THE ROLE OF TECHNICAL AIDS IN PROMOTING PARTICIPATION: A CASE STUDY CONSIDERING THE PROSTHETIC FIELD

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Abstract

Technological aids can play a very relevant role in strengthening the personal potentials and limiting the environmental barriers following an impairment. To this aim, technology alone is not sufficient. A multidisciplinary approach has to be followed, to be confident in the outcomes of an intervention in terms of activity and participation. The aim of this work is to provide an example of the approach followed by Centro Protesi INAIL on this regard, by considering the story of a patient with a partial hand amputation who was fitted and trained with the first myoelectric prosthetic solution available on the market for this level of trauma, namely the TouchBionics "ProDigits" technologies.

Introduction

Technical aids refer to a broad range of devices intended to assist a subject with disability in every-day-life activities, strengthening the personal potentials and limiting the effect of environmental barriers following an impairment. Specifically, we can refer to the ISO 9999 classification, which includes technologies for therapy, prostheses and orthoses, personal care, transportation and locomotion, home-case, building adaptation, communication, information and warning, manipulation of object and control, games and recreation. Despite the diversity, the common principles behind the provision of a technical aid are:

1) the definition of the needs of the client and his/her psychosocial background, including psychological distress, social support, motivations and expectations;
2) the identification of the optimal device, considering its quality, cost, flexibility, assistance and maintenance;
3) the application of the technology through customization and training/rehabilitation;
4) the quantitative assessment of the outcomes and application of corrections, if needed.

Only through a careful implementation of these steps by a multidisciplinary team a *technology* becomes a technological *aid* and provides the bases for an active and participated life. The aim of this study was to provide insight into the benefits that a patient can gain through an appropriate technology selection. For this purpose, we will address a case study regarding the upper-limb prosthetic fitting, which is among the most difficult in terms of acceptance and active use by the amputees.

Text

Upper-limb amputations are a relevant social concern. In Italy the National Healthcare Service [1] counts about 4.000 cases/year, i.e. about 25% of the total number of amputations. The most frequent cause of amputation is traumatic, with percentages ranging from 53% to 69% depending on the

source [2, 3]. Upper-limb amputations taking place during work are about the 75% of the total work-related amputations. Among the anatomic segments of the upper-limb, the hand is the most affected, i.e. about the 95% of cases at National level [1]. Statistics regarding work-related upper-limb amputations confirm this trend, with an 85% of the total.
From the prosthetic perspective, patients' satisfaction remains a challenge, with USA statistics reporting a documented rejection rate or non-wear of about 25% [4, 5]. Functional limitations and ease of use can discourage amputees from the active use of the artificial arm, especially for more proximal levels. These statements seem to be further supported by the UK statistics [3], which highlight that only 4% of the annual referrals to the national prosthetic centers are related to upper-limb amputations, which is a percentage far below the expected distribution between upper- and lower-limb amputations; this can be interpreted by stating that upper-limb amputees do not even attempt a fitting.
Italy can count on a specialized unit of the Italian Workers' Compensation Authority (INAIL) to assist upper-limb amputees, namely Centro Protesi INAIL. Centro Protesi INAIL was among the first in the '60 to attempt the construction of a mechatronic prosthesis controlled through surface EMG signals from residual muscles, now commonly known as "myoelectric prosthesis". Since then, Centro Protesi INAIL has maintained a major role in the field and now assists about 400 of the new upper-limb amputations taking place every year. Despite being part of INAIL, Centro Protesi provide services, alongside injured workers, to civil injuries, disease-related amputees and congenital malformations. Centro Protesi INAIL treats all upper- and lower-limb levels of amputation, for more than 12.000 services per year. The technical stuff consists of about 280 professionals, forming a multidisciplinary team of prosthetists, physical medicine and rehabilitation doctors, physiotherapists, nurses, psychologists and biomechatronics research scientists. The team as a whole is involved in defining, with each patient and his/her family, the best prosthetic and rehabilitation program, which can be based on inpatient or outpatients treatments, to ensure an active and participated life.
The choral intervention of the team took place also for A.R., a 50 years-old male, that suffered a work-related amputation in 2009, with the loss of the four long fingers and part of the palm, while maintaining an intact thumb (both in terms of range of motion and strength) (Figure 1a).

