Prosthetics and Orthotics International, 1986, 10, 117–124

Prescription of above-knee and below-knee prostheses

G. RUBIN, E. FISCHER and M. DIXON

Veteran's Administration Prosthetics Center, New York

Abstract

New developments in socket design, materials and fabrication are briefly reviewed. A series of charts is presented which summarize the below-knee and above-knee prescription procedures followed at the Veterans Administration Prosthetics Center.

Introduction

It is the purpose of the authors to present one clinic team's approach to the prescription of above-knee and below-knee prostheses.

Prosthetic prescriptions have varied significantly under relatively similar circumstances from centre to centre, in the experience of the authors. There are many different knee components, prosthetic feet and socket designs available. Modifications of older concepts are continually being added to the armamentarium of the clinic team.

Although the prescription procedures acceptable to the authors appear to have worked well for them and the amputees they serve, they may not be as readily acceptable to others.

If the charted outline of prescription and component selection stimulates discussion and controversy, its purpose will have been accomplished.

Since no two amputees will have the same general physical status, individual stump characteristics, or vocational or occupational problems, a rigid approach is not possible. In some instances, climate, terrain and cultural differences will also affect the prescription. A basic concept, however, with an understanding of such individual restrictions, is presented in this paper.

It is challenging and of continuing importance that new techniques are being tested in various centres throughout the world. Many of these are logical and promising and will undoubtedly, after adequate testing, become firmly established tools of the prosthetist.

Until, however, they have been widely used by a sufficient number of prosthetists other than the developers, and the reports of their experience become available, a final judgement must be held in abeyance.

The newer developments which the authors have recently adopted have prompted them to revise an earlier presentation outlining their clinic team's approach to the selection of components for lower limb prostheses (Rubin and Fischer, 1982).

The format employed in the previous article has been used here with pertinent chart and text modifications to reflect changing attitudes in specific instances. The authors have been very conservative in developing the charts and have preferred to include in the text advances in prosthetics which are still not universally employed rather than in the charts, per se. These include such potentially significant developments as the "Scandinavian Flexible Socket" (Jendrzejczyk, 1985) the "Normal Shape-Normal Alignment" above-knee prosthesis (NSNA) (Long, 1985) and the "Contour Adducted Trochanteric Controlled Alignment Method" (CAT-CAM) (Sabolich, 1985), among others. The authors' experiences with the Scandinavian flexible socket have been quite positive. The amputee's response to the action and cosmesis of the Seattle foot (Burgess et al, 1984), also a recent development, has been generally favourable. There are problems, as with everything new, which will undoubtedly be eliminated by the developers. The very active amputee still experiences too frequent breakage. With the advent of the Seattle foot, other feet incorporating the stored energy concept are continually becoming commercially available. There is, incidentally, some similarity in this concept to the shoe with the addition of a long steel spring and rocker bar that is advisable in orthotics when a solid ankle orthosis is used.

All correspondence to be addressed to Dr. G. Rubin, Orthopedic Consultant, Special Clinic Team, Veterans Administration Medical Center, First Avenue at East 24th Street, New York, NY10010.

Another foot-ankle that has not yet had broad acceptance is the Mauch hydraulic ankle. This centre was involved in the initial testing of the Mauch ankle, in spite of which it has had limited experience with it. It does have capabilities that other feet do not have, such as adjustability to the terrain when walking up and down-hill. There had been a frequent malfunction problem with this device which limited the frequency of prescription. The authors look forward to gaining experience with the new, lighter, and, presumably sturdier version. It promises to be a very sophisticated ankle.

