Quantifying Changes in Mouthguard–Dentition Fit to Support Head Impact Measurement Validity

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Introduction: Mild traumatic brain injury (mTBI) is a major public health concern where sports related concussions contribute substantially and are often associated with contact and collision sports that experience frequent head impacts [1,2]. Concussive and subconcussive impacts have been associated with acute neurological impairment and potential long-term adverse outcomes, underscoring the need for accurate measurement of head kinematics during sport [3]. Instrumented mouthguards (iMGs) are increasingly used for this purpose, as rigid coupling to the dentition enables more accurate estimation of linear and rotational head motion than helmet- or skin-mounted sensors, with high accuracy demonstrated under optimal laboratory fit conditions [4,5,6]. However, data validity during extended real-world use remains uncertain, as repeated use can lead to material deformation, degrading fit and dentition coupling over time [7,8]. Reduced coupling may introduce relative motion artifacts and bias injury risk estimates, yet no standardized or generalizable method currently exists to quantify dentition–mouthguard fit or track changes longitudinally. Developing an objective measure of mouthguard fit is therefore critical for evaluating long-term sensor validity and improving interpretation of head impact exposure (HIE) data.

Objective: The objective of this study is to quantify temporal changes in the physical fit between the upper dentition and a boil-and-bite mouthguard using micro-CT imaging and segmentation in Dragonfly ORS, followed by distance- and volume-based analyses to quantify mouthguard fit through spatial separation at the dentition-mouthguard interface.

Methodology: Dental casts and corresponding boil-and-bite mouthguards were collected at baseline and at subsequent stages of use. Dental casts (stone) and mouthguards were µCT-scanned (Nikon XT H 225 ST), and image data were processed in Dragonfly ORS (version 2025.1). Dentition and mouthguard structures were segmented using a marker-based watershed transform, with manually defined markers and a landscape function derived from a Gaussian-smoothed 3D Sobel gradient image. Surface meshes were generated from segmented volumes using a fixed threshold and isotropic voxel sampling. Deviation map analysis was performed with the dentition mesh designated as the reference surface. Shortest Euclidean distance measurements across the mouthguard surface were used to quantify spatial separation and compute volume gap metrics between the dentition and mouthguard over time.

Results: Quantitative fit metrics, including shortest Euclidean distance and dentition-mouthguard volume gap measurements, will be extracted at each time point to characterize changes in dentition-mouthguard coupling. Deformation of the mouthguard is expected to produce heterogeneous, region-specific changes in fit, with localized reductions in distance and volume gap metrics reflecting improved conformity in some areas and increases in other regions indicating loss of dentition-mouthguard contact or coverage. It is expected that the premolar and molar regions will exhibit the greatest changes whereas the incisor and canine regions will remain relatively constant. These opposing trends will reflect nonuniform shape changes that accumulate with repeated use.

Conclusions: This work provides an objective method for tracking boil-and-bite mouthguard fit to the dentition. This method can be used with boil-and-bite iMGs to evaluate the impact of change in fit on head kinematic measurements. The findings will inform guidelines for mouthguard use, replacement, and interpretation of longitudinal HIE data.

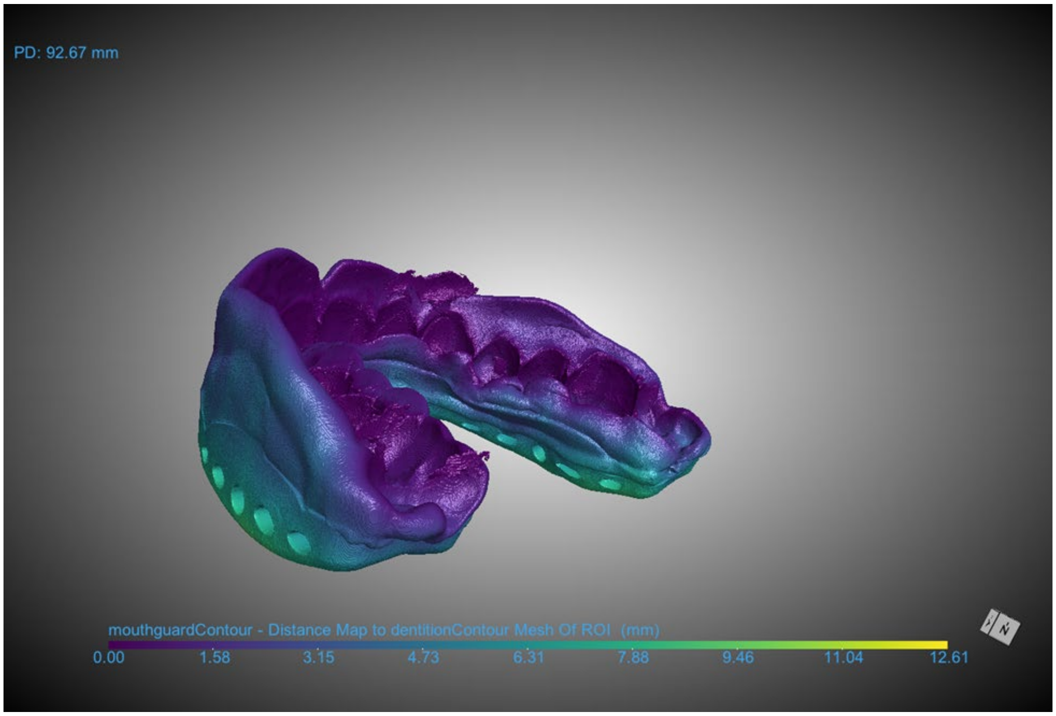

Figure 1. Distance based deviation map showing the spatial separation between the iMG and the dentition. The mouthguard surface is colored by the shortest Euclidean distance to the dentition reference mesh, computed from microCT derived surface contours. Warmer colors indicate larger separations, and cooler colors indicate closer contact, providing a spatially resolved visualization of mouthguard fit across the dental arch.

References

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