Newsletter...

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AAOP

Prosthetics and Orthotics Clinic

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A Proposal for Delivery of Externally Powered Upper-Limb Prostheses

There are about 322,000 amputees in the United States today. Of this number, approximately 9,000 people have upper-arm amputations and 16,000 have forearm amputations. Many arm amputees choose not to wear a prosthesis for three major reasons; 1) lack of sensory feedback, 2) poor function and 3) poor cosmesis.

Unfortunately, the vast majority of physicians, therapists, and prosthetists seem to believe that new amputees should always be provided a hook first, and a hand later, if the hook is accepted. Nearly all patients, however, want a hand first and dread the thought of using a hook for obvious cosmetic and psychological reasons. In a great number of cases, the hook and prosthesis are rejected due to the undue amount of attention attracted to the wearer.

Body powered mechanical hands are heavy, cumbersome, and far less functional than hooks. The same amount of harnessing and body power is required to control these hands as with the hooks. The cosmetic gloves that cover these hands are easily stained, torn, and discolored. The major indication for prosthetic hands has been for unilateral amputees who are engaged in light-duty work and are very conscious of cosmesis.

The introduction of the VA- Northwestern University, Otto Bock, Variety Village, and other powered hands and elbows for prostheses should change the dismal attitude concerning prosthetic hands. These prostheses are extremely cosmetic, and require very little body motion and little or no harnessing to control the hand. The hand can be controlled easily whether the wearer is reaching for something over his head or behind him, which was previously very difficult. Powered prostheses are of greatest value for patients with high amputations, whether they are unilateral or bilateral. These patients are normally present complicated problems because they lack the muscle power and leverage to control mechanical prostheses, but they can easily control powered prostheses by myoelectric or switch controls.

"Powered prostheses have received a very cool reception in the United States due to—high cost and a greater expertise required to fit."

Powered prostheses have received a very cool reception in the United States due to a number of factors; the cost of the prostheses is high—four to five times that of conventional prostheses—and therefore many third-party payers refuse to pay for them. The prosthetist fitting an externally powered prosthesis must be well trained in order to evaluate myoelectric potentials and to properly fit and maintain the prosthesis. As most prosthetists have no background in electronics, more that a short orientation course is required. Even after thorough training is obtained, the prosthetist may only see two or three patients per year requiring these types of prostheses, and therefore much of the information will be forgotten. In many cases, components that were intended to be modular in concept and simply plugged in need to be reworked or redistribued around on the socket in order to accommodate a long or non-standard type of amputation. In a study conducted by the Veterans Administration 18 prosthetists were involved in an evaluation of powered prostheses. All prosthetists were given a one-to-two-week course by the VA on myoelectric prostheses and patients were referred to them through VA clinics for fittings. Despite all this education, prosthetist errors were responsible for more malfunctions than any other cause. Faced with all of the above facts plus the fact that the cosmetic glove is still a problem, most prosthetists chose not to handle externally powered prostheses. Further, since such a small percentage of the amputee population can be fitted with this type of prosthesis,

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most prosthetists find it impractical to invest the great amount of time and money for education and equipment before they can provide satisfactory service.

It has been shown that in areas where prosthetists learned enough about powered prostheses to be able to properly fit and maintain them, the prostheses received wide acceptance. John Billock, C.P.O., in Warren, Ohio uses a number of different powered prosthesis systems, including hybrid models using components of different systems on severely disabled upper-limb amputees that are referred from all over the Midwest. William Sauter at Ontario Crippled Childrens Center has also proven the practicality of powered systems on adults and children. In each area, however, institutional support has been the determining factor. Mr. Billock's success was achieved after years of participation in the research program at Northwestern University and Mr. Sauter's work is done in a large Rehabilitation Center. Similarly, the Bock system is used in Minneapolis due to a great amount of support from the Germany-based Otto Bock Company to its United States headquarters in Minneapolis. The Otto Bock Company is presently offering a free one-week course on the basic below-elbow system, and plans future courses on advanced powered components.