Xeroradiography(R) (Varnau et al, 1985), has been introduced to prosthetics, but the authors have viewed the routine use of this technique with caution, because the radiation dosage is nine times as high as with routine X-ray exposure and "Syme level as well as long above-knee residual limbs require two pictures merely to complete the image for one projection" (Varnau et al, 1985). If two projections each of an antero-posterior and a lateral view are employed, the basic dosage will be nine times the routine X-ray dosage, quadrupled. A good deal of useful similar information is obtainable with the clear socket method and the occasional use of routine X-ray when specifically indicated (and after consultation with the physician member of the Clinic Team). From the medical point of view excess exposure to radiation should be limited unless no other reasonable alternative exists. Varnau et al (1985) do indicate their concern for the juvenile patient and advise that the "benefits of Xeroradiography(R) must be weighed against the greater radiation dose". It is suggested that this cautionary approach be broadened to include adults as well.

Above-knee amputation socket design is undergoing dramatic evolutionary changes at this time. The reports of Lehneis (1985) Long (1985) and Sabolich (1985) are most significant in this regard. The CAT-CAM of Sabolich and the NSNA of Long have had extensive testing by the originators, and Lehneis, in cooperation with the U.S. Veterans Administration, is at present engaged in investigating the special design indications for the geriatric amputee's socket.

Currently, many other prosthetists are learning and using the CAT-CAM system. Their reports, when available, will make an important contribution to the acceptance of this method.

Similarly, below-knee sockets are being fabricated with flexible plastic at several centres and this concept also appears to have merit. Sidney Fishman and his group at NYU in conjunction with the U.S. Veterans Administration are also involved in exploring the use of a frame and socket configuration for the B/K.

CAD-CAM (Computer Aided Design — Computer Aided Manufacture), a sophisticated approach to the eventual increase in speed of production of prostheses has been under development by several prosthetic centres.

As Murdoch (1985) has indicated the "individual prosthetist will be able to fit more patients in a given time", but his clinical experience and expertise will be required to modify the CAD-CAM product.

The enthusiasm for acronymic description of prosthetic techniques has led to the identification of the "Icelandic Roll-On Suction Socket" as the Ice-Ross system (Kristinsson, 1985a) and the "Icelandic Pull-On Suction Socket" as the Ice-Poss system (Kristinsson, 1985b). Both of these systems employ injection moulded sockets to achieve B/K suction and both are not widely accepted by prosthetists. Because the designs referred to above are still undergoing changes (Sabolich is preparing a new report on a procedure he designates as SCAD-CAM) they have not been included in the basic charts which are part of this paper.

Summary

A series of charts has been presented summarizing the above-knee and below-knee prescription procedures which have been followed at the Veterans Administration Prosthetics Center. There is a very significant evolution in socket design, materials, and fabrication which everyone involved in prosthetics is observing carefully. However, new developments do require extensive trial before becoming universally accepted and these new developments are undergoing such a trial at present. "It would be a truism to point out that some of the devices categorized as research items at the time of this writing will no longer be considered to be such by the time this book *(sic)* is published. Some will be accepted and others discarded" (Rubin and Wilson, 1981).

