# An evaluation of influence of brain simulant stiffness on intracranial displacements and strain


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BIPED HEADFORM
DRDC | RDDC

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## INTRODUCTION

New tools, such as biofidelic deformable head surrogates (headforms), are being developed to investigate mild traumatic brain injury (mTBI) [1]. These headforms have elastomeric brain simulants that can be used to measure intracranial strains [2].

Brain tissue has a highly rate sensitive response, being notably stiffer at strain rates associated with blunt impact brain injury [3]. While Sylgard 527 has a stiffness that is quick similar to that of brain under quasi-static loading rates [4], our comparison between cadaver [5] and headform [1] brain response showed a notably stiffer response in the cadaver brain [6]. In this work, we evaluate different brain simulants based on Polydimethylsiloxane (PDMS) mixtures.

## METHODS

The headform used in the work was the BIPED [1] with embedded markers for deformation tracking under high-speed X-ray (HSXR), using digital image correlation [2,5]. The headform had a falx-tentorium membrane and a brain stem model (Fig.1a). It was perfused with water to float the brain, and impacted by a neoprene end cap on a linear impactor at a speed of 3 m/s. The brain deformation was monitored using a HSXR capturing the motion at 5 kHz. The brain surrogate stiffness was tuned by mixing two commercially available PDMS elastomers, Sylgard 527 and 184 (Fig. 1b).


(a)

| 527:184 | Stiffness |
|---|---|
| Pure 527 | Low |
| 40:1 | |
| 20:1 | |
| 10:1 | High |

(b)

**Fig. 1: (a) Photograph of the headform components. (b) PDMS brain materials.**

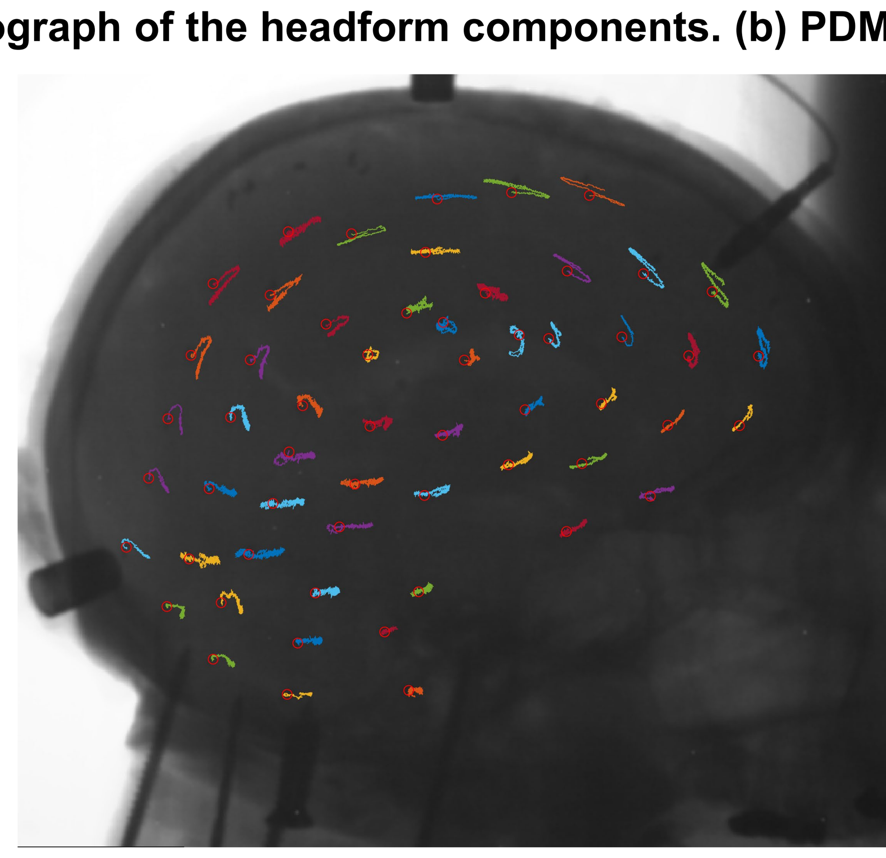


**Fig. 2: Brain displacement paths from a cadaver impact [4].**

Digital Image Correlation (DIC) analysis was used to calculate displacement and strain fields within the headform. DIC parameters used were:

