Comparison of Particulate Matter Eye Injury Between PMHS and Porcine Eye Surrogates.

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I. INTRODUCTION

Over 55 million eye injuries occur each year, leading to at least one day of activity restriction according to the World Health Organisation [1]. Many such eye injuries occur in the workplace, where over 20% of closed globe injuries occur in workshops and metal shops [2]. Workplace injuries tend to be due to particulate matter or chemical exposure, leading to corneal foreign bodies, lacerations, and other severe injuries [2]. Most studies focused on eye injury investigate situations such as airbag impacts, however, only a limited number have studied particulate matter exposure [3–4]. As part of a broader effort to address this gap in literature, the objective of this study is to evaluate porcine eyes as surrogates for PMHS eyes for studying particulate matter injuries.

II. METHODS

Eye Procurement and Particulate Matter Impacts

A total of 16 porcine eyes from a local abattoir on the day of sacrifice and 12 PMHS eyes from Wake Forest School of Medicine's Center for Experiential and Applied Learning were obtained for use in this study. All specimens were tested within 12 hours of procurement and never frozen. Specimens were cleaned of any remaining papillary muscle and connective tissue before being potted in gelatin within a custom printed holder. After the gelatin solidified, baseline imaging was completed, and the holder was loaded into the testing apparatus (Fig. 1). Saline hydration of the specimens was maintained throughout the process. Each eye was exposed to 0.1g of one type of four different particulate matter types, including sand (<2 mm), small glass particles (<2 mm), large glass particles (>2 mm), and metal shavings, at 4 m/s. A total of 12 tests were completed with PMHS eyes, with three repeats for each particulate type. The porcine eyes had four repeats for each particulate type for a total of 16 tests. Following the impact, each specimen was gently flushed with 1 mL of saline to remove non-embedded particles, similar to standard first aid guidelines [5].

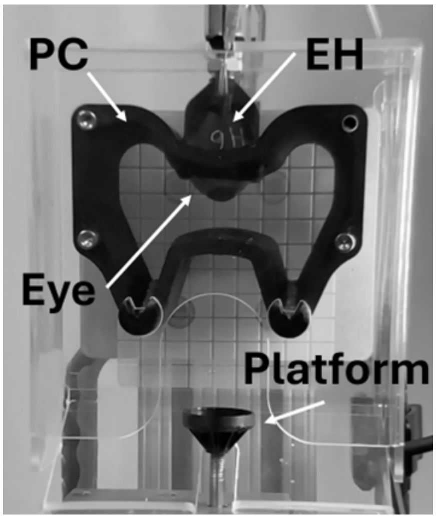

Fig. 1: Eye mounted within holder, within particulate matter impact test rig. PC – Particulate Containment, EH – Eye Holder.

Imaging and Injury Evaluation

Prior to impact, each eye specimen was imaged using a stereo microscope (MU1803, Amscope, Irvine, CA USA), with and without fluorescein dye, to characterise any pre-existing damage. Fluorescein dye is used clinically for corneal abrasion diagnosis [4]. Following impact, the fluorescein dye was reapplied and imaged to visualise corneal abrasions and residual particulate (Fig. 2, left). A MATLAB script was used to analyse the final image to obtain the surface area ratio (fluorescing area/total corneal area) as a measure of eye injury. Residual particulates were included as a part of the affected surface area, due to underlying damaged epithelial or stromal layers.

Optical coherence tomography (OCT) was utilised to visualise the depth of the embedded particles, as the depth of the particle indicates scarring risk (Anterion, Heidelberg Engineering Inc., Heidelberg, Germany), as seen in Fig. 2. Embedded particle depth was quantified as particulate penetrating depth can increase risk of medical complications and long-term consequences, such as scarring. The ratio of embedded particle penetrating depth to the uninjured corneal thickness was quantified as an injury metric in order to normalize across subjects. For