BELOW–KNEE AMPUTATION				
STUMP LENGTH (From medial tibial plateau)	MODIFYING FACTORS	PROSTHESIS	SUPENSION	FOOT/ANKLE UNIT
10 cm. to above Syme level	No stump problems	After stump has matured following use of temporary prosthesis, PTS is preferred–PTB is second choice	1. For PTB, cuff type (if snug suprapatellar suspension cannot be tolerated, or additional security needed, waist belt and auxiliary anterior suspension strap should be added) 2. Wedge, as below, for PTS	1. SAFE foot as first choice 2. SACH foot as second choice 3. See text concerning Seattle and Single Axis feet.
4 cm. to 10 cm.	No stump problems	PTS, or if 4 cm. to 7 cm. PTS-SP (Patellar Tendon Supracondylar, Suprapatellar)	1. Soft insert with built-in wedge, first choice 2. Removable wedge or removable medial wall, second choice	As above
Either of above	1. Unstable knee 2. Occupational considerations requiring maximum stability 3. Short BK stump and contralateral limb problem, such as AK amputation.	Thigh corset side joints prosthesis.	Thigh corset Waist belt and fork strap if needed	1. SACH as first choice 2. Single axis, second choice
Any length	Extremely hypersensitive soft tissue unable to tolerate pressure (prior to removing a patient in this group from any of the above categories, a trial of a gel socket should be made)	Prosthesis should be fabricated with quadrilateral socket, freely suspended stump, double bars to distal shank segment and SACH foot. A knee lock or offset knee joints should be used. This will be an A/K prosthesis	Flexible plastic hip joint and pelvic band, with belt	Single axis
Any length	Stump problems which are not as severe as above (amputee can tolerate limited pressure, but trial of a PTB or PTS with gel socket has failed)	Gluteal or ischial bearing thigh corset, side joints at knee, and socket with soft insert.	Thigh corset Waist belt and fork strap if needed	1. SACH as first choice 2. Single axis second choice
4 cm. to 10 cm.	Flexion contracture up to 30° (a longer stump, or one with a greater contracture cannot be fitted with a BK prosthesis)	PTS	Supracondylar	SACH
4 cm. to 10 cm.	Flexion contracture greater than 30°,	Bent-knee Prosthesis (highly undesirable but may be only option)	Molded plastic laminate thigh socket with velcro closure, lacing, or distal anterior window, or medial window	1. SACH as first choice 2. Single axis second choice

ABOVE-KNEE AMPUTATION–PHYSIOLOGICAL AGE: ACTIVE

STUMP LENGTH (From Ischial tub.)	SOCKET	SUPENSION	KNEE	KNEE STABILIZATION	STRUCTURAL TYPE	ANKLE-FOOT UNIT
From 5 cm. to above flare of femoral condyles	1. Total suction for the young, active, adult amputee 2. Partial suction for the older amputee if this is an initial fitting. If older amputee has previously used total suction then continue. 3. Non-suction if failure of 1. and 2. (For the amputee with a very short residual limb high lateral and anterior walls should be used, preferably with total suction and auxiliary suspension	1. Suction (see socket column) – total or partial 2. For partial suction, auxiliary support is needed: a. Rigid metal hip joint, waist band and belt for very short stump. b. plastic joint and waist band with belt if amputee has adequate hip control and stump is at least 12 cm. or longer. c. Silesian belt for longer stump. 3. Non-suction: –auxiliary support as above.	1. Fluid control preferred. 2. Single axis as second choice	1. If SNS is used, then stability achieved by the special stabilizing function and fluid flow characteristics of the unit, plus proper alignment. 2. If fluid control units other than SNS are used, stability is achieved by fluid flow characteristics of the unit, plus proper alignment 3. If a single axis unit is used, stability is achieved by alignment	1. Either Exoskeletal or Endoskeletal if knee unit selection not in doubt. (Subjective choice of amputee) 2. If knee unit selectior is in doubt then Universal, Knee-Shin Set-up, or multiplex, to allow trial of various units.	1. SAFE foot as first choice 2. SACH as second choice Single Axis foot as third choice Refer to comments in text concerning Seattle foot
Approximately 5 cm.	1. If stump soft tissue is bulky, assign to less than 5 cm. category, below, and treat as a hip disarticulation. 2. If stump soft tissue is lean and problem-free, assign to 5 cm.+ category, above, and treat as an above-knee amputation.					
Less than 5 cm.	Treat as hip disarticulation with molded socket	Socket contoured to achieve pelvic suspension	1. Low resistance hydraulic or pneumatic unit as first choice 2. Single axis as second choice	weight-activated knee preferred	Exoskeletal or Endoskeletal	Single axis
Trans-condylar (femoral)	Partial end-bearing without suction	1. Soft insert with supra condylar suspension as first choice 2. Waist belt as second choice a) plastic hip joint, waist band and belt if hip is stable b) metal hip joint, waist band and belt if hip control is inadequate	1. Four-bar linkage with fluid control as first choice 2. Single axis with outside joints only if amputee is habituated to this system and refuses change	1. The four-bar linkage unit's stability is based upon the geometry of the unit plus proper alignment. 2. The stability of the single axis knee is achieved by alignment (Single axis hydraulic if amp does not object to comesis)	Exoskeletal or Endoskeletal	Same choices as in 1st category, above

