Introduction and Definitions

Prosthesis and orthosis

A prosthesis is a device designed to replace, as much as possible, the function or appearance of a missing limb or body part. An orthosis, in contrast, is a device designed to support, supplement, or augment the function of an existing limb or body part.

Characteristics of a successful prosthesis

Ideally, a prosthesis must be comfortable to wear, easy to put on and remove, light weight, durable, and cosmetically pleasing. Furthermore, a prosthesis must function well mechanically and require only reasonable maintenance. Finally, prosthetic use largely depends on the motivation of the individual, as none of the above characteristics matter if the patient will not wear the prosthesis.

Considerations when choosing a prosthesis

- Amputation level
- Contour of the residual limb
- Expected function of the prosthesis
- Cognitive function of the patient
- Vocation of the patient - For example, whether the patient is employed at a desk job or at manual labor
- Avocational interests of the patient (ie, hobbies)
- Cosmetic importance of the prosthesis

- Financial resources of the patient

Reasons for lower extremity amputation

Most lower extremity amputations occur in individuals older than 60 years and result from disease complications. Complications of diabetes and peripheral vascular occlusive disease are the leading causes of amputation (65%), followed, among disease-related causes, by complications of thromboembolic disease and vasculitis. Trauma is the second most common cause of lower extremity amputation (25%) and typically occurs in the young male population. Tumors and congenital malformations less commonly (5% each) result in lower extremity amputation.

Terminology and types of amputations

- Transphalangeal amputation - Excision of part of 1 or more toes
- Toe disarticulation amputation - Resection through the metatarsophalangeal joint or joints

- Ray amputation - Resection of the toe and part or all of the corresponding metatarsal
- Transmetatarsal amputation - Resection through all metatarsals
- This amputation is designed to provide a functional, weight-bearing foot with an adequate forefoot lever arm to permit reasonably normal walking without major prosthetic restoration.

- Lisfranc amputation - Resection through the metatarsal and tarsal joints
- Because the insertions of the dorsiflexors of the ankle are sacrificed with this amputation, to provide for a balanced ankle and avoid development of an equinovarus deformity the distal tendons of the peroneus brevis and the anterior tibialis must be reattached proximally in the residual foot to the cuboid and to the neck of the talus, respectively.
- The shape and shortened length of the residual foot increases the difficulty of fitting it with a partial foot prosthesis that can provide adequate suspension and/or a forefoot lever for ambulation. Successful prosthetic restoration often requires a prosthetic or orthotic design that is more substantial and extends proximal to the ankle.

- Chopart amputation - Resection through the calcaneocuboid and talonavicular joints

- To prevent equinovarus deformity, the peroneus brevis tendon must be transferred to the cuboid and the anterior tibialis tendon must be transferred to the neck of the talus.
- The shape and length of the residual limb make the limb even more difficult to fit with a partial foot prosthesis than it would be after the Lisfranc amputation.

- Syme amputation - Ankle disarticulation with or without removal of the medial/lateral malleoli and distal tibia/fibula flares
- The advantage of this amputation is that it provides a residual limb with an end-bearing surface.
- The length of the residual limb limits the prosthetic foot options compared with a more proximal transtibial (below-knee) amputation.
- This amputation leads to a poorer cosmetic prosthetic result because of the need for the prosthesis to accommodate the bulbous distal shape of the residual limb (which is produced by the malleoli). This is especially true for slim patients.
- Careful surgical technique is required to prevent heel pad migration from the distal end of the residual limb. If this occurs, the weight-bearing advantage of this amputation level could be compromised.

- Transtibial amputation - Below-knee amputation (BKA); resection through the tibia and fibula
- The ideal length is from the proximal one third to the middle of the limb.

- Knee disarticulation amputation – Through-the-knee amputation; resection through the knee joint
- The advantage of this amputation is that can provide a broad, end-bearing surface for the residual limb and a maximal lever arm for powering and controlling a prosthesis
- The disadvantage of this amputation is that it does not provide an ideal length for prosthetic restoration, because it limits the amount of space available for the knee joint components in the prosthesis. This limits the options for prosthetic knees that can be used to maintain the symmetry of the knee-joint centers.

