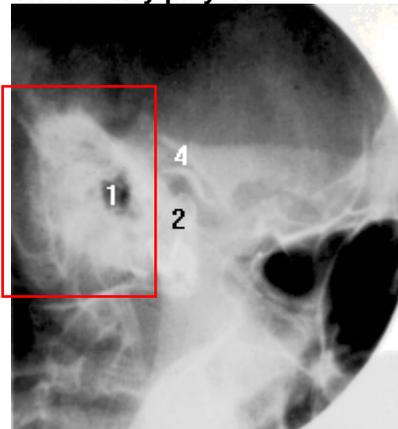
- B) There is also a dramatic pyramidal reshaping of the glenoid fossa (4).

This injury pattern occurs in taller athletes having the propensity toward repeated impact under the chin. This angle of impact drives the condyle up and into the glenoid fossa.

C) The increased radiopacity or characteristic U-shape scaring pattern of the tympanic temporal bone (3).

This injury is due to the repetitive impacts to the chin and headgear that are transmitted through the chin-cup to the condyle and onto the tympanic temporal bone, see picture 4.

The hockey player:



Picture 5. Seasoned hockey player:
Note the broad area of scarred bone pattern of tympanic temporal bone of ear canal and depressed fracture of glenoid fossa.

Symptoms: Loss of hearing in right ear;

Pathology: The radiograph of the hockey player of picture. 5 revealed:

- A) the broad circumferential pattern of scaring of the tympanic temporal bone or ear canal is viewed inside in picture. 5.
- B) depressed fracture of posterior slope of glenoid fossa (4),
- C) C) destruction of ossicles of right ear.

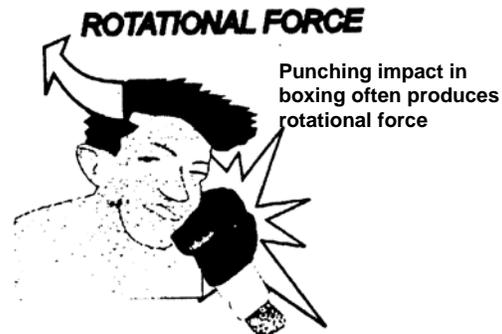
These injury patterns are associated with the repetition and the magnitude of impact achieved by the speed of acceleration on skates and the aggressive play on ice.

TMJ injuries are the precursor of Concussion;

“An estimated 250,000 reported concussions are sustained each year in contact sports and eight of these will result in death. Twenty percent of high school football players will sustain a concussion

during a single season and many of these players will sustain more than one¹.”

The word concussion implies violent shaking and agitation of an organ (in this case the brain) or the transient functional impairment that is the consequence. Despite numerous studies to demonstrate the physical changes in the nerve cells' axons, dura or myelin sheathes, no convincing confirmation exists governing these vibration effects. It is implicit by the experts or authorities of concussions that only the rotational forces in the brain as opposed to linear forces are the forces responsible for features of concussion.



Adapted from:Green GA, Jordan SE. Chronic Head and Neck Injuries. The U.S. Soccer Sports Medicine Book.

Figure 1

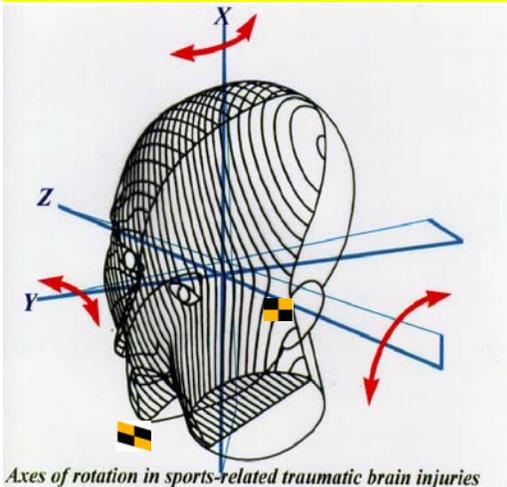
In the pugilistic sport of boxing, most boxing authorities recognize that the "upper cut" or "up the middle" punch landing on the symphysis mandibulae or chin button produces more concussion syndromes than any other punch. This punch or impact produces linear forces of acceleration to the brain responsible for the concussion or knock-out (*a popular term for a clinical syndrome due to mechanical, usually traumatic forces; characterized by immediate and transient impairment of neural functions, such as alteration of consciousness, disturbance of vision and equilibrium, etc.*) of the athlete. The point implied here is that the words concussion and knock-out are synonymous. The same linear components of force or area and angle of impact occur daily in many children participating in intramural and little league sports. To postulate that rotational forces in the brain as described by the authorities are the primary or only forces responsible for concussions is comparable to testing head impacts without a jaw joint. It may be in the best interest of sports and biomechanics to readdress the rotational component of force responsible for concussions as it may apply to contact and impact sports. I propose that we look at the head as having three axes of rotation:

¹ Journal of the American Medical Association (JAMA) Nov. 27, 1991:2867

- A) The X-axis is the pole through the top of the head into the cervical spine with a lateral path of motion,
- B) the Y-axis is the pole through the center of the head in the anterior-posterior direction with the path of rotation in a side to side motion which is more anatomically restricted,
- C) the Z-axis is the pole through the side of the head assuming the ears with the path of rotation in an inferior-superior or up and down motion of the head.

The headform of Triaxeses take upon itself the basic principles of the "Laws of Newton," as they apply to matter at rest, inertia, and impacts. Working towards a solution for concussion these principles must be applied.

Triaxeses, the principle of traumatic head rotation



From this postulation, with all head impacts the brain will have a combined linear and a rotational component of force. Therefore, the brain may rotate around any axis or in any quadrant composed of two or more axes. In sports related brain injuries, the dominant component of force and the path of brain rotation will primarily depend upon the angle, incidence and force of impact and the neck reaction.

With the impact from the upper-cut, the principle variables in sports-related traumatic head injury's equation that will influence the grade of concussion are:

- 1. predisposed structural damage and the integrity of the temporomandibular joint (direct access or port of entry to the brain),
- 2. the concentrated force of impact from the condyle onto the basal surface of the skull and joint space,
- 3. mass moments of inertia between the skull, brain, and brain covering tissue at the time of impact,

- 4. the head and brain's range of rotational forces around the predominant Z-axis resulting from the impact,
- 5. linear forces of impact, and
- 6. predisposed traumatized brain tissue.

The products of concussion from this type of impact will be the summation of the linear and rotational forces under the dominion of this triaxial phenomena, and the other principal variables described in the sports-related traumatic brain injuries equation. Outside of stopping the sport or changing the composition of the game the only variable in the equation of traumatic brain injury (TBI) that can be changed or removed from the equation is (2). To remove the concentrated force of impact from the condyle onto the basal surface of the skull and joint space, greatly diminishes the forces in this equation of head trauma and significantly reduces the risk of concussion and sports-related traumatic brain injuries. The safety method employed to prevent the condyle from slamming against the base of the skull (variable # 2) will be discussed later in this text.

The described integral forces would also be responsible for the concussion episode depicted in picture 8.



Adapted from: Green GA, Jordon SE. Chronic Head and Neck Injuries The U.S. Soccer Sports Medicine Book.

The accepted wisdom associated with the concept of linear force is riddled with errors and must be reevaluated in the interest of concussions, risk management, soccer and sports. Many soccer participants understand that this ball impact will "ring your bell" and induce concussions (to ring a child's bell today, may effect his personality and behavior tomorrow). All of the described variables come into play with this type of impact in soccer.

I emphasize that the state of concussion is a generic syndrome of multiple causation and mechanisms. Impacts to the jaw and jaw joint will produce symptoms consistent with the key features of concussions or induce the misdiagnosed TMJ disorders of a non-specific origin. In the sports community, to continue to overlook the existence of the jaw joint, omit its protection and ignore the mechanisms of injury described herein is working with an incomplete

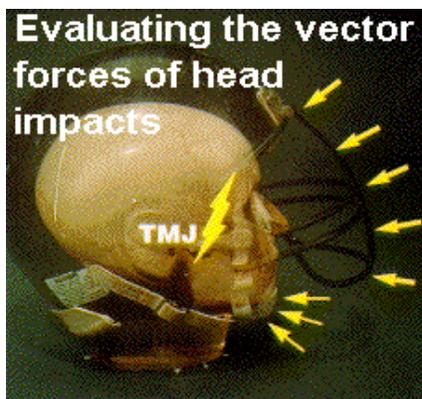
model. To reduce the incidence of concussions look to the basal side of the skull.

The jaw joint consequence of helmet impacts

In all contact and aggressive sports the jaw joint is repeatedly exposed to potentially injurious forces significantly beyond the tolerable load design of this limited joint space. Like any other joint space, repetitive excessive load forces will weaken the joint and predispose the brain to greater injuries.

Evaluating headgear and faceguard impacts with headforms containing a jaw joint is essential in understanding this mechanism of injury for concussions in helmeted sports.

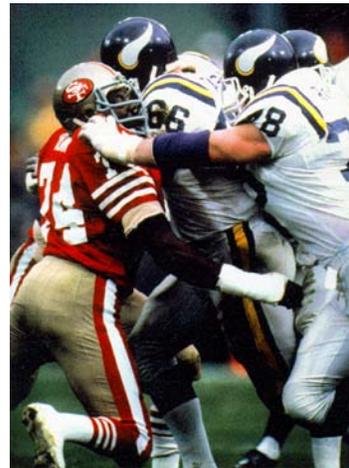
Inherent in the design of football helmets is the retention performance of the four point chin-strap-chin-cup assembly. This four point chin-strap-chin-cup assembly contributes to the progression of damage identified in the radiographic study of the jaw joint of football player in fig. 4.



Picture 6. Impacts to facegear are transmitted through chin cup to unprotected jaw joint.

The chin-cup securing the helmet to the head, pulls the lower jaw back and up into the joint space. This antagonistic position compresses the condyle into the delicate and time injured joint space. This bothersome positioning of the condyle, unbeknownst to the athlete, decreases strength and performance and predisposes the jaw joint to greater injury. The physical effect of this antagonistic condylar position is exemplified by the constant unsnapping of the chin strap immediately after each play. It is commonly taught that the chin strap should be tight, centered, and always kept snapped². However this scenario prepares the jaw joint for injury and predisposes the athlete to concussions.

