COMPOSITE HYDROGEL: A NEW TOOL FOR REPRODUCING THE MECHANICAL BEHAVIOUR OF SOFT HUMAN TISSUES

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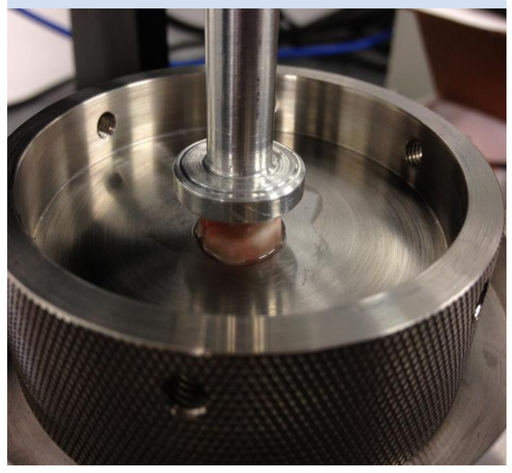
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INTRODUCTION

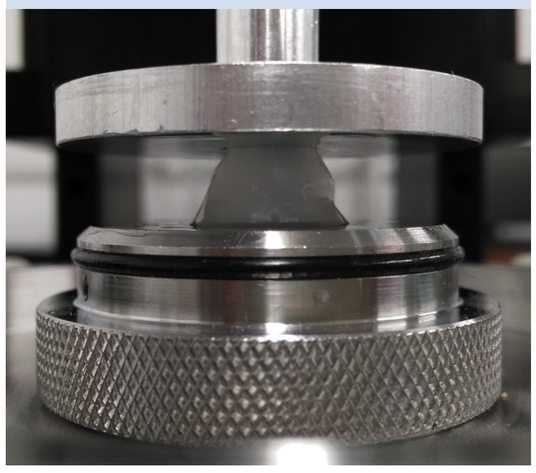
Experimenting with real soft tissue is important to understand its behaviour. However, this is difficult due to ethics, cost of equipment and availability. There is a need for synthetic materials that can mimic real tissues. A composite hydrogel (CH) constituting of PVA and phytagel is able to reproduce the viscoelastic responses of various soft tissues at certain concentrations [1]. Varying the concentration of PVA and phytagel results in a CH with different viscoelastic properties. Here we report an example of brain shift mimicking for robotic surgical experiments.

MATERIALS AND METHODS

Porcine brain compression-relaxation tests

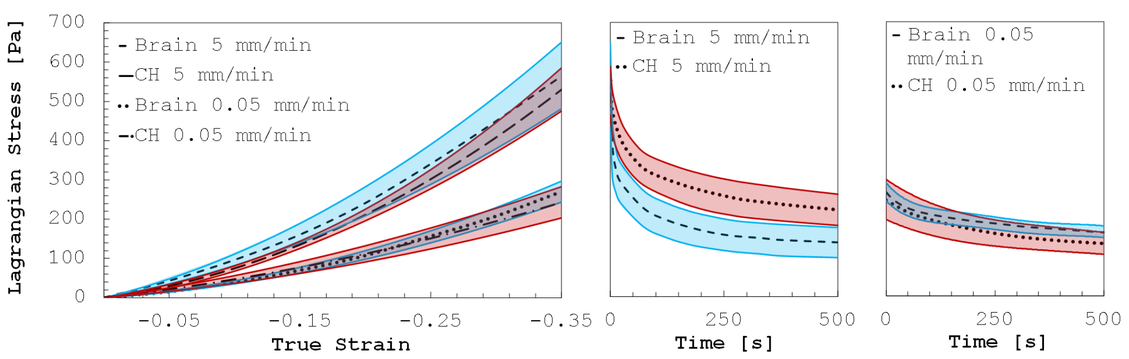


Synthetic CH compression-relaxation tests



In order to tune the behaviour of the CH, unconfined compression tests were performed at 30% strain and 1, 0.01 and 0.0001 s-1 strain rates for both the porcine brain and the composite hydrogels. The stress and viscoelastic properties at 30% strain were calculated.

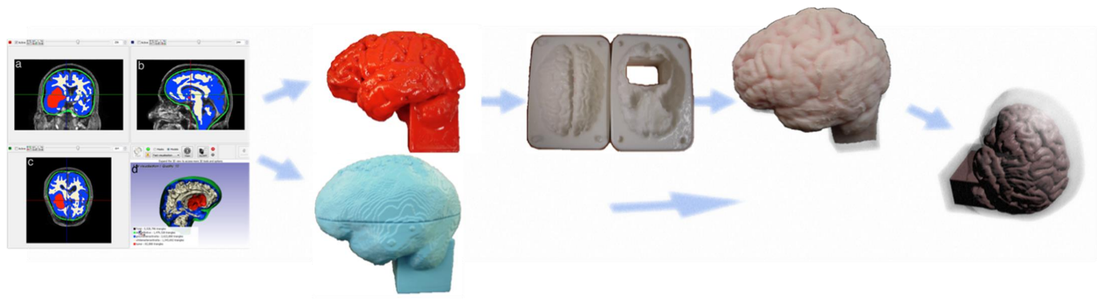
CH TUNED TO REAL BRAIN



The optimal composition of CH that matches the mechanical behaviour of porcine brain tissue was found to be 5% PVA 0.59% phytagel (wt).

