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O&P · REHABILITATION · HOME HEALTH CARE
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Calendar

May 24-27, 2009
3rd United Frontiers Forum: The Central America O&P Regional Meeting, Hotel Playa Bonita, Panama, Panama. Info: www.ispopanama.org

June 3-6, 2009
EFORT, European Federation of National Associations of Orthopaedics and Traumatology, 10th Congress, Vienna, Austria. Info: www.efort.org

June 18-21, 2009
Amputee Coalition of America, 20th Annual Conference, Atlanta, GA, USA. Info: www.amputee-coalition.org

August 20-22, 2009
Technology for Quality Living, Asian Prosthetic and Orthotic Scientific Meeting, The Hong Kong Polytechnic University, Hung Hom, Hong Kong, China. Info: www.aposm2009.org

September 20-23, 2009
AOPA National Assembly, Washington State Convention & Trade Center, Seattle, WA, USA.
Info: www.aopanet.org

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Foot Care

Exchanging knowledge during the IVO 2009 international exhibition and conference

This November, professionals in the field of foot care from all around the world will converge on the World Forum in The Hague for a two-day conference. The Netherlands' local NVOS Orthobanda association has the honour of organising this year's event. Co-organiser and orthopaedic shoe technician Rob Verwaard explains: "The knowledge we share with one another during such a conference enables us to achieve personal development and improvement in our field. And our clients ultimately reap the benefits."

The seventeenth IVO Conference is to be held on 13 and 14 November 2009. The results of various leading studies in the field are presented during this prestigious event, while professionals are also given the opportunity to share their knowledge and skills. Preparations are already in full swing. Mr Verwaard continues: "Many researchers pull out all the stops in order to present the findings of their studies during the conference. It is the platform for innovations, training and technology. And given that we only congregate once every three years, it has become something of a benchmark. After all, a great deal can happen in the course of three years. CAD/CAM techniques become further refined, while we gain increasing insight into treatment methods, for instance, for diabetes or rheumatism sufferers."

Partnership in foot care

IVO stands for Internationaler Verband der Orthopädie-Schuhtechniker, which is German for the "International Orthopaedic Shoe Technicians' Association". The topic of the forthcoming event is Partnership in Foot Care. "The fact that increasing numbers of disciplines in the field of foot care are cooperating with one another prompted us to opt for this theme. Various partnerships have already been forged in the Netherlands. This offers patients access to a chiropodist, orthopaedic shoe technician and physiotherapist, for example, under the same roof. This approach is already common practice in Japan and the USA. During one of these conferences, we have the opportunity to exchanges thoughts with colleagues from all over the world. It can be particularly interesting to compare working methods with one another."

Global differences

Various international studies are to be presented during the conference. The orthopaedic shoe technician explains: "The largest study performed by NVOS Orthobanda itself was to protocol syndromes. We have carefully recorded step by step which treatment methods can best be applied and when. In addition, we are to present the findings of a study into the global differences in health care insurance, treatment and approach. The findings are to be publicly announced during the final session."

Conscious division

NVOS Orthobanda has consciously opted for a clear division of the conference programme.

"It is expected to be a well-attended conference, with a vast number of points on its agenda. Visitors are to be given the opportunity to choose in advance from a range of interesting topics, which have therefore been divided into the following categories: Economics, Research and Development, Education, State of Industry and Lifestyle. This should enable everyone to attend the particular sessions that interest them most, thereby rendering both the conference and the exhibition highly effective."

Mario Lafortune, Erica Terpstra, and many other prominent guests

A number of prominent speakers are to attend the conference, each of whom will cast a little more light on "Partnership in Foot Care" in their own particular fashion. Erica Terpstra is a prime example, while Mario Lafortune of the Nike Sport Research Laboratory will also hold a presentation. This leading sports brand also manufactures sports shoes for diabetics, for instance. It focuses on making life as comfortable as possible, despite people's foot problems. This is after all the ultimate aim of all professionals in the field of foot care. Foot problems are often painful, annoying or restrict people's freedom of movement. Our aim is to help people live as conveniently as possible, despite their problems.

IVO 2009
13 and 14 November, at the World Forum in The Hague,
The Netherlands.
Further information is available at www.ivo2009.eu, by email via info@ivo2009.eu, or telephone at 00 31 (0)35 588 04 95.

Prosthetics

S. Brunelli, T. Averna, S. Delusso, M. Traballesi

Vacuum assisted socket system in trans-tibial amputees: Clinical report

Introduction

Trans-tibial amputation is a common sequela of vascular disease, involving patients suffering from peripheral atherosclerotic disease, diabetes mellitus, or both. Prosthesis fitting is the only way to regain walking ability and to reach a new daily independent life in patients with lower limb amputation.
According to Van Velzen et al. [16], before fitting a prosthesis, the stump should meet several criteria: the surgical wound must have healed; the oedema must have been resolved; the stump has to be conically shaped and stump maturation should be achieved. Suggested general measures employed in dysvascular patients with wound healing problems include complete bed rest, optimization of diabetic control and good nutrition [10]. The importance of proper treatment of skin lesions must be stressed because

major factors that could predispose vascular amputees to re-amputation are infection due to repeated ulceration, unsatisfactory healing of wounds, reduced blood flow and lower oxygen levels. Recent studies report that 19 per cent of the patients with below-knee amputation underwent a revision of the original amputation [12], and that nine per cent of stumps required revision or conversion to a higher level within 30 days [6].