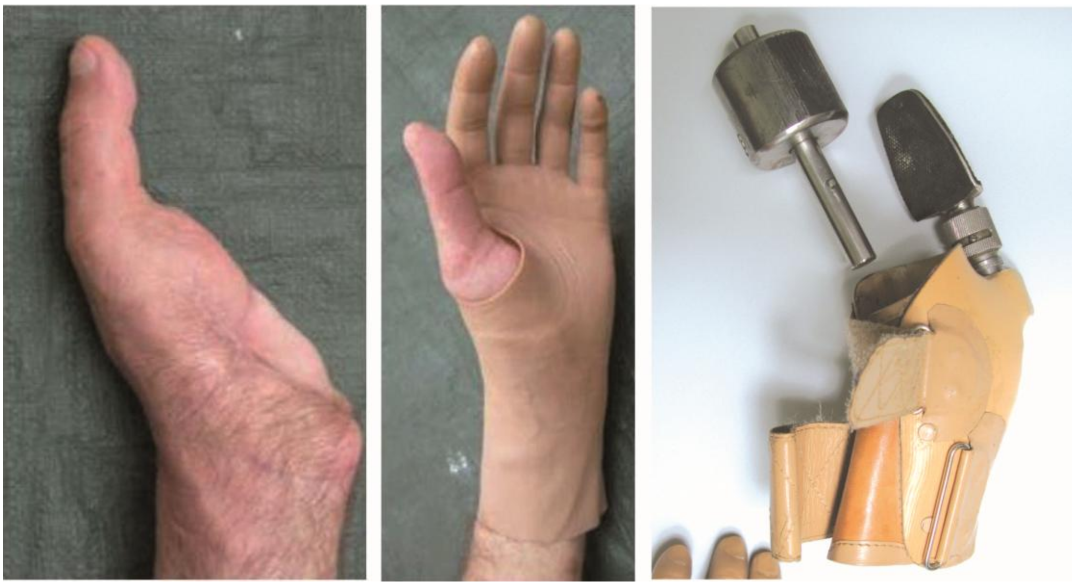

Figure 1 – (a) level of amputation of A.R.; (b) cosmetic solution; (c) prosthesis for working activities

At the time of the trauma, A.R. was running a very successful artistic job, living with his wife and two kids. He presented a broad social support, keeping a high level of social integration. For prompt coping with the amputation and to support his return to an active social and working life, two prostheses were initially provided. Firstly, a cosmetic solution, with the purpose of providing a pleasant opposing structure to the active thumb (Figure 1b). The prosthetic fingers in the cosmetic solution can be passively adjusted with the controlateral sound side. The second prosthesis was specifically designed for working (Figure 1c). The socket does not attempt to replicate the appearance of a natural hand, but is intended to be useful to accomplishing specific tasks while being comfortable. For this reason, the socket presents a linkage system which allows to mount a set of working tools.
While A.R. was generally satisfied by the working prosthesis, he was only partially satisfied by the "every-day-life" one since it did not incorporate any active grasping function. In other terms, he was looking for:

1) a single active prosthesis to be used in both the working activities and standard activities of the daily living;
2) a prosthesis that could allow him to obtain a driving license without car adaptation, since adaptations would have restricted his possibility to rent cars, which was a requirement for a new consultant job that he was offered.

A.R. was then identified as a potential candidate for a research project, aimed at evaluating the effectiveness of the first myoelectric solution available on the market for partial hand amputations.
This solution, named "ProDigits", is developed by TouchBionics (UK). ProDigits consists of a set of independent fingers (Figure 2), each embedding a micro-motor inside the proximal phalanx.

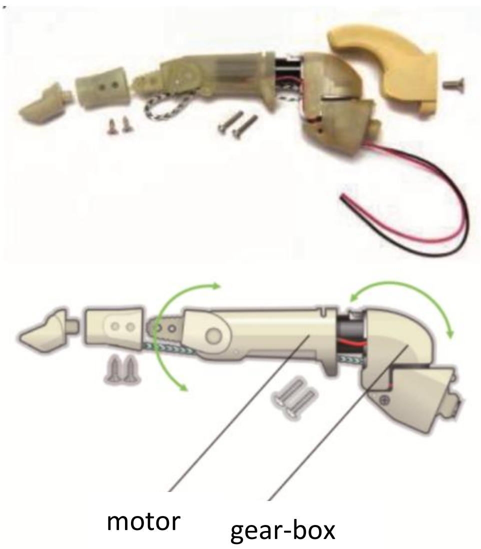

Figure 2 – ProDigit finger and schematics (*image courtesy of TouchBionics*)

The motor, through a gear-box, enables the flexion and extension of the metacarpophalangeal (MCP) joint, for a maximum range of motion of 82°. The proximal interphalangeal joint (PIP), instead, follows passively the movement of the MCP for a range of movement of about 105°, though a cable pulling system. The extension of the PIP is ensured by a spring-return system. In case of contact of an object with the fingers, the MCP joint provides the resistance of the mechanical joint when inactive (non-back-drivable system), while PIP can reach the maximum flexion. The distal interphalangeal joint (DIP) is not implemented into the finger and as such the third phalanx is fixed relative to the second with a flexion of about 16°. The motors are connected to a control unit, which is powered through a battery. The fingers, control unit an battery form the core of the prosthesis (Figure 3).