- Transfemoral amputation[1,2] - Above-knee amputation (AKA)
- The ideal length is about 8 cm proximal to the knee joint, so that the femoral condyles are excised with adequate room to accommodate prosthetic knee options

- Hip disarticulation amputation - Resection through the hip joint; pelvis intact
- Hemipelvectomy amputation – Resection of all or part of the hemipelvis and of the entire lower extremity

Myoplasty and myodesis

There are 2 approaches to managing the muscle in the limb during amputation: myodesis and myoplasty.

With a myodesis, the muscles and fasciae are sutured directly to the distal residual bone through drill holes. The objective of this technique is to provide a structurally stable residual limb, with the insertions of the residual muscles securely attached to maintain their function; this ultimately results in better prosthetic control and function. Myodesis is not always performed, because when attempted by even the most experienced surgical hands it often fails. Myodesis is contraindicated in patients with severe peripheral vascular disease, because the blood supply to the muscle may be compromised.

Myoplasty requires the surgeon to suture the opposing muscles in the residual limb to each other and to the periosteum or to the distal end of the cut bone. Sufficient muscle stretch must be provided to maintain active muscle control of the residual limb following amputation, but without producing so much muscle tension that the blood supply is compromised. A well-performed myoplasty can provide some distal soft-tissue padding over the residual bone and result in a stable, functional residual limb. On occasion, some myoplasties will not securely anchor to the distal residual limb, resulting in a movable soft-tissue sling, with a bursa developing between the soft tissues and the underlying bone. Some of these bursa can become symptomatic and painful.

End-bearing (weight-bearing) amputations

Amputations that provide an end-bearing residual limb are advantageous for prosthetic restoration. These amputations theoretically permit the weight-bearing forces within the prosthesis to be concentrated in a circumscribed area of the residual limb, or specifically, the residual limb's weight-tolerant, distal end. This can simplify prosthetic socket fitting considerations and minimize many of the prosthetic fitting complications, most of which are related to residual limb socket interface issues. Because of their shape and length, some end-bearing residual limbs limit the prosthetic options that are available for prosthetic restoration. End-bearing lower extremity amputations include the following:

- Partial foot amputations - These are more weight bearing than end bearing.
- Transmetatarsal amputation
- Lisfranc amputation
- Chopart amputation

- Syme amputation
- Ertl transtibial osteomyoplasty amputation procedure - An osteoperiosteal tube joins the ends of the bones, which ossify to form a sturdy, weight-bearing bone bridge.
- Shrinkers for limb shaping are not advisable after this procedure because they will compress the fusion site.
- Preparatory prosthetic fitting is delayed until the bony bridge has completed fusion.

- Knee disarticulation

Determinants of a successful outcome with prosthetic use

To insure a successful prosthetic outcome, it is necessary to determine the goals of each individual amputee. This should include the patient's expectations for functional activities with the prosthesis. The physical, as well as psychologic or emotional, status of the patient (including any pre-existing or limiting comorbidities) are important considerations.[3] These could include such issues as strength, endurance, joint contracture, ambulatory status, hemiparesis from a prior stroke, and retinopathy resulting from diabetes. The patient may have been nonambulatory for months and therefore be deconditioned. A program of preprosthetic training would improve the needed upper extremity strength and overall endurance required for prosthetic training.

Some patients may not want to ambulate with a prosthesis but may instead wish to use a prosthesis only for cosmesisandimprovedself-esteem. Ideally,these discussions should begin preoperatively and should involve the surgeon, the physiatrist, the physical therapist, the prosthetist, the patient, and, whenever possible, a peer counselor (if the patient is open to this).

Once it is decided the patient wishes to proceed with prosthetic restoration, several factors related to the prosthesis itself will impact on whether the outcome is successful. The prosthesis must be comfortable to wear, easy to put on and remove, light weight and durable, and cosmetically pleasing. Furthermore, the prosthesis must function well mechanically and require reasonably low maintenance. Successful prosthetic intervention should be judged by patient-specific functional outcomes. A nonambulatory patient may report an improved quality of life with a prosthesis used for transfers (movement from one position or surface to another) as opposed to one employed for ambulation.