² National Youth Sports Safety Foundation, Inc. Fact Sheet, helmets



Picture 7. Point of contact is faceguard, common to football; This kind of impact concentrates massive forces delivering them through chin cup to jaw-joint complex.

In helmeted sports such as football, lacrosse and hockey, damage to the jaw joint and surrounding structures is induced by blows to the faceguard and helmet, see pictures 6 and 7.

The impact shown in picture 7, represents a high velocity transport of force or energy that is common to the sport. The force of this impact is equal to the mass of the athletes times their speed of acceleration at time of impact. Consider the relative speed and size of player 66 and the force impact he exerts onto the faceguard of player 74 in picture 7. This force is further multiplied by the speed and size of player 74 when they collide. This massive magnitude of force is transmitted from the faceguard impact through the chin cup, concentrated at the condyle and executed onto the fossa and joint space at the base of the athlete's skull.

In hockey the faceguard is born or supported by the chin and load forces to the faceguard are transmitted directly to the jaw joint. This is further intensified by the speed of acceleration on skates. The conclusive effects of these impacts exceed the structural strength and integrity of the thin bones of the jaw joint and the base of the skull generating devastating consequences to the brain and tissue structures. Most high exposure athletes, if not having suffered a concussion during their sports career, will suffer TMJ pathology. Many of the consequences of jaw-joint injuries are the physical and neurocognitive disorders that occur during the time of play and long after the games are over. Many of the symptoms are listed in the following table.

TABLE OF SYMPTOMS FOR JAW-JOINT INJURIES AND TMJ DISORDER
EYES

- Sensitivity to light
- Pulsating pain behind eyes
- Bloodshot eyes

MOUTH

- Discomfort when chewing
- Discomfort when at rest
- Pain when opening mouth
- Clicking or popping when opening mouth
- Limited opening of mouth
- Jaw jumps or deviates to one side when opened
- Jaw locks in open position when eating, yelling, or yawning
- Teeth don't fit together properly; can't locate "bite"
- Unconscious grinding of teeth, especially during times of anxiety or when asleep
- Tender, sore or loose teeth

HEAD

- Radiating Headache pain from forehead to eyebrow area
- Pain and pressures similar to sinus problems
- Ache in temple area - above and in front of ear
- Hair or scalp painful to touch
- Radiating pain in back of head
- "Migraine" type headaches

EARS

- Decrease in hearing capacity
- Earache but no infection
- Constantly clogged or itching ear with no infection or foreign body present
- Dizziness or vertigo; ringing, hissing or buzzing sound

THROAT & NECK

- Sore throat but no infection
- Sore, tired, and stiff neck muscles
- Pain and numbness in arms and fingers
- Frequent shoulder and neck pain
- Recurring stiff-neck pain

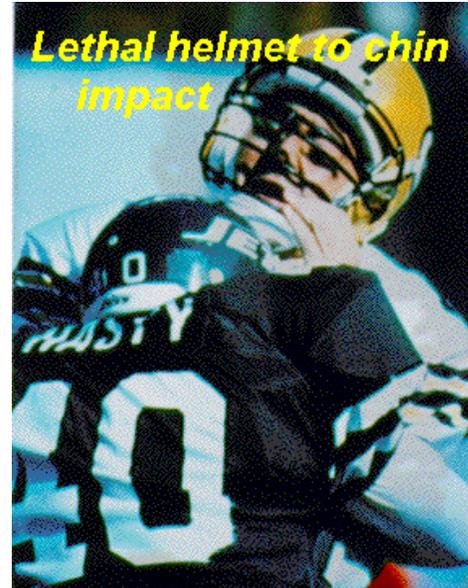
MOTOR FUNCTIONS

- Impaired and slurred speech
- Frequent episodes of nausea and vomiting
- Impaired sense of balance
- Noted increase fatigue in normal training routine
- Rotator-cuff like involvement
- Parkinsonian-like condition

This explosive force many times will produce the constellation of concussion and closed head injury symptoms. Protective headgear well engineered to protect the head and reduce the incidence of closed head injury, for the most part does an exceptional job. However, a mechanism of injury to the jaw joint is induced in part by the protective headgear. The jaw joint is an indispensable and vital component of the head that can be protected in helmeted and non-helmeted sports by the use of jaw-joint protectors. Jaw-joint protectors will be discussed later in this text.

Considering this mechanism of impact to faceguard and helmet injury, the most lethal force is the direct assault from the opposing helmet to the athlete's chin. The direct chin impacts will most often produce the constellation of concussion and closed head injury symptoms. These kinds of impacts are actual cranial impacts and the point of entry is the basal aspect of the skull through the jaw-joint complex.

After one traumatic brain injury, the risk for a second injury is three times greater; and after a second TBI, the risk for a third injury is eight times greater³. If a concussed child is allowed to continue playing and receives another blow to the head, the child may go into a coma or even die. This is known as "second impact syndrome."⁴



Picture 8. The lethal head to chin impact the components of force with concussion consequence;

Why is it so difficult for the authorities in sports to associate the concussion episodes and brain motion injuries with basal skull impacts? Load forces to this surface are very common on the playing fields and having a direct port of entry to the brain through the delicate jaw-joint structures. Does one block his mind to the occurrence, incidence and biomechanics of a helmet to chin impact? Or have the testing societies overlooked the importance and mechanism of injury for basal skull fractures? Or have we been blinded to basal skull injuries by the absence of articulated headforms?

Biomechanics of basal skull impacts

A basal view of the skull demonstrating the undeviating port of entry to the brain through the thin transparent glenoid fossa (4); High velocity head and facial impacts are condensed to the condyle then executed onto the glenoid fossa, producing basal fractures and damaging rotational and linear forces in the brain.

³ Annegers JF. Garbow JD. Kurkand LT. et al. The incidence, causes and secular trends of head trauma in Olmstead County, Minnesota, 1935-1974. *Neurology* 1980; 30:912-919.

⁴ Injuries: Just part of the game?. Sportswise, Micheli, L.J. Houghton Mifflin Company. 1990.

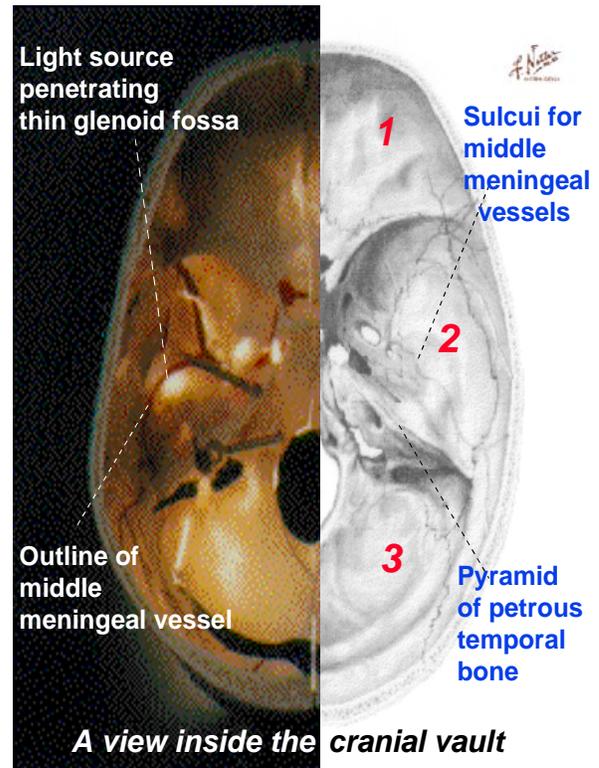


Picture 9. Legend: (4) glenoid fossa, (6) articular eminence, (7) internal carotid canal, (10) teeth, (11) hard palate, (12) foramen magnum, (13) zygomatic arch.

In head impact injuries, concussion studies or sports-related brain injury assessments, most examiners never consider the complexity of the jaw joint area for the influence that head impacts will have on the brain, vascular and nerve tissue in this area. At the least, impact from the condyle on the glenoid fossa will certainly induce an abrasive action between the pia mater covered brain surface and the buttress bony irregularities of the petrous temporal bone. Inside the skull in the middle cranial fossa, the middle meningeal artery crosses the glenoid fossa. The middle of the brain. Hence, these structures become the direct recipient of condylar trauma resulting from head impacts.

The thin and rather rigid glenoid fossa of the basal skull, unlike the bones of the calvariae or upper skull, absorbs little to no energy, thereby, increasing skull stress (force per unit area). This phenomena intensifies the pressure changes to the neural tissue or brain in this area.

The response of the brain to a blow to the head in sports is largely determined by the mechanical impedance of the bony structure covering the brain area at the point of impact. With little to no mechanical impedance of the glenoid fossa the force of impact is directly transmitted to and absorbed by the brain. With head impacts, the force of gravity plays a role of greater significance on basal surface (seating the brain against the glenoid fossa), than that of the calvarium surface or top of the head.



A view inside the cranial vault
1-anterior, 2-middle, 3-posterior cranial fossa
Figure 4.

This force is of great importance when evaluating the causes of concussion or other cerebral tears.

A cerebral or brain contusion is an impairment of neuronal function resulting from structural damage ("bruised brain"). Focal contusions occur under the site of impact. With impacts to the glenoid, the target tissue of this impact is the posterior branch of the middle meningeal artery and the temporal lobe. These impact injuries to the temporal lobe may be responsible for subtle or unexplained personality and behavior changes in athletes. Epidural hematomas occur most frequently in the temporal region due to tears of the middle meningeal arteries and its branches⁵. Clinical findings can include neurologic abnormalities and loss of consciousness.

The lower jaw not being attached to the skull, is influenced by any impact to the upper jaw, head or headgear. According to the Laws of Newton, every force produces an equal and opposite directional component of force. Therefore, head impact produces an equal jaw joint component of force acting upon the basal surface of the skull. The results of many head impacts occurring in sports will be tempromandibular joint pathology, closed head, and brain injury at the basal surface.