The problem of the unhealed stumps

The presence of an open surgical wound does not necessarily exclude weight bearing; repeated wound assessment and modification of the treatment plan as needed to perfectly fit the prosthesis are important and a decision on modifying the prosthesis should be based on the progression or deterioration of the particular wound [3]. Many lower limb amputations do not heal in a primary fashion and it is not uncommon that patients referred to prosthetic rehabilitation have small stump wounds requiring secondary healing and a period of minor wound care [3]. Anyway, in clinical practice, to avoid major complications, the rehabilitation training usually stops in the presence of an unhealed stump because the mechanical stress could worsen the skin lesions. In fact, the soft tissues of the stump are not adapted to load bearing; thus prosthesis users may develop ulcers on their stump as a consequence of pressure and shear forces exerted by the prosthetic socket interface. Therefore, the mechanical insults represent the main cause of recurrent skin ulcerations and pressure damages [13]). These mechanical insults are highly repetitive during locomotion and may damage the tissue by accumulating their individual effects [11]. Besides, a longer exposure can likely reduce the threshold of mechanical load tolerance of the soft tissue [5], and high mechanical stress is the major cause of pain [11].

Good stump quality is one major determinant of mobility. Efforts should be made to minimize stump complications [15] and to avoid delayed prosthesis fitting, which is the main cause of increased costs of rehabilitation after amputation [17].

The „ideal prosthesis“

In the light of these considerations orthopedic and prosthesis researchers are pushing for the construction of the „ideal prosthesis“

An ideal prosthesis should provide adequate setting not only to enable comfortable mobility, but also to ensure an adequate environment to the residual limb, thereby keeping it healthy and free of wounds to allow for a faster post-operative rehabilitation and healing process. The ideal prosthesis should reduce the pressure peaks and the shear stress on the stump to avoid pain and to reduce the risk of inducing or worsening skin lesions.

Moreover, fitting the prosthesis as early as possible is crucial to obtain greater patient autonomy. If prosthesis fitting is delayed the patient will achieve lower mobility [14].

At present, a prosthesis having nearly the desired characteristics is commercially available: the TEC Harmony of Otto Bock HealthCare, Germany.

This is a total surface bearing socket where an active vacuum (about –78 kPa) anchors the liner to the socket. The system is called VASS (Vacuum Assisted Socket System); the negative pressure is created at the expulsion port by a pump attachment.

VASS-TEC Harmony prevents daily volume loss of the stump that usually occurs when using a normal socket [4]; this explains the reduced pistoning of the stump in the socket which minimizes skin irritations and breakdown.

As a matter of fact this vacuum system forces less fluid out of the stump during stance phase due to a four to seven per cent reduction of the pressure acting on the stump as compared to regular sockets. During swing phase it draws more fluid into the stump due to a 27 per cent increase in vacuum acting on the stump. Thus, unlike regular sockets VASS Harmony shifts the fluid balance in the residual limb to maintenance or even slight gain of volume [2].

It also results in maintaining more oxygenated fluids in the residual limb [2]. Moreover, the negative pressure created by the vacuum system should be useful for healing a stump wound. As a matter of fact negative pressure is successfully used for treatment of complex diabetic foot wounds [1]. These studies are based on systems with negative pressure (vacuum system), which are used to promote healing in chronic and acute wounds in patients affected by a diabetic foot syndrome. The authors referred that vacuum wound healing system delivered a higher proportion of healed wounds, faster wound closure, more rapid and robust granulation tissue response.

The study

The aim of this study is to analyze the effect of fitting the VASS (TEC Harmony) in trans-tibial amputees (TT) with open stump wounds in terms of:

- Achieving the same mobility as amputees without wound healing problems fitted with patellar-tendon bearing prosthesis (PTB),
- Pain control during walking with prosthesis (compared to amputees fitted with PTB),
- Effect on wound healing.

Material and methods

From December 2005 to December 2007, we enrolled all dysvascular TT amputees for VASS Harmony fitting who were consecutively admitted to our in-patient rehabilitation hospital and met the following inclusion criteria:

- Wound healing failure after amputation or chronic dermal ulceration of the stump,
- First time ever prosthesis fitting or long term amputees using a PTB socket,
- Age 45 to 75 years,
- Absence of severe clinical comorbidities,
- K-level 2 or 3 (Medicare Supplier Bulletin).

ITEM	SCALE			
1. Get up from a chair	0	1	2	3
2. Walk in the house	0	1	2	3
3. Walk outside on even ground	0	1	2	3
4. Go up the stairs with a handrail	0	1	2	3
5. Go down the stairs with a handrail	0	1	2	3
6. Step up a sidewalk curb	0	1	2	3
7. Step down a sidewalk curb	0	1	2	3
Basic activities score	_/21			
1. Pick up an object from the floor (when you are standing up with your prosthesis)	0	1	2	3
2. Get up from the floor (e.g., if you fell)	0	1	2	3
3. Walk outside on uneven ground (e.g., grass, gravel, slope)	0	1	2	3
4. Walk outside in inclement weather (e.g.,snow, rain, ice)+	0	1	2	3
5. Go up a few steps (stairs) without a handrail	0	1	2	3
6. Go down a few steps (stairs) without a handrail	0	1	2	3
7. Walk while carrying an object	0	1	2	3
Advanced activities score	_/21			
Total score	_/42			

Fig. 1 Locomotor capability index (reprinted from Grisé MCL, Gauthier-Gagnon C, Martineau GG. Arch Phys Med Rehabil 1993) [9].

