PROSTHETIC KNEE SYSTEMS

OF ALL PROSTHETIC COMPONENTS, THE KNEE SYSTEM IS ARGUABLY THE MOST COMPLEX. IT MUST PROVIDE RELIABLE SUPPORT WHEN STANDING, ALLOW SMOOTH, CONTROLLED MOTION WHEN WALKING, AND PERMIT UNRESTRICTED MOVEMENT FOR SITTING, BENDING AND KNEELING.

Prosthetic knees have evolved greatly over time, from the simple pendulum of the 1600s to those regulated by rubber bands and springs or pneumatic or hydraulic components. Now, some knee units have advanced motion control modulated through microprocessors.

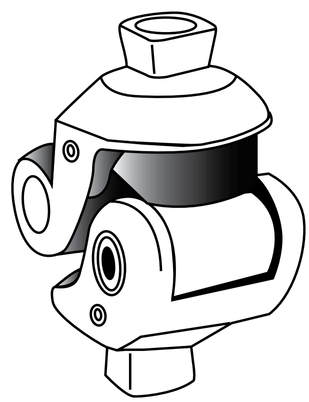
For the transfemoral (above-knee, including hip and knee disarticulation) amputee, successful function depends on selecting the correct knee to fit the person's age, health, activity level and lifestyle. The latest or advanced knee is not necessarily the best choice for everyone. For some amputees, safety and stability are more important than functional performance. Active amputees, on the other hand, prefer a knee that will give them a higher level of function even if it requires greater control.

Given the wide variety of choices and consumer needs, prosthetists and rehabilitation specialists can help amputees choose the best prosthetic knees for their individual requirements. They can also teach amputees how to use their new knees properly, which is critical for avoiding discomfort, stumbling and falling.

A key way to evaluate an individual's prosthetic needs is to observe his or her walking cycle, which can be divided into two parts: the "stance phase" (when the leg is on the ground supporting the body) and the "swing phase" (when the leg is off the ground, also referred to as "extension"). The happy medium between these two extremes (stance, or stability, versus ease of swing, or flexion) is different for each individual.

Although over 100 individual knee mechanisms are commercially available, they can be divided into two major classifications: mechanical and computerized. Mechanical knees can be further separated into two groups: single-axis knees and polycentric, or multiaxis, knees. All knee units, regardless of their level of complexity, require additional mechanisms for stability (manual or weight-activated locking systems) and additional mechanisms for control of motion (constant or variable friction and "fluid" pneumatic or hydraulic control).

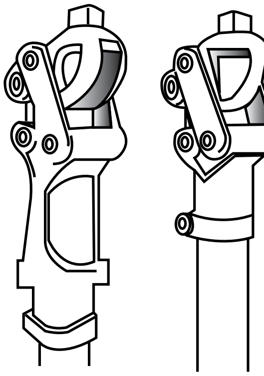
Single-Axis Vs. Polycentric Knees



The single-axis knee, essentially a simple hinge, is generally considered the "workhorse" of the basic knee classes due to its relative simplicity, which makes it the most economical, most durable, and lightest option available.

Single-axis knees do have limitations, however. By virtue of their simplicity, the knees are free-swinging and have no stance control; amputees must use their own muscle power to keep them stable when standing. To compensate for this, the single-axis knee often incorporates a constant friction control and a manual lock. The friction keeps the leg from swinging forward too quickly as it swings through to the next step.

Polycentric knees, also referred to as "four-bar" knees, are more complex in design and have multiple axes of rotation. Their versatility is the primary reason for their popularity. They can be set up to be very stable during early stance phase, yet easy to bend to initiate the swing phase or to sit down. Another popular feature of the knee's design is that the leg's overall length shortens when a step is initiated, reducing the risk of stumbling.



Polycentric knees are suitable for a wide range of amputees. Various versions are ideal for amputees who can't walk securely with other knees, have knee disarticulation or bilateral leg amputations, or have long residual limbs.

