

How Mouthguards Work



Including: Concussion Prevention
With Custom Mouthguards

Dr Anthony Lovat BDS

INTRODUCTION

Having been a Dental Surgeon for the best part of 20 years, I gave up my private practice in the mid 1990's to focus all my time and effort in the field of oral protection and mouthguards.

Whilst my children will suggest that this makes me a fairly 'sad' individual, I believe that the years spent studying the science of oral protection suitably qualifies me to write this booklet on the subject.

I have been prompted to put finger to keyboard, following my recent review of the various 'do it yourself' mouthguards available and after reading the rather alarming claims being made which, in my opinion, are focused on selling product often at the potential expense of the wearer's safety.

I guess this booklet also aims to sell a product - the Custom Fitting Mouthguard. But you will be delighted to hear that all the information you are about to read is based upon scientific research carried out over decades and an in-depth review of papers on the subject of oral protection published in independent and respected Medical, Dental and Sports journals across the world.

This is not a marketing fantasy!

QUOTES FROM INTERNATIONAL JOURNALS

Virtually all scientific papers state that Custom Mouthguards are preferable to any other type of mouthguard, especially boil and bite.

Here is a short selection of quotes from various international journals:

*"Custom-fitted mouthguards are universally acknowledged as the most effective means of preventing oro-facial injuries in all collision sports"*ⁱ

*"The most desirable mouth guard is the custom-made mouth guard. The advantages of the custom-made mouth guard over the boil-and-bite mouthguard are that it provides a better fit and better protection. It is also more comfortable."*ⁱⁱ

"The custom-made mouthguard is fabricated over a model of the wearer's teeth. They are acknowledged as providing the highest level of protection and greatest comfort"^{.iii}

"There is little doubt that the most acceptable and desirable form of mouthguard would be the individually made type. In addition to preventing direct and indirect injuries to the teeth, this type of mouthguard will also protect the lips and cheeks from laceration against the teeth, absorb forces which might fracture the mandibular angle or condyle, and instill a greater degree of confidence in players"^{.iv}

"The custom mouthguard made by a dentist from models of a person's teeth conforms most closely to the ideal type of mouthguard"^v

(The sources of these quotes can be found at the end of this booklet).

THE SCIENCE (YAWN!)

The science of mouthguards is considerably more complex than what you are about to read however here is a brief review which I have broken down into three sections, **TIME**, **AREA** and **ELASTICITY**

TIME

Damage is inversely proportional to duration of impact

$$f=ma \Rightarrow f=m\left(\frac{v-u}{t}\right) \Rightarrow f \propto \frac{1}{t}$$

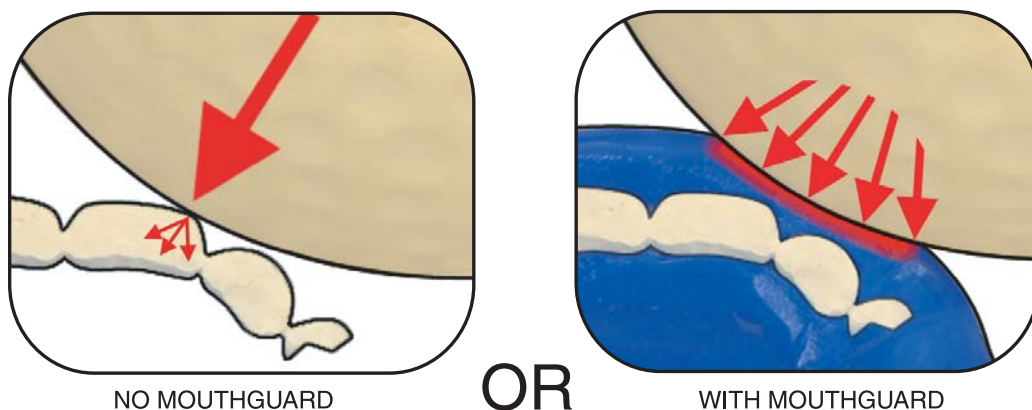
f =force m =mass a =acceleration v =end velocity u =start velocity t =time

The greater the force applied, the greater the damage. That damage will be reduced by lengthening the time over which the force is applied which has the effect of reducing the peak force.