In the same period we enrolled all the TT amputees without wound healing failure after amputation or chronic dermal ulceration of the stump for PTB prosthesis fitting. The inclusion criteria for this second group (PTB Group) were the same as for the VASS group (except for the wound healing failure or chronic ulcerations).

Each subject was monitored once every week in the first two months, than every month until the end of the study after nine months.

Digital photographs of the subjects' residual limb were taken at determined time points to document limb health and viability. Documentation requires five digital pictures that were taken to capture the entire limb. We registered the localization, description, type and size of the wound, skin ulcers, scars or necrosis, the trend of wound healing and residual limb health.

All the enrolled subjects were tested for pain during walking by means of a Visual Analogical Scale (VAS). The ability to use the prosthesis was tested with the Locomotor Capability Index (LCI) [9], a 14-item scale that has a total maximum score of 42, (fig. 1).

The clinical evaluations were used to show the tendency in skin lesion healing in the VASS group. All limb characteristics, namely wound health, size, and infection were examined and documented.

The ethical committee of the Fondazione Santa Lucia, Rome, Italy approved this study, and the subjects gave their written informed consent to participate

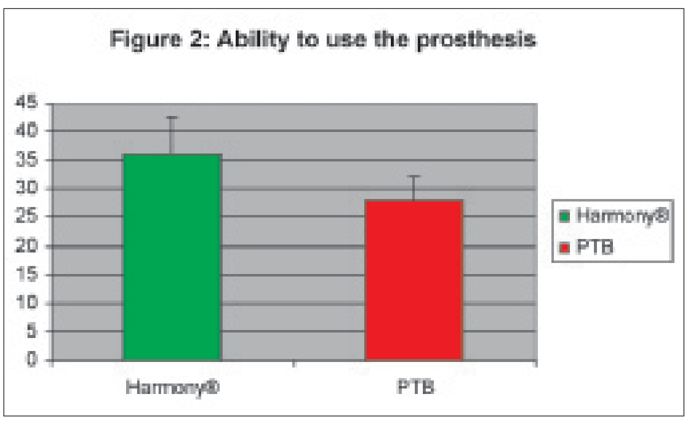

Fig. 2 LCI in the vacuum assisted socket system group and in patellar tendon bearing group at nine months follow up.

Results

13 TT patients with wound healing failure were consecutively admitted to our Institute. Nine patients met the inclusion criteria (mean age 66 ± 17) and were enrolled to be fit the VASS. In the VASS-group we had two drop-outs (one for clinical heart complication and one for personal problems). So we report the data of seven VASS-group TT amputees (four with skin lesion due to PTB socket use, three with wound healing failure after amputation, mean age: 62 ± 11 years).

In the PTB group we enrolled a sample of 17 TT subjects (mean age 67 ± 11 years); we excluded another 25 patients without wound healing failure from this group because they didn't meet the inclusion criteria.

Ability to use the prosthesis: After nine months LCI score was 36 ± 6.7 for VASS group and 28 ± 4.2 for PTB group (fig. 2).

The data shows that the VASS Harmony group achieved higher levels of locomotion capabilities than patients fit with a standard PTB prosthesis. It is important to note that VASS patients scored 36 points on LCI which is a good level of mobility with respect to the presence of some unhealed wounds on the stump and to the high mean age of these subjects.

Pain: VAS after one month of training was 6.3 ± 2.2 for VASS group and 7.5 ± 2.5 for PTB group. After nine months the score was 4.6 ± 1.3 for VASS group and 7 ± 1.8 for PTB group (fig. 3).

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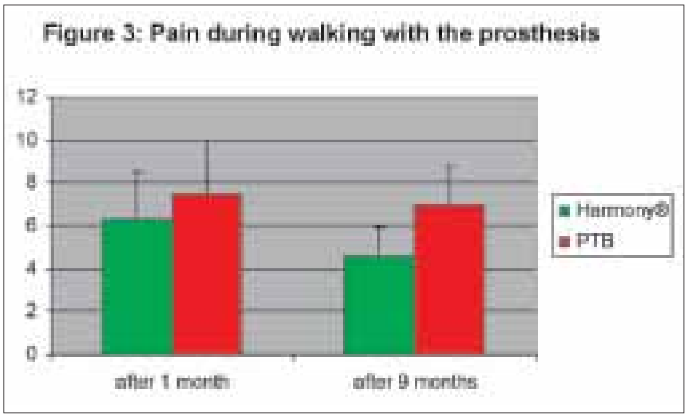

Fig. 3 *Pain during walking in the two groups after one month and after nine months wearing a Harmony (VASS group) or a PTB (PTB group).*

Even in pain control the use of VASS Harmony shows better results than a standard PTB prosthesis. There is a reduction in pain in both groups during the observation period, but in the VASS group it is more pronounced.