ABOVE-KNEE AMPUTATION– PHYSIOLOGICAL AGE: LIMITATION OF ACTIVITY

STUMP LENGTH (From Ischial Tub.)	SOCKET	SUSPENSION	KNEE UNIT	KNEE STABILIZATION	STRUCTURAL TYPE	ANKLE-FOOT UNIT
From 5 cm. to above flare of femoral condyles	Partial suction (open end if above contra- indicated by stump problems or rigid habit pattern)	1. Rigid metal hip joint and waist band, with belt, for short stump or weak hip muscles. 2. Flexible plastic hip joint and waist band, with belt, for longer stump and stable hip.	1. Low resistance fluid control as first choice 2. Single axis knee as second choice	1. If fluid control is used then stabilization is achieved by fluid flow characteristics and alignment 2. If single axis is used then stabilization is achieved by alignment. (weight-activated lock may be added if needed)	Endoskeletal lightweight Titanium components as first choice Exoskeletal as second choice	1. If stump is short, single axis as first choice (SACH as second). 2. If stump is of intermediate length, or long, SACH as first choice (single axis as second) 3. Single axis for the blind amputee
Approximately 5 cm.	1. If stump soft tissue is bulky, assign to less than 5 cm. category, below, and treat as hip disarticulation. 2; If stump is lean and problem-free, assign to 5 cm.+ category, above, and treat as AK amputation.					
Less than 5 cm.	Treat as hip disarticulation with molded socket	Achieve by molding socket over the pelvis.	Single axis	Stabilization achieved by alignment	Endoskeletal See Above	Single axis
Trans-condylar (femoral)	Partial end-bearing. No suction.	1. If hip control is unimpaired, then flexible soft socket insert with supra-condylar suspension 2. If rotational hip control needed, then Silesian belt. 3. If moderate hip control needed, but retention of limited motion is desirable, then flexible plastic hip joint and band, with belt. 4. If hip control is poor, (weak muscles) then metal hip joint and waist band with belt.	1. Four-bar linkage knee without hydraulic as first choice 2. Outside knee joints, single axis, as second choice	1. Stability of the four-bar linkage is dependent upon the geometry of the unit 2. Stability of the single axis is dependent upon alignment.	Endoskeletal See above	1. SACH as first choice 2. Single axis as second choice

ABOVE-KNEE AMPUTATION–PHYSIOLOGICAL AGE MARKED LIMITATION OF ACTIVITY — Household Bathroom

STUMP LENGTH (From ischial tub.)	SOCKETS	SUSPENSION	KNEE	STABILIZATION	STRUCTURAL TYPE	ANKLE-FOOT UNIT
From 5 cm. to above flare of femoral condyles	1. Partial Suction as first choice 2. Open end if partial suction contraindicated by status of stump, or if amputee is habituated to open end socket and refuses change	Metal hip joint and band, with belt	Single axis	Stability of knee achieved by alignment, and, if needed, a weight-activated lock; or a manual lock may be added to provide adequate stability	Endoskeletal Titanium 1st choice. Exoskeletal. 2nd choice	Lightweight SACH or single axis
Approximately 5 cm.	1. If stump soft tissue is bulky and amputee is considered to have the potential for utilizing the prosthesis for household or bathroom ambulation, or limited exercise purposes, then assign to less than 5 cm. category, below, and treat as hip disarticulation. 2. If stump soft tissue is lean and problem-free, assign to 5 cm.+ category, above, treat as AK amputee and consider addition of hip lock, as well.					
Less than 5 cm.	Molded pelvic socket as for hip disarticulation (see 1. immediately above)	Achieved by molding socket over pelvis	Single axis	1. Knee stability achieved with manual knee lock. 2. Hip stability achieved with stride control hip lock.	Titanium. 1st choice. Exoskeletal 2nd choice	Single axis or Sach See above
Transcondylar (femoral)	Partial end-bearing. No suction	Metal hip joint and band, with belt	Single axis	1. Weight-activated lock preferred 2. A manual knee lock should be used if indicated by the clinical status of the amputee	Either endoskeletal or exoskeletal (patient preference)	Single axis or Sach See above