Factors to consider when choosing prosthetic components

Consider the following factors when choosing prosthetic components for successful prosthetic restoration:

- Amputation level and residual limb strength
- Contour of the residual limb
- Health status
- Physical status (ie, balance, strength) and fitness level
- Activity tolerance from underlying medical comorbidities (ie, atherosclerotic heart disease, ischemia)
- Effects of peripheral vascular disease and diabetic nephropathy, which may cause unstable residual limb volume
- Impaired cognition or other neurologic deficits (ie, stroke)
- Sensorimotor deficits caused by peripheral nerve dysfunction
- Visual impairments resulting from diabetic retinopathy, or other ophthalmic disorders

- Expected function and needs of the prosthesis
- Patient's vocation (for example, desk job vs manual labor)
- Patient's avocational interests (ie, hobbies)
- The cosmetic importance of the prosthesis

- The patient's financial resources (ie, medical insurance, worker's compensation)

Description

There are several levels of lower limb amputation, including partial foot, ankle disarticulation, transtibial (below the knee), knee disarticulation, transfemoral (above the knee), and hip disarticulation. The most common are transtibial (mid-calf) and transfemoral (mid-thigh). The basic components of these lower limb prostheses are the foot-ankle assembly, shank, socket, and suspension system.

Foot-ankle assembly

The foot-ankle assembly is designed to provide a base of support during standing and walking, in addition to providing shock absorption and push-off during walking on even and uneven terrain. Four general categories of foot-ankle assemblies are non-articulated, articulated, elastic keel, and dynamic-response. One of the most widely prescribed foot is the solid-ankle-cushion-heel (SACH) foot, due to its simplicity, low cost, and durability. It may be inappropriate, however, for active community ambulators and sports participants. Articulated assemblies allow motion at the level of the human ankle; this motion may occur in one or more planes, depending on whether it is a single-axis or multi-axis foot. These assemblies offer more mobility at the cost of less stability and increased weight. The elastic keel foot is designed to mimic the human foot without the use of mechanical joints; the dynamic-response foot is designed to meet the demands of running and jumping in athletic users.

Shank

The shank corresponds to the anatomical lower leg, and is used to connect the socket to the ankle-foot assembly. In an endoskeletal shank, a central pylon, which is a narrow vertical support, rests inside a foam cosmetic cover. Endoskeletal systems allow for adjustment and realignment of prosthetic components. In an exoskeletal shank, the strength of the shank is provided by a hard outer shell that is either hollow or filled with lightweight material. Exoskeletal systems are more durable than endoskeletal systems; however, they may be heavier and have a fixed alignment, making adjustments difficult.

Socket

The socket contacts the residual limb and disperses pressure around it. A hard socket offers direct contact between the limb and the socket, resulting in decreased friction, no liner bulk, easy cleaning, and increased durability. It is, however, difficult to fit and adjust in response to residual limb changes. A soft socket includes a liner as a cushion between the socket and residual limb. This provides additional protection for the limb but may increase friction and bulk. Transtibial socket types include: patellar tendon-bearing (PTB), silicone suction, energy-storing, or bent-knee designs. Transfemoral socket types include: quadrilateral, ischial containment, and contoured adducted trochanteric-controlled alignment method (CAT-CAM) designs. A prosthetic sock is usually worn to help cushion the limb from forces and accommodate for volume changes. Prosthetic socks are available in a variety of materials and thickness, and may be worn in layers to achieve the most comfortable fit.