Mouthguards are made from a flexible and compressive material which allows the impacting object to slow down and reach a halt over a longer period of time and hence the resulting transmitted force is reduced. If, for example, a blow is slowed down by the flexible surface of a mouthguard in 4 milliseconds, rather than the 1 millisecond it would take if the same blow directly struck the hard surface of a tooth, then the maximum force transmitted would be $\frac{1}{4}$ the size. A very dramatic reduction!

AREA

Damage is inversely proportional to area over which force is applied



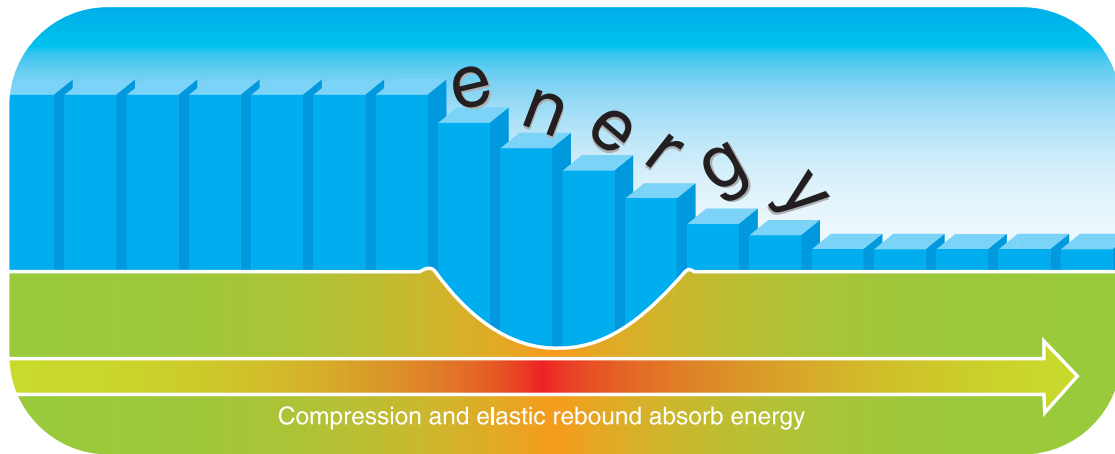
Apply a force to a small area and the result can be destructive.

Now apply exactly the same force but use a mouthguard to spread it over a significantly larger area and the force applied to each point under the mouthguard is dramatically reduced.

ELASTICITY

Energy is absorbed by Elastic change

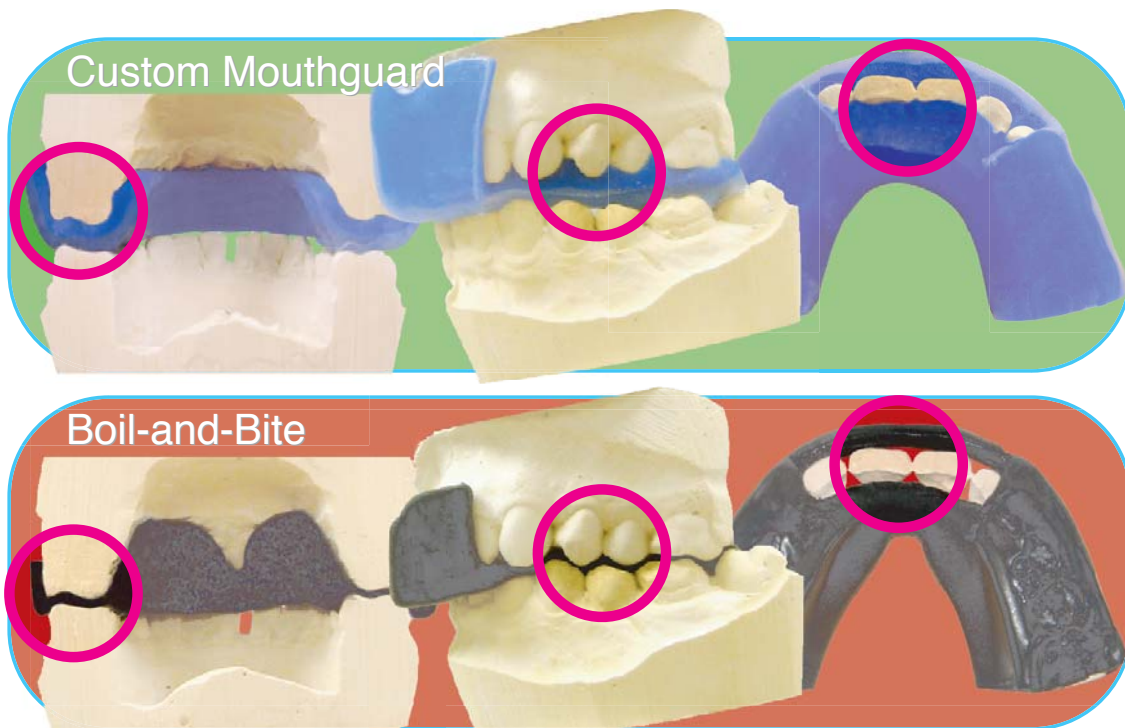
A fundamental principle of Physics is that **'Energy can neither be created nor destroyed'**.