Figure 3 – Fingers mounted on the socket. Inside the socket the battery and the control unit are inserted, when possible, in the free space left by the amputation of the palm.

The number of fingers to include depends on the number of missing fingers. The amputee can control the opening and closing of the fingers as a whole or the activation of specific grasping patterns, through the generation of one or more surface EMG signals generated by muscles of the residual stump, on which specific sensors are positioned. The EMG signals are input into the control unit that activates the motors accordingly. In other words, through EMG sensors positioned into the prosthesis (that go in contact with residual muscles that the amputee is able to voluntarily activate once the prosthesis is donned), the control unit acts on the motor of the fingers to close or open, realizing different grasping patterns.
At present, ProDigits is not considered suitable for every partial hand amputation. In particular, it is important to consider some aspects:

1) fingers have a fixed length; in case of amputation at the MCP joint level, noticeable asymmetries can emerge that can compromise the use of the prosthesis; in particular, in case of thumb amputation, other highly innovative solutions are preferable, like the osseointegration, already used by Centro Protesi INAIL [6];
2) ProDigits requires the use of a battery and an electronic control system; it is fundamental to correctly identify their positioning in the socket. When the patient has an intact wrist joint, it

is necessary to carefully consider whether the proximal placement of electronic components affects the use of the prosthesis;

3) the patient must be able to selectively contract at least one muscle, avoiding involuntary activation during the movement of the upper-limb in space or during objects manipulation using the prosthesis;
4) the cosmetic glove of the hand might limit the full speed of the hand and the actual aesthetic function can only be realized once the prosthesis is developed.

Patients with the amputation of the four long fingers and of part of the palm featuring an intact thumb, as it was the case of A.R., were identified by Centro Protesi INAL as those preferable for the application of ProDigits, at this stage. The pros and cons of ProDigits were presented to A.R.; during the interview, he did not refer to avoid social situations due to being an amputee and he reported to feel himself self-confident even with strangers or in public places. He described himself as an active person, with many interests. He showed an optimistic attitude to life: even if aware of limitations related to his condition, he claimed to have never doubted to be able to return to his “normal” life. Patient’s words proved his good capability to count on available resources to face aversive situations, adopting support seeking and problem-focused strategies of coping. He showed realistic expectations about potentials and limitations of the new prosthetic technology. A.R. was then confirmed as a candidate for the experimentation of ProDigits and he granted is willing to participate in the study, giving his informed consent.

For the prosthesis construction, a selectively controllable muscle signal was available in the central part of the stump of the palm of the patient (Figure 4).

Figure 4 – (top row) position of the electrode on the skin and inside the socket; (middle) battery and control unit inside the socket; (bottom) final prosthesis and prosthesis donned by the patient

Therefore, a socket with a single EMG sensor placed in that area was realized. The battery and the electronic control system were placed in the missing part of the palm, between the socket and the laminated external structure. By means of a technique named “alternating single-site”, the electronics was set-up to enable the hand opening and closing though a single signal. In details, the hand was programmed to allow the whole fingers opening and closing as well as the opening and closing of the index finger. The fingers were placed on the external laminated structure by means of a single block (name “knuckle block”) which imposes them to be parallel; the orientation of the knuckle block was defined to optimize the thumb opposition.
After the prosthesis fabrication and set-up, A.R. followed a specific training program based on (Figure 5):

1) selective control of the hand opening and closing function;
2) integration of the prosthesis in basic reaching, grasping, holding and transport activities;
3) integration of the prosthesis in ADLs and patient specific ADLs.

Figure 5 – training with ProDigits at Centro Protesi INAIL

Once at home, he started using the prosthesis every day, in house and at work, especially for fine manipulation. After about 10 months from the prosthesis construction, he obtained the driving licence without any car adaptation, also based on the technical documentation provided by the Mobility Area of Centro Protesi INAIL: he was the first patient to obtain this goal with ProDigits in Italy. At 1.5 years from the fabrication, the prosthesis has been proving to be reliable and the patient to be greatly satisfied. He is conducting a very active life, working, taking care for his family and travelling.

Conclusion

Technology can become a technical aid only if a careful multidisciplinary approach is carried out. This is the case of prosthesis in particular, which are the core of the activities of Centro Protesi INAIL. The case study, regarding a partial hand amputee, was intended to exemplify the approach and demonstrate how the right prosthesis for the right person allows an active and participated life, despite the very relevant trauma that the patient suffered.

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