⁵ Harry Morgan MD, Chair. Department Radiology, J.F. Kennedy Hospitable, Phila., PA

With the use of high speed video cinematography, the assessment of high velocity head impacts in sports will point directly or indirectly to impacts from the lower jaw. The results are these concussion episodes that are escalating in sports. This critical path of condyle impact onto the jaw joint space and the tympanic bones of the skull can be described as the *intolerable zone*. This is the measurable distance between the numbers 2 - 6, 2 - 4, 2 - 5, 2 - 3, 2 - 1 and the related structures see picture.10.

In sports, resultant forces of the high velocity impacts are concentrated at the ballpeen hammer shaped condyle, magnified and transmitted directly to the glenoid fossa (the thinnest bone of the skull) and the approximating structures.

Normal condyle position lends to injury:



Picture 10. The critical path of the condyle slamming against the base of the skull;

The bone of the glenoid fossa is less than 1/16 of an inch in thickness and supported on this thin bone is a delicate tissue of **the brain**. It is obvious that the thin bone of the glenoid fossa cannot absorb the accelerating force of impact of contact sports. Therefore, it is reasonable to say that the accelerating forces of impact directly or indirectly will be absorbed and attenuated by the brain tissue. Through this anatomical jaw-joint structure the brain is directly exposed to a considerable magnitude of force from the high velocity head impacts in sports.

The phenomenon associated with these high velocity head impact forces concentrating at the condyle is comparable to the energy exchange of water under pressure traveling through a six inch diameter hose that is instantly reduced to one inch diameter hose without modification of the back pressure. The water at the reduced end of the hose is converted to a high velocity projectile. It becomes apparent from this analysis that the condyle becomes a rapidly moving high velocity projectile or striker clubbing the base of the head with plundering forces. Even though the skull may not be penetrated and fragments of bone may not

be driven into its cavity, the brain is involved in an inertia reaction from the blow and may suffer gross damage. The resultant high velocity forces on the jaw joint in sports are hazardous and compromise the health and safety of the athlete. They expose the athlete to infirmities of concussions and other internal head injuries.

It was not the intention, design or function of the jaw-joint complex to absorb this brute force under any circumstance. These magnified resultant forces executed on this thin fossa will fracture bone, induce subdural hematomas, produce concussions and other vascular disturbances of the brain matter. The grade of this injury or concussion is directly related to the size and extent of the fracture, the severity of the tissue tear (dura), and the intensity of the forces that are directly applied to the brain through the joint space at this unprotected point of entry.

It should become clear that sport impacts to this unprotected jaw-joint area will produce intracranial and extracranial injuries. The end results of these lethal forces are the convincing presence of symptoms that are consistent with the key features of the vague concussion syndrome. Objectivity with prudent observation on and off the playing field, coupled with common sense will support the view that traumatic insults to the delicate area of the jaw joint will result in the disturbance and symptoms of concussions. Cynicism must give way to the mechanism of injury, radiographic assessment of injury patterns, and clinical evidence supporting the load forces terminating at the unprotected jaw joint in sports.

Other anatomical considerations of joint structure

The mechanism 1; In Picture 10, structure # 7 is the internal carotid canal housing the internal carotid artery. The internal carotid artery is the principal artery supplying blood to the anterior components of the brain. Impact or trauma to an artery of this size produces traumatic fissures or cuts on the inside or intima surface of the vessel. Upon healing, these fissures become small nidus or scars that collect plaque. This accumulating plaque developing at this *strategic location* progressively diminishes the blood and oxygen supply to the brain. It is also unfortunate that in this area the internal carotid artery loses its compliance when it enters the bony sheath of the internal carotid canal.

With progression of plaque diminishing the blood to the brain, the athlete will exhibit functional impairment, lethargic and malaise physical

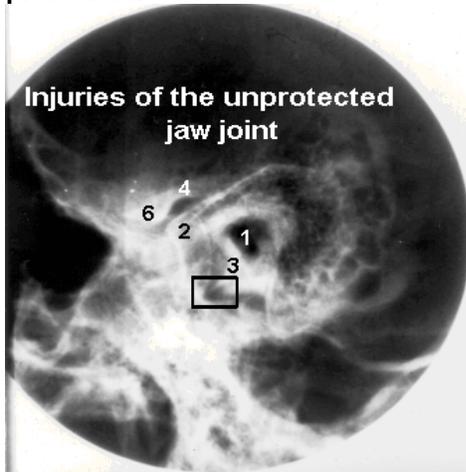
patterns, Parkinsonian like tremors, and other encephalopathies. With this plaque accumulation in this confined region of the skull the athletes become predisposed to cerebral vascular accidents commonly known as strokes.

The mechanism 2; Trauma to the internal carotid artery will weaken the arterial wall causing a tearing of the internal elastic lamina from the medial layer. This rupturing causes the extravasation of blood into the arterial wall that occludes the lumen and produces a hematoma.

This scenario, occluding the blood vessel, will diminish the blood supply to the brain and evoke other pathophysiological manifestations adverse to the health of the athlete. This scenario may establish a probable cause in sports of arteriosclerotic vascular disease of the internal carotid artery. This disease of the internal carotid artery may result in multiple foci of infarctions in the brain or a cerebral vascular accident.

These kinds of injuries are health issues.

The boxer: This athlete has a ring age in excess of twenty years. The chronic structural pathological changes of this jaw-joint complex were induced by wearing mouthguards. The neurocognitive and vascular pathology would have been reduced by wearing jaw-joint protectors.



Picture 11. Erosion of the protective covering;

Pathology: The radiographic studies of the heavyweight world class boxer revealed in picture 11:

- A) displaced fracture of the glenoid fossa
- B) a radiopaque healed fracture lesion associated with squamotympanic fissure,
- C) a fracture at the superior surface of the anterior wall of the temporal tympanic bone of the ear canal,

- D) the exposure of the internal carotid canal.

This pathology can be viewed radiographically inside the in picture 11. This pathology is caused by the posterior surface of the condyle (2) repetitively clubbing the inferior surface of the anterior wall of the temporal tympanic bone (3) resulting from the exchanges in boxing. In the absence of the explosive speed of acceleration as seen in football, hockey and other sports, the anterior walls of the tympanic temporal bone complex do not generally exhibit the green stick fracture characteristics as seen in picture 4. The protective temporal bones in boxing are eroded away by the frequency of the punch, creating micro-fractures on the exterior surfaces of these bony plates.

The consequence of this erosive phenomena or micro-fracturing of the tympanic bones is the traumatic exposure of the cranial nerve trunks and vital vascular channels at the basal surface of skull. This specific pathology increases the exposure of the internal carotid artery and other cranial nerves to more devastating impacts of boxing and increases the risk for the constellation of neurocognitive disorders.

Juxtaposition to the internal carotid canal is the jugular foramen. The jugular foramen ports four (4) cranial nerves directly from the brain. It is worth mentioning that these are the nerve trunks before they begin branching into the body. The four cranial nerves and their numbers porting the jugular foramen are as follows:

Vagus (X) Nerve

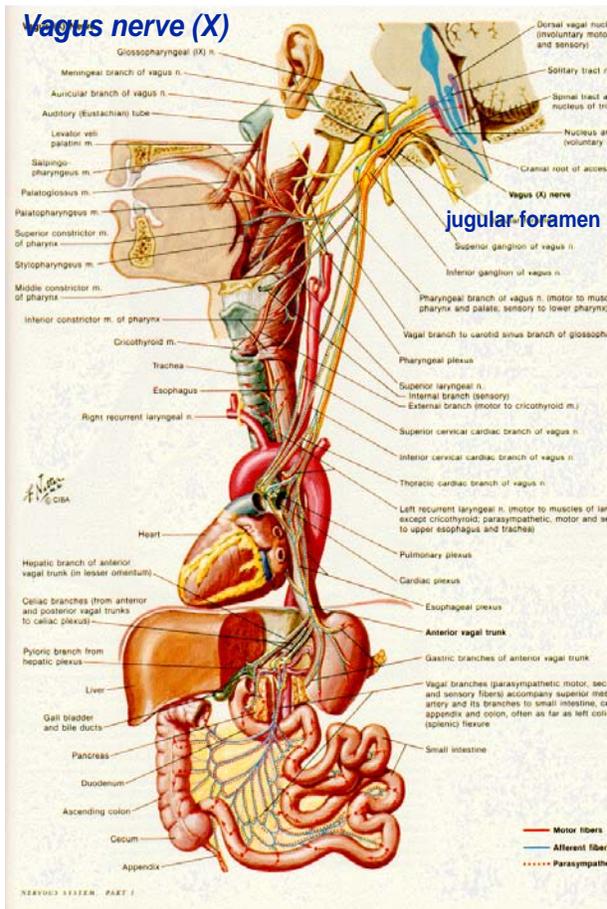


Figure 6.

The vagus nerve as the name implies is widely distributed. The afferent and efferent parasympathetic fibers are distributed to the visceral and vascular structures in the neck, thorax and the abdomen. Some of these structures include: the heart, diaphragm, and the stomach. The afferent fibers are responsible for many of the motor and sensory reflex mechanisms of the body. These mechanisms will vary widely from vasodilatation to muscular contractions. Many wonders of the vagus nerve are still a mystery to modern science. Hence, the boxer receiving the minor impact to the left damaged jaw-joint, experienced a vago-vagal response and vomited. Refer to case study of heavyweight boxer on page 15.

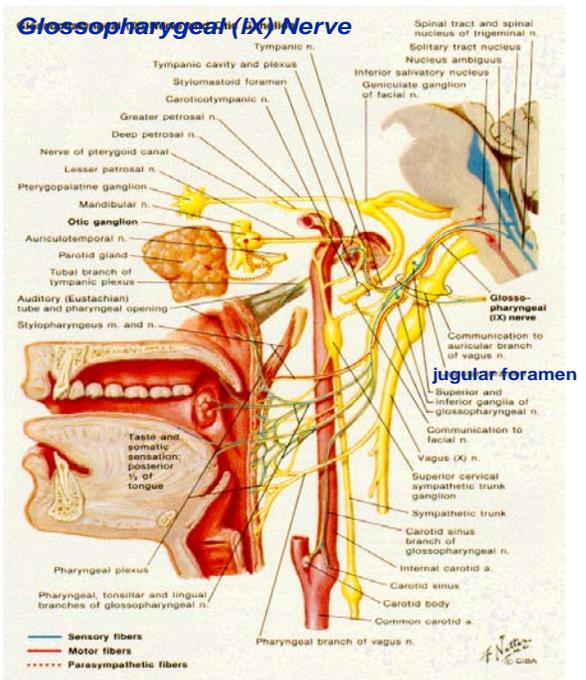


Figure 5.