A mouthguard is made from flexible material, which will compress on impact and then return to its original shape (if the distorting force is within the mouthguard's elastic limit). That compression and return takes energy. The thicker the material, the more it can compress and the more energy it can 'absorb' from the impacting object.

(Note: The scientists amongst you will easily see the lack of detail in this section. However, I hope you can also see that by developing each of these concepts, the general conclusions will still apply.)

THE FIT

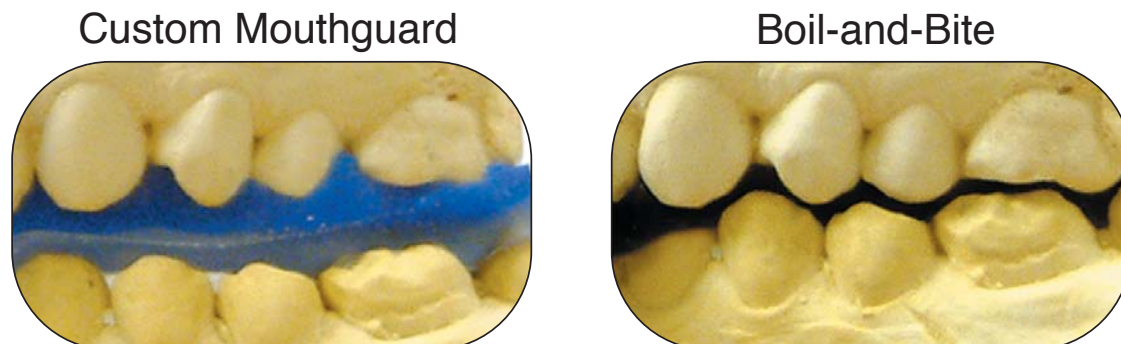


All the safety qualities of a mouthguard are directly related to the fit. Better fit (retention) means better safety. It's as simple as that.

Custom Mouthguards adapt far more closely to teeth than boil-and-bites. The reason for this is simple - the machines that make custom mouthguards work at far higher temperatures than can be applied in the mouth and at pressures many times greater than can be produced by biting and sucking! For exactly the same heat and pressure reasons, the thickness of a Custom Mouthguard can be optimised in the laboratory, whereas a boil and bite will be thinner and will vary widely depending on the user.