Wound healing in the VASS group: At admission, the open wounds surface area of the 7 patients ranged from 0.5 x 0.5 cm to 11 x 5.5 cm (on average 4.1 x 2.2 ± 3.9). At the follow-up evaluation we reached a complete healing of the wounds in all subjects who completed the study.

Case reports

We report two patients with skin lesions on the stump who were successfully fitted a VASS Harmony prosthesis.

Fig. 4 *Stump condition of patient #1 at recovery admission.*

The first case is a 45 year old man, obese patient (height: 190 cm; weight: 140 kg; BMI >35) with diabetes of ten years duration, who presented several complications and comorbidities: light nephropathy, somatic neuropathy, peripheral vascular disease, and arterial hypertension.

When he was 42, he underwent a major amputation (transtibial level) secondary to gangrene of the left limb. The patient was fitted a patellar tendon-bearing modular prosthesis made by a skilled prosthetist. He was affected by recurrent skin lesions of the stump due to mechanical insults that he did not feel because of sensory neuropathy. Recurrence of the skin lesion caused frequent prosthesis discontinuations and damage to his psycho-functional status (i. e. minor depression).

To avoid recurrent skin ulcers, he was fit several prosthetic sockets, but all of them failed to prevent skin ulcerations. In fact, when the patient arrived at our Institute he had a very large ulcer in the popliteal region (major axis: 8.5 cm; minor axis: 5.5 cm; wound area about 36.6 cm², fig. 4).

Near the lesion were some blisters and other superficial lesions. Because of sensory neuropathy and of the posterior localization of the lesions, the patient was unaware of the damage caused by the regular prosthesis use. After two months of weekly follow-ups as an out-patient, wound healing was still slow despite mechanical relief due to interruption of prosthesis use and local wound care.

Clinical history and delayed stump wound healing, complicated by the difficulty of fitting the prosthesis, led us to try a Harmony VASS in order to promote wound healing.

When VASS was fitted, the patient was able to walk immediately (LCI = 41). During the rehabilitation program, he wore the prosthesis, without wound pad, for eight hours per day, and continuously for three or four hours.

After seven months of VASS fitting, complete wound healing was obtained (fig. 5). Due to daily prosthesis use, he regained the maximal score of the LCI (42). The patient had no recurrent skin problems during the following two months of follow-up.

In the second case the patient was a 60 year old male affected by severe vascular disease with complications (retinopathy, nephropathy) secondary to type two diabetes. In January 2005, he underwent a trans-tibial amputation of the right limb. In October 2005, the stump wound required

Fig. 5 *Complete wound healing in patient #1 after seven months of Harmony use.*

minor surgical revision of the skin and subcutaneous tissue due to infection. In April 2006, he was admitted to our Rehabilitation Institute. He suffered from a deep

Fig. 6 *Stump condition of patient #1 at recovery admission.*

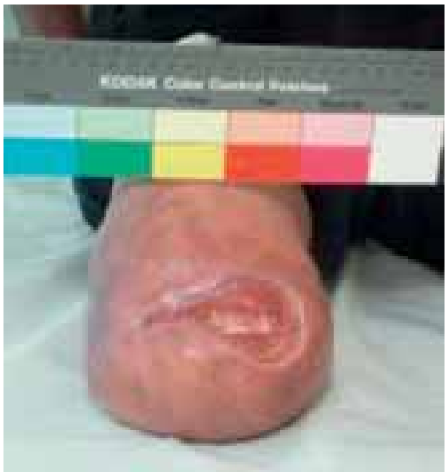

***Fig. 7** Wound condition in patient #2 after four months of Harmony use.*

open stump wound whose dimension were as follows: the horizontal axis was 11 cm, the vertical axis 5.5 cm (surface area about 47.4 cm^2) that made it impossible to fit a standard prosthesis (fig. 6)

The patient was fitted with the vacuum-assisted socket system (VASS). He wore the prosthesis for 8 hours per day and attended the gait training program. Notably, the patient was able to wear the prosthesis continuously for 3-4 hours with slight pain during weight bearing and locomotion activities. Thus, with the prosthesis fitting he was able to walk (LCI equal to 41) in spite of the presence of the open stump wound. After four months of daily VASS prosthesis use, a reduction of the wound area was obtained, as shown in figure 7. Wound measures at this time were the following: the horizontal axis was eight cm, the vertical axis 4.5 cm, (the surface area was reduced to 28.2 cm^2), about 41 per cent smaller than at the first evaluation.

Two month later the wound demonstrated a further reduction (4.8 X 3.8 cm), with a surface area of about 14.3 cm^2. Unfortunately we do not have further reports because of drop out for personal reason.

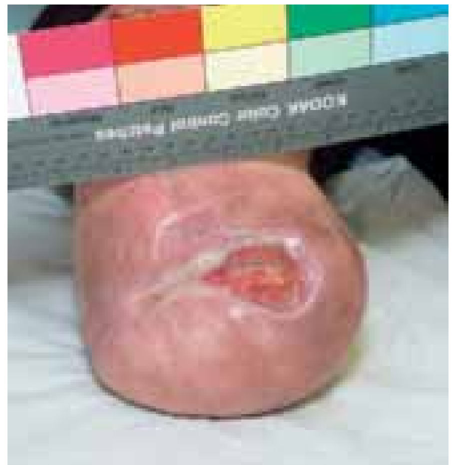

***Fig. 8** Wound condition in patient #2 after six months of Harmony use. Wound size reduction of 70% as compared to admission.*

Conclusion

We can assert that patients fitted the VASS Harmony had an excellent compliance with the prosthesis and all of them showed an improvement in wound healing.