A standard polycentric knee has a simple mechanical swing control that provides an optimal single walking speed; however, many polycentric knees incorporate fluid (pneumatic or hydraulic) swing control to permit variable walking speeds. The most common limitation of the polycentric design is that the range of motion about the knee may be restricted to some degree, though usually not enough to pose a significant problem. Polycentric knees are also heavier and contain parts that may need to be serviced or replaced more often than those of other types of prosthetic knees.

STABILITY OPTIONS

Manual Vs. Weight-Activated Locking Systems

Some amputees need or desire the security of a knee joint that locks in extension to prevent buckling. One option is the manual locking knee, which incorporates an automatic lock that can be unlocked voluntarily. This is the most stable knee available. Walking is possible with the lock either engaged or disengaged, although the locked knee requires excessive energy to use and produces a stiff, awkward gait. The manual locking knee is appropriate for weak or unstable patients as well as more active individuals who frequently walk on unstable terrain.

Another option is the weight-activated stance-control knee. This knee is very stable and is often prescribed for a first prosthesis. When weight is placed on the prosthesis, the knee will not bend until the weight is displaced. This system functions as a constant-friction knee during leg swing but is held in extension by a braking mechanism as weight is applied during stance phase. This knee is a common choice for older or less active amputees.

MOTION CONTROL OPTIONS

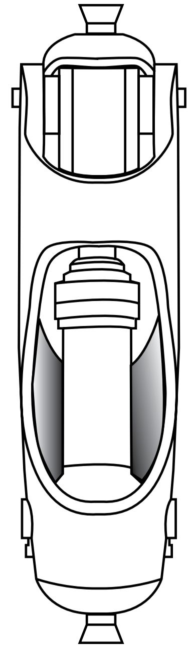
Constant Friction Vs. Variable Friction

All knee systems require some degree of swing control to maintain a consistent gait. In many cases, this control is provided by mechanical friction at the axis of rotation and is adjusted to match the normal cadence of the opposite leg. Constant-friction knee units are simple, lightweight and dependable. Their main disadvantage is that the knee is adjusted for a single walking speed at any given time.

Variable friction provides increased resistance as the knee bends from full extension. This provides "cadence response," allowing variable walking speeds; however, this system requires frequent adjustment and replacement of moving parts and is considered less advanced than fluid control knee systems.

Fluid Control Systems: Pneumatic Vs. Hydraulic

Advanced swing control for prosthetic knees uses fluid dynamics to provide variable resistance, enabling amputees to walk comfortably at different speeds. These units consist of pistons inside cylinders containing air (pneumatic) or fluid (hydraulic). Pneumatic control compresses air as the knee is flexed, stores the energy, then returns the energy as the knee moves into extension. Gait control can be further enhanced with the addition of a spring coil. Pneumatic systems are generally considered to provide superior swing control to friction knees but to be less effective than hydraulic systems.



For active amputees, hydraulic systems provide the closest thing to normal knee function. Hydraulic systems use a liquid medium (usually silicone oil) instead of air to respond to a wide range of walking speeds. Although hydraulic knees provide a smoother gait, they are heavier, require more maintenance, and a higher initial cost.

Microprocessor Knees

Microprocessor knees are a relatively new development in prosthetic technology. Several such new knees are now available or in development. Onboard sensors detect movement and timing and then adjust a fluid /air control cylinder accordingly. These microprocessor-controlled knees lower the amount of effort amputees must use to control their timing, resulting in a more natural gait.

In spite of all of the amazing inventions and constant tweaks and improvements, the perfect prosthetic knee has yet to be invented; otherwise, there wouldn't be over 100 different designs on the market. As advanced as the technology seems today compared to the earliest designs of the 1600s, one can only imagine the developments that will eventually result as researchers further explore the potential of mechanical, hydraulic, computerized and "bionic," or neuroprosthetic, technology.

—by Bill Dupes