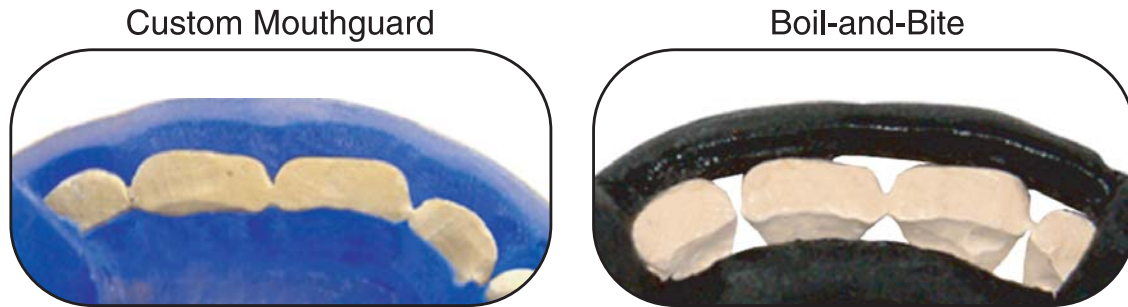
TIME

Typically, boil-and-bite mouthguards are substantially thinner in the important areas than Custom Mouthguards. For example the normal thickness of a boil-and-bite



mouthguard's biting surface is as little as $\frac{1}{2}$ - 1mm after fitting whereas the corresponding area of Custom Mouthguard will usually be in the region of 3mm thick.

This extra thickness provides more sponginess which in turn ensures that an impacting object will decelerate over a longer time.



Photograph showing contact area of mouthguard

Longer Time = Less Damage

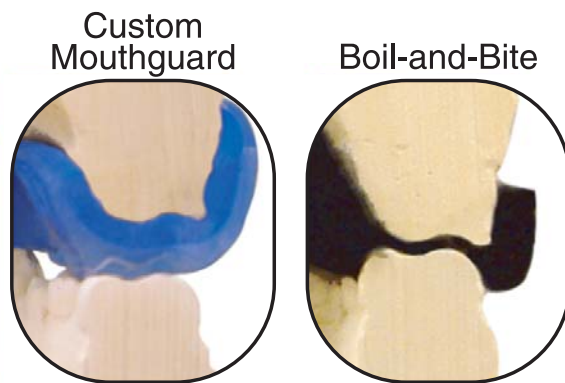
AREA

It may not look as though Custom Mouthguards contact a larger area than boil-and-bite mouthguards but the detailed fit of the inside of the Custom Mouthguard ensures that the area of contact is considerably greater.

Greater Area = Less Damage

ELASTICITY

The extra thickness of the Custom Mouthguard means that it can be compressed far further than a boil-and-bite mouthguard before springing back. This 'sponginess' uses a great deal of energy and thus less energy remains to be translated as Force to the recipient.



Cross Sectional View

Greater Elasticity = Less Energy = Less Damage

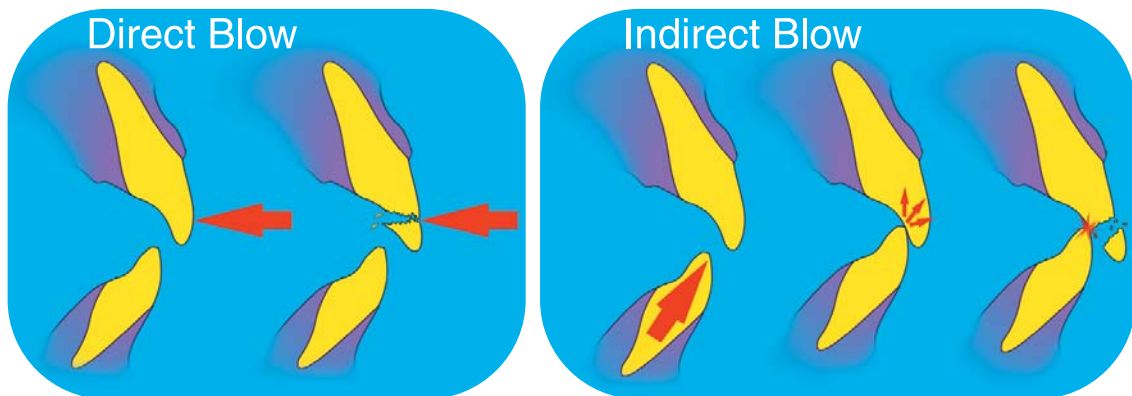
HOW MOUTHGUARDS PREVENT/REDUCE INJURY

There are two main types of traumatic strike to the upper jaw and base of skull - the Direct and Indirect Blows.

