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Fresh eyesight insights bring human eye into sharp focus

EU-funded researchers are unlocking the secrets of the human eye, creating cutting-edge digital models that are transforming the quality of eye surgeries.

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For 89-year-old Mercedes Alvarez from the northern Spanish city of Gijón, cataract surgery was more than a routine medical procedure, it was a life-changing experience.

“At first, I didn’t want to do it, even though I had trouble seeing anything,” Alvarez said. “I spent sleepless nights worrying because, at my age, even a simple procedure felt risky.”

However, after doctors reassured her that age was not a barrier to treating cataracts – a clouding of the lens of the eye – she decided to go ahead. Delighted with the result, she can now appreciate life’s small details again, such as reading the newspaper every morning.

“I put on my glasses, and I can read even the small print!”

Alvarez is one of more than four million people who undergo cataract surgery in the EU every year, according to Eurostat – the EU’s statistical office.

Her experience is a testament to the major advances in cataract surgery and eye care in recent years, driven in part by international collaborative research funded by the EU.

Optical illusion

Dr José Manuel González-Méijome, founder and coordinator of the Clinical and Experimental Optometry Research Lab at the University of Minho in Braga, Portugal, coordinates one such research initiative – a four-year EU-funded project called OBERON that will conclude in 2025.

The OBERON research team brings together eye experts from universities in Belgium, Poland, Portugal, Spain, Switzerland and the UK, along with non-academic partners from the Netherlands and Spain.

Combining optics and biomechanics, they are developing state-of-the-art computer models of the eye that will help make eye surgery safer and more accurate. The team also educates 15 young researchers, helping them to embrace the latest interdisciplinary advances in eye structure, function and treatment.

González-Méijome, a professor of optometry and vision science at the University of Minho, describes the eye as a biological tissue with both optical and biomechanical properties interacting between them.

The computer models developed are able to faithfully mimic these properties, providing valuable guidance to vision scientists, optometrists and eye surgeons on predicting the behaviour of eye tissues under normal development and different clinical conditions.

Delicate procedure

To help understand the surgeon's task, González-Méijome explains that a human eyeball weighs only about 7.5 grams and measures around 2.3 centimetres.

"It's incredibly small and complex and the surgeon must navigate inside without harming the different layers, while for vision scientists in general, it is critical to understand how all those structures interact as the eye develops," he said.

During cataract surgery, doctors remove the cloudy eye lens and replace it with a clear, artificial lens. According to Eurostat, it is the most common surgical procedure in the EU. In 2021, France recorded the highest number of these procedures per capita, followed by Austria, Estonia and Luxembourg.

Modern modelling techniques, such as those being developed by the OBERON researchers, enable a shift from traditional trial-and-error methods to personalised and more precise treatment plans for each patient.

Their approach allows surgeons to tailor surgical solutions to each patient based on their specific anatomical characteristics rather than relying on generic averages, which results in a much better outcome for the patient.

On top of that, the researchers are also developing new treatments that will be able to reduce or even prevent eye lens malfunction, which usually develops with age, thus removing the need for surgery. This is increasingly important, given Europe's ageing population.

An increasingly short-sighted world

González-Méijome and the OBERON research team are also addressing eyesight issues that affect younger people, such as myopia, or short-sightedness – a condition that causes distant objects to appear blurry. This is becoming increasingly common among children in Europe.

According to González-Méijome, short-sightedness is influenced by both environmental and genetic factors. Recent studies have shown a link between higher education levels, increased screen time and the rising incidence of myopia in children in Europe.

"While intensive near-work tasks seem to increase myopia development, we can't tell children not to study – we usually advise the opposite," said González-Méijome. "So we need to better understand how to manage excessive eye growth despite the tasks posed on our children's visual system."

As a result, myopia is unlikely to disappear in the foreseeable future and there will be an increased reliance on vision scientists and eye care practitioners to mitigate the problem by reducing myopia onset and slowing its progression through better optical and surgical options.

The modelling techniques on eye optics and function, laser refractive surgery or cataract surgery developed in OBERON can help to ensure that optical and surgical interventions are as accurate and safe as possible.

Mathematical precision

Part of the important advances being made in eye surgery comes from applying mathematical precision to the biological and physiological workings of the eye.

From 2014 to 2017, Professor Hrvoje Šikić, a professor of mathematics at the University of Zagreb, Croatia, led an EU-funded research project called MOLEGRO which developed the world's first mathematical model of eye lens growth.

Successfully blending mathematical theory with biological insights made it possible to decode the complex biology of how the eye lens develops. For Šikić, this interdisciplinary approach presented an intriguing challenge.

"At first, I wasn't sure, but then I realised there would be some interesting mathematical challenges to work on," said Šikić, who had limited prior experience in applying mathematical models to biology.

The idea came from a friend of his, US biologist Dr Steven Bassnett, a renowned leader in the field of lens cell biology.

The challenge, says Šikić, was to set aside the typical lone-wolf mentality of the mathematician, used to working in the abstract world, and learn to work as part of a larger team operating in the real world.

Unique growth process

The joint venture created the first mathematical model of lens growth that shows how cells in the eye lens change over time, as the lens evolves throughout a person's lifetime.

The eye lens is unique in that it grows by adding new cells inside the capsule, an elastic membrane surrounding the lens. The old cells are not discarded, but are packed into the centre of the organ.

The findings of Šikić's team have been helpful in guiding cataract surgery techniques.

The team has also identified how the eye's growth process contributes to the development of cataracts in combination with known risk factors, like exposure to ultraviolet light. This provides insights into how we could delay or prevent the development of eye problems.

"The impact of cataracts remains quite significant worldwide, especially in developing countries, where they continue to be a leading cause of blindness," said Šikić.

Cancer proof

Together with Bassnett, Šikić is now investigating one of the more surprising aspects of their research: why the eye lens appears to be cancer-proof.

"In itself, there's nothing special about the lens cells that would stop cancer, the tissue is similar to skin," Šikić explained. "We are currently investigating whether the absence of cancer in this tissue is linked to its unique growth process."

“The idea came to us as we were working in MOLEGRO. It is intriguing and new and will certainly be met with scepticism. That’s why it must be really well argued. But we are analysing various concrete models and believe that within two years, we should have the work completed and sent for review.”

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