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The major advantages observed in VASS group patients are: 1) possibility to use the prosthesis even when the stump presents unhealed wounds; 2) a strong trend to healing of these wounds, 3) better walking autonomy with less pain compared to patients fit PTB sockets. The amputees fit with Harmony referred a good balance, stability and control over the prosthesis due to improved proprioception and the awareness the patient has of his or her leg in space.

Nevertheless we observed some issues to be considered with the early use of VASS: in two post surgery cases, the use of Harmony was helpful to heal the skin lesions but a new socket for a perfect fit of the prosthesis was necessary after six months because of the large reduction of stump oedema.

VASS Harmony is a dramatically new approach to manage below knee amputee´s health and comfort. The system is designed to work seamlessly together, responding to the physical changes of the patient minute-by-minute. It can be fit earlier after amputation and it may help to heal stump wounds.

However, we have to admit that the whole number of enrolled patients is still not enough to make a generalization for the whole patient population and to make a strong statistical analysis. Our next focus for research on the effectiveness of VASS Harmony intends to enroll more patients.

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Prosthetics

G. Stark

20 ideas that upper extremity specialists use

Prosthetists that specialize in upper extremity often employ a variety of techniques in external and body power control systems that optimize prosthetic use. These techniques, individual to the patient and prosthetist, often arise from personal experience and empirical results. Often it is difficult to develop this clinical knowledge since upper extremity prosthetics constitutes roughly 10.13 per cent of the total amputee population. For a locally based prosthetist, upper extremity amputees are relatively few in number and require individual solutions based on limb length, ROM, and a variety of other factors. Often increased creativity, people skills, or mechanical acumen are sited as the resource that specialists use, but in reality it is the ability to draw upon a large number of solutions a number of individual fittings and adapt them to an individual case. This situational recall and adaptability aptitude allows these prosthetists to create solutions for external or body power prostheses. As Jack Uellendahl, CPO notes, „Body power solutions can often be considered more challenging with regard to control application and optimization. Often they become more problematic if the basic function is not understood“. Admittedly these solutions are non-evidence based and drawn from successful applications where the specialist has seen, heard, and performed techniques with other colleagues and patients. Typically a „fitting logic“ is developed among these specialists to optimize fit and performance and limit fitting variables. Although there are a multitude of individual solutions, below are more than 20 of these solutions that have been helpful in a number of special cases.

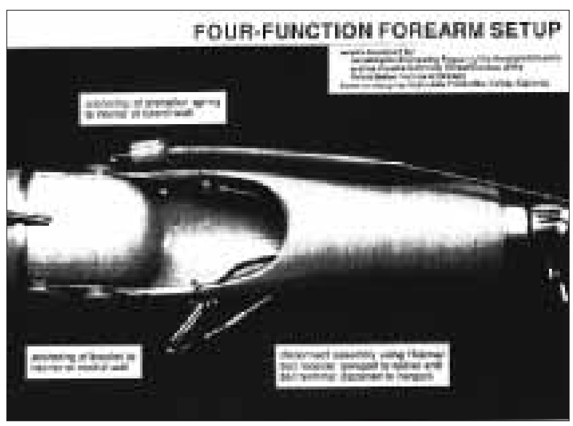

Fig. 1

(1) The 4-Function is named for the four functions of the wrist that it control Pronation/Supination, Flexion/Extension (Fig. 1). These movements are critical especially for shorter limb length or bilaterally involved patients. The classic device was created from various components, but primarily used separate rotation and flexion wrists. These wrists were spring-loaded using a wound cable housing for the rotating wrist and a rubber band for flexion. When released the springs acted to pull the hook into pronation and flexion. The control cable pulled the hook into the correct angle of pro/supination and that mode was locked with a proximal “bump or brush“ latch. The flexion angle was then adjusted by again pulling on the control cable and a distal latch on the wrist flexion device was then activated. This fairly simplistic device was able to add two more modes of active positioning with the control cable. The disadvantage was that many of these components were adapted individually by Jim Caywood, CP and others and remain fairly singular. Off-

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the-shelf versions have been created, but the mode latches still need to be created or adapted from much larger „nudge“ controls for elbow control.

(2) A less obtrusive nudge or bump latch can be made for the 4-function wrist above or other components requiring modal controls such as elbow or wrist locking with standard components (Fig. 2). A cable hanger may be silver soldered to both the cable and the cable housing, then attached to a D-ring which is anchored to the external lamination by an anchor plate. It is important to attach the hanger, cable and cable housing all to each other so the cable housing can act as a return spring. The D-ring swivels and angles the hanger proximally as it is pushed. The housing also acts as the return spring and helps to pull the hanger back distally since it is affixed to the hanger and cable.