Direct Blow

Possibly the less common of the injury types is a direct frontal blow to the upper jaw. If unprotected, this may lead to damage to, movement or loss of a tooth or teeth.

The mouthguard reduces the force of the impact according to the Time/Area/Elasticity principles. This is how frontal tooth damage is reduced and, also, the risk of concussion is lessened (see 'concussion' below).



Indirect Blow

The more common and probably more concerning is the blow to the lower jaw which slams the lower teeth upwards bringing them into contact with the upper teeth.

If unprotected the following possibilities exist.

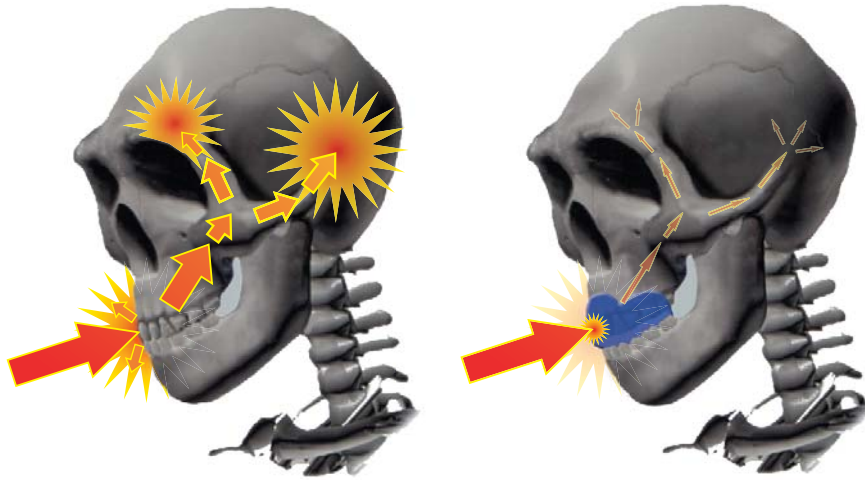
Firstly, the chisel like lower incisors can punch into the back of the upper incisors moving them forwards or fracturing them. Secondly, damage may occur to other teeth, depending on the particular occlusion and angle of the blow.

Time/Area/Elasticity principles apply. Instead of a hammer blow by the narrow lower incisors onto a sharp and small contact zone, the area of contact can be spread very widely and evenly over the whole biting plane and the reduction of the force is dramatic.

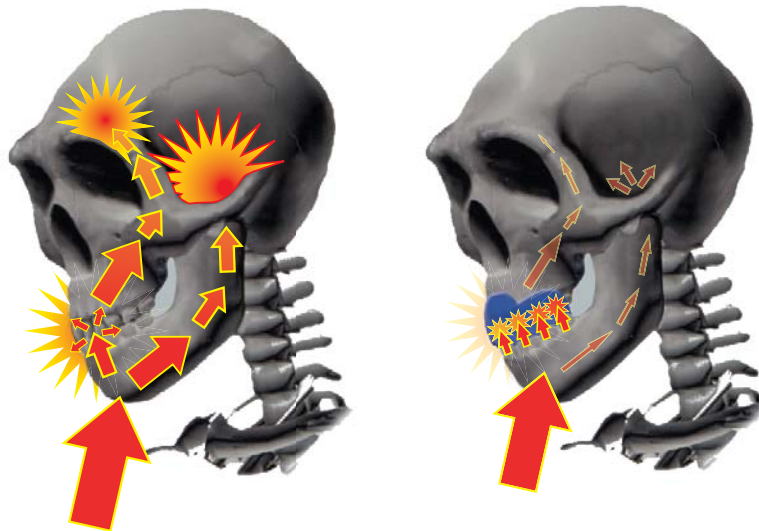
This blow to the lower jaw is also one of the common causes of concussion and the Custom Mouthguard offers yet one more level of protection.

CONCUSSION

A force applied to the jaw can be transmitted to the brain by one of two primary routes:



1. via the upper teeth which are embedded in the maxilla, which in turn is connected to the bones of the base of the skull. The Time/Area/Elasticity principles keep this to a minimum.