We are faced with the situation that powered upper-limb prostheses are presently available but are not used for the many reasons stated previously. How do we solve the service delivery problem, particularly for the more severely disabled upper-limb amputee? I suggest that specialized fitting centers are the best solution to the problem. Such centers can be privately owned or located in an institution. The advantage of this system is that the prosthetist would see enough patients to become truly expert in the area of powered prostheses, and could well afford the expense of taking all relevent courses or preceptorships and obtaining the necessary staff and equipment.

"It seems obvious—"powered prostheses will be more common than body powered prostheses."

I have visited one such center in Warren, Ohio, which is owned by John Billock, C.P.O. Mr. Billock and his staff at Warren Orthotics and Prosthetics Restoration Laboratory fit three to four powered upper-limb prostheses per month, including all levels of amputation. His staff includes a full time electrical engineer and an electronics technician. There are enough equipment and spare parts available so that essentially all maintenance is carried out on the scene, which avoids long delays when repairs are done elsewhere. Patient referrals are mostly from the Midwest and East Coast, although patients from the West Coast are not uncommon. One patient being seen during my visit had a right shoulder disarticulation and a left above-elbow amputation and was being fitted with powered hands, elbows and wrist rotators controlled by switches. Components from at least three manufacturers had to be made compatible in the ten-month long project.

I feel that a total of four centers in the United States could adequately handle the patient load. The average prosthetist with a good understanding of powered prostheses will be able to treat most unilateral below-elbow patients, so referrals to a powered prosthesis center will usually be for more difficult cases. It will be important for private centers to be closely allied with a rehabilitation center, as these patients will require therapy, counseling, and other services while the prosthetic services are being performed.

It seems obvious to me that powered prostheses will be more common than body powered designs within the next twenty years, and it is time now to establish an efficient service delivery system.

by
Michael J. Quigley, C.P.O.

Concerning Suspension Alignment, and Control

In the prescription of any prostheses consideration is naturally given to the proper means of suspending the prosthesis and maintaining it in place. In contrast, not as much concern seems to be given to this crucial matter in the prescription of an orthosis.

Paradoxically, this relative state of neglect is undoubtedly due to the very success with which suspension has been incorporated in most conventional orthosos. To cite but one example, the shoe that inevitably must be used with any ambulatory AFO, KAFO, or HKAFO provides for suspension of the device as well as providing support to the ground.

In recent years with the expansion of new technology in the area of prosthetics and orthotics there has developed a corresponding interest in new techniques to overcome shortcomings in conventional devices. In the process, however, new problems can arise as a result of the intertwining roles played by various components of the device under consideration, and it would therefore appear worthwhile to attempt to sort out these various roles with special emphasis on suspension in order to clarify the picture, and possibly, as a result, to suggest new and unique applications for the various suspension systems available.

For clarity a brief glossary has been prepared, and is included at the conclusion of this article.

Maintenance of Alignment

For any prosthesis or orthosis to provide the maximum benefit possible, it must be held in proper position relative to the body segments concerned. The prevention of inappropriate motion can be classified broadly as maintenance of alignment by either suspension or stabilization depending upon the direction of the motion. As it is defined, suspension is concerned with the prevention of linear displacement along the longitudinal axis, and it will be seen that no discrimination is made as to whether the direction is distal or proximal. Thus, the perineal straps that may be attached to a spinal orthosis to prevent proximal displacement ("riding-up") are just as much a suspension aid as is a suprapatellar cuff suspension strap on a below-knee prosthesis.

Considered in this light, the weightbearing component of any given device naturally prevents proximal displacement, and, thus, may be confused as a suspensory component. The distinction must be made on the basis of intended function.

Weightbearing is a primary characteristic of a lower-limb prosthesis or a weightbearing orthosis without which it cannot function. Suspension is a secondary characteristic inasmuch as it is but one of a number of different components intended to ensure proper weight bearing and thus function of the device. It can be seen, therefore, that the intended role of a weightbearing component is quite a bit different than suspension. However, the use of this same component as a non-weightbearing device for purposes other than weightbearing is not inconceivable. It is possible, if not practical, to use PTB brims about the knees of a patient to prevent proximal displacement of a corset, and the use of quadrilateral sockets as anchor points (1) for the powering of upper-limb prostheses comes to mind.