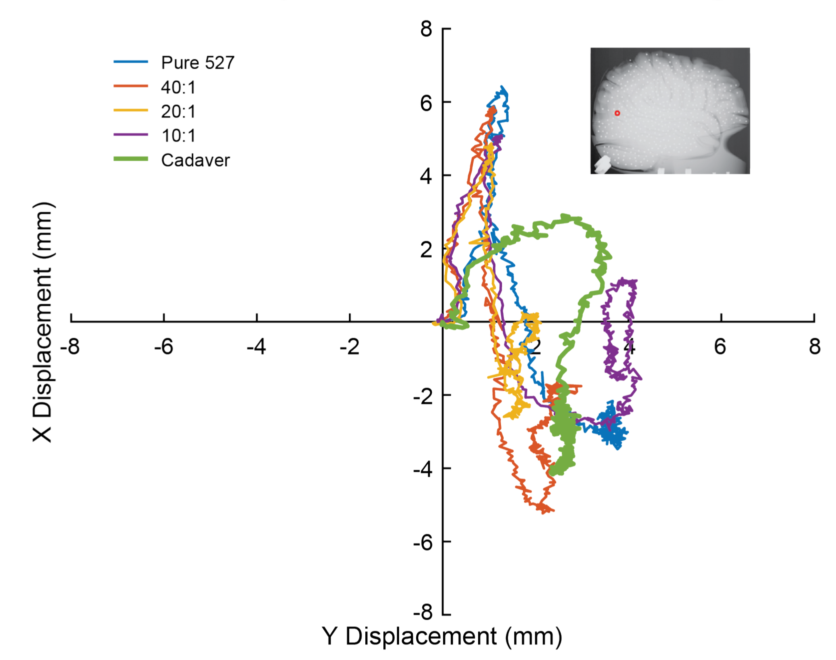
| DIC Software | Subset Radius (px) | Subset Spacing (px) | Strain Radius (px) |
|---|---|---|---|
| Ncorr | 25 | 1 | 20 |

A CORA analysis was performed on intracranial displacements from the present work and cadaveric test data (Fig. 2) using the following settings:

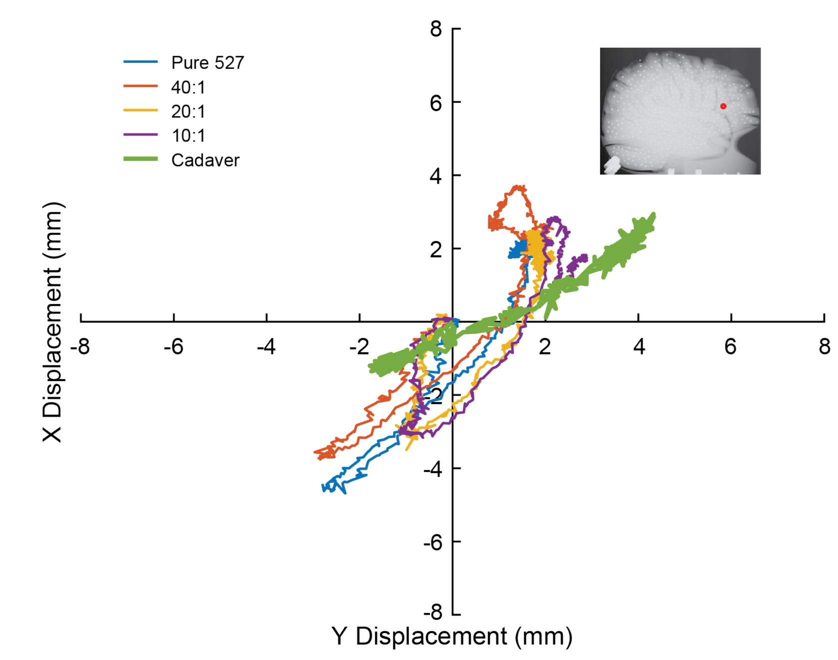
| CORA Software | D_MIN<br>D_MAX | G_1<br>G_2 | K_V<br>K_P<br>K_G | G_V<br>G_P<br>G_G |
|---|---|---|---|---|
| Settings | 0.01<br>0.40 | 0<br>1 | 3<br>1<br>1 | 0.333<br>0.333<br>0.333 |

## RESULTS

The displacement trajectories in the headform involving different brain simulant materials, were compared to cadaver data for the same impact conditions in Fig. 3. The results of the CORA analysis for displacement in all regions of the brain are shown in Table 1, averaging the response of 50 points evenly distributed throughout the brain.




