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Title
New Generation of Clinical Bionic Limbs - Overview

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Summary
Modern prosthetic hardware is highly versatile yet we are still not able to sufficiently interface it with the human body. However, we are now at the verge of a potential large-scale application of technologies that may present a radical paradigm shift in the replacement of lost limbs.

Introduction
The extensive clinically relevant advances in osseointegration, nerve rerouting, implantable muscle and nerve electrodes, and control algorithms are all indicating that next generation bionics will make strong advances towards true limb replacement in the foreseeable future.

Methods
We make a critical analysis of the frontier technologies that are set on becoming the next clinical state-of-the-art in bionic limbs. While focusing on their features, we anticipate the impact and patient benefits that each of the technologies may provide in the near future.

Results
Reports show osseointegration being able to eliminate the limitations of the classic socket design. It also provides the means to preserve the available degrees of freedom. The extensive use of this procedure is currently only limited by the risks of infections due to the percutaneous implant. However, recent large cohort studies document local infection rates at less than 5%, with minimal revision rates [1].
Chronically implanted electrodes have intrinsic properties that are highly beneficial for assuring robust control. Intramuscular wireless sensors (e.g., IMES and MIRA) have been clinically tested with promising outcomes. Still, high energy consumption and interferences with other metallic implants may limit their use. Implanted EMG sensors are compatible with controllers

developed for surface EMG to a large degree, with the advantage of having rich information content and stable signal characteristics over multiple uses of the prostheses.

Non-invasive sensory substitution faces challenges related to the variability of elicited sensation for different locations of the actuators or electrodes. On the other hand, long-term nerve implants have now been proven feasible [2], [3], though their translation still needs substantial developments with respect to device stability, integration into fully implantable systems, and modularity of electrode-cable modules with implantable pulse generators.

Conclusion

The large-scale clinical application of osseointegration, targeted muscle reinnervation (TMR), implanted sensors, advanced control algorithms, and implanted nerve electrodes for sensory feedback, is a realistic prediction for the near future since all these components have been already clinically tested in humans. Tests have shown that these technologies are not only safe but also provide a fundamental breakthrough in the performance of lower and upper limb prostheses.

The most likely signal targets for control will remain muscles since nerve and brain interfacing have still limitations in providing clinically stable and long-term feasible prosthetic control. For sensory feedback, most current efforts focus on re-establishing tactile feedback while providing proprioception remains elusive, despite the importance of proprioceptive feedback in human motor control [4]. Considering the clinical need for control and still extensive challenges in artificial sensory feedback, it is expected that the advances in control will have an earlier clinical impact than those in artificial sensory feedback.

References

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