Stabilization, as it is defined, is concerned with the prevention of displacement about the various rotatory axes of the body rather than along the linear axes. Motion does take place undoubtedly includes some linear motion, either laterally or anterioposteriorly, but in the author's opinion the rotary displacement is inevitably the predominant component. How then is stabilization to be differentiated from control which, as it is defined, is also involved, in part, with the prevention of motion?

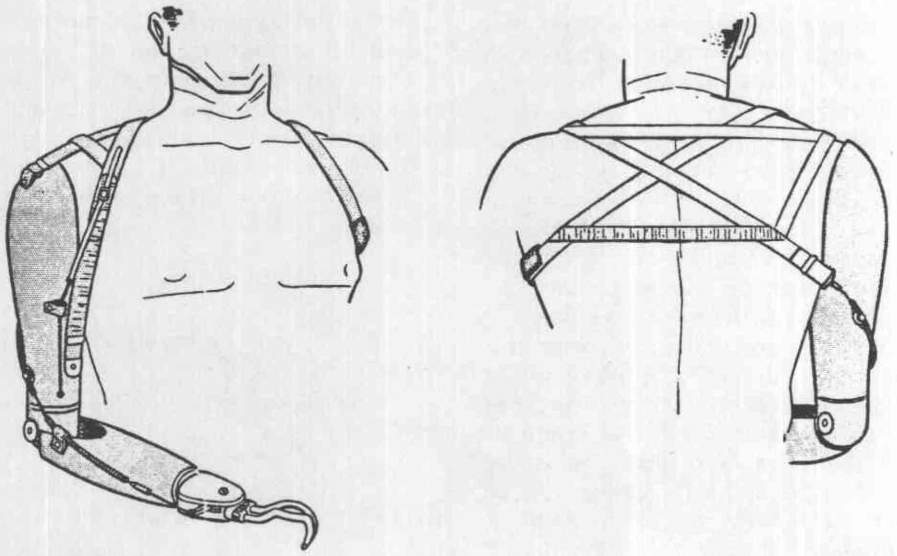

Fig. 1. One Version of the Figure-8 Harness for Above-Elbow Amputees

Two separate but interrelated definitions of the word control are given. In both instances control is to be considered as a primary characteristic. In the first definition control refers to the regulation of motion in one portion of the body segment relative to another portion, while stabilization (a secondary characteristic) refers to the regulation of the device relative to the body segment. In the second definition control refers to volitional regulation of motion in the device by the patient; while stabilization holds the device in firm contact with the body segment in order to maximize the efficiency of this volitional regulation.

In any event, it can be appreciated that any given component of a prosthetic or orthotic device may play multiple roles in the function of that device. A hip joint and pelvic band fitted to an above-knee prosthesis while providing suspension also provides stabilization against lateral and rotary motion. The same component is likely to be fitted to an HKAFO to control motion about the patient's hip, and is unlikely to be used for suspension or rotary stabilization of the HKAFO since both of these functions are provided effectively by the fit of the foot in the shoe. Supracondylar wedge suspension in a below-knee prosthesis also provides effective stabilization against lateral thrust, while a cuff suspension strap fitted to a below-knee prosthesis does not. A figure-8 harness (Fig. 1) fitted to an above-elbow prosthesis not only provides suspension, but also stabilization against lateral or rotary motion of the socket and control of the elbow and terminal device, while a butterfly harness and Bowden cable (Fig. 2) fitted to a shoulder-driven WHO provides only control of motion in the metacarpal-phalangeal joints of the index and ring finger and neither suspension nor stabilization.

These are but a few of the many examples that could be cited in designing or prescribing a device for a given situation. Consideration must be given to the many intertwining roles played by the many available design elements and selec-

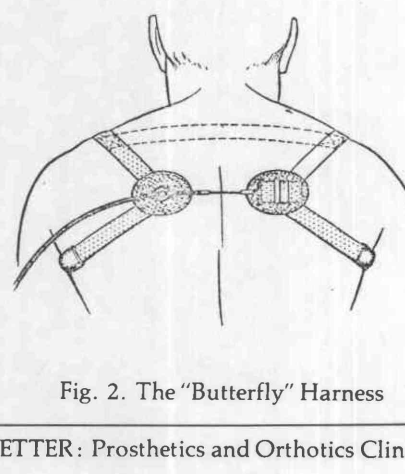

Fig. 2. The "Butterfly" Harness

tion be made of those elements that perform the intended function with maximum benefits and a minimum of adverse side effects.