The glossopharyngeal nerve is a mixed nerve distributed mainly to parts of the tongue and pharynx. The glossopharyngeal nerve is closely associated with the vagus through much of its course. Hence, damage to this nerve trunk may attribute to the raspy voice patterns of many athletes.

Spinal Accessory (XI) Nerve

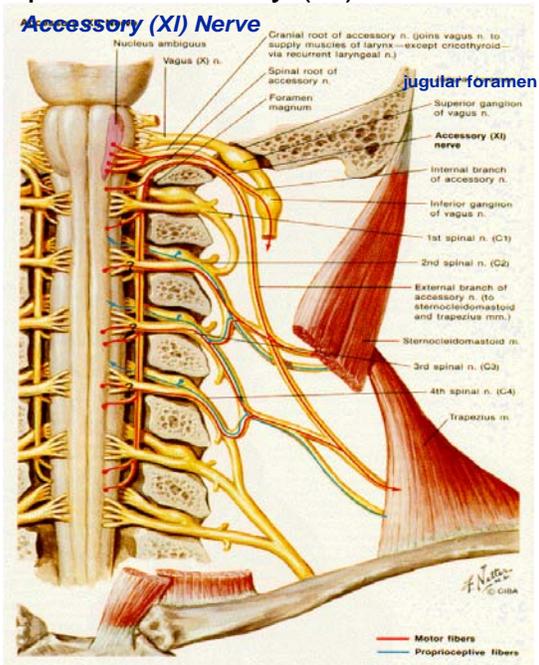


Figure 7.

This nerve consists of a cranial and spinal route. After these routes separate the cranial route becomes the internal branch which joins the vagus nerve, while the spinal route continues to the external branch. The external branch transverses

Glossopharyngeal (IX) Nerve

through the sternocleidomastoid, trapezius and other muscle groups. Hence, this nerve injury may contribute significantly to recurring stiff neck and rotator cuff pains.

Hypoglossal (XII) Nerve

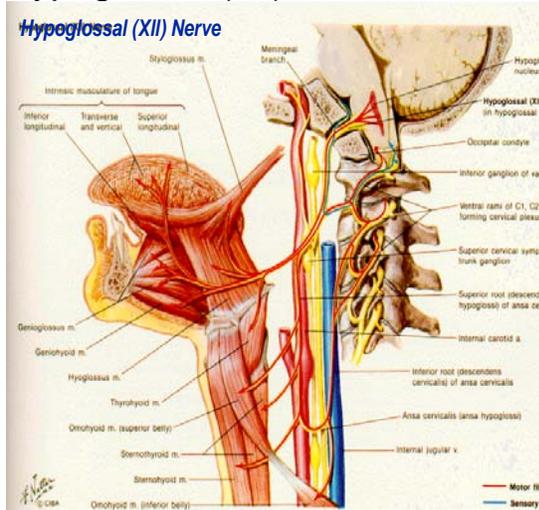


Figure 8.

Even though the hypoglossal nerve exits the hypoglossal foramen it enters the jugular sheath with the other nerve trunks. This nerve is the motor nerve of the tongue.

Injury to this nerve is exemplified by the “tongue tied” or blurred speech patterns exhibited by many boxers.

It appears that the trend of thought on concussions is more interested in the presence or absence of brain injury than in the fracture of the skull itself. However these basal skull fractures cannot be dismissed because they assume importance in indicating the site and possible severity of brain damage and provide an explanation for the cranial nerve deficits, internal carotid artery pathology and other transient functional impairments. The injury assessment of basal skull fractures and these cranial nerves will be addressed in another document under another heading.

Progressive injuries to the jaw joint as seen in the aggressive sport of soccer.

Approximately 5% of all soccer players receive a brain injury and there are an estimated 18 million players in the United States⁶.

Rapidly moving blunt impacts to the face or head as often seen in soccer demonstrated in picture 12, slams the condyle onto the vulnerable area at the skull base which will produce bone fractures,

concussions, brain motion injuries and temporomandibular joint disorders.



Picture 12. Evaluating the mechanism of head injuries as they occur on the field.

There is a misnomer shared by many, that soccer is not an aggressive or contact sport. Soccer is the only sport where the head is consciously used to make contact with the ball. When evaluating the forces of head impact in any sport, one must understand that the lower jaw is not attached to the skull. The amount of force at the moment the ball impacts against the head of a soccer player is approximately 200 joules of force. Every force produces an equal and opposite directional component of force. At the moment the ball impacts the head, the opposite directional component of force is transformed to the lower jaw slamming it against the base of the skull. This event weakens the integrity and structure of the jaw-joint mechanism. As a result the athlete becomes predisposed to TMJ disorders, bone fractures, internal head injuries and concussions. Taking the jaw joint out of harms way by repositioning the condyle with a jaw-joint protector will help the athlete concentrate on the proper way to head the ball. This will significantly reduce the risk of TMJ and other internal head injury in this sport. The security and confidence acquired when wearing the jaw-joint protector contributes to the psychological assurance of the player.

Case study of a soccer player.

This soccer player, a young 23 year old pleasant female, presented with tension triggered migraine-like headaches, facial pain, deviated jaw movements and recurring neck and shoulder pain. These pathological bone patterns are the etiology to the migraines and facial pains experienced by this athlete. Neck and shoulder pains symptoms quite frequently accompany jaw-joint pathology. The spinal accessory nerve trunk innervating the

⁶ Primary Care 1994. 11: 17-194.

cervical and subscalpular areas is impaired by the traumatic impacts from the medial pole of the condyle. Remember, this cranial nerve exits the brain through the jugular foramen. This spinal accessory nerve injury is also responsible for many non-specific rotator cuff pains experienced by many athletes.

History: Her past history revealed headaches and jaw problems that appeared after being hit with a soccer ball on the left side of the face.

The young player, a child of 14 years, was removed from the game dazed with an excruciating headache but conscious, fell asleep with her head under a blanket (perhaps an undiagnosed concussion with photophobia).

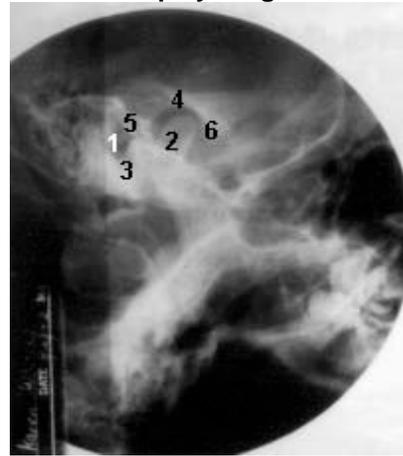
Symptoms:

- A) recurring cluster headaches,
- B) facial pains,
- C) neck and shoulder pain,
- D) transient cognitive disorders,
- E) other neurological phenomena.
- F) jaw locking upon opening

The symptomology persisted through out her teenage development. At the age of nineteen, following an unsuccessful series of neurodiagnostic testing and numerous failed non-invasive medical treatment modalities to relieve the excruciating reoccurring headaches, facial neck and cervical pains, the young adult underwent surgery. The procedure, a condylectomy or the removal of her left condyle, revealed in picture 14, had no apparent physical benefits only short term pain relief.

Today, as an adult, the consequence of the condylectomy adversely impacts on her social life, her ability in the work place and psychological output. She currently not only suffers the many symptoms of temporal mandibular joint disorder and cranial facial pains, but also experiences limited oral functions, poor mastication and the mandible deviates to the left with pain upon opening.

The soccer player right side:



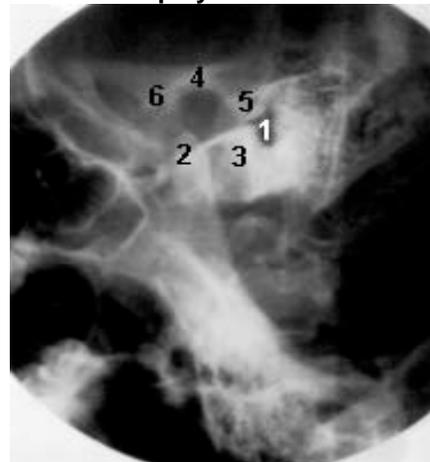
Picture 13. Right transcranial projection 23 year old female soccer player with field experience of thirteen years.

Pathology: The x-ray of the right transcranial (picture 13) reveals:

- B) the condyle (2) is positioned high in the broad recess of the glenoid fossa (4),
- C) A feathering pathology of the round slopes of the articular eminence (6). This is indicative of the condyle interfering with the articular eminence when opening the mouth.
- D) Increased radiopacity with U-shaped pathology and green stick fracture of the anterior wall of the tympanic temporal bone (3).

These commonly revealed injury patterns of sports would have been prevented by the use of jaw-joint protectors

The soccer player left side:



Picture 14. Left transcranial- The condylectomy

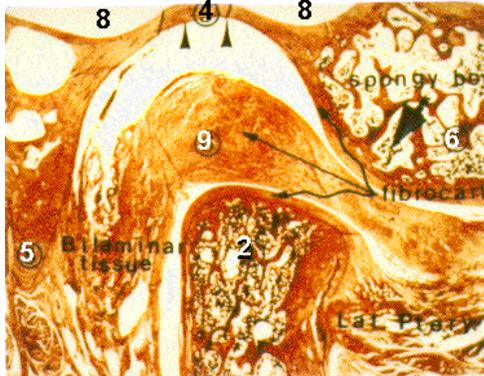
Pathology: The left transcranial reveals in picture14:

- A) condylectomy (2) with restricted movement upon opening.

- B) This correlates to the deviate jaw movement to the left with opening.
- C) Feathering pathology of the articular eminence (6),
- D) a non displaced fracture between post glenoid process (5) and tympanic temporal bone (3).