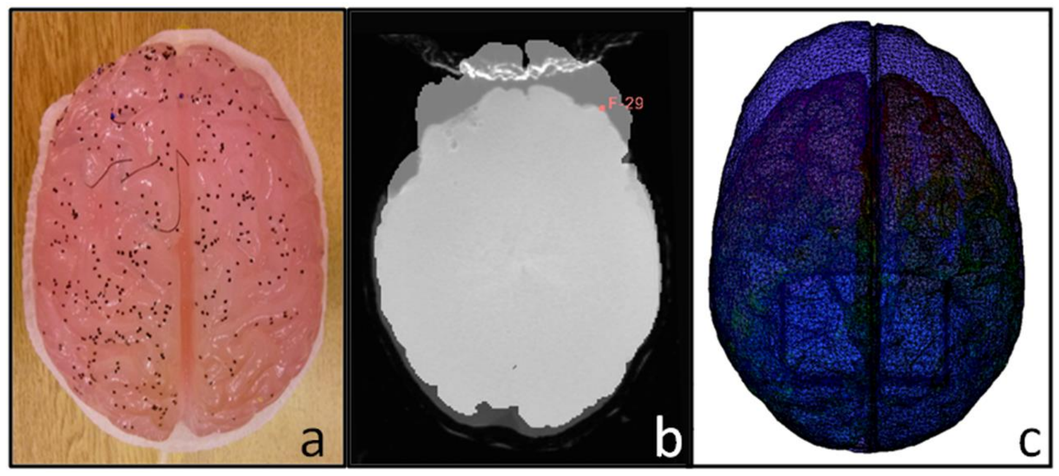
PATIENT SPECIFIC PHANTOM WORKFLOW

Patient MRI scans → 3D printed Brain and skull → Brain negative silicone mould → Patient specific brain phantom → Experimental apparatus



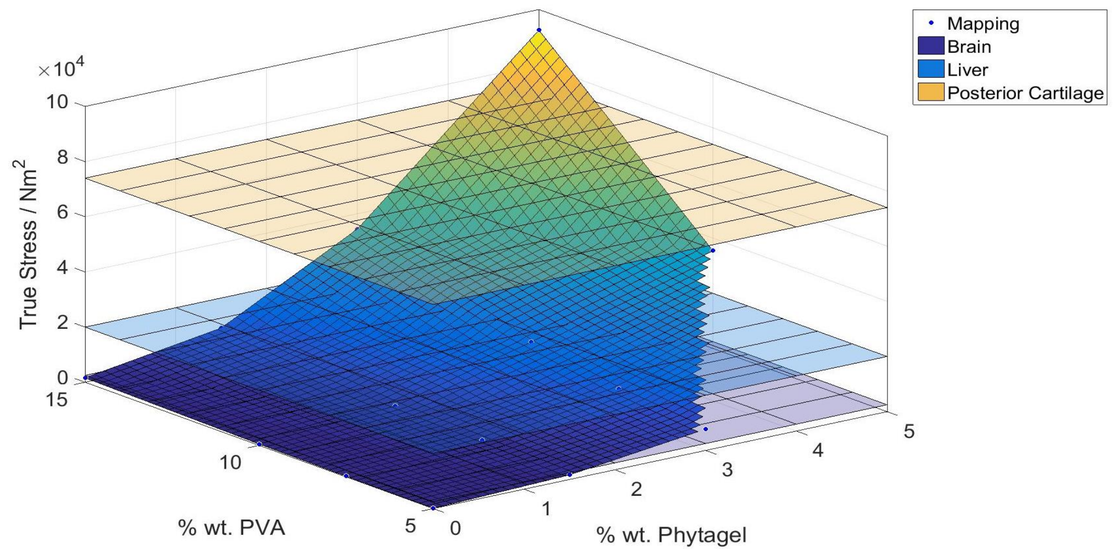
Real size geometries can be obtained from MRI scans. The gel can be cast in patient specific silicon mould to reproduce the surgical scenario. The scenario can also be modelled with finite element techniques for surgical pre-operative planning.

FROM PHANTOM TO 3D MODELLING



A comparison between the brain shift deformation measured by MRI scans (b) and the results provided by the 3D finite element model (c) is shown here.

PHANTOM APPLICABILITY TO OTHER TISSUES



By means of a systematic testing protocol, the mechanical behaviour of the CH was studied for a wide range of compositions. We are now able to reproduce a series of human soft tissues by simply varying the constituent concentrations of the CH. Examples of the CH compositions that match various soft tissue mechanical behaviours from literature are:

Brain [2] - 5% wt. PVA 1.81% wt. phytagel

Liver [3] - 10% wt. PVA 3.33% wt. phytagel

Posterior cartilage [4] - 15% wt. PVA 4.45% wt. phytagel

CONCLUSIONS AND FUTURE WORK

It is possible to reproduce the mechanical behaviour of human soft tissues using a custom designed synthetic material called CH.

The use of realistic phantoms enable more controlled experimental setups that offer a reliable ground truth for advanced computational modelling for surgical/traumatic scenarios.

The hydrogel is cheap, easy to reproduce, widely accessible, non-toxic, MRI compatible and can be cast in complex 3D shapes.

Thanks to the tunability of the novel polymer blend we are now exploring the suitability of the CH for the reproduction of other human soft tissues (liver, cartilage, lung).

REFERENCES

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