A particularly troublesome example of this dilemma is to be found in the design of an orthosis to control knee motion without involving the ankle-foot complex, the traditional source of suspension and rotary stabilization of devices to regulate the knee. If supracondylar suspension is used as with the IRM supracondylar knee orthosis (Fig. 3) or Iowa knee orthosis (to name but two examples of this class of orthosis) adequate suspension and stabilization may be gained initially from the critical fit about the knee, but the patient may not be able to tolerate it, and with compression of the soft tissues fit and, thus, suspension may be lost. The CARS-UBC knee orthosis (Fig. 4) avoids these problems by using a waist belt and suspension strap. Waist belts, however, are not well tolerated by many patients, and considerable effort must be taken in

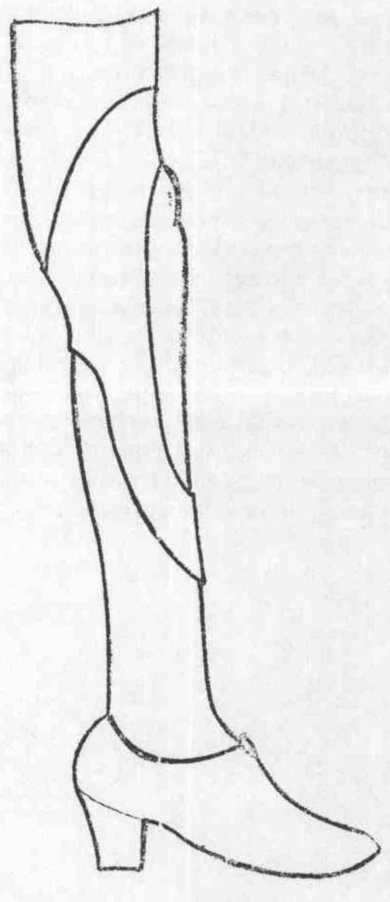

Fig. 3. IRM Supracondylar Knee Orthosis

fitting the device to achieve adequate rotary stabilization.

In any given instance it is necessary to weigh the pros and cons of the applicable suspension components available, and select the one that best fits the needs of the patient.

Fig. 4 CARS-UBC Knee Orthosis

Classification of Suspension Types

In most instances, suspension is secured by obtaining a purchase above a flaring bony prominence (epicondyle, adductor tubercle) or other body segment (buttocks, shoulder). This general principle is the same regardless of type of suspension. Suspension may be classified into two major groups and a third miscellaneous one (Fig. 5).

A. Extrinsic Suspension: The means of suspension are not contained within the proper borders of a device, and must be gained by the addition of extraneous elements that pass beyond the borders of the device and may not be otherwise absolutely necessary for the function of the device. However, the extrinsic elements may also serve as means of stabilization or control.

1. Examples of extrinsic suspension are:

a. PTB cuff suspension strap
b. Knee joints and thigh corset
c. Waist belt
d. Rubber suspension sleeve
e. Hip joint and pelvic band
f. Silesian belt
f. Suspenders
h. Perineal straps on a spinal orthosis
i. Various harnesses used in upper-limb orthotics and prosthetics

B. Intrinsic Suspension: Suspension is gained by means of some element(s) contained within the proper borders of the device. The element(s) may also serve as a means of stabilization.

1. Examples of intrinsic suspension are:

a. All self-suspending prostheses
b. All orthoses with few exceptions

A shoe is necessary for the proper function of lower-limb orthoses while a waist belt used on a KO is not absolutely necessary for the function of the KO as suspension can be accomplished by other means. Therefore, an AFO is a case of intrinsic suspension while a KO is not necessarily an example.