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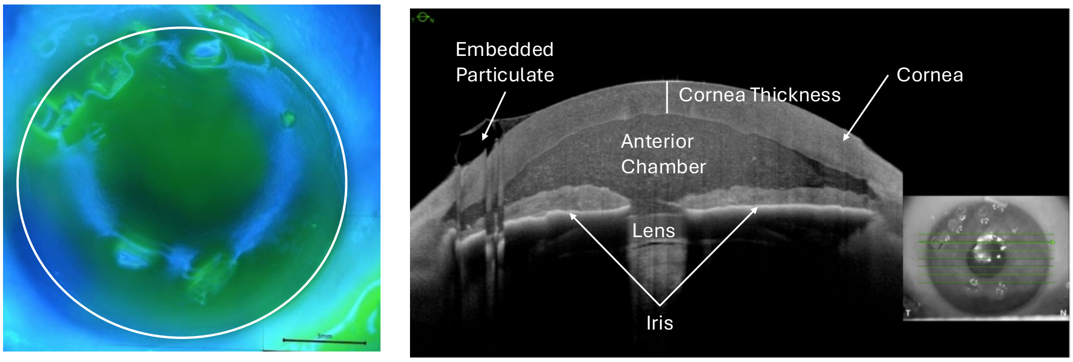

Fig. 2: PMHS eye impacted with sand post-impact fluorescein imaging with the total corneal area outlined in white (left) and corresponding OCT imaging (right).

specimens exposed to metal shavings, OCT images could only be partially used to assess penetrating depth due to fragment opacity. Two-way ANOVAs with a post hoc Tukey test were used to compare the surface area ratio and OCT maximum particle depth values across both species and particulate types ($\alpha = 0.05$).

III. INITIAL FINDINGS

Injury outcomes for porcine and PMHS samples were not found to be statistically different in both surface area ratio and OCT maximum depth metrics ($p > 0.05$). Considering the four particulate types, sand was statistically different from large glass, where large glass had higher values than sand, indicating that large glass is more likely to produce larger amounts of injury than sand ($p = 0.04$). The resulting spread of surface area ratio and OCT depth ratio can be seen in Fig. 3.

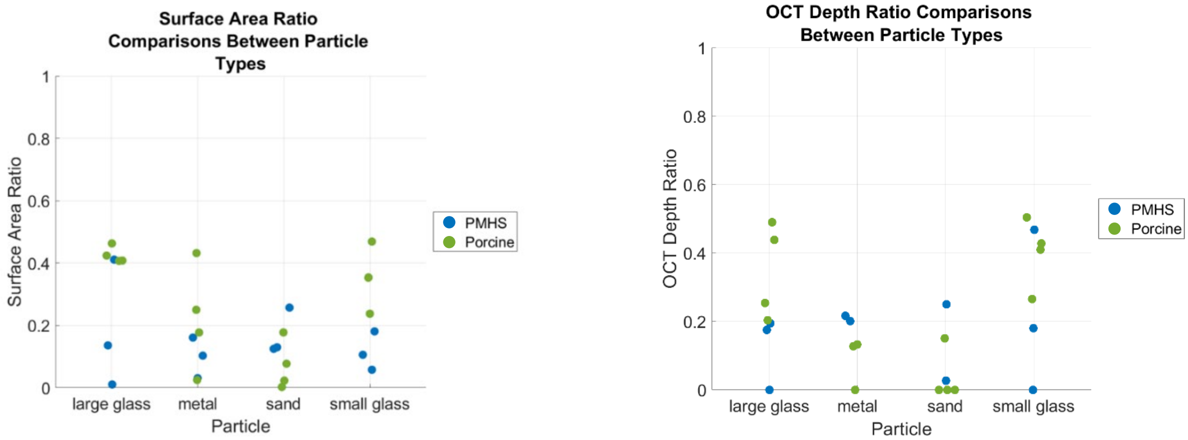

Fig. 3: Resulting data spread for the surface area ratio (left) and OCT depth ratio (right) by particle type.

IV. DISCUSSION

The objective of this study was to evaluate porcine eyes as surrogates for PMHS eyes for studying particulate matter injuries. Large glass had higher surface area ratios than sand, likely due to the large size of each of the particulates, as most of the particulates became embedded in the epithelial layer of the cornea. The large glass group had significantly fewer particles within the bolus, as each large glass particle had more mass than each particle in the sand or small glass groups. While the total kinetic energy of the bolus was the same between particle groups, each large glass particle had higher energy than each particle in the small glass or sand groups due to the quantity of particles. The initial findings show that porcine eyes are a good surrogate for PMHS eyes due to the lack of differences found in both the quantitative measures tested, surface area ratio and OCT depths. Future work will introduce a greater range of impact velocities, injury risk on a per particle basis, as well as injury scales based on clinical impact to vision and the need for medical intervention, particularly focusing on long-term clinical outcomes based on clinician review.

V. REFERENCES

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