UCD Impact Case Study

Research to Literally Get Under the Skin of Things

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TECHNOLOGICAL HEALTH ECONOMIC

ACADEMIC SOCIAL

SUMMARY

An unusual research topic for her doctoral thesis led Dr Aisling Ní Annaidh into the fascinating world of tissue biomechanics – the study of research into the mechanical and physical properties of tissue – and developing a particular focus on the skin. This has in turn led her and her team to undertake a wide range of research over the past decade with significant practical healthcare impacts. The outcomes include unexpected results leading to changes to EU standards for helmet testing, supporting innovation in Ireland's world-leading medical devices sector and, most recently, a novel approach to the age-old challenge of customising wheelchairs for people who have a physical disability.

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Tissue Biomechanics has Widespread Applications

The opportunity to undertake research for a PhD 13 years ago into the mechanics of stabbing provided Aisling Ní Annaidh with the opportunity to explore new avenues in what she candidly admits is the specialised niche area of tissue biomechanics. The Associate Professor of Mechanical Engineering Design and her students now undertake a wide range of studies into how tissues in the body behave. Their work, a combination of experimentation and modelling, provides practical benefits for a range of individuals.

It all began when Dr Ní Annaidh was looking for a thesis topic for her doctorate at UCD. Her Supervisor, Prof Michael Gilchrist, suggested she respond to a request for help from the Irish State Pathologists Office, which wanted to understand the force required to stab someone and cause significant damage, with a view to determining criminal intent.

"We looked at parameters affecting this, such as the amount of clothing, speed and differences in the types and sharpness of knives. The topic caught people's attention and it was interesting in itself. But more than this, at the end of the day it has also allowed me to specialise in the area of skin biomechanics. And that, in turn, has allowed me to develop my interests in different applications within this niche area," she says.

The topic of skin biomechanics is not just niche, it is also

complex, offering a variety of avenues for research that yield highly practical impacts. "The thickness of skin differs from person to person and age has a big effect on its material properties in terms of strength and composition; in an older person layers shrink and dehydration can become an issue," Dr Ní Annaidh adds. "As well as differing from person to person there's also variation in the properties of skin in different parts of the body."

From Cadavers to Non-Invasive Experiments

Unlike her initial research, which was conducted experimentally using cadavers, Dr Ní Annaidh's focus now is on finding ways to conduct non-destructive and painless experiments on living people. 'If you are going to be undertaking surgery on someone, for example, and you want to predict how their skin is going to behave, then you really should not be using a one size fits all approach. So our focus now is on patient-specific measurements of tissue," she says. For this she uses suction based devices, which measure skin behaviour when a vacuum is applied to it, and acoustic (ultrasound-type) techniques. Development of newer techniques is an area of potential opportunity, subject to the availability of the necessary funding.

"I try to do a combination of experiments and modelling in everything I do. There's absolutely no point in having a sophisticated model that has no basis in reality. The experiments provide us with the information we need to create more sophisticated models – so they both have a place in our work and complement each other very well. By measuring the tissues themselves we can predict how they will behave in different scenarios, in extreme conditions such as a traffic or sporting accident or in surgery, for example."

Unexpected Result Leads to New Helmet Standards

The output of this research is evident in a range of applications. Research by one of her PhD students, Dr Antonia Trotta, for example, undertaken as part of a larger EU project to improve sports helmet design, looked at the level of friction created between a person's scalp and the lining of their helmet in an accident.

Motorcyclists and sports participants are urged to wear a close fitting helmet that will stay in place if there is an impact. This advice remains true but, counterintuitively, Dr Trotta discovered that a reduced level of friction between the scalp and the helmet lining, allowing slight movement of the head within the helmet, actually resulted in improved protection. These findings have directly led to changes in European standards for helmet testing, with specific requirements now set for the amount of friction present in the dummy head.