2. Types of intrinsic suspension can be broken down as follows:

a. Supracondylar: purchase is obtained above any of the various condyles or epicondyles of the body.

b. Flaring body segments other than bony prominences: purchase is obtained above any of the flaring body segments not covered in Item 1, such as the buttocks or shoulders.

c. Suction, or negative atmospheric pressure: In general, suction suspension is used with amputation stumps that exhibit a high soft-tissue-to-bone ratio with few prominent subcutaneous bony prominences such as above-knee or above-elbow stumps; however, suction suspension has been used with below-knee prostheses in Europe and there is a current resurgence of interest in it in America.

d. Muscular grasp: This is the often greatly overlooked ancillary of suction suspension and other suspension types. Rudolf Poets (2) has described briefly the principle of an

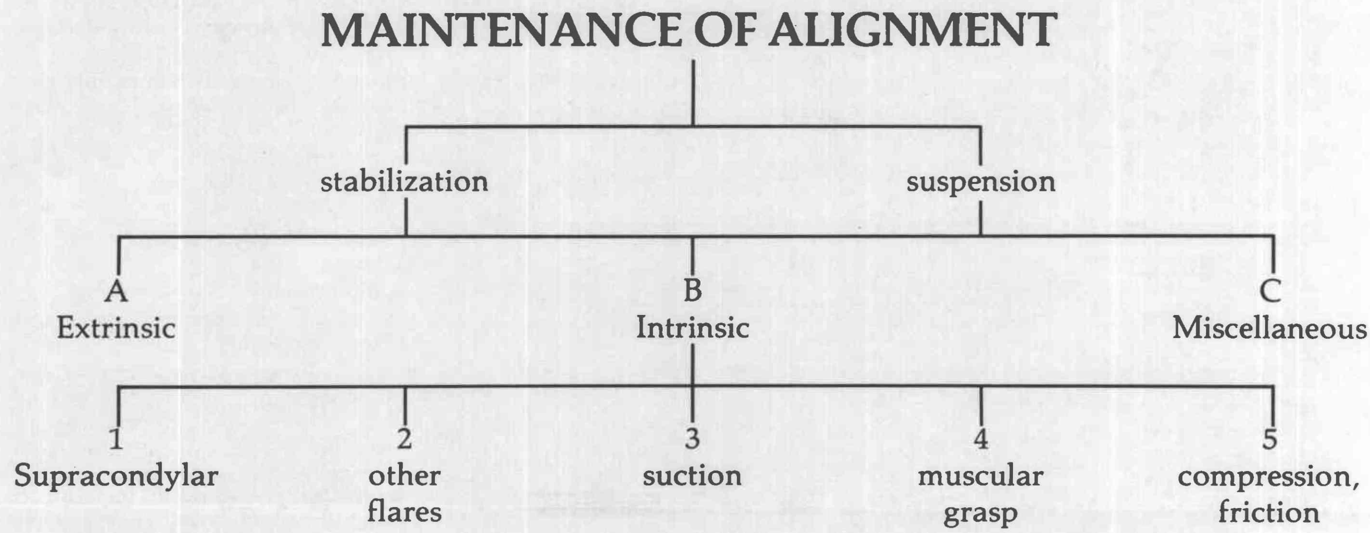

Fig. 5. Diagram showing elements of alignment.

"undercut socket" he attributes to Dr. Oskar Hepp, and every clinician is familiar with the admonition to the patient that he should use his stump muscles to hold the above-knee prosthesis on. Many below-knee amputees have reported being able to hold their prosthesis on with muscular contractions, and Dr. Ernest Burgess is currently studying how to capitalize on this phenomenon.

e. Compression of soft tissue and friction: This means of suspension serves for such lightweight, elastic, and readily conformable devices as a spinal corset or knee support and may be used in conjunction with other means of suspension.

C. Other Miscellaneous: This serves as a catch-all division to contain those means that do not readily fit in the other divisions and are rarely used in prosthetics and orthotics.

1. Examples of the miscellaneous category are:

a. Medical grade adhesive used with rigid dressings, some cosmetic finger prostheses, facial restoration, and stoma appliances.

b. Skeletal attachment. While under active consideration by some, this means of suspension is not currently in use.

Selection Criteria

As can be seen in Figs. 6 and 7, selection of an appropriate means of suspension for a specific device can often pose problems. A variety of factors must be considered, a few of which are listed here.