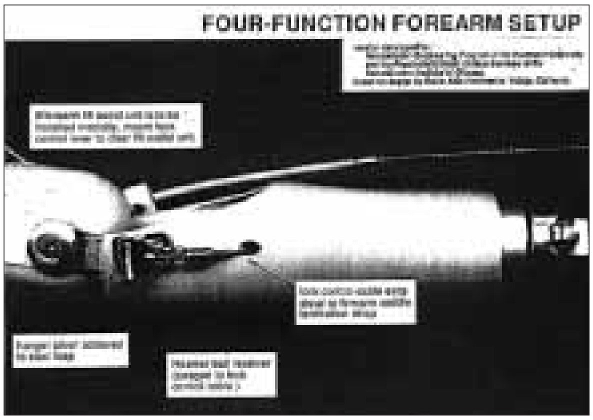

Fig. 2

Fig. 3

Other designs employed a larger „paddle“ design with a piece of plastic, 70 mm long, mounted on two D-rings that swivels in the same fashion to activate the lock. While functionally equivalent it is much larger and requires more cable hardware then the aforementioned simplified design.

(3) Harnessing the transhumeral patient can be challenging because of the increased excursion demands and the limited power requirements. The average patient requires approximately 62 mm to lift the forearm fully and 50 mm to open the terminal device; adding to 112 mm to fully use the prosthesis. This can be quite challenging for the medium to short transhumeral amputee. To preserve excursion and maintain an inferior position of the harness many prosthetists employ an elastic cross-back strap (Fig. 3). The strap must be elastic to make donning the harness possible. Although this preserves some excursion it may not fully capture all of the motion available. A Z-strap is a cross back strap variation that is more rigid in nature. The control attachment strap passes through the control cable hanger and passes across the back to the adjustable 4-bar buckle on the axillary pad or strap. This variation still allows easy donning but not sacrifice excursion demands. As the patient activates the control cable, the hanger will swivel into position and „find“ the optimal position based on prosthetic orientation.

(4) For the transradial amputee self-suspension interface design two methods have predominated. The Otto Bock-Muenster, first developed by Otto Fruzinsky, CPO is ideally suited for medium to short limb lengths placing particular emphasis on A-P cubital to triceps bar loading as well as supracondylar M-L modifications to allow full ROM. This design maximizes the loading of the limb by pulling the cubital tissue inside the interface. The Northwestern Design developed by John Billock also employs M-L supracondylar loading, but drops the trimline to within 50 mm of the distal end. The A-P tension with the triceps bar is created with slight loading along the anterior trimline. This allows the Northwestern design to offer push-in donning. The prosthetist can utilize both designs depending on limb length and hybridize them at the medium limb length by increasing the cubital loading for shorter limbs and increasing M-L pressure and dropping the anterior trimline for longer limb lengths (Fig. 4).

(5) The St. Anthony Circuit, also known as the cookie crusher is often used for a simplified one-sit control for juveniles, but it can also provide simplified control for high level upper extremity prostheses such as shoulder disarticulation or interscapular thoracic level. Muscular contraction usually provides the signal for opening and relaxation returns the device to a gripping position. The disadvantage is that the maximum gripping force is applied everytime so the grip force of the hand needs to be decreased to 6-9 lbs instead of the normal 24 lb. force. This control can also be incorporated into a three position pull to provide multiple modes for elbow flexion, extension, and hand function.

Fig. 4

(6) Sometimes the small nuances of upper extremity design are a great aid for the patient. During unilateral donning, it is fairly difficult to hold the prosthesis on while the anterior chest strap is fished through a D-ring. A backpack buckle is also difficult for unilateral amputees since both sides of the buckle must be positioned, inserted, then squeezed closed with one hand. A sliding D-ring and clip, often used for anterior closures in orthotic devices, as an aid for unilateral donning. The sliding D-ring can be easily placed in the clip attached to the prosthesis and sinched tight or removed (Fig. 5). It may be necessary to open the clip slightly to allow easier insertion.

(7) Tom Andrew, CPO first

developed this transhumeral interface to design to create a tighter interface that could index electrode placement and to help off load the increased weight of external power control systems. Using a splinting technique he separated

Fig. 5

the distal volumetric containment with the proximal loading of the deltopectoral groove and infraspinous scapular region. The distal interface was created with loading on the M-L of the humeral shaft and A-P loading of the shoulder. The proximo-lateral trimline could then be lowered to the axillary level (Fig. 6). Although the anterior trimline reduced the amount of glenohumeral flexion, it created a tighter fit with less lost motion in the interface and increased abduction range of motion. The same A-P pressure was also used with shoulder disarticulation designs to off load the shoulder for external control systems.

(8) A mechanical elbow and electric arm hybrid is advantageous with transhumeral fittings for a variety of reasons. The most obvious is the decreased cost associated with the elbow. The expense is focused on the terminal device component that is used the more often and has the benefit of increased pinch force. If the harnessed correctly, the body power elbow is usually faster when compared to externally controlled elbows. The hybrid also has the advantage of separate simultaneous control of the elbow and terminal device. Using body power to lift the elbow, the patient has increased proprioception of the gross movement which directly links body motion to elbow position. External control of the hand remains fully functional during flexion, rather than waiting for the arm to be locked into position, making manipulation of objects faster. Although a standard mechanical elbow can be configured to use external controls, more options have been developed specifically for hybrid control. When reconfiguring a standard mechanical system the wiring for the electronic controls needs to be made longer, should be routed posterior to the elbow axis, and enclosed in automotive flexible cable covers. Usually an internal battery system is used and it is preferred that it is in the humeral section if it is cosmetically acceptable to decrease live lift load and wiring issues. Hybrid control can also be applied to elbow disarticulation where there are few external elbow control options.

