Flexible Force Sensors to Improve Safety and Training in Operative Birth

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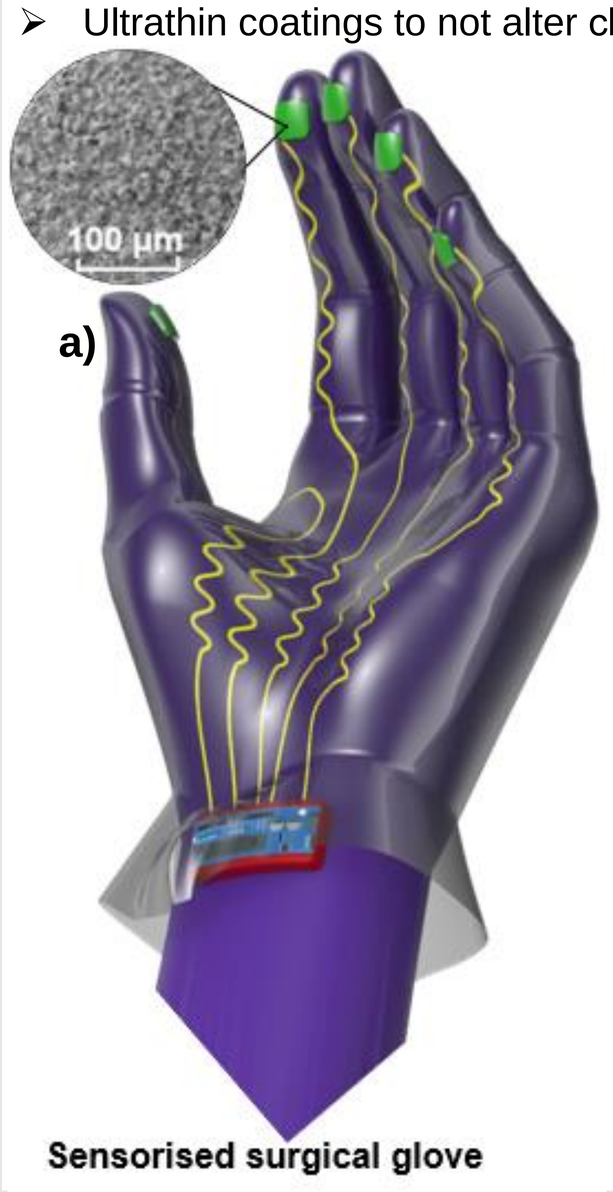
Introduction and clinical need

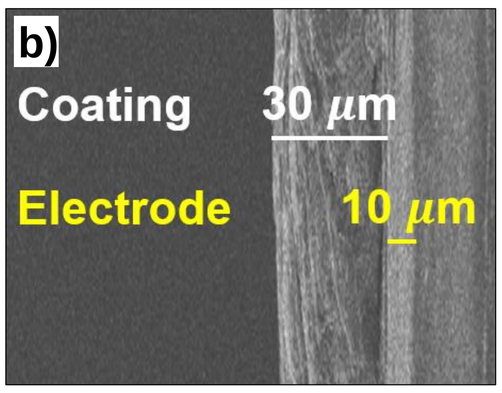
- Tactile sensors are useful to map contact and force for different applications. Using these sensors together with machine learning, gesture, grasp, and object recognition are achieved. We find inspiration in these to develop our own nanocomposites for healthcare.
- Following the need for interventional surgery devices, we are contributing in the simplest way of manufacturing a triboelectric nanocomposite coatings to act as a tactile sensors.
- The sensors work even with a second layer of sterile surgical glove on top, ensuring sterility and safety.

Multifunctional sensorised glove to address the need

- Coating can be directly integrated onto healthcare devices.
- Ultrathin coatings to not alter clinicians' tactile perception.



Ultrathin sensors



Non-cytotoxic

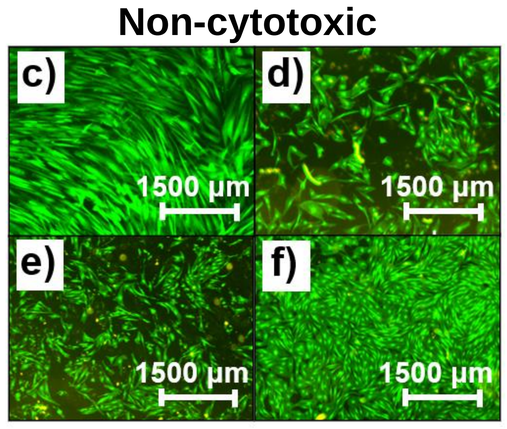


Figure 1. a) Sensorised surgical glove with triboelectric, ultrathin sensors on fingertips. b) SEM image of the cross-section of the triboelectric sensor, showing the thicknesses of the coating and the electrode. c-f) Fluorescence microscopy images showing c) control Human Dermal Fibroblast (HDF) cells (without sample) and d), e) and f) are HDF cells treated with samples for 24, 48 and 72 h extracts respectively

Force/stiffness calibration

- Customizable rig (achieving 0.0088 N sensitivity) assembled.
- Position motor, data acquisition card and force gauge working simultaneously by means custom software developed using LabView.
- Sensors achieve 45 N force range and 0.1 N sensitivity.