(a)




(b)

**Fig. 3: Full displacement trajectories over 90 ms for locations in the (a) occipital and (b) frontal regions.**

The strain response in the frontal region for a headform with different brain simulant materials, were compared to cadaver data for the same impact conditions in Fig. 4.

| | Pure 527 | 40:1 | 20:1 | 10:1 |
|---|---|---|---|---|
| Cross-Correlation | 0.741 | 0.734 | 0.694 | 0.731 |
| Progression | 0.697 | 0.690 | 0.627 | 0.602 |
| Size | 0.527 | 0.513 | 0.454 | 0.590 |
| Phase | 1 | 1 | 1 | 1 |

**Table 1: Summary of average CORA values from displacement comparisons to a cadaveric dataset [4].**

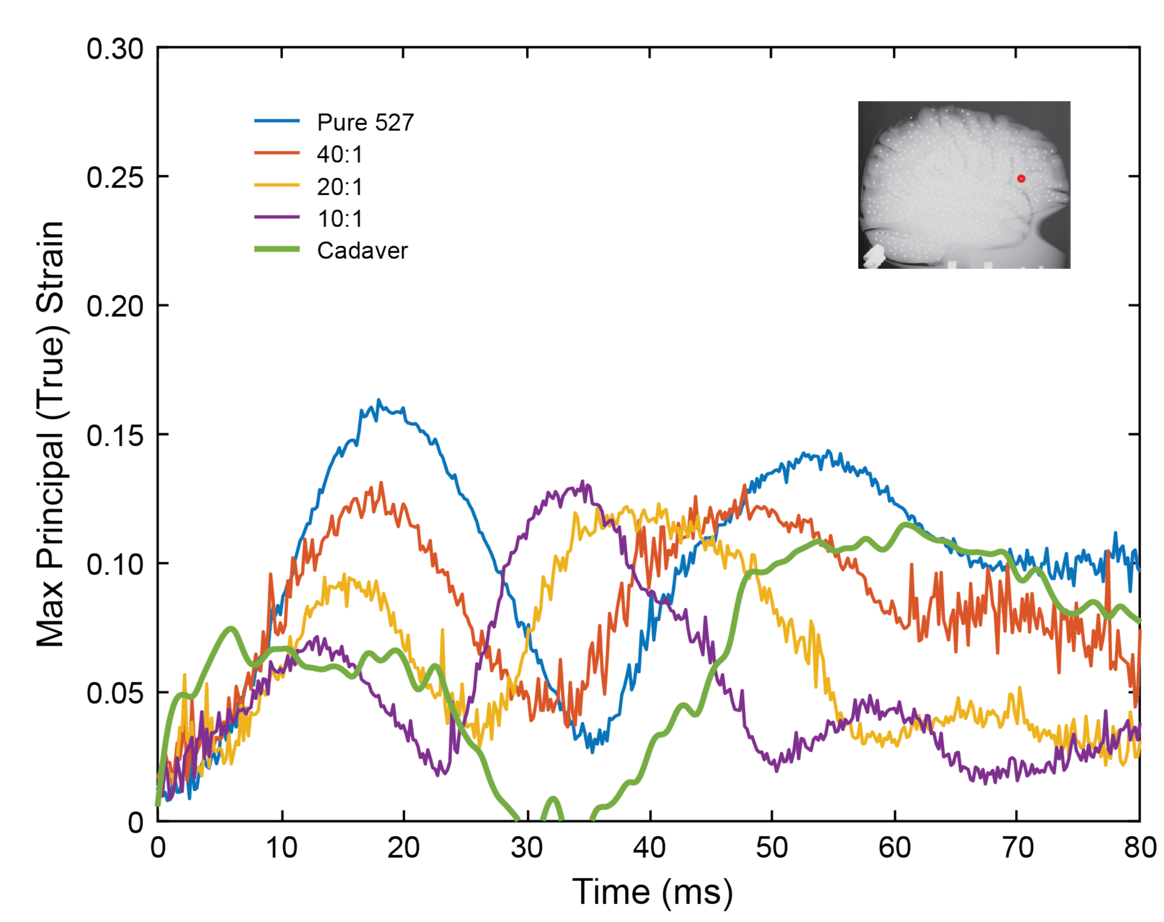



**Fig. 4: Strain response comparison between different tissue simulants and cadaver in the frontal region.**

## DISCUSSION

The results show that the pure Sylgard 527 had the closest approximation of the displacements seen in the cadaver, although when optimizing for displacement amplitudes, the 10:1 ratio was best (Table 1). When comparing strain responses, the strain amplitudes in the 10:1 mixture was best. Although the progression (shape) of the Pure 527 simulant response was best (Fig. 4). Further optimization of the boundary conditions are required to improve biofidelity of the headform.

## REFERENCES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