(9) Along with hybridization of body and external control systems, different external control systems may be mated together. When matching different components,

Fig. 6

there are a variety of factor to consider. The first is the control output to the device and second is the control voltage. The components that are the easiest to hybridize usually have no controller internally. One hybrid option that can be used for a transhumeral prosthesis is to use a transradial control system that can operate the hand and the wrist control can be used for a simple two-wire elbow device. This allows a much less expensive transhumeral prosthesis to be created, but may require a modal switch to switch between hand to elbow control.

(10) The use of low friction donning sheaths may not seem like a large technologic advancement, but it makes the use of tighter fitting interfaces and vacuum suction for external control much more practical. This is extremely important to prevent the development of painful tissue rolls in the medial humeral axilla area as well as the cubital fold. Anecdotally there seems to be less tissue distraction that may contribute to myosite migration in the definitive prosthesis.

(11) The fitting of partial hand amputations can be challenging due to the lack of distal space for the attachment and wrist components. One characteristic among upper extremity components is that the majority are ½-20 screw thread regardless if it is an adult or even infant size. An infant size wrist is small and compact so it can be used with an adult terminal device to utilize for a partial hand prosthesis. The wrist is small enough to be mounted in the palmar aspect of the hand. The infant wrist may also be used for other attachments hat use a ½-20 thread including a shoulder or elbow rotation.

(12) Harnessing alternatives are needed to provided stability and comfort with as few straps and attachments as possible. Cross point harnesses are frequently used

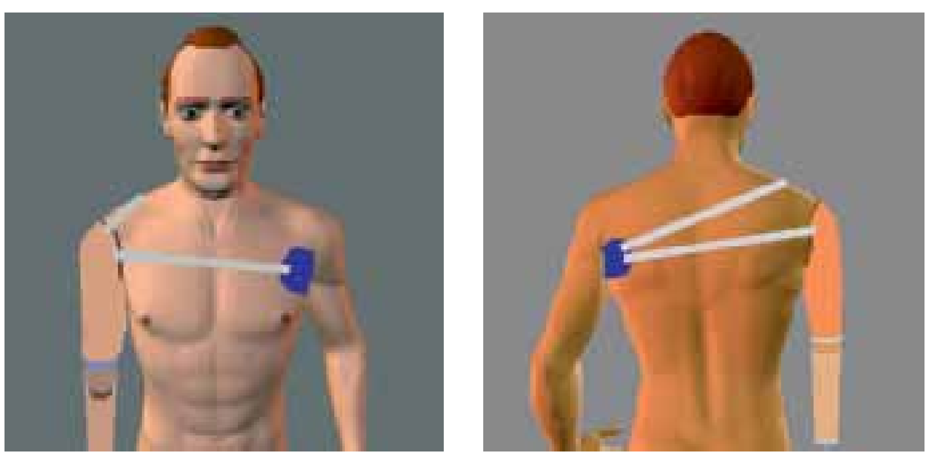

Fig. 7

to optimize excursion responsiveness, but often cause discomfort or even permanent nerve compression issues in the axilla. More elastic designs can be used to increase comfort at the expense of excursion and function. Chest strap and shoulder pad harnesses can be used to transfer the weight away from the axilla to the thoracic area of the chest. However these harnesses are more encumbering and involved strapping configurations. When using external power a simple three strap harness may be used to lessen the overall harnessing. A three strap harness involves a simple cross-back strap, chest strap and a superior back strap that attaches just anterior to the apex of the deltoid to provide suspension (Fig. 7). Normally a chest strap is not utilized for the female anatomy, but the axilla pad may be constructed to have the attachment more superior so the chest strap traces across the sternal notch.

Fig. 8

(13) In the past it was fairly difficult to combine the superior suspension of gel liner sleeves with myoelectric sensors. Previously, holes were cut in the sleeves to allow access to the myo sites, but the soft tissues would migrate to the area and insulate the myoelectric signals. Wayne Daley, CPO utilized modified remote myosites, originally used by therapists to test muscle activity, to create a „snap-on" electrode (Fig. 8). These smaller diameter electrodes could rolled on with the liner attached through the gel layer to a series of external snaps. The elastic tension of the gel liner maintained intimate skin contact, with perspiration contact, in all functional positions with little gapping. The disadvantage is that holes need to be cut in to the frame to accommodate the higher profile attachment and the myosites were snapped into everytime the devices was donned. This increase in donning time led Karl Fillauer, CPO to created stud electrodes which were broad plates that make contact with the inner set of liner electrodes.

(14) Leather straps and pads have the advantage of providing multidirectional strength, body conformance, and pliable comfort. Unfortunately it is an organic porous material that readily absorbs odors especially in the axilla area. Spenco can also be used as an alternative to leather for its conformability, but does exhibit long-term strength, is still somewhat porous, and cannot be riveted. TPE materials are not as elastic, but can readily conform to body shape and are easily formed at low temperature. Their non-porous nature resists the absorption of odor for shoulder saddles and axial pads (Fig. 9). It has greater stiffness for rivets, but will still cold flow with localized force.

