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Magazine for clinicians and professionals

Special edition on TMR

Selective nerve transfer

for the intuitive control of arm prostheses

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Selective nerve transfer for the intuitive control of arm prostheses

The aim of a TMR prosthesis is to generate simultaneous movement sequences using a mind-controlled muscle signal

Targeted muscle reinnervation (TMR) describes an established treatment method after amputation of the upper arm or shoulder disarticulation. In a surgical procedure, nerves that were previously used to control the missing limbs are given a new function. Reconnecting the nerves with muscles in intact areas of the body makes it possible for the patient to control the arm prosthesis he or she will be fitted with later by "thought signal" and thus perform several movements simultaneously, quickly, and intuitively. After the appropriate training, the patient is able to move the hand, the wrist, and the elbow simultaneously through his or her thoughts.

While movements are controlled sequentially using two muscle signals in a conventional arm prosthesis, the TMR prosthesis allows 6 movement sequences to be controlled simultaneously. For the user, being fitted with a TMR prosthesis not only saves a considerable amount of time, it also results in a high degree of independence in daily life.

TMR prosthesis (DynamicArm Plus)	**Conventional myoelectric prosthesis (Dynamic Arm)**
Control using up to 6 muscles (6 electrodes)	Control using 2 muscles (2 electrodes)
Up to six different thoughts control one movement of the prosthesis	The prosthesis is always controlled by two signals.
Each of the 6 involved muscles controls one of the 6 prosthesis movements: · Simultaneous control of several movements · Faster execution of movement combinations · Easy, intuitive prosthesis control	Two muscles control 6 possible prosthesis movements: · Movements are executed one after another · The user has to switch to the desired joint (e.g. by briefly tensing both muscles) · Prosthesis movements are sequential, resulting in the delayed execution of complex movement sequences
Natural and intuitive movement pattern	
Neuroma pain is treated or prevented. Neuroma formation is counteracted by the transfer of the nerves.	
Wearing a myoelectric prosthesis can reduce phantom pain.	Wearing a myoelectric prosthesis can reduce phantom pain.
A TMR operation can lead to a further reduction of phantom pain.	

History of TMR

Since 2006 Ottobock has cooperated closely in research & development with RIC – the Rehabilitation Institute of Chicago. The innovative method of selective nerve transfer was developed by the physician and biomedical engineer Todd Kuiken and first performed by plastic surgeon Gregory Dumanian in the USA in 2002.

As a result of this cooperation, Ottobock presented a globally acclaimed breakthrough in medical technology to the public for the first time in Vienna at the end of 2007 and in Germany in 2008: the mind-controlled arm prosthesis.

Since 2010, Ottobock's TMR patients have been routinely fitted with the DynamicArm Plus.

On Jan. 1, 2012, cooperation was begun between Ottobock and the Christian Doppler Laboratory at the Medical University of Vienna. Together they promote research in this area.

Components of TMR

Overview of the various components of a TMR prosthesis

1 Custom TMR socket with electrodes (13E200) or (13E202)
2 DynamicArm Plus (12K110N=50)
3 Electric Wrist Rotator (10S17)
4 MyoHand Vari PlusSpeed (8E38=L/R)
5 For amputations at shoulder level: MovoShoulder Swing (12S6)

Adjusting the prosthesis
The ElbowSoft TMR adjustment software and Bluetooth Dongle (60X5) are required to adjust the prosthesis (6)

Signal training
ElbowSoft TMR is used for signal training before fitting with the definitive prosthesis.

The whole is more than the sum of its parts – the TMR team introduce themselves

Vienna team

Univ. Prof. Dr. Oskar Aszmann
director Christan Doppler Laboratory for the Restauration of Extremity Functions

Birgit Bischof
physiotherapist and TMR expert, Ottobock

Michaela Buhl
coordinator of international activities, Ottobock

Dr. Christian Hofer
coordinator of clinical research, Ottobock

Agnes Sturma
physiotherapist, Christian Doppler Laboratory

Duderstadt team

Erik Andres
prosthetist, Ottobock

Yvonne Begau
coordinator for D, AUT, CH, Ottobock

Daniela Wüstefeld
occupational therapist, Ottobock

TMR fittings are exclusively provided by trained specialists at the aforementioned locations. For a professional support of the patient through the TMR process, please consult the contact persons of the TMR centers listed at the TMR website:
www.tmr-rehabilitation.com/contact

“We recognise movement patterns”

Univ. Prof. Dr. Oskar Aszmann gives a glimpse into the future of arm prostheses

What research projects will be emphasised in the future?

Aszmann: The clear focus is on work in TMR (targeted muscle reinnervation). This revolutionary development allows the user to intuitively make faster, more precise movements with the arm prosthesis. Moreover, for the first time in the history of prosthetics, several joints can be moved simultaneously.

How does that work?

Aszmann: By controlling the prosthesis with the nerves that originally supplied the amputated arm. For a TMR arm prosthesis, an operation – the selective nerve transfer – must first be performed.

