Bionic hand merges with user's nervous and skeletal systems, remaining functional after years of daily use

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Neuromusculoskeletal hand prosthesis. Credit: Ortiz-Catalan et al.

Karin's life took a dramatic turn when a farming accident claimed her right arm more than 20 years ago. Since then, she has endured

excruciating phantom limb pain. "It felt like I constantly had my hand in a meat grinder, which created a high level of stress and I had to take high doses of various painkillers."

In addition to her intractable pain, she found that conventional prostheses were uncomfortable and unreliable, and thus of little help in daily life. All this changed when she received groundbreaking bionic technology that allowed her to wear a much more functional prosthesis comfortably all day. The higher integration between the bionics and Karin's residual limb also relieved her pain. "For me, this research has meant a lot, as it has given me a better life."

A remarkable fusion of human and machine

Mechanical attachment and reliable control are two of the biggest challenges in artificial limb replacement. People with limb loss often reject even the sophisticated prostheses commercially available due to these reasons, after experiencing painful and uncomfortable attachment with limited and unreliable controllability.

A multidisciplinary group of engineers and surgeons solved these problems by developing a human–machine interface that allows the prosthesis to be comfortably attached to the user's skeleton via osseointegration, while also enabling electrical connection with the nervous system via electrodes implanted in nerves and muscles. This research is now published in the journal *Science Robotics*.

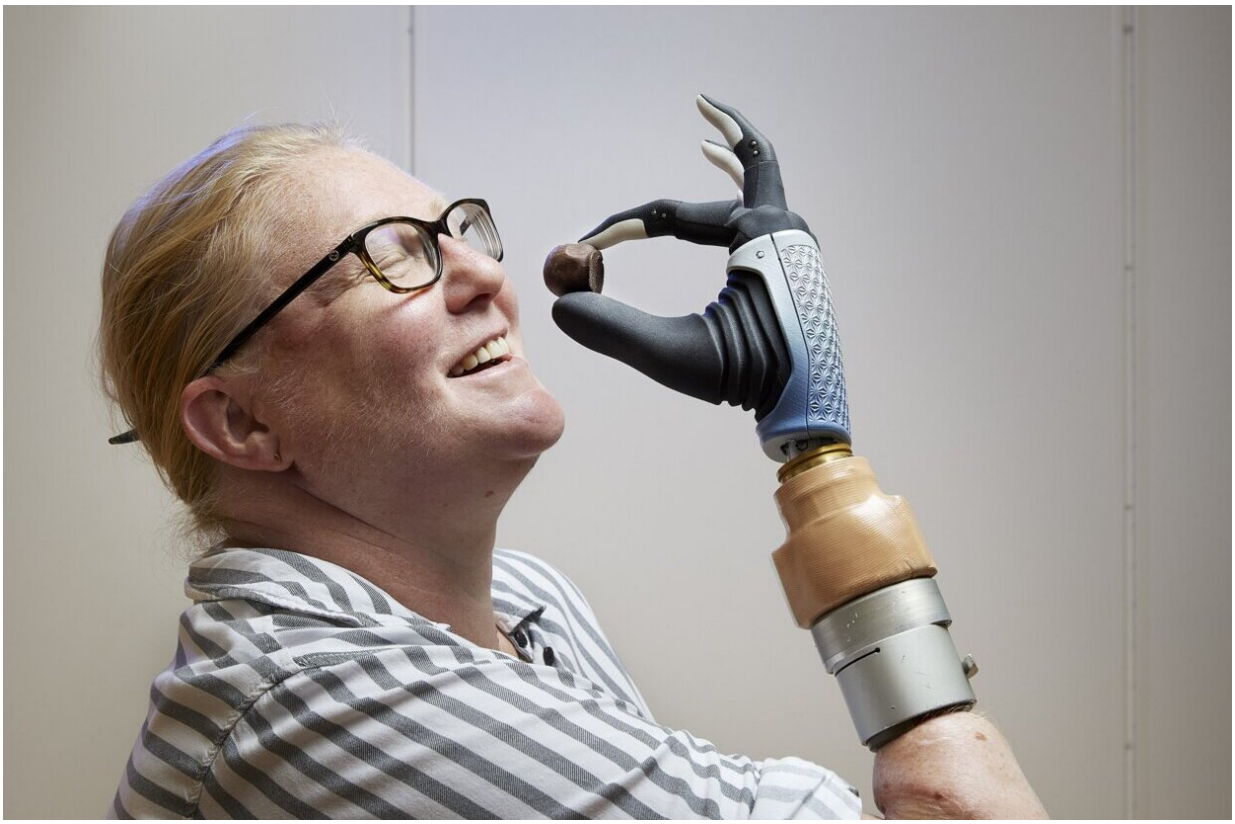
The research was led by Prof. Max Ortiz Catalan, head of neural prosthetics research at the Bionics Institute in Australia and founder of the Center for Bionics and Pain Research (CBPR) in Sweden.