It is important to understand the dynamics and the seriousness of jaw-joint injury that can not only affect the quality of life, but also can be life threatening to the athlete.

Histological Considerations Microscopic view of jaw-joint complex,



Picture 15.

Legend and Histologic Consideration:

2) mandibular condyle in the open mouth position and in sports becomes a rapidly moving blunt object subjecting the brain to concussive forces, 4) the thinnest bone of basal skull, glenoid fossa, less than 2mm in thickness, is subject to fracture in many sports and once fractured-damaged forever (note the mechanical impedance to impact is little or none), 5) the post glenoid process with densely packed bone cells, designed to absorb condyle impacts within normal limits, 6) articular eminence showing bone marrow spacing and less densely packed bone cells, 8) the brain of the temporal lobe in the middle cranial fossa, 9) The disc or meniscus that is often torn, herniated or destroyed as the result of sports. Note the disc is soft tissue and will not be seen on the x-ray. However, it has been referred to as assumed disc space.

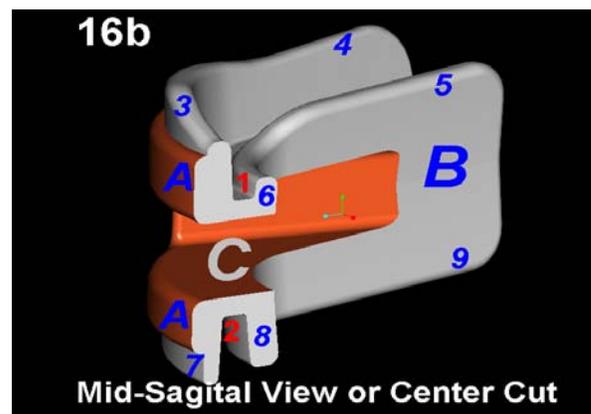
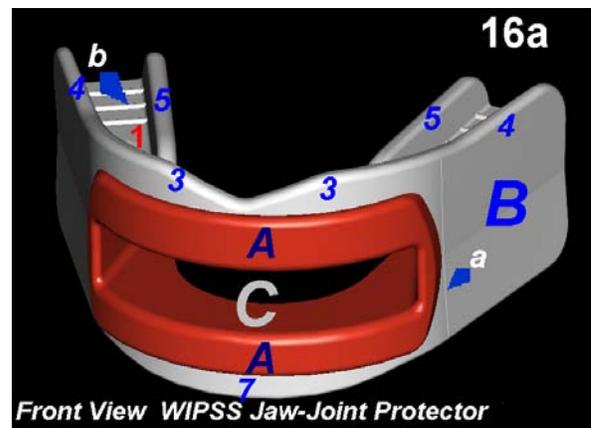
Picture 15 is histological view of a sagittal section of the jaw-joint complex. Applying the concepts of biomechanics to this anatomical configuration, one soon realizes that this area was never intended to withstand the high velocity and excessive load forces of sports.

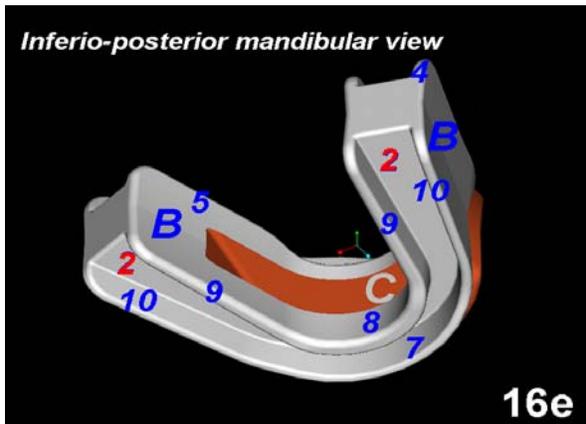
Evaluating the efficacy and design of the jaw-joint protector- a new sports product for the reduction of concussions.

The jaw-joint protector is a laminated intra-oral double arch orthotic appliance (see pictures 16a-e). The design and engineering through the fusion of two thermoplastic materials (A and B) repositions and locks the mandibular arch in a down and forward (pseudoprognathic) position. The thermoplastics A and B act in concert as an absorption buffer for head impacts which attenuates and redirects the energy away from the skull base.

This complex joint space is anatomically a lethal port of entry to the brain for the violent forces of sports.

The A thermoplastic material holds the form and maintains the pseudoprognathic position while the appliance is subjected to boiling water for the custom fit. This component of the jaw-joint appliance has a durometer range hard enough to absorb the high impact energy of sports, but resilient enough to protect and not shatter teeth





legend 16a-e: 1) maxillary bite channel, 2) mandibular bite channel, 3) anterior maxillary flange, 4) posterior maxillary buccal flange, 5) posterior maxillary lingual flange, 6) maxillary anterior articular rim, 7) anterior mandibular flange, 8) deep mandibular lingual lock and flange, 9) mandibular lingual flange, 10) mandibular buccal flange.

The **B** thermoplastic material softens in boiling water to form the impression of the upper and lower dentition creating the fit. The maxillary and mandibular teeth lock in their upper (1) and lower (2) channels respective (picture 16b), repositioning the mandible and creating the margin of safety in the joint space (see picture 17).

The anterior freeway space (**C**) facilitates:

- 1) passive and active breathing,
- 2) talking and shouting,
- 3) expectorating or spitting.

The jaw joint protector absorbs and redistributes those forces of head impact that are transmitted from the condyle to the base of the skull, preventing these forces from directly impacting the temporal lobe of the brain. These redirected forces are distributed and dissipated in the jaw-joint protector and the upper and lower dental arch complexity. The teeth and jaw-joint protector are more adequately equipped to handle these explosive forces in sports-related head injuries than the thin bone of the glenoid fossa and vital structures of the middle cranial fossa. Coupled with the custom bite there are other intrinsic features such as the deep mandibular anterior lingual lock (8) and mandibular flanges facilitating the locking and stabilizing mechanisms of the lower arch. The jaw-joint protector does not have a palatal portion fitting against the hard palate or roof of the mouth. The lack of the palatal component, common to mouthguards, adds to the comfort, minimizes the gag-reflex response in many athletes, and also makes breathing and speaking effortless with an intra-oral appliance. On the maxillary bite channels (1 in picture's 16a) in the posterior region, note, three bilateral fitting guide lines (b). The appliance may be cut on these guide lines to be sized for proper fitting.

Protect the jaw joint by locking and repositioning condyle away from the base of skull.

The jaw joint protector changes the measurable distance described as the intolerable zone, refer to picture 10, and creates a new margin of safety (the force attenuation space see picture 17) for competitive sports. Repositioning and locking the condyle down and forward will virtually eliminate the clubbing forces of the condyle against the skull's intolerable zone and will greatly reduce the risk of concussion and other internal head injuries.

New condyle position for all sports



Picture 17. Repositioning the condyle converts the intolerable zone into a force attenuation space.

The jaw-joint protector increases the margin of safety for the athlete without changing the composition of the game. The jaw-joint protector also reduces the traumatic lateral displacement of the lower jaw and enhances the stability of the jaw joint during the traumatic exchanges in the ring. This traumatic displacement of the mandible and jaw joint complex is intensified by the use of mouthguards. This issue will be covered under another heading.

The consequence of facial impacts:

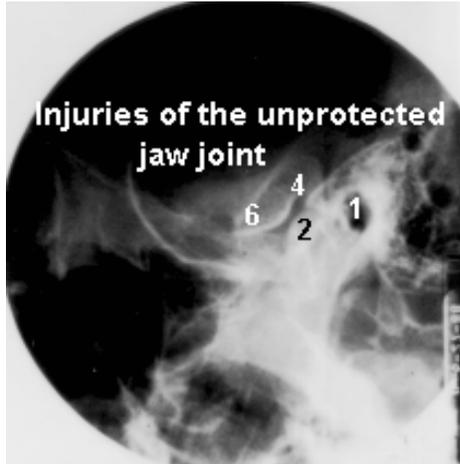


Picture 18. The unstable or displaced lower jaw and jaw joint exemplified by the traumatic facial distortions often seen in boxers, wearing mouthguards, when the punch has landed

Case study: heavyweight boxer

This case study is of a heavyweight boxer that competed for the world's heavyweight title. While using the standard mouthguard, he experienced nausea and vomiting (n & v) following a punch or an impact to the left jaw.

The boxer with N & V:



Picture 19. Closed mouth position without jaw- joint protector in place;

History: The professional boxer presented with the chief complaint of the onset of nausea and vomiting with relatively light forces from a punch landing on the left jaw.

Pathology: Radiograph's examination revealed the following:

- A) the head of the condyle (2) is distally displaced onto damaged post glenoid process,
- B) a depressed fracture and remolding of the glenoid fossa (4),
- C) thinned anterior wall of the tympanic temporal bone.
- D) the loss of the surface congruency of condyle to fossa (2 to 4),
- E) multiple fractures in area of anterior wall of the temporal tympanic bone, including the inferior and superior surfaces.

Boxers will invariably exhibit greater pathology on the left jaw-joint structure. This pathology is due to the force of the right hand punch landing on the left side of the head. Many of the jabs thrown from the left hand are also slipped to the left side of the head.

Solution to N & V:

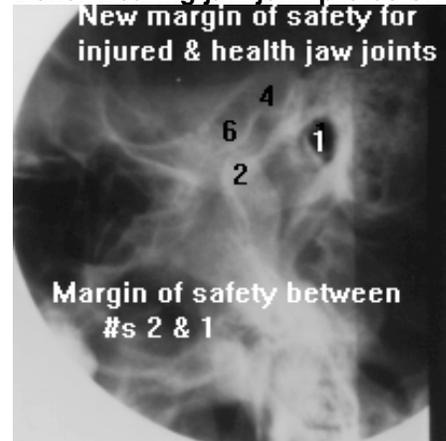
With the jaw-joint protector in place the fractured tympanic temporal bone, ear canal (1) and glenoid

fossa are out of harms way of the traumatically impacting condyle. The airway space and the jaw position inherent in the design of jaw-joint protectors facilitates the ease of breathing. This feature decreases the oxygen debt of the boxer and enhances the energy level of the wearer.