KNEE DISARTICULATION

MODIFYING FACTORS	SOCKET	KNEE	SUSPENSION	STRUCTURAL TYPE	ANKLE–FOOT
1. Unmodified stump with or without retention of retracted patella, and no stump problems 2. Gritti-Stokes amputation	End-bearing, as well as support provided at all aspects of the stump-socket interface by well-contoured fit.	1. Single axis hydraulic knee preferred if amputee does not object to cosmesis. 2. Four bar linkage hydraulic 2nd choice 3. If amputee refuses change then outside joints	1. Soft socket insert fabricated to achieve supracondylar suspension as first choice. 2. Flexible plastic hip joint and band, with belt, as second choice, or Silesian belt.	Either Endoskeletal or Exoskeletal	1. Safe foot 1st. choice 2 Sach foot as second choice 3. Single axis as third choice
Stump modified by removal of medial and lateral condylar prominences	As above. If potential for end-bearing is limited, then include quadrilateral **socket** with proximal support.	As above	1. Supracondylar suspension not adequate Use flexible plastic hip joint and band, with belt, or Silesian belt (see above)	As above	As above
As above but cannot tolerate end-bearing	As above	As above	As above	As above	As above
Bilateral knee disarticulation	As in the appropriate category, above	1. SNS knees preferred. 2. Single axis with outside knee joints only if amputee will not accept fluid control (*bilateral* four-bar linkage knees difficult to manipulate since knees must be un-weighted to allow sitting).	As above	As above	As above

REFERENCES

Burgess, E., Hittenberger, D. A., Carpenter, K. L. (1984). The VA Seattle foot. In: Veterans Administration Rehabilitation R & D Progress Report, p5.

Jendrzejczyk, D. J. (1985). Flexible socket systems. *Clin. Prosthet. Orthot.* **9(4),** 27–31.

Kristinsson, O. (1985a). The Ice-Ross System (abstract) *AOPA Almanac* **33(10),** 50.

Kristinsson, O. (1985b). The Ice-Poss System (abstract) *AOPA Almanac* **33(10),** 57.

Long, I., A. (1985). Normal shape-normal alignment (NSNA) above-knee prosthesis. *Clin. Prosthet. Orthot.* **9(1),** 9–14.

Lehneis, H. R. (1985). Beyond the quadrilateral. *Clin. Prosthet. Orthot.* **9(4),** 6–8.

Murdoch, G. (1985). Editorial *Prosthet. Orthot. Int.* **9,** 1–2.

Rubin, G., Fischer E. (1982). Selection of components for lower limb amputation prostheses. *Bull. Hosp. Joint. Dis. Orthop. Inst.* **42,** 39–67.

Rubin, G., Wilson, A. B. (1981). Research trends in lower limb prosthetics. In: American Academy of Orthopedic Surgeons. Atlas of Limb Prosthetics. St. Louis, MO: C.V. Mosby, p 435–439.

Sabolich, J., (1985). Contoured Adducted Trochanteric — Controlled Alignment Method (CAT-CAM): Introduction and basic principles. *Clin. Prosthet. Orthot.* **9(4),** 15–26.

Varnau, D., Vinnecour, K. E., Luth, M., Cooney, D. F. (1985). The enhancement of prosthetics through Xeroradiography[R]. *Orthot. Prosthet.* **39(1),** 14–28.