A. Medical contraindications
B. Donning difficulties
C. Clinic team preferences
D. Patient preferences
E. Maintenance
F. Fitting difficulties and problems maintaining proper fit.
G. Necessary related functions (stabilization or control) provided by a specific suspension system.
H. Aesthetics

In any event the essential matter is to balance the pros and cons of the various suspension systems available and select the one that offers the most advantages with the fewest disadvantages. The matter becomes even more important when the emphasis is shifted from routine clinical prescription to the design of one-of-a-kind applications for a specific patient's unique problems or in research and development of a new style device.

Conclusion and Summary

Suspension is inevitably related closely to a wide variety of interrelated factors, all of which are involved in the determination of proper fit. An attempt has been made to logically sort out the various factors and concentrate on suspension. Further, suspension has been broken down into various categories and some of the inherent difficulties in selecting between a number of suspension techniques relevant to a specific patient or prosthetic or orthotic device have been suggested.

Literature Cited

1. Blakeslee, Burton (ed.), *The limb-deficient child*, University of California Press, 1963.

2. Poets, Rudolfe, *The fitting of the above-knee stump*, Orth. and Pros., 28:1, March 1974.

Glossary
(Definitions for this article)

Orthosis: An externally applied device for the control of motion about the

Device	A Extrinsic	B Intrinsic 1 Supracondylar	2 Other Flares	3 Suction	4 Muscular Group	5 Compression	C Other
	SUSPENSION						
F. O.			8				
A. F. O.			8				
K. O.	3, 2	9					
K. A. F. O.			8				
H. K. A. F. O.			8				
H. O.			10				
S. I. O.	11		10			12	
L. S. O.	11		10			12	
T. L. S. O.	11		10			12	
C. T. L. S. O.	11		10			12	
C. O.		13					
H. O.		14					
W. H. O.		11					
E. O.	15	16					
E. W. H. O.	15	15, 16					
S. E. W. H. O.	15	15, 16					
S. O.	15		13				
Symes/ Partial Foot	2, 3	17					
B. K.	1, 2, 3, 4, 5	9		X	X	X	
K. D.	3, 6, 7, 5	9			X		
A. K.	6, 7, 5			X	X		
H. D.	5		10				
Partial Hand	15	14		18			19
W. D.	15	14					
B. E.	15	16					
E. D.	15	16					
A. E.	15			X	X		
S. D.	15		13				

1 - Rubber Suspension Sleeve
2 - Cuff Suspension Strap
3 - Waist Belt
4 - Joints and Corset
5 - Suspenders
6 - Hip Joint and Pelvic Band
7 - Silesian Bandage
8 - Foot/Shoe
9 - Adductor Tubercle
10 - Pelvis
11 - Perineal Straps
12 - Abdominal
13 - Shoulder(s)
14 - Styloids
15 - Shoulder Harness
16 - Epicondyles with or without the olecranon
17 - Malleoli
18 - As used in a Finger Restoration
19 - Glue, as used in a Finger Restoration
X - Self Explanatory

Fig. 6. Suspension Methods versus Orthosis Level

Suspension Technique	Stabilization	Control: Corrective	Control: Volitional	Non-Related
1. Foot/Shoe	x	x	x	x
2. Waist Belt		Extension Assist?		
3. Adductor Tubercle	x	x		
4. Pelvis	x	x	x	
5. Perineal Straps				
6. Abdominal Compression	x	x	x	x
7. Shoulder(s)	x	x		
8. Styloids	x	x		
9. Shoulder Harness	x	xx	x	
10. Epicondyles w./w.o. Olecranon	x	x		
11. Cuff Suspension Strap				
12. Malleoli	x	x		
13. BK Joints and Corset	x	x		
14. Rubber Suspension Sleeve				
15. Suspenders			x	
16. Hip Joint and Pelvic Band	x	x		
17. Silesian Bandage	x	x		

Figure 7. Suspension Techniques and Additional Auxiliary Function Possible.

joints of a body segment.

Prosthesis: (Artificial Limb)-an externally applied device to substitute for a missing body segment.

Suspension: The method of maintaining a prosthesis or orthosis in proper place relative to the affected body segment and resisting linear displacement along the longitudinal axis.