"Karin was the first person with below-elbow amputation who received this new concept of a highly integrated bionic hand that can be used

independently and reliably in daily life. The fact that she has been able to use her prosthesis comfortably and effectively in daily activities for years is a promising testament to the potential life-changing capabilities of this novel technology for individuals facing limb loss."

The challenges at this level of amputation are that the two bones (radius and ulna) that should be aligned and loaded equally, and that not much space is available for implanted and prosthetic components. The research team nevertheless managed to develop a suitable neuromusculoskeletal implant that connects the user's biological control system (the nervous system) with the electronic control system of the prosthesis.

"Our integrated surgical and engineering approach also explains the reduction in pain, as Karin is now using somewhat the same neural resources to control the prosthesis as she did for her missing biological hand." Treatment and prevention of post-amputation pain is another major goal for Prof. Ortiz Catalan's team. Karin says, "[I now have] better control over my prosthesis, but above all, my pain has decreased. Today, I need much less medication."



First person with a below-elbow amputation who received a bionic hand directly connected to her neuromusculoskeletal system. Credit: *Science Robotics* (2023). DOI: 10.1126/scirobotics.adf7360. https://www.science.org/doi/10.1126/scirobotics.adf7360

A key feature of the new bionic technology is the skeletal attachment of the prosthesis via osseointegration—the process by which bone tissue embraces titanium creating a strong mechanical connection.

Prof. Rickard Brånemark, research affiliate at MIT, associate professor at Gothenburg University, and CEO of Integrum, led the surgery and has worked with osseointegration for limb prosthesis since they were first used in humans. "The biological integration of titanium implants into bone tissue creates opportunities to further advance amputee care," said

Prof. Brånemark.

