DIRECT NEURAL SENSORY FEEDBACK AND CONTROL VIA OSSEOINTEGRATION

Max Ortiz-Catalan[1,2], *Enzo Mastinu*[1], *Rickard Brånemark*[3,4], and *Bo Håkansson*[1]

[1] Chalmers University of Technology, [2] Integrum AB, [3] Sahlgrenska University Hospital, [4] University of California San Francisco

BACKGROUND

Prosthetic technology has the potential to restore the functional lost after limb amputations. Osseointegration has been used over decades for the direct skeletal attachment of limb prosthesis resulting in proven improvements in prosthetic functionality and quality of life[1]. Control technologies on the other hand, had been limited to use surface electrodes and provide limited to no sensory feedback.

AIM

We investigated the feasibility of creating a clinically viable, self-contained prosthetic system that allowed for direct skeletal attachment, neural control, and direct neural sensory feedback via neurostimulation.

METHOD

The OPRA Implant System (Integrum AB, Mölndal, Sweden) was enhanced to provide bidirectional communication between implanted neuromuscular interfaces and external devices (osseointegrated human-machine gateway – OHMG), while preserving the original features that allow for osseointegration and stable percutaneous interfacing[2]. We designed an embedded system, named as Artificial Limb Controller (ALC), to read from the implanted muscular electrodes and translate myoelectric signal into prosthetic movements via direct control or pattern recognition. Artificial sensors in the prosthetic terminal device deliver signals related to grip force to the ALC, which in turns produce charge-balanced biphasic electric pulses to stimulate the afferent nerve fibers, thus producing the perception of tactile sensations. Grip force was encoded using frequency modulation.

RESULTS

The OHMG was implanted in the first patient in January 2013 and continue functional until today. The patient used a first analogue version of the ALC for direct prosthetic control, and without neural sensory feedback, since 3 weeks after implantation in activities of the daily living. The new digital version of the ALC in use since January 2017, which include direct neural feedback, has shown to improve controllability by allowing the patient to grab delicate objects, such as grapes or eggs, without damaging them while blindfolded.

Figure 1. Osseointegrated human-machine gateway (OHMG) providing bidirectional communication between the self-contained artificial limb controller (ALC) and implanted neuromuscular interfaces. The patient is capable to grab a grape blindly by receiving direct neural information from sensory embedded in the thumb of the hand.

DISCUSSION & CONCLUSION

Here we present a clinical solution based on osseointegration and implanted neuromuscular interfaces (OHMG), along with the self-contained embedded system for both control and direct neural sensory feedback (ALC). This is the first neuroprosthetic system that allows both control and sensory feedback via implanted electrodes that can be safely used in activities of the daily living. This close-loop controlled neuroprosthesis is now used by patients and its efficacy will be monitored for at least two years in up to 18 patients to be implanted in 2017.

REFERENCES

1. Brånemark *et al.* 2014, *Bone Jt J.*
2. Ortiz-Catalan *et al.* 2014, *Sci Transl Med.*

Ortiz-Catalan M., Mastinu E., Brånemark R., and Håkansson B., Direct Neural Sensory Feedback and Control via Osseointegration, XVI World Congress of the International Society for Prosthetics and Orthotics (ISPO), May 8-11, 2017, Cape Town, South Africa.