

BIOFIDELITY REQUIREMENTS FOR AN ADVANCED HEADFORM FOR THE PREDICTION OF EYE INJURIES

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INTRODUCTION

The rate of eye injuries has dramatically increased in warfare from approximately 2% during World War I and World War II, to nearly 13% during Operation Desert Storm (Heier 1993, Wong 2000) (Figure 1). In order to assess the capability of protective equipment in reducing eye and facial injuries, a new advanced headform is being developed that can predict fracture of facial bones, as well as eye injury from impact loading. Because of its emphasis on eye and orbital injuries, the name of this new advanced headform will be the FOCUS Headform, which stands for Facial and Ocular CountermeasUre Safety Headform (Figure 2).

METHODS

In order to develop the FOCUS headform for eye injury response, the response of the human eye to impact was characterized. A

two-part study was utilized to develop biofidelity requirements and develop eye injury risk functions.

First, the force-deflection response of the human eye was determined by dynamic impact testing of eyes in-situ. Human eyes were impacted by a spring powered impactor to determine the amount of force required to displace the eye a given distance into the orbit. The FOCUS synthetic eye was subjected to the same test to assess its biofidelic response to impact.

Second, injury risk functions for five frequently occurring eye injuries were developed based on data from blunt projectile impacts. In addition to existing data reported in the literature, 126 projectile tests were conducted to determine injury response. Logistic regression was used to determine the eye injury risk based upon the normalized energy (J/m^2) of the projectile.

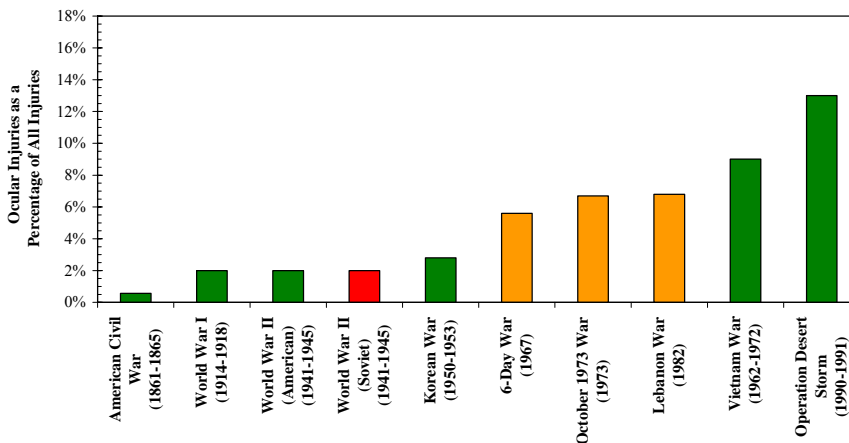


Figure 1: Ocular injuries shown as a percentage of total war casualties from 1861 to present (Heier 1993, Wong 2000). The incidence of ocular injuries has risen from approximately 2% during World War II to over 10% in modern conflicts.



Figure 2: The FOCUS headform is designed to predict eye and facial injuries.

RESULTS AND DISCUSSION

Force-deflection results for individual tests were determined from test data, and from the complete dataset the overall force-deflection corridor is generated (Figure 3). This corridor defines the biofidelity requirements for the FOCUS headform, so that the force-deflection response of the synthetic eye in the headform matches that of the human eye *in-situ*.

Eye injury risk functions were developed based on an extensive database of all eye injury impact tests reported in the literature and from experimental tests (Figure 4). Using over data from 251 eye impact tests, normalized energy (energy per projected area) value was found to be a significant predictor for corneal abrasion, hyphema, lens dislocation, retinal damage, and globe rupture ($p \leq 0.001$ in all cases). These injury risk functions will serve as the basis for the development of new injury risk criteria that use the load measured by the FOCUS eye load cells to predict injury risk.

SUMMARY/CONCLUSIONS

The relative severity of both eye and facial injuries is much greater for the military than

in the civilian population; however, these injuries in both the civilian and military sectors can be severely debilitating and pose an enormous health cost. Due to a lack of instrumentation, the prediction of eye and facial injuries using anthropomorphic test devices is not currently possible. The current study presents biofidelity design requirements for a new headform to determine the risk of eye and facial injuries from impacts. This technology will be useful not only for the military to evaluate protective equipment prior to deployment, but also will be useful in the civilian population for evaluation of various facial impact scenarios, such as sports injuries and automotive accidents.

REFERENCES

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ACKNOWLEDGEMENTS

The authors would like to acknowledge the United States Army Medical Research and Materiel Command for their support of this research and development program

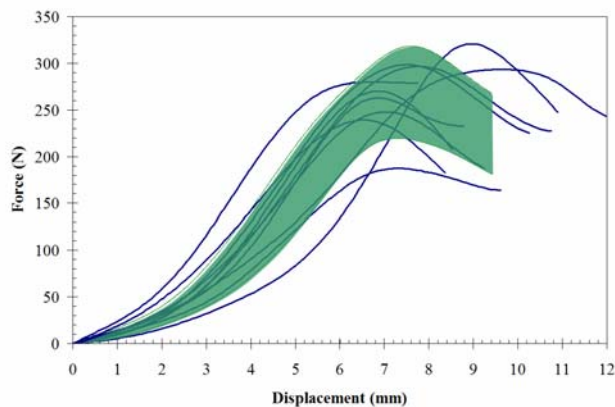


Figure 3: Force-deflection curve of *in-situ* human eye from blunt impact at 10 m/s. The individual lines represent each test. The shaded region represents the corridor for typical force-deflection response.

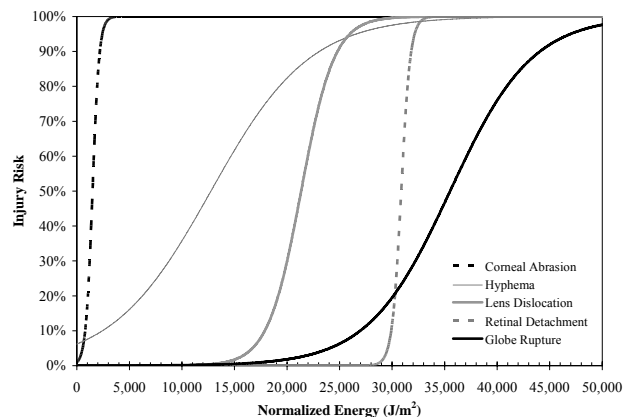


Figure 4: Parametric eye injury risk functions for predicting corneal abrasion, hyphema, lens dislocation, retinal detachment, and globe rupture from impact. These are the basis for eye injury risk functions for the FOCUS.