Keen to take advantage of the body of research work undertaken over the past decade within the School of Mechanical & Materials Engineering by Dr Ní Annaidh and her team, Ireland's flourishing medical devices sector regularly seeks her advice. "Companies will often come to me with a product that they've had an issue with and they want to investigate it further and do some modelling of their product and how it interacts with the skin," she says.

A Pain Free Future for Jabs?

UCD has been an active player in the development of one of the up-and-coming technologies transforming medicine today – microneedles. Dr Ní Annaidh has contributed valuable technical expertise to the work in this area undertaken by the UCD Medical Device Design Group led by her colleague Dr Eoin O'Cearbhaill, Director of the UCD Centre for Biomedical Engineering. The Group's work has already led to the establishment of one spin out company to exploit its commercial potential in one application.

Microneedles, typically shorter than the thickness of a sheet of paper and about the width of human hair, penetrate the top layer of dead skin to reach the living layer, the epidermis, below. Avoiding contact with nerve endings, they do not cause pain normally associated with the delivery of drugs or vaccines by needles. They offer benefits, too, in diagnostics.

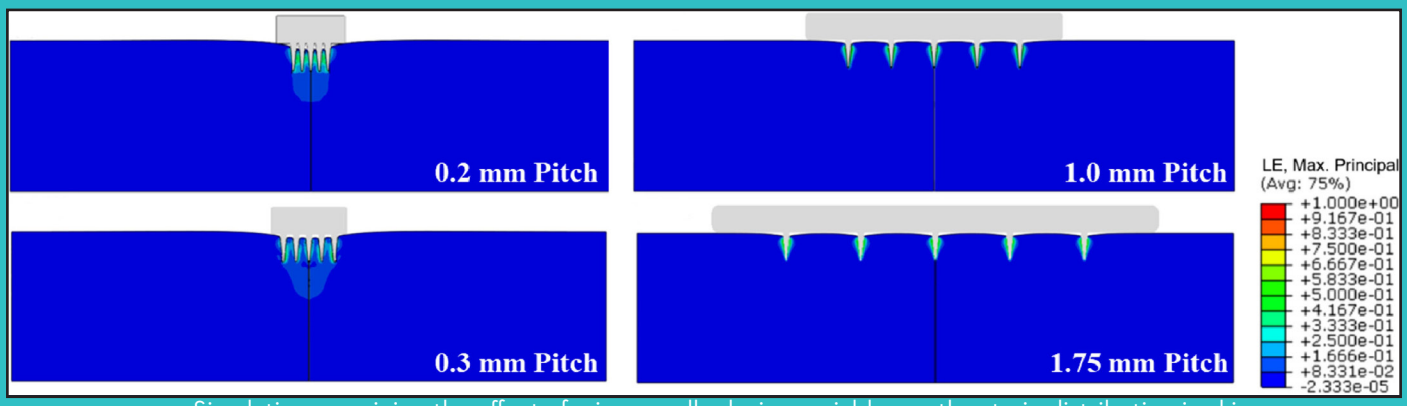
Dr O'Cearbhaill acknowledges that a lot has been achieved but there is a lot more to do in this area. "There is some understanding of what's involved but it is actually really complex and the field of microneedles depends on interdisciplinary research. We need the inputs from experts in drug formulation, engineers and vaccinologists and we really value the contribution of Dr Ní Annaidh, who brings a deep understanding of the skin's morphology and function to our work."

Together with Dr O'Cearbhaill, Dr Ní Annaidh is now undertaking a project examining the role of skin biomechanics in microneedle deployment and efficacy. Their doctoral student, Wenting Shu, is using a combination of experiments and simulations to help facilitate the design and optimisation of new microneedles.

Addition is Better than Subtraction for WheelChair Users

In another project, doctoral student Susan Nace, who is also an employee of non-profit disability services provider Enable Ireland, is currently developing an improved way of designing custom-contoured wheelchairs for people with specialised requirements in order to prevent pressure sores and correct postural problems.