Suspension

Suspension devices should keep the prosthesis firmly in place during use and allow comfortable sitting. Several types of suspension exist, both for the transtibial and transfemoral amputation. Common transtibial suspensions include sleeve, supracondylar, cuff, belt and strap, thigh-lacer, and suction styles. Sleeves are made of neoprene, urethane, or latex and are used over the shank, socket and thigh. Supracondylar and cuff suspensions are used to capture the femoral condyles and hold the prosthesis on the residual limb. The belt and strap method uses a waist belt with an anterior elastic strap to suspend the prosthesis, while the thigh-lacer method uses a snug-fitting corset around the thigh. The suction method consists of a silicone sleeve with a short pin at the end. The sleeve fits over the residual limb and the pin locks into the socket. With a transfemoral prosthesis, suction and several types of belt suspension also are available.

Transfemoral amputations also provide the additional challenge of incorporating a prosthetic knee unit. The knee unit must be able to bend and straighten smoothly during ambulation, in addition to providing stability during weightbearing on that limb. Knees are available as single-axis, polycentric, weight-activated, manual-locking, hydraulic, and pneumatic units. Technology using microprocessors in knee units is becoming a reality, although costs can be prohibitive.

Operation

Use of an actual prosthesis usually follows a period of postoperative management that includes addressing issues of **pain**, swelling, and proper positioning. In addition, **physical therapy** for range of motion, strength, bed mobility, transfers, and single limb ambulation often takes place during the initial rehabilitation period. In some cases, an individual may be fitted with an immediate post-operative prosthesis to allow for early double-limb ambulation. Many individuals will be fitted with a temporary prosthesis when the wound has healed. A temporary prosthesis allows for ambulation and continued shrinkage of the residual limb until a definitive prosthesis is fit.

When evaluating a prosthesis before use, the prosthetist and physical therapist should ensure that the inside of the socket is smooth and that all joints move freely. The socket should fit securely on the residual limb, and the overall prosthesis length should match the length of the intact leg. The patient must learn how to properly put on the residual limb sock and the prosthesis itself. A variety of techniques are used, depending on the type of socket and suspension system.

Maintenance

The user should be aware of how to properly care for and maintain the prosthesis, liner, and socks. Most plastic sockets and liners can be wiped with a damp cloth and dried. Socks should be washed and changed daily. Due to the wide variety of componentry and materials used in the fabrication of prostheses, the prosthetist should be the source for instructions regarding proper care and maintenance for each individual. In general, the patient should return to the prosthetist for any repairs, adjustments or realignments.

Health care team roles

The patient's primary care physician, surgeon, neurologist, prosthetist, physical and occupational therapists, nurses, and social worker are all important players in the multidisciplinary health care team. Surveys of patients with amputations have shown that the physical therapist, along with the physician and prosthetist, plays one of the most valued roles in providing information and help both at the time of amputation and following amputation. The entire team's input, along with the patient's input, is vital in determining whether a prosthesis should be fit and the specific prescription for the prosthesis. Input should be provided regarding the patient's medical history, premorbid level of function, present level of function, body build, range of motion, strength, motivation, and availability of familial and social support.

The physical therapist usually plays a major role in training an individual to walk with a prosthesis, and also is the health care professional who can evaluate prosthetic function immediately and over time. The physical therapist is trained in gait assessment and should watch for compensations and gait deviations that may indicate a problem with the prosthesis.

Training

The main goal of prosthetic training usually is smooth, energy-efficient gait. This includes the ability of the individual to accept weight on either leg, balance on one foot, advance each leg forward and adjust to different types of terrain or environmental conditions. Principles of motor learning often are used in training, progressing from simple to complex tasks. Individuals begin with learning to keep their bodies stable in a closed environment with no manipulation or variability. An example may be practicing standing balance on one or both legs. Mobility, environmental changes, and task variability are added slowly to further challenge the individual as tasks are mastered. In the end, an example of a more complex task practiced may be the ability walk in a crowded hallway while carrying an object in one hand. In addition to ambulation training, the patient also should be taught how to transfer to and from surfaces, assume a variety of positions such as kneeling or squatting, and manage **falls**. Depending upon the individual's previous and present level of function, use of a traditional cane, quad cane, or crutches may be indicated. Patient motivation, comorbidity, level of amputation and level of function are all factors in determining the outcome of rehabilitation.