(15) Titanium terminal devices and wrists were not offered previously because of difficulty forging and shaping the metal. Titanium provides the same strength as 17-4 PH Stainless Steel, but at 60 per cent of the weight. For moderate use, Aluminum devices are strong enough although contact points cold flow and can fatigue long term. Titanium devices are lighter, but also have a higher spring constant that resist deformation, but also make them harder to machine and make.

Fig. 9

(16) Although well known in Europe, the triple control harness provides a number of alternatives to figure of 8 harnesses commonly used in the US. It provides simultaneous control since the medial cable is used to lift the elbow and the lateral cable operates the terminal device. An elastic strap, used for elbow locking is seated at the base of the neck and all straps tie into the anterior axilla attachment. The cross point was also allowed to migrate as the prosthesis is used in different positions. The only main disadvantage is the elbow cable excursion loss due to the medial placement of the cable.

Fig. 10

(17) Bill Sauter, CPO of Toronto Canada separated the transradial interface into four separate quadrants, proximal-distal, anterior-posterior. He advocated the removal of the proximal posteror quadrant to increase comfort by creating a window over olecranon (Fig. 10). The patient has sensation when holding the limb on a table, but this necessitates relief over the ulnar shaft. Also the relief should not exceed the M-L at the epicondyles or the elbow may migrate through the window at full flexion. Anecdotally the supracondylar M-L tension may need to be increased with the window to maintain suspension at 90°. The triceps bar, proximal to the olecranon remains as a counterforce to the anteriorly directed cubital or anterior trimline. Dick Plettenburg, Ph.D. with the WILMER research group from the University of Delft has also shown a transradial design with detachable triceps bar of padded metal that can provide a more open interface design.

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(18) The trend for Shoulder Disarticulation and Interscapular Thoracic interface design is to decrease the interface coverage area to the most functional structural components. By utilizing A-P pressure in the deltopectoral area and the subspinous area of the scapula, con-

Fig. 11

tact above the shoulder is greatly decreased or obviated and can be opened. Utilizing thin and strong composites, Randy Alley, CP and John Miguelez, CP advocated a Micro-Frame or X-frame construction. The upper X is the deltopectoral and scapular area (Fig. 11). The lower X forms the base support of the anterior and posterior costal margin. Both advocate corrugations to increase stiffness. This interface design allows a more open proximal margin will maintaining the compression of the lower costal region for stability. The harness is formed with elastic or Spenco straps wrapping on the contralateral thoracic area.

(19) Along with the interface the design the shoulder component can be altered to increase function of the shoulder disarticulation prosthesis. The attachment for a friction shoulder joint can be inverted to fit with the X-frame Micro construction. The metal attachments can also be replaced with thermoformable carbon material to make the layer even thinner. Also one of the attachment bolts can be removed as a conduit for the electrode wires that originate from the interface design.

(20) While many prosthetists adjust the elbow flexion attachment in body power to allow easier lifting for the forearm many do not take the time to optimize the base plate placement. This is crucial for the cabling of short limb lengths that must optimize excursion responsiveness. The baseplate should be placed 10 mm proximal to the cut end of the humerus in the posterior lateral corner. As an aid it can be soldered to a padded adjustable ring strap to adjust its placement. The baseplate should be placed more anterior and proximal to increase lifting power at the expense of increased excursion need. A more distal posterior position decreases excursion, but increases the power requirement to flex the elbow. Often two retainers are required to maintain excursion with a distal attachment, but keep the most proximal attachment proximal to the cut end of the bone so the arm does not rotate laterally (Fig. 12).

Fig. 12

The reader has been promised 20 ideas, but two more act as a baker's dozen and it is hoped, insure approval.

(21) A double cross point ring is frequently applied for body power users with broad backs. As they use a typical figure of 8 harness the cross point may have a tendency to ride up the back. A double ring harness, attached by a short 35 mm strap, insures that the cable attachment remains inferior as the patient uses the harness and that it will not ride on the

Fig. 13

neck (Fig. 13). Bob Radocy from TRS has presented a one-piece plastic version that is an elongated cross point.

(22) Microprocessor control now allows for multiple inputs for terminal device, wrist, elbow, and shoulder control. Now it is possible to achieve simultaneous function for many controls without relying on modal switches between function. This speeds the switching of control and allows the amputee. Also the interpretation of the controls has a greater impact in control switching. For example a myo signal with a quick rate may have a wrist function, where a slightly slower rate As a result there are many combinations of controls.

Of course there are many more concepts that are utilized by upper extremity specialists. The preceding list is a synopsis of the ideas that have been more commonly used. Without question the list is incomplete, but hopefully introduce and stimulate interest for those wishing to develop their upper extremity prosthetic ability.

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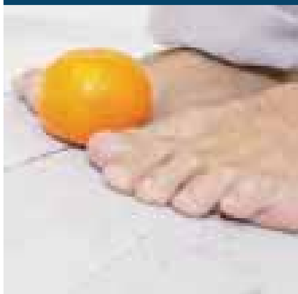

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