Simulation was used to rigorously study the cushioning and support provided by sports mouthguards in protecting teeth and surrounding tissue from damage.

# Taking a Bite out of **Sports Injuries**

## Finite element analysis illustrates that both cushioning and support are needed to adequately protect teeth and surrounding tissue from impact injuries.

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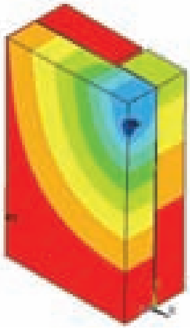
Mouthguards have been used for dental protection in sports since the early 20th century, and a good mouthguard will significantly reduce soft and hard tissue damage. Despite the variation of available mouthguards, they are without question an effective and necessary piece of protective equipment in many sports. Their ability to protect the lips and gums from laceration by covering the incisive edges of teeth definitely warrants their use in contact sports.

The precise mechanisms by which the device provides such protection are still not well understood, however, and in particular there are no rigorous criteria by which their performance can be assessed or compared. Indeed, the degree to which they protect teeth and surrounding structure has not been thoroughly established due to a lack of meaningful data on key variables that affect their performance. To gain greater insight on the capacity of the mouthguard to absorb and spread the energy of impact, finite element analysis was used to evaluate the complex biomaterial requirements of the devices in relation to impact parameters such as peak force, loading time, and contact area.

Mouthguards provide protection by cushioning and supporting the teeth. Cushioning imposes a soft layer between the teeth and a hard colliding body, thus reducing contact stresses by spreading loads over a larger area and for a longer period of time. Lowering maximum stresses in this way reduces injuries, especially those characterized by brittle fracture and localized damage to soft tissue.

For support, the mouthguard typically is shaped to fit closely around the teeth. This design allows a concentrated load applied to the front surface to be shared by neighboring teeth. The support depends on the rigidity of the guard and its ability to resist local deformation, which is in conflict with the requirements for good cushioning behavior.

Using a 2-D axisymmetric model, the cushioning effect of the soft layer of a mouthguard was analyzed with an explicit finite element code to predict the impact force given the geometry, material properties and impact velocity. This force was used in a 3-D simulation with ANSYS Structural software to determine tooth displacement. The results were scaled appropriately to study the supporting effect of the mouthguard.



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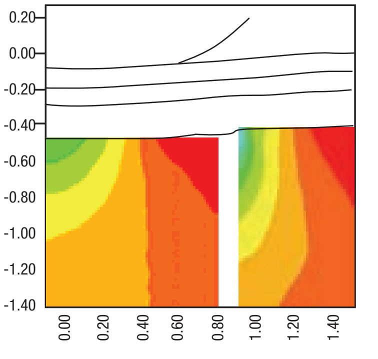
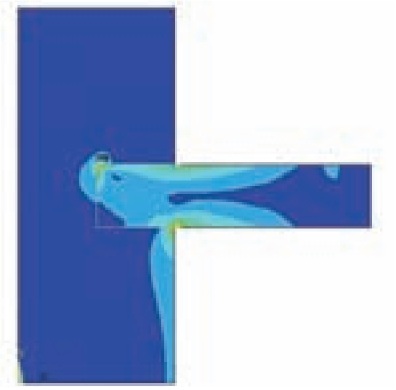



The supporting effect of the mouthguard and biomaterials was studied with ANSYS Structural. Contact elements represented the low friction contact between the mouthguard and teeth.



Cantilever beam models were used to determine stresses in teeth, socket and gum tissue resulting from impact.

The ANSYS model consisted of rectangular cantilevered beams representing the teeth plus a layer in front of the teeth representing the mouthguard with a static pressure distribution. Meshes were constructed with 3-D solid, tetrahedral and general hexahedral elements. Contact elements represented the low friction contact between the mouthguard and teeth. [1]

The analyses demonstrated that with a fixed load, the best overall support for the teeth is provided by highly stiff mouthguards. When the variation of impact load is taken into account, however, the cushioning effect of a soft coating outweighs the benefits of increased support provided by a stiffer layer.

The study thus provides significant insight into a modulus of elasticity and thickness for mouthguard materials that achieve optimal cushioning while not being so compliant that support is overly compromised. In this way, simulation improves the understanding of how mouthguards protect teeth and surrounding tissue so that better criteria for design, testing and standards may be developed.

Finite element analysis was indispensable in providing the level of data to rigorously study the protective performance of sports mouthguards, given the conflicting requirements of cushioning and support, the number of variables such as geometry and impact force. In the future it also may help to represent biomaterial behavior. ANSYS software was particularly well-suited to handling these complexities. Contact elements were especially valuable in representing the mouthguard, teeth and, although surrounding soft tissue behavior is too complex to model accurately at this stage, ANSYS allowed the substructures modeled to be combined into a single composite model as a flexible first approximation of the entire problem. The simulation provided insight into an important area of sports safety that heretofore was not as well understood or exhaustively assessed. ■

**Reference**

1. http://phoenix.open.ac.uk/~Rehana_Malik/Listing%20Folder/