What does the more distant future hold?

Aszmann: Another research project at the Christian Doppler Laboratory with the aim of approaching natural arm movement even more closely is recognising individual patterns of muscle activity that correspond with a movement the user wishes to make. To do this, a matrix of myosensors is placed on the residual limb and the signals measured are sent to a microcontroller or computer. This information is decoded there using signal processing techniques and different activity patterns are recognised – also known as “pattern recognition”. The muscle contractions that are generated can then be assigned to the desired movements. The results of pattern recognition processing are transferred to the prosthesis as a movement configuration. This means that the prosthesis recognises when the user wants to open the hand, for example, and executes this movement. The decisive advantages of this system are greater functionality and reliability. It also accelerates the fitting process and simplifies the user’s control of the prosthesis considerably.

How does this work?

Aszmann: Before the prosthesis is used by the user, it must first “learn” to detect the user’s intentions. To accomplish this, the prosthesis is put through a set-up routine after it is put on. Certain movements are carried out with the no longer existent limb according to a protocol and the muscle activity that is generated is measured. The specific activity patterns for each movement are saved to allow individual adaptation of the prosthesis. When the prosthesis is used in everyday activities, muscle activity is compared with the patterns that were learned and if they coincide, the prosthesis carries out the respective movement. Using these patterns, the high-tech prosthesis can be individually adapted. This system is currently in the experimental stage, but we expect its practical application in one and a half years at the latest.

Background information

The Christian Doppler Laboratory for the Restoration of Extremity Functions

The Christian Doppler Research Association is an organisation that promotes joint research by companies and universities, universities of applied sciences, and research facilities. Science and business are equal partners that advance innovative developments. Ottobock is the business partner of the Laboratory for the Restoration of Extremity Functions that is headed by Prof. Oskar Aszmann.

The aim of the research is to improve the integration of prosthesis systems in the body image of affected patients in order to enable them to lead a life that is as independent as possible. The TMR prosthesis is a result of this successful cooperation.

The importance of therapy for TMR

Therapy for a TMR prosthesis is considerably more extensive than for a conventional prosthesis. This therapy has 5 rehabilitation stages and requires specific knowledge of the upper limb and a good understanding of the TMR process as well as technical know-how and intensive interdisciplinary cooperation.

"Therapeutic support until the patient is fitted with an optimised prosthesis is absolutely essential. Without accompanying therapy and rehabilitation, the full potential of the prosthesis cannot be utilised"

Birgit Bischof, physiotherapist and TMR expert at Ottobock

Overview of the 5 rehabilitation stages:

Stage 0 – Preparing for surgery
The therapist is involved in the medical examination. Various tests are carried out to assess the prosthetic fitting therapeutically and prepare the patient for this step.

Stage 1 – Reinnervation (from surgery to the first muscle activity)
Therapy supports wound healing, especially through treatment of edema and pain management. In addition, general physical training is carried out (coordination and balance training, strength training, and improving mobility). Therapy is rounded out by the first specific TMR exercises such as imagining movement, mental training to support the cortical representation of the non-existent arm and its movements, and active bilateral movement patterns of large muscle chains.

Stage 2 – Signal training (improving neuromuscular control)
In this phase, special emphasis is placed on improving neuromuscular control of the new target muscles. Together with the patient, specific movements that correspond with the transferred nerves are learned, the separation of all signals is trained, and the optimal electrode position (hotspot) is defined for each muscle. This helps the prosthetist determine the electrode positions in the socket. Therapy and check sockets simplify training. "Signal training" is the longest of all rehabilitation stages and is decisive for the success of the TMR fitting.

Stage 3 – Fitting the prosthesis
After defining the final positions of the electrodes of all reinnervated muscles and successful signal training, the definitive prosthesis is fitted by the prosthetist. Then the user practices controlling the prosthesis using a step-by-step training concept.

Stage 4 – Quality controls
After the successful fitting with a TMR prosthesis, regular follow-ups with an interdisciplinary team ensure the long-term success.

"The rehabilitation process of a TMR fitting extends over many months to years and can vary greatly depending on the patient. This makes each therapy training a fascinating challenge with success depending on the close cooperation between prosthetist and physician. Optimal training of a TMR patient requires a great deal of experience with users of upper limb prostheses, but specific knowledge of functional anatomy is also helpful."

Birgit Bischof

The socket is key for a functioning TMR prosthesis

The role of the prosthetist in the TMR fitting process – an overview

A big challenge in TMR prostheses is the optimal socket fitting. Numerous training and check sockets are needed before the patient can wear the definitive prosthetic socket. A maximum of 6 electrodes must be embedded in the prosthetic socket. The signal positions are often very close to each other – the prosthetist needs precision and manual dexterity.

A TMR fitting is the most complex type on the market for the prosthetist. There are 3 different types:

1. Therapy socket
2. Check socket
3. Definitive fitting

Therapy sockets allow the therapist to flexibly align the electrodes along the muscles. During the nerve regrowth phase (reinnervation), the position of the electrodes can change. The therapist can simply and easily reposition the electrodes that are attached to a strap when needed.