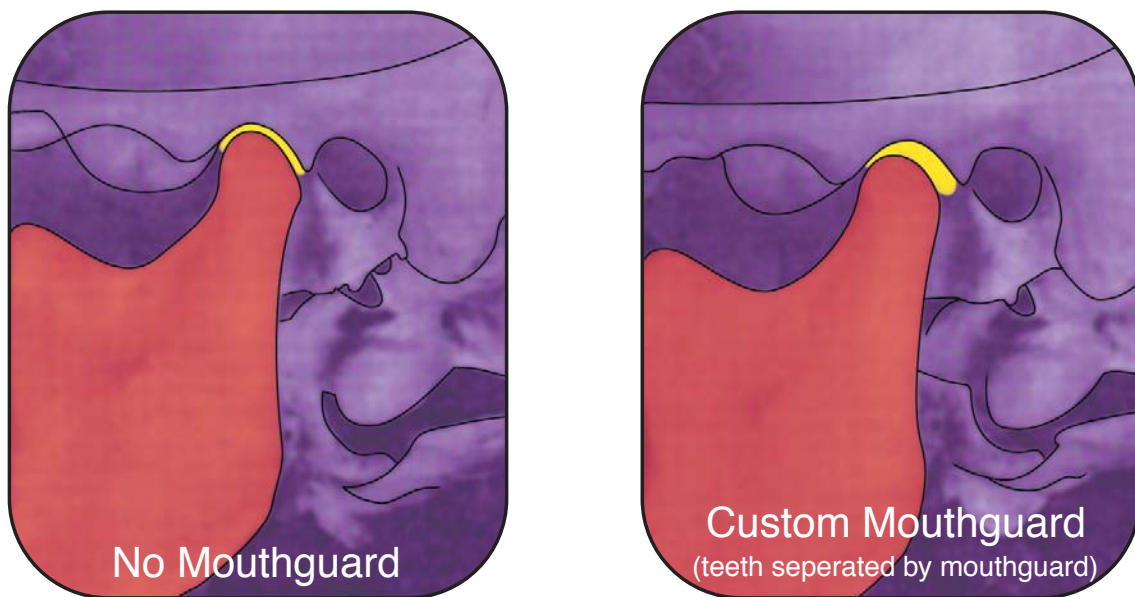
2. via the mandibular condyle. The condyle is the 'ball shaped' upper-rear-most part of the mandible which fits into the cup shaped fossa on the base of the skull. This joint is called the TMJ (temporomandibular joint).

With no mouthguard in place and the jaws shut, the rear aspect of the condyle sits against the posterior wall of the fossa, and any impact can be transmitted.

With a Custom Mouthguard in place with a typical thickness of around 3mm and with the teeth clenched into the mouthguard, the condyle has now moved forward and downwards (part of the normal mouth opening movement) and a gap has been created between the condyle and the skull. This gap could be a major reason why concussion is so greatly reduced when a well fabricated mouthguard is worn as another buffer is introduced to help prevent transmission of any impact.

Of course the protection of the joint is directly related to the thickness of the biting surface of the mouthguard. Too thin (boil-and-bites) and the gap may be too small to

Diagrams showing gap in TMJ with jaw closed



prevent the bones coming into contact if a hard blow is received. Too thick (like some double arch mouthguards) and whilst the risk of concussion may be reduced, there is another risk introduced - dislocation of the TMJ or condylar fracture, as the condyle has been moved a long way from its protected zone. This added risk may occur even if the blow would not have induced a concussion.

Conclusion

Opening the TMJ to a sensible degree may help reduce/prevent concussion. However over-opening should be avoided and under-opening may be ineffective.

OTHER ASPECTS OF MOUTHGUARDS

A quick mention should also be made of two other types of injuries, namely **soft tissue laceration** - reduced by the intervention of the soft smooth outer surface of the mouthguard and **bone fracture** which will be reduced by Time/Area/Elasticity principles.

Speech

Often forgotten, and whilst not a safety feature, the ability of a sports person to communicate whilst on the field of play is paramount.