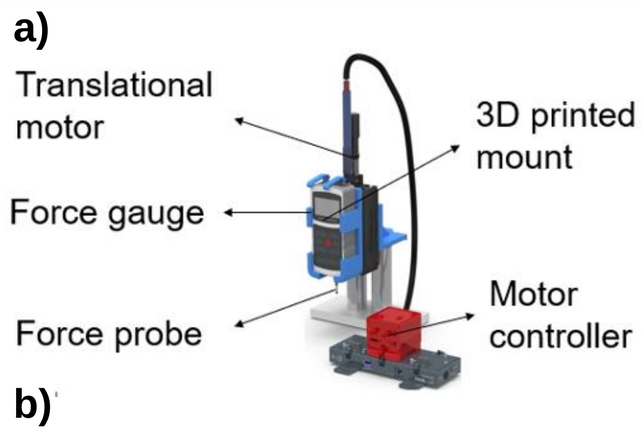


Figure 2. a) Force/stiffness calibration test setup. b) Force calibration curve for a specific sensor.

Patient & Public Involvement (PPI) panel

- PPI panels have welcomed the device with great enthusiasm.
- Feedback was gained on the design and functionality.
- > 90% of women indicated they would want to be examined with the glove in labour if it could improve safety outcomes.

Clinical application: Fetal orientation detection and real-time force readings to improve the safety of operative birth

- Vaginal examination in labour subjective and distinguishing the between fontanelles is key indicator of fetal position but challenging.
- Instrument placement suboptimal in 30% cases and operative vaginal birth injuries highly litigated.
- Operative birth rates decreasing-lack of confidence.
- Neonatal phantoms developed to replicate sutures, fontanelles, caput and molding.
- Glove provides force readings and detects phantom sutures (peaks in figure 3b) due to stiffness change.
- Software to alert clinician when excessive force applied and to display fontanelle encountered.

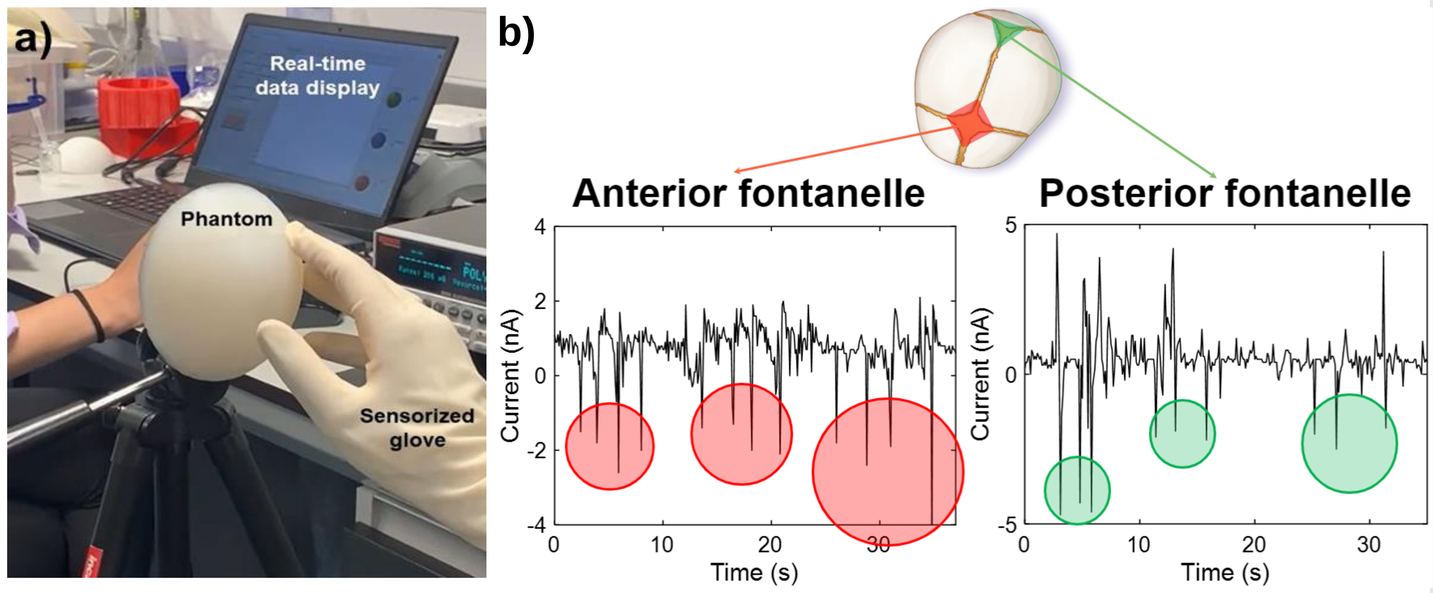


Figure 3. a) Test setup. b) Current results using the glove for anterior and posterior fontanelle examination on the phantom (each peak corresponds to a crossed suture, peaks counted to distinguish fontanelles – 4 peaks/sutures for the anterior fontanelle and 3 peaks/sutures for the posterior fontanelle).

Conclusions

- Sprayable nanocomposite based triboelectric force sensing layer as first proof of concept to meet healthcare requirements.
- Accurate detection of fetal sutures and real-time force readings on neonatal phantoms leading to improved training and safety of operative birth in the future.

Future work

- Finalize extensive cytotoxicity tests on the sensors to support clinical translation.
- Fully self-powered tactile system and apply machine learning.
- Future pilot study on women in labour to demonstrate feasibility.

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