The conventional approach to this is hand cutting and shaping of foam materials, a labour intensive and wasteful subtractive process. The new approach is a more efficient 3d printed one which facilitates designs with internal structures to create airflows through the chair and thus reduce the risk of pressure sores and improve skin comfort.



Simulation examining the effect of microneedle design variables on the strain distribution in skin. This can help us understand how much force is needed to penetrate the tough outer skin surface.

Research References

Insights into the mechanics of solid conical microneedle array insertion into skin using the finite element method

W Shu, H Heimark, N Bertollo, DJ Tobin, ED O'Cearbhaill, A Ní Annaidh Acta Biomaterialia 135, 403-413

The presence of Wormian bones increases the fracture resistance of equine cranial bone, LA Zambrano M, D Kilroy, A Kumar, MD Gilchrist, A Ní Annaidh, PloS one 16 (4), 2021

Mechanical Characterization and Modeling of the Porcine Cerebral Meninges, B Pierrat, L Carroll, F Merle, DB MacManus, R Gaul, C Lally, MD Gilchrist, A. Ní Annaidh, Frontiers in Bioengineering and Biotechnology 8, 801, 2020

Biofidelic finite element modelling of brain trauma: Importance of the scalp in simulating head impact, A Trotta, JM Clark, A McGoldrick, MD Gilchrist, A. Ní Annaid, International Journal of Mechanical Sciences 173, 105448, 2020

Manufacturing custom-contoured wheelchair seating: A state-of-the-art review, S Nace, J Tiernan, A Ní Annaidh, Prosthetics and orthotics international 43 (4), 382-395 3, 2019

Tension lines of the skin, A Ní Annaidh, M Destrade, Skin Biophysics, 265-280, 2019

Effect of brain matter in torsion, V Balbi, A Trotta, M Destrade, A Ní Annaidh, Soft matter 15 (25), 5147-5153, 2019

Evaluation of the head-helmet sliding properties in an impact test, A Trotta, A Ní Annaidh, RO Burek, B Pelgrims, J Ivens, Journal of biomechanics 75, 28-34 22, 2018

The importance of the scalp in head impact kinematics, A Trotta, D Zouzias, G De Bruyne, A Ní Annaidh, Annals of biomedical engineering 46 (6), 831-840 16, 2018

Characterization of the anisotropic mechanical properties of excised human skin, A Ní Annaidh, K Bruyère, M Destrade, MD Gilchrist, M Otténio, Journal of the mechanical behavior of biomedical materials 5 (1), 139-148, 2012

Automated estimation of collagen fibre dispersion in the dermis and its contribution to the anisotropic behaviour of skin, A Ní Annaidh, K Bruyère, M Destrade, MD Gilchrist, C Maurini, M Otténio, Annals of biomedical engineering 40 (8), 1666-1678, 2012

Media & Social Media References

https://www.ucd.ie/research/impact/researchimpact/case-studies/pdf/CASE_STUDY_TROTTA.pdf

https://www.irishexaminer.com/news/arid-30937482.html

https://irishtechnews.ie/mechanics-of-a-twisted-brain-how-side-impacts-to-the-head-can-be-as-damaging-as-frontal-impacts/

https://www.engineersireland.ie/Engineers-Journal/News/the-mechanics-of-stabbing-assessing-stab-penetration-forces

https://soundcloud.com/michel-destrade/smaller-interviewmp3?fb_action_ids=315307898644348&fb_action_types=soundcloud%3Apublish

https://www.irishexaminer.com/news/arid-20290990.html

https://www.technologyreview.com/2013/02/26/179675/experiments-on-cadavers-settle-100-year-old-puzzle-over-human-skin-strength/

Funding acknowledgements

This research was / is supported by the HEADS project (Head protection: a European network for Advanced Designs in Safety), an Innovation Training Network funded under the European Commission's Marie Sklodowska-Curie Programme; The Irish Research Council and Enable Ireland under the Irish Research Council's Employment Based Postgraduate Programme; and the UCD-CSC (University College Dublin - China Scholarship Council) scholarship.