A. Not weight-bearing

B. Displacement due to:

1. gravity
2. momentum
3. "oozing" "creeping" (movement due to compression of a conical section)

Weight-Bearing: The transmission of a person's mass (or weight) to the ground from a relatively distant body segment by means of a prosthesis or orthosis.

Stabilization: The method of maintaining a prosthesis or orthosis in proper placement relative to the affected body segment and resisting angular or rotary displacement about one of the three axes.

A. Due to:

1. Moments created by the eccentric application of forces about the various axes or centers of rotation.

Control:

A. Orthotic: The maintenance of a body segment in a desired position or positions by an orthosis (also called correction or corrective control).

B. Orthotic or Prosthetic: The voluntary activation of a prosthesis or orthosis (or of an artificial articulation thereof) by means of the body segment enclosed in the device or by a signal generated by a remote body segment and transmitted to the device or articulation by means of a mechanical, hydraulic, pneumatic, or electric linkage (also called volitional control).

Alignment: The relationships that exist or are to be created between the components of a device or between the device as a whole and the affected body segment.

Pistoning: The cyclical linear displacement that takes place along a body segment with the cyclic application and removal of a load and due to inadequate suspension.

"Bell-Clappering": Cyclical angular displacement in the A-P or M-L planes due to inadequate angular stabilization.

Whipping: A specific form of rotary instability that occurs in AK Prostheses.

Primary Characteristic: An absolutely essential property of a device if it is to carry out its intended function.

Secondary Characteristic: A property of a device necessary to facilitate one of its primary characteristics but not itself absolutely necessary to achieve the intended function of the device.

by
Charles H. Pritham, C.P.O.

NOTES AND COMMENTS

In the last issue of the Newsletter, where we reported on comments received from our readers to the article entitled "Should Functional Ambulation Be A Goal For Paraplegic Persons," a few typographical errors were made which we would like to correct at this time.

Mr. Robert Penny, C.O., of the Shelby State Community College and Mr. Leo Betzelberger, R.P.T., of the V.A. Spinal Cord Injury Center, Memphis, Tennessee, stated that they have had 3,000 spinal cord injury patients as of 1978, not 1948. Also, they stated that they gradually abandoned the use of LSHKAFO'S (not LASKAFO) as they were just thrown in the closet. They also indicated that they try to keep their patients in metal AFO's, not KAFO's, as we had it printed. The purpose of these AFO's is to prevent equinus and damage to skin and bone during transfer. We apologize for these errors and trust that the record is now set straight as to the procedures being used at the V.A. Spinal Cord Injury Center in Memphis, Tennessee.

It has been noted by the Editorial Board that we have received very few comments from both occupational therapist, as well as counselors. This could be simply due to the fact that they have not become acquainted as yet with our publication. We would very much appreciate all of our current readers helping us to acquaint the members of these disciplines with the Newsletter so that we can obtain the benefits of their comments on our subject matter.

We would be pleased to send a complimentary copy of our most current Newsletter if they would simply write to me in care of AAOP, 1444 N Street, N.W., Washington, D.C. 20005.

Please continue to send in your comments to the current articles in the Newsletter, as well as any subject matter that would be of interest to you and other clinic team members.

Joseph M. Cestaro, C.P.O.
Editorial Board

NOTICE OF TECHNICAL MEETINGS AND SEMINARS

Other Agencies and Organizations

1978, Aug. 8-11 Third Strathclyde Seminar, Rehabilitation of the Disabled — Clinical and Biomechanical Aspects, Costs and Effectiveness.
University of Strathclyde, Glasgow, Scotland (Professor R.M. Kenedi, Bioengineering Centre, 106 Rottenrow, Glasgow Gr ONW)

1978, Aug. 28 - Sept. 1 The Sixth International Symposium on External Control of Human Extremities, Dobrounik, Yugoslavia

American Academy of Orthotists and Prosthetists Seminars

1978, July 10-11 Orthotics and Prosthetics
Goat Island Sheraton Inn, Newport, Rhode Island

1978, July 27-28, Orthotics and Prosthetics; Marriott Hotel, Chicago, Illinois

1978, Aug. 24-26, Pediatric Orthotics and Prosthetics and Cast Procedures; Towsley Center, University Michigan Medical Center, Ann Arbor, Michigan

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