As a sparing partner of a world's heavyweight champion, the boxer wore the jaw joint protector. With the new margin of safety and the more stable jaw position achieved as seen in picture. 20, this boxer then deliberately presented the left jaw for the impact of the right hand punch.

After receiving the rapid moving blunt impact from the right hand of the world's heavyweight champion on the left side of the head, to his delight the symptoms of nausea and vomiting were not present

Boxer wearing jaw-joint protector:



Picture 20. Athlete in Picture 19 with jaw-joint protector repositioning and locking condyle of lower jaw in place;

Mechanism: With the thinning of the protective bony plates of the temporal bone as seen in picture 20, the vagus nerve trunk is more susceptible to trauma from the punch or impact. With the many functions of this cranial nerve, it also innervates the heart, diaphragm, and stomach. Impact to the vagus trunk would cause a vago-vagal response. The consequence of this is the emetic reflex or vomiting.

Mouthguards induce jaw-joint injuries in contact sports.

The mouthguard has contributed significantly to jaw-joint injuries and concussion syndromes by destroying the locking mechanism of the teeth or interdigitation. The strongest and most stable configuration for the upper and lower jaw and jaw joint occurs when the teeth interdigitate.

Mouthguards prevent the interdigitation of teeth and on impact, the mouthguards allow the teeth of the lower jaw to slide against its lubricated (by saliva) lower bite surface. This sliding phenomenon violently impacts the condyle (2) onto the vital joint space at the base of the skull and the brain is involved in an inertia reaction to the blow (see page 23).

This scenario is also illustrated by the facial distortion and an unstable jaw configuration of the boxer wearing a mouthguard in picture 18. The honorable intent of the mouthguard was to prevent dental injuries. However, it has been shown through biomechanical injury assessment that the injurious consequences of mouthguards promotes condyle slamming against the basal skull, This trauma increases the risk of concussions closed head injuries, jaw-joint pathology, and. knock-outs.

As seen in this photograph, this athlete wore custom made mouthguards throughout his career. Today he enjoys a handsome smile, but suffers extensive pathology of the jaw joint complex. His jaw joint pathology would have been prevented and all neuro-cognitive symptoms reduced by the use of jaw-joint protection.

The dental injuries can be repaired and rehabilitated, however the brain and jaw joint once injured are subjected to irreversible scarring and damage.

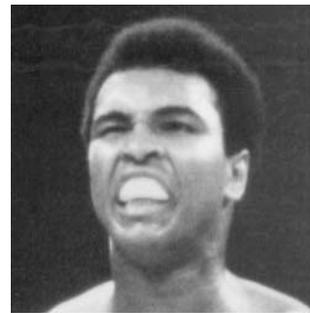
How can jaw-joint protectors enhance the performance and strength of the athlete?

With the insertion of the jaw-joint protector the athlete with the pathology in picture 19, has increased his upper and lower body strength by 35%. This is due in part to the fact that most seasoned athletes will have sustained injury to the unprotected jaw joint. In brief, there is a reflex mechanism that is activated by clenching the teeth and facilitated by the vagus nerve allied with the jaw joint complex. The sensory impulses of the vagus are associated with clenching or oral proprioception. These sensory impulses travel to the brain, elicit the reflex mechanism activating the motor impulses. The motor component of this vagal reflex activates many muscle groups producing strength and endurance. Jaw-joint injury will impair the sensory impulses of the vagus nerve. This in turn, limits the motor impulses of this reflex mechanism. The net effect to this loss of the neural impulses is a decrease in strength and endurance of the athlete without their knowledge.

The jaw-joint protector repositions the condyle of the lower jaw away from the injured or

predisposed jaw-joint complex and base of the skull, while locking the teeth into a clench-like bite. This new jaw position appears to stimulate those impaired sensory impulses, increasing the motor output. The net effect of this repositioning is enhanced strength and performance of the athlete, while preventing injury to this delicate area. This restoration of strength will enable the athlete to reach their full potential that otherwise will be handicapped with jaw-joint injury. This inherent function of condyle repositioning and jaw joint stability becomes of utmost importance in the trenches of sports, patient rehabilitation, physical therapy, conditioning training, weight lifting and others.

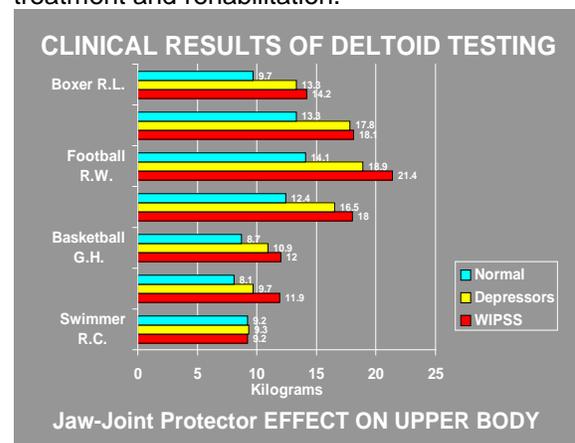
Studies of seasoned athletes have shown upper and lower body strength increases up to 35% while wearing jaw-joint protectors.



The attitude of wearing any new piece of sport equipment or jaw-joint protector is easily overcome when the athlete immediately experiences the increase in strength and endurance. Understanding jaw-joint protection instills

a sense of well-being and psychological calm and assurance to the athlete.

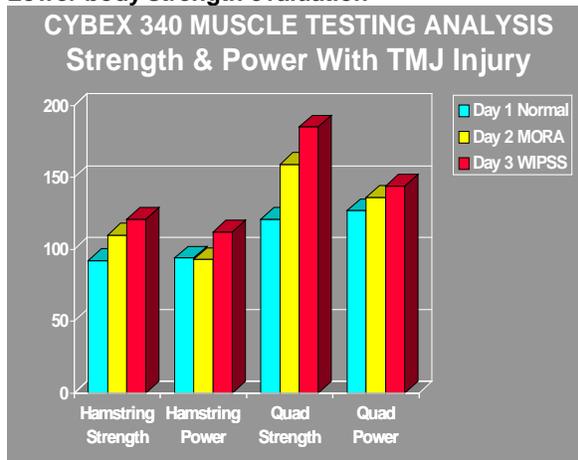
Upper body strength evaluation This strength differential is the consequence of jaw joint injury. These tests, though quantitative in strength, are definitive indicators of jaw-joint injuries. Hence, the jaw-joint structure should be clinically and radiographically evaluated to ensure proper treatment and rehabilitation.



Picture 22. Upper body deltoide testing performed: 1. normal bite [blue square], 2. tongue depressors [yellow square], 3. Jaw-joint protector [red square]

The consequence of jaw-joint injury will plague the athlete long after the games are over.

Lower body strength evaluation



Picture 22. Cybex testing of athlete with depressed condylar fracture on the right side

The lower body strength can be tested on the basketball courts with vertical leap measurements.

It is noteworthy to express that those who show no sufficient increase in the strength phenomena have little to no damage of the jaw-joint complex. It is of utmost importance that one takes the position "To preserve the quality of life for the athlete long after the games are over, the jaw joint must be protected."

The efficacy of jaw joint protectors

With the world's only articulated headform as seen in picture 23, a study by Dr. V.R. Hodgson, [National Operating Committee On Standards For Athletic Equipment(NOCSAE) and Biomachanics Research Center, Wayne State University]⁷, corroborated the jaw-joint protection claims. His study examined the force-attenuation potential of different types of conventional mouthguards and the jaw-joint protector with impact reference to the jaw joint.

Dr. Hodgson's results, through the use of an articulated headform (picture 23) mounted to the helmet drop assembly (picture 24), demonstrated several important facts:

A) The enormous impact forces that are transmitted directly to the load cells at the base of the skull and in the jaw-joint space when the

helmeted headform is dropped onto the faceguard at various heights.

These forces shattered the epoxy headform in the impacted area of the jaw joint at the 60 inch drop height. This impact force is of the magnitude to fracture the long bone of the leg. This data:

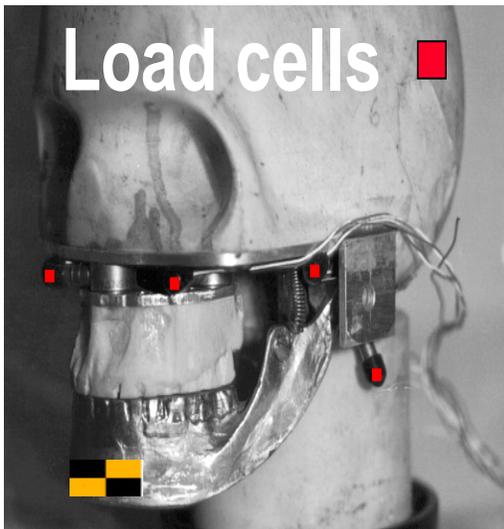
- 1) corroborated the clinical findings and the pathologies presented,
- 2) amplified the necessity of articulated headforms in head impact studies,
- 3) demonstrated the kinds of forces executed on the basal aspect of the skull in contact sports,
- 4) verified the efficacy of jaw-joint protectors in dissipating the forces of impact away from the base of the skull.
- 5) produced forces that mimicked the faceguard impact forces that actually occur on the playing field
- 6) created the kinds of forces identified in other head impact studies that would have produced the symptoms consistent with the key features of concussions.

B) The load forces were dissipated throughout the dental arch and onto the jaw-joint protector, attenuating the force loads to the jaw joint and base of the skull.

C) Mouthguards were shown to absorb the force loads in the anterior tooth segment, however transmitted the posterior components of force directly to the joint space or load cells.

Articulated headform of Wayne State

⁷Hodgson V.R., "Standard Method Of Impact Test And Performance Requirements For Football Faceguards and Mouthguards Impact Test 7 Load Rind Triaxial Accelerator Model" Personal correspondence 1994.



Picture 23. Articulated epoxy headform⁸ with impact load cells; The headform contains upper and lower dental forms for the adaptation of mouthguards. The epoxy headform has been validated to be closely aligned to the mechanical impedance of bone. Mechanical impedance test were conducted to show that the steady-state vibration response of the epoxy headform matched those of human cadaver heads. Piezo electric load cells are placed in strategic locations to measure the load locations to measure the load distribution from impacts to the mandible and to Measure the attenuation of forces through the intra-oral appliances.