Check sockets prepare the patient optimally for the definitive fitting. The long rehabilitation process is also used to allow the user to become accustomed to the weight of the prosthesis, especially for a shoulder disarticulation. The weight of the check socket is gradually increased. One positive side effect is that the increase in weight counteracts muscular imbalance. This counteracts physical damage that arises from poor posture.

The prosthesis can weigh up to 4 kg. The user then begins training with the prosthesis. When the user has completed therapy, the definitive socket is fitted.

> "The orthopaedic prosthesis can be fitted optimally only if the therapist has done excellent work. Teamwork is the essential."
>
> Hans Oppel,
> prodthetist and TMR specialist OTH Döbling, Vienna

"A TMR fitting is the most complex prosthesis on the market for the prosthetist."

Hans Oppel

“The prosthesis is a good support in everyday activities.”

Thanks to his positive attitude and stamina, Robert S. managed to return to normal life after a serious traffic accident. With the aid of his arm and leg prostheses, the baker can work in his former occupation again.

Robert, you wear an arm and a leg prosthesis. What happened?

Robert S.: Eight years ago I was driving my delivery van when I suddenly and inexplicably found myself on the wrong side of the road. Then I crashed into another vehicle.

What were the consequences of the accident?

Robert S.: My left foot and my left arm were severed in the accident. I was fully conscious and experienced everything. I remember asking the emergency doctor how I would provide for two young children without an arm and foot. After two weeks of coma I woke up in the hospital and three days later I stood next to my bed for the first time – on one foot.

How did you cope with the new situation?

Robert S.: Generally speaking, I adjusted quickly. Of course, I had a few setbacks and was impaired. Especially when confronted with routine situations that did not use to be difficult.

How long did it take before your life was normal again?

Robert S.: For me that went quite quickly, just like everything else. After ten weeks of rehabilitation I began to work again. But I found there were limits to what I could do, especially with the foot prosthesis, and I had to take frequent breaks. I often took off the prosthesis and worked from my wheelchair.

You wear the targeted muscle reinnervation (TMR) prosthesis on your arm – how did you happen to be fitted with this innovative prosthesis?

Robert S.: I was approached by Ottobock to be a test user. Prof. Aszmann immediately offered me an appointment for surgery. The anaesthesia was difficult, but I was willing to accept that.

You use this prosthesis in everyday life. Can you tell the difference yet?

Robert S.: I am completely satisfied with the arm prosthesis. Because I don’t have to switch functions, every movement is faster than with my former arm prosthesis. That’s a big relief in everyday life. For example, paying for purchases at the cash register. There always used to be a line behind me until I got my prosthetic hand in the right position. It felt like it lasted forever to get hold of the wallet, take money out of it, and hand it to the cashier. Now that doesn’t happen to me anymore. Movements are fast and fluid. Of course the prosthesis is not comparable with a healthy foot or arm. But the prostheses are still a big help in my daily life that I would not want to do without. I carry my purchases with the arm prosthesis for example, and the right hand is free for unlocking the door.

What is your everyday life like on the job and in your spare time with the prostheses?

Robert S.: Working in the bakery is a big challenge for my body and for the prostheses, because I have to stand a lot in high temperatures. I try to walk or sit down as often as possible. An optimal fitting is necessary for ensuring that working does not mean permanent stress for me as a prosthesis wearer. I have hardly any limitations in my free time – I still go hiking and skiing with my family. Instead of riding my motorcycle on racetracks, which I had to give up, I bought a sports car. It is just as fun!

About the TMR prosthesis wearer
Robert S. is 43 years old and lives in Lower Austria. He is married, has two children, and is a baker with his own bakery and 28 employees. He spends his spare time with his family outdoors and with sports.

TMR Treatment Cycle

Follow-up

Follow up checks and continuous support after final fitting.

Assessment

Examination of clinical assesments and functional tests to decide on TMR surgery and fitting. Providing recommendations and detailed information for the patient.

Prosthesis training

The user learns how to correctly handle the prosthesis in everyday life. Following the prosthetic training concept of upper extremity. (Rehabilitation stage 3)

Therapy

Preparing the patient for TMR surgery. (Rehabilitation stage 0)

Rehabilitation team and family

People

Fitting

Final TMR prosthesis fitting with up to 6 electrodes embedded in the socket. (Rehabilitation stage 3)

Surgery

Selective transfer of the residual arm nerves to other target muscles. (TMR = Targeted Muscle Reinnervation)

Production

Fabrication of various test sockets and final TMR prosthesis according the rehabilitation process.

Post-surgery Training

Apart from the classical post-surgery treatment, the focus in this phase is on mental training which supports the neuromuscular reinnervation.

Interdisciplinary TMR specific rehabilitation

Signal Training

The specific intended movement and the optimum electrode position are defined for each reinnervated muscle. Intense training of the signal control and separation of the Myo signals.

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