Speech is achieved by a complex set of muscular movements, but two of the main components are the tongue and the lips.

A poorly fitting boil and bite mouthguard will make speech difficult and interfere with clarity. The tongue and lips will be used (often subconsciously) to stabilise the boil-and-bite mouthguard and to do this task as well as speak is quite a feat!

A Custom Mouthguard does not need stabilisation, and thus makes speech much easier. It is still true that the clarity of the spoken word may still be impeded as the mere presence of the mouthguard changes the air flow dynamics, however with a little bit of patience fairly clear speech can be achieved.

Breathing

Optimum athletic performance requires unrestricted flow of air into the lungs. Any object that restricts the flow of this air will also reduce the athlete's uptake of oxygen.

A well fitted Custom Mouthguard will not move around the mouth and will therefore allow the athlete to open their mouth to inhale or exhale fully. Looser boil-and-bite mouthguards will require athletes to modify their breathing to accommodate the mouthguard. This can inevitably mean reduced oxygen uptake and reduced performance

Bi-maxillary mouthguards (that fit the top and bottom jaws with a 'hole' at the front) clearly have a restrictive aperture through which air can pass and have the most detrimental effect of all.

Comfort

In truth, the best mouthguard is one that the athlete forgets he or she is wearing. Any item that is uncomfortable or causes irritation can reduce the athlete's performance.

Every published study that I have read confirms that players find Custom Mouthguards to be the most comfortable to wear.

Personalisation

Only Custom Mouthguards can be truly individual, particularly as the wearer's name can be included within the laminations. This will prevent another person from picking it up and trying to put it into their mouth.

Whilst this Custom Mouthguard wouldn't fit another person, the risk of infection from bacteria or viral causes cannot be ignored and personalisation can prevent this.

Orthodontic Braces

Can Custom Mouthguards be made for individuals with fixed orthodontic braces? YES, but only if properly made.

If a mouthguard is made highly retentive and the teeth move, then the mouthguard will be painful to put in place, or will simply not fit. Orthodontic mouthguards do involve compromises and possibly some ongoing management.

The principles are that the mouthguard should not adapt to the teeth or the brace itself, but be made with some space inside to allow movement of the teeth. Only if or when the teeth move to the point they contact the mouthguard on insertion, will some modification be required.

This compromise in fit does mean the mouthguard may be somewhat looser. It should not be as loose as a self boil mouthguard as it will be in contact with the gums, and engage the natural undercuts of the mouth. But it won't be tight.

The improved shape of the palate will still mean that an athlete can speak and breath better than with a boil and bite mouthguard and he or she will have protection against the brace or brackets injuring the lips.

Conclusions

Scientific research from all over the world concludes that Custom Mouthguards offer the best level of protection from injury and concussion as well as comfort. I hope this booklet has shown why this is so.

The Custom Mouthguard offers greater safety for the wearer, greater performance for the athlete, and is simply better in every single aspect apart from one:

The cost

Traditionally Custom Mouthguards have cost 25 to 250 times more than a boil and bite. So what if someone could find a way to bring that price down.....?

References:

- ⁱ Bank J, McCrory PR. Mouthguard Use in Australian Football. *Journal of Science and Medicine in Sport* 1999;2(1);20-29
- ⁱⁱ Park JB, Shaull KL, Overton B, Donly KJ. Improving mouth guards. *Journal Prosthetic Dentistry* 1994;72:373-380
- ⁱⁱⁱ Westerman B, Stringfellow PM, Eccleston JA. Forces transmitted through EVA mouthguard materials of different types and thickness. *Australian Dental Journal* 1995;40(6);389-391
- ^{iv} Davies RM, Bradley D, Hale RW, Laird WRE, Thomas PD. The Prevalence of Dental Injuries in Rugby Players and their Attitude to Mouthguards. *British Journal of Sports Medicine* 1977;11;72-74
- ^v Chapman PJ. The Prevalence of Orofacial Injuries and the Use of Mouthguards in Rugby League. *The Australian Journal of Science and Medicine in Sport* 1985;17(3);15-18