The development of the more reliable articulated headform, is more realistic in response characteristics. This headform will more accurately predict the effect of the helmet impacts on jaw-joint injuries, qualifying and quantifying the data presented in this document. When helmets work in unison with the jaw-joint protectors will create the best traumatic head impact attenuaters in sports.

The force attenuation drop study measured the ability of the over the counter boil and bite mouthguard, the custom made mouthguard and jaw-joint protector to attenuate and redirect the forces of impact away from the jaw-joint mechanism onto the mouthpiece appliance and teeth.

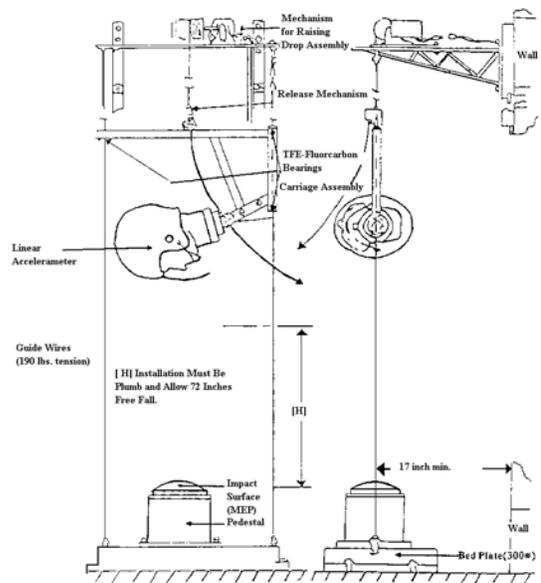
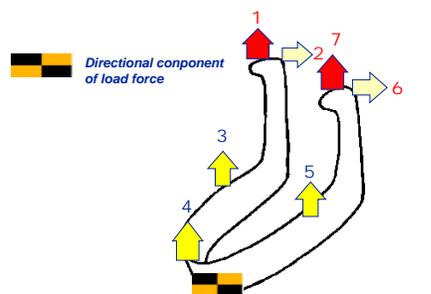


Fig. 1 Schematic of Helmet Drop Assembly

Picture 24. Helmet drop assembly schematic

An accelerometer is mounted at the center of gravity of the headform, with the positive X-axis pointing in the posterior-anterior direction. The impact attenuation is measured by determining the headform model resultant center of gravity acceleration-time history when the head model-helmet-faceguard assembly is dropped in guided free-fall to land with the faceguard striking a flat, rigid anvil having an diameter of 7 in. and padded with a .13 in. thick, 70 shore "A" durometer, natural rubber surface.



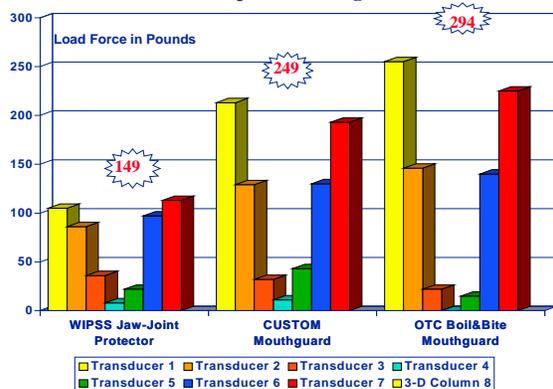
**LOAD FORCE DISTRIBUTION TESTING
Load Cell Position Relating to Mandible Impact**

Picture 25. These tests were conducted to evaluate the ability of mouthguard appliances to absorb and redistribute the load force of head impacts (mimicking that which occurs during play) away from the jaw-joint complex.

⁸ Headforms available at Wayne State University Department of Biomechanics, Tim Walilko

LOAD FORCE DISTRIBUTION ON TEETH & TMJ

36 in. Drop - Steel Faceguard



Picture 26

The study in picture 26 revealed the following:

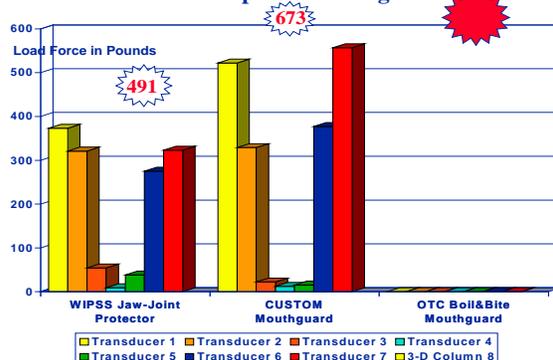
- at the low velocity impact of the 36 inch drop height the jaw-joint protector demonstrated an average decrease in the attenuation of force in an anterior-posterior direction of 40% in the jaw joint over the custom mouthguard
- 50% decrease in the forces attenuated in the jaw-joint space over the over-the-counter boil and bite mouthguard.

At the low impact heights the trauma to the jaw joint increases bone stress, weakens the joint space and increases the vulnerability of the athlete to greater injury.

The 60 inch drop height has been validated to being equivalent to an abrupt stop from 17.8ft/sec impact velocity on the field⁹. The load forces produced in this study are more than adequate to fracture bone, induce temporomandibular joint pathology, and concussions (all of which has been discussed in this document).

LOAD FORCE DISTRIBUTION ON TEETH & TMJ

60 in. Drop - Steel Faceguard



Picture 27

-  Impact force fractured jaw joint assembly
-  Peak resultant force at the jaw-joint

⁹ National Operating Committee on Standards for Athletic Equipment football helmet certification program, Voigt R. Hodgson

The study in picture 27 revealed the following:

- at the high velocity impact of the 60 inch drop height the jaw-joint protector out performed custom-made mouthguard 35% in the ability to decrease the force of impact measured at the jaw-joint
- the force of impact measured at the 60 inch drop height with the over-the-counter boil and bite mouthguard fractured the jaw-joint complex of the articulated headform.

This is indicative of the excessive force loads delivered to the jaw-joint during sport.

Rehabilitating a concussed athlete

A knockout in boxing is consistent with the key symptoms of concussion in other sports. Many fighters experience the concussion episodes with the manifestation of the "glass jaw syndrome." This syndrome is defined in time as losing the ability to take the punch. Implicit in this definition are certain non-medical connotations. However, this syndrome has been given many different meanings in both medical and non-medical writings.

History: A middle weight champion boxer in picture 28, with great defensive boxing skills, turned professional at the age of eighteen. He began boxing as a skinny 55-pound 10 year- old and has won five world titles. He was proudly characterized in the boxing circle as "being able to strike and move like a cobra."

At the time of his examination, the intensity of his battles and the time in the ring had created the "glass jaw" and he had become the target for the great knockout. Trauma to the lower jaw or chin would produce neurocognitive changes characterized by:

- rubbery legs or unstable balance,
- glassy eye syndrome, abnormal pupillary response
- muscle tremors,
- post-traumatic dementia
- acute confusion state, and other transient disorders activated by impacts to the lower jaw .

The systemic evaluations of these affective and cognitive functions permit one to reach certain conclusions regarding the mental or concussion state of the athlete. It is implied that a concussion does not always denote temporary abolishment of consciousness. In other words, if these same symptoms appeared in a football, soccer, or hockey player he would have been diagnosed as having suffered a concussion.

Clinical Sign of Interest:

- A) the early signs of the thick tongue syndrome, a quantitative neurological deficiency, this injury is consistent with trauma to the hypoglossus, or 12th cranial nerve which innervates the tongue. This cranial nerve exits through the jugular sheath associated with the jugular foramen an area described previously. The jugular sheath containing the four cranial nerves,
 - 1) Hypoglossus, 12th,
 - 2) Vagus, 10th,
 - 3) Spinal accessory, 11th,
 - 4) Glossopharyngeus, 9th.

This jugular sheath approximates the medial pole of the condyle and is therefore constantly traumatized on impacts from the punch.

- B) Radiographically the transcranial and submental vertex projections revealed numerous chronic pathological change.

After compiling the data the fight was postponed for three months and the boxer underwent rehabilitation for the structural injuries radiographically identified. Through out this rehabilitation period, while exercising and training, he wore the jaw-joint protector. For his sixth world title fifteen round championship fight, he presented in ring wearing the jaw-joint protector instead of the mouthguard. When evaluating traumatic jaw or facial displacement, compare the stability of the jaw and face of an athlete wearing a jaw-joint protector in picture 28 to the athlete wearing a mouthguard in picture 29.

No Traumatic Facial Distortion-Stable Jaw



Participant wearing WIPSS jaw-joint protector

Picture 28. This athlete openly remarked that he was able to hit harder and take a better punch while wearing the jaw-joint protector.

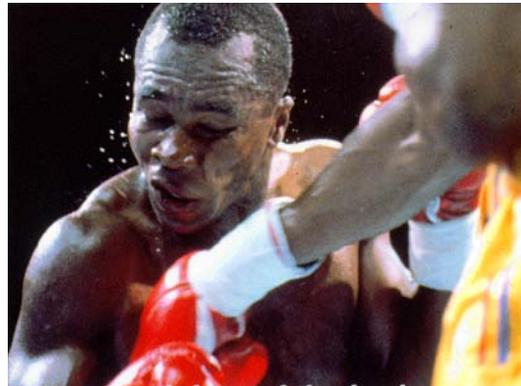
At the end of one of the most grueling, toe-to-toe, action packed, 15 round slugfest the participant did not exhibit the neuro-cognitive symptoms of

the “glass jaw syndrome” described previously. However the facts remain as follows:

- A) The jaw-joint protector redirected the impact forces, which were responsible for the neurocognitive changes described previously, away from the base of the skull into the protector and upper and lower dentition, stabilizing the jaw.
- B) The crippling clinical and radiographic findings revealed by this athlete would have been substantially reduced with the wearing of the jaw-joint protector as opposed to the mandated wearing of the mouthguards through out his entire career

On impact, mouthguards allow the teeth of the lower jaw to slide against the bite surface of the mouthguard, violently impacting the condyle of the lower jaw against the jaw-joint, and base of the skull.