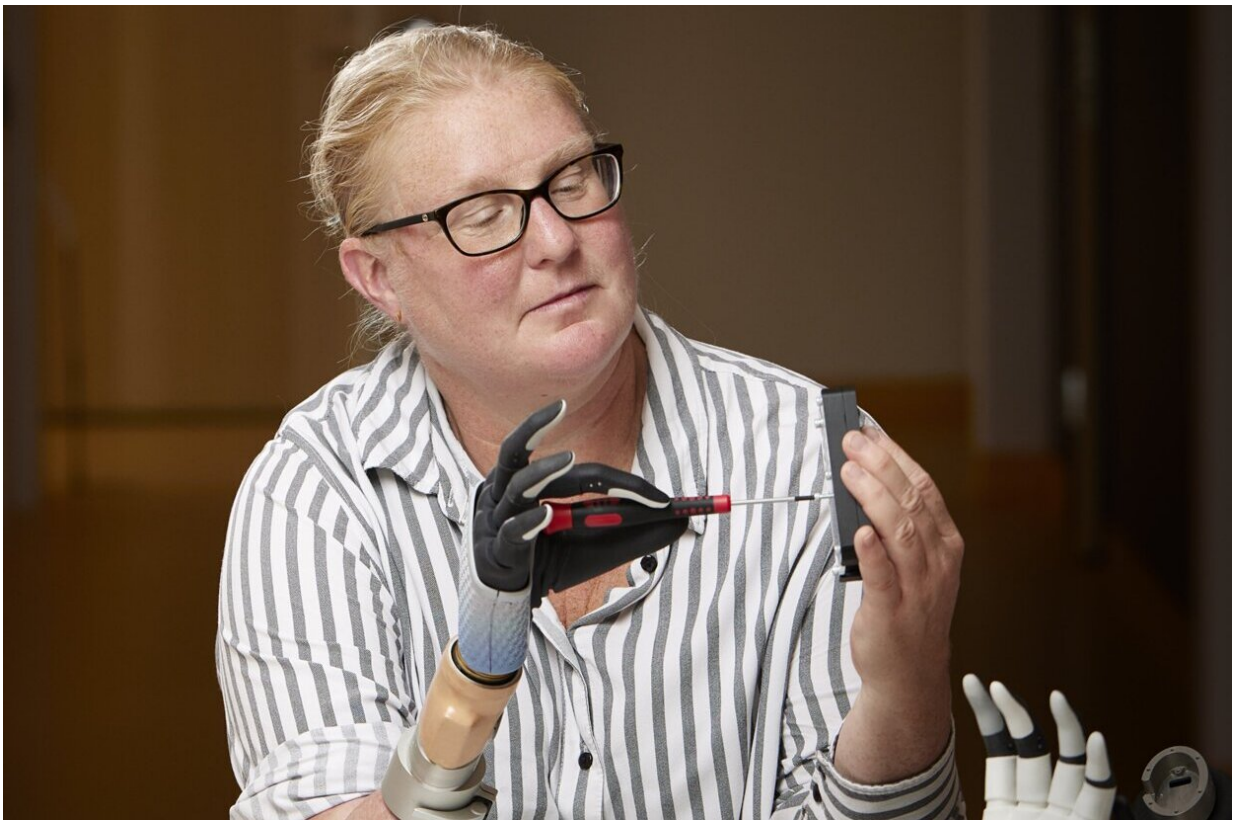
"By combining osseointegration with reconstructive surgery, implanted electrodes, and AI, we can restore human function in an unprecedented way. The below-elbow amputation level has particular challenges, and the level of functionality achieved marks an important milestone for the field of advanced extremity reconstructions as a whole."

The nerves and muscles in the residual limb were re-arranged to provide more sources of motor control information for the prosthesis. Dr. Paolo Sassu conducted this part of the surgery that took place at the Sahlgrenska University Hospital in Sweden, where he also led the first hand transplantation performed in Scandinavia.

Dr. Sassu said, "Depending on the clinical conditions, we can offer the best solution for our patients which sometimes is biological with a hand transplantation, and sometimes is bionic with neuromusculoskeletal prosthesis. We are continuously improving in both." Dr. Sassu is presently with the Istituto Ortopedico Rizzoli in Italy, and the Center for Bionics and Pain Research in Sweden.

"The DeTOP project, funded by the European Commission," says Coordinator Prof. Christian Cipriani, from Scuola Sant'Anna, Pisa, "offered a great opportunity of collaboration which made possible the consolidation of state-of-art prosthetic and robotic technologies available in our institutions, that may have a terrific impact on people's life."

Karin with her integrated bionic hand and Prof. Max Ortiz Catalan. Credit: *Science Robotics* (2023). DOI: 10.1126/scirobotics.adf7360. https://www.science.org/doi/10.1126/scirobotics.adf7360



The highly integrated bionic hand in use. Credit: *Science Robotics* (2023). DOI: 10.1126/scirobotics.adf7360.
https://www.science.org/doi/10.1126/scirobotics.adf7360

A highly integrated bionic hand in between many others. Credit: *Science Robotics* (2023). DOI: 10.1126/scirobotics.adf7360. https://www.science.org/doi/10.1126/scirobotics.adf7360

The robotic hand developed by Prensilia, namely Mia Hand, featured unique motor and sensory components that allowed the user to carry out 80% of the activities of daily living. "The acceptance of the prosthesis is critical for its successful use," says Dr. Francesco Clemente, Managing Director of Prensilia.

"Besides technical performance, Prensilia struggled to develop a hand that could be fully customizable aesthetically. Mia Hand was born to be shown and not hidden. We wanted the users to be proud of what they are, rather than ashamed of what was lost."

More information: Max Ortiz-Catalan et al, A highly integrated bionic hand with neural control and feedback for use in daily life, *Science Robotics* (2023). DOI: 10.1126/scirobotics.adf7360. www.science.org/doi/10.1126/scirobotics.adf7360

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