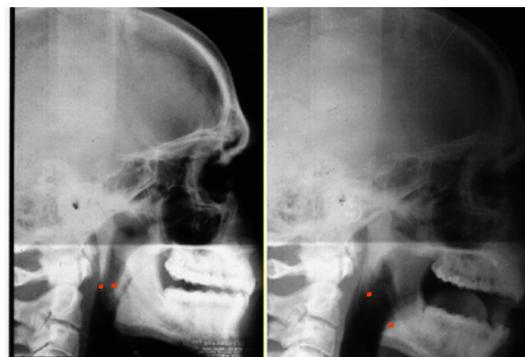
Participant wearing conventional mouthguard



Traumatic Facial Distortion-Unstable Jaw

Picture 29. Mouthguards will significantly add to the injury of the jaw-joint complex and the incidence of concussions.

The unstable jaw induces permanent brain damage.



Increasing airway space decreases oxygen debt

Picture 30.

The radiographic projections in picture 30 demonstrate the increase in airway space with the insertion of the jaw-joint protector. This contributes significantly to the state of proficiency in muscular function of athletes. This concept and appliance are also applicable in maintaining the airway space of those who snore.

Closure:

Once the jaw-joint is fractured, it is fractured forever. This fracture intensifies the risk of concussions and brain contusions and will be an ongoing TMJ disorder. This injury can happen at any time on any field of play at any age and the consequences will affect the participants:

- A) quality of play,
- B) career expectancy,
- C) physical and emotional strength,
- D) quality of life during the games and long after the games are over, and
- E) this injury may be life threatening.

Once it occurs, the jaw-joint injury is progressive and most often goes undiagnosed.

During the injury assessment of concussions and knock-out, (based on the principle of Newton's Laws) one must reevaluate the point of head contact and the impact that it has on the jaw joint and basal surface of the skull. While jaw-joint protection will not totally eliminate all concussions and knock-outs from sports. The protectors will, however, drastically reduce the incidence of concussion by absorbing any impacts directed to the middle cranial fossa from the base of the skull.

Once again, our primary concern is not to debate the many constellation or causations of concussions but to reduce the incidence of their occurrence by:

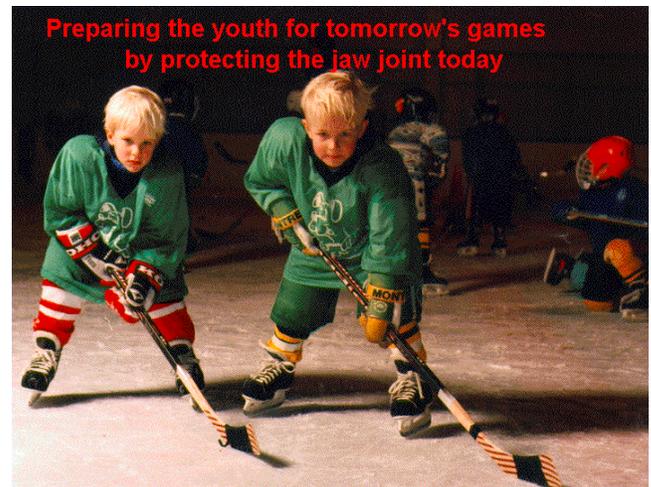
- A) identifying a serious injury in sports responsible for the onset of many concussions,
- B) assessing the cause of the injury as it relates to concussions in sports,
- C) establishing and validating preventive measures against this incapacitating injury and
- D) implementing these measures in the interest sports and safety.

This neglected anatomical structures of the jaw joint, base of the skull, and middle cranial fossa are of vital importance to the health and quality of life of the sport participant and risk management in sports. It is irresponsible to continue with the attitude in sports that the jaw joint does not exist

and is of little consequence to concussions or sports¹⁰.

To control the unacceptable rise in sports related concussions and the escalating associated health cost, we must protect and defend the jaw-joint space from harm. My overwhelming fears are that, if we continue to ignore the seriousness of jaw-joint injuries, this will cease to be a sport, biomechanical or medical issue. It will become a legal issue with devastating impacts on the future of sports.

According to the "Brain Injury Association" ten percent of all traumatic brain injuries occur in sports and recreation. The estimated cost of these sports-related brain disorders in the United States is \$4.83 billion annually¹¹



Lets do it for the kids. We are their caretakers and must mandate their safety. It is the right thing to do in all sports.

¹⁰ After all, the jaw joint may prove to be the missing link in the kinetic chain of life.

¹¹ Lewin-CF. *The cost of Disorders of the brain.* Washington DC: The National Foundation for the Brain, 1992.



Rodeo, the first sport in America, demands jaw-joint protection. Little Britches Rodeo Association. WIPSS the common sense jaw-joint protection.

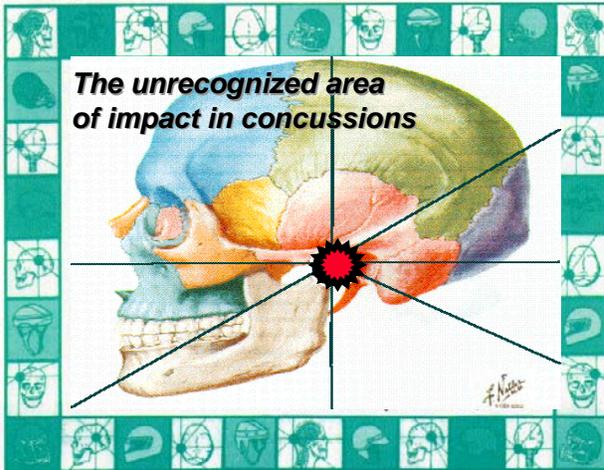
Contributory negligence

Head and helmet impacts test are performed on solid headform without jaw joint

Benign neglect



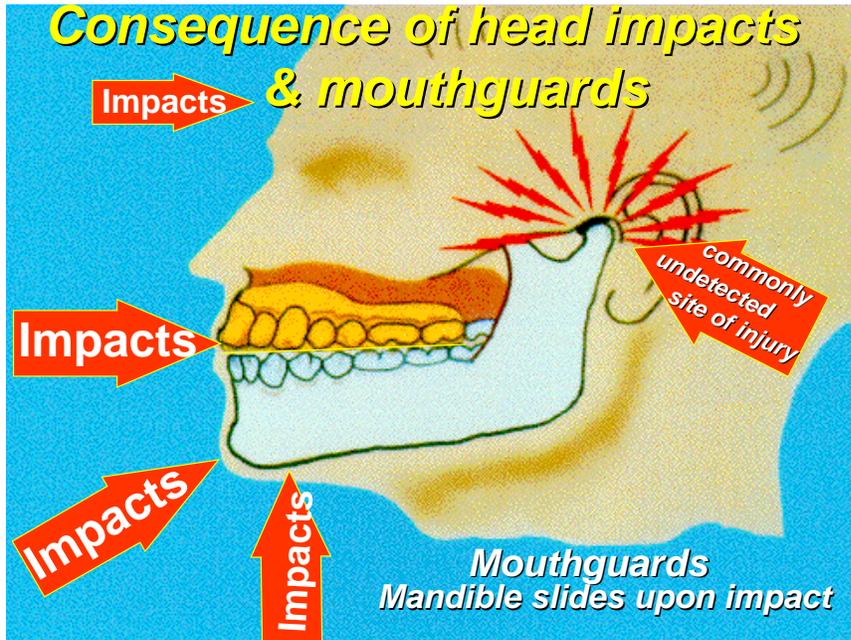
Anthropomorphic test dummy



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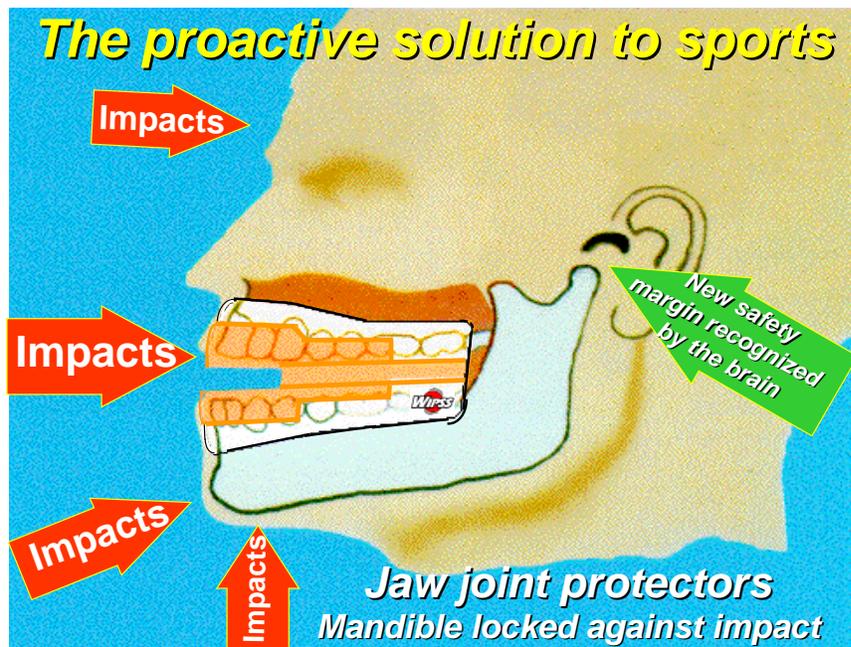
Any traumatic head impact will deliver a component of force to the jaw joint. The jaw joint is a direct port of entry for the traumatic forces of head impacts and predisposed the athlete to concussions and closed head injuries.

The impulsive forces of head impacts, responsible for concussions, are targeted to the temporal lobe of the brain.



That was then!

Mouthguards promote unstable jaw and slamming of the condyle onto base of skull with traumatic head impacts in sports! These forces are directly transmitted to the temporal lobe of the brain. These repetitive assaults of the brain tissue stress this tissue beyond its tolerable load limits inducing concussions.



This is now!

Jaw-joint protectors down load and lock the lower jaw for safety readiness and redistributing the load forces away from the temporal lobe onto the protector. This redistribution of traumatic forces of head impacts greatly reduces the risk of concussions, jaw-joint pathology (TMJ) and headache experienced by many athletes!