VIRGINIA PROSTHETICS
THE ORTHOTIC & PROSTHETIC CENTER

UPDATE

Current Developments in Prosthetics & Orthotics No. 58

‘Smart’ Knees Alter Prosthetic Landscape

A revolution is under way in prosthetic rehabilitation, and tiny computers—microprocessors—are leading the way, most notably in the development of knee componentry for above-knee replacement limbs.

Even the most sophisticated pneumatic and hydraulic mechanical knees lack one essential ingredient: the ability to “sense” and react quickly to changes in the wearer’s gait and operating environment. While variable cadence is possible with those components, changes in walking speed occur only gradually.

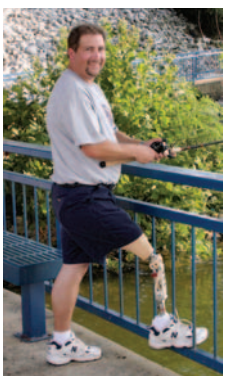
Prosthetics Today

But with computerized (AKA “smart”) knees such as the Rheo Knee®, C-Leg®, Smart Adaptive knee and others, these cadence changes can occur almost instantly, producing a more natural and energy efficient gait. Sensors constantly channel information to the microprocessor about what the limb is doing—for example, a sudden increase in walking speed or a step onto different terrain.

Prosthetic Knee Systems

Lower-extremity prosthetic rehabilitation takes on a whole different character when addressing limb loss above the knee. The combination of a shorter residual limb, reduced musculature, and absence of the knee joint introduces added complexities for restoring ambulation to a patient who has undergone a transfemoral amputation, knee disarticulation or limb removal at hip level.

For such amputees, a key determinant of success is the prosthetic team’s ability to provide an appropriate knee component to match the patient’s age, state of health, activity level and mental acuity. Knee selection involves consideration of many attributes: biomechanical performance, energy requirements, safety, ease of maintenance, cost, and operational complexity, among others. The knowledge and experience of the prosthetist are vital to getting the knee choice right.



Entegra hydraulic knee *Courtesy Hosmer-Dorrance Corp.*

This newsletter examines the current generation of prosthetic knees and the methods we use to find the most appropriate system for each patient. We hope you find the material informative.

In real time the decision-making chip signals the swing-phase control to react so the limb will be ready for heel strike at the appropriate instant and place. Then at heel strike, the microprocessor signals the knee to restrict flexion until late stance phase, providing needed stability for full weight-bearing, then gradually allows flexion in preparation for toe-off. Smart knees can further detect danger of falling or slipping and react to keep the knee from contributing to a fall.

‘Smart’ knees like the C-Leg® help amputees with life’s ups and downs.
Courtesy Otto Bock Health Care

Beyond functional considerations, computerized knees can substantially enhance the amputee comfort factor, so essential for sustained prosthetic success. Comfort begins in the socket, of course, but there is a dynamic component as well: In optimizing each gait step, smart knees minimize abnormal or excessive muscle use, and thus energy expenditure, employed to stabilize or move the prosthesis. Another benefit is mental relaxation as these

(Continued on page 2)

On the Cutting Edge of O&P

As a Beta test facility, Virginia Prosthetics has been fortunate to have been involved in the development of the current generation of microprocessor-controlled prosthetic devices including feet, upper-extremity terminal devices, and knee systems such as the models shown here. These state-of-the-art components have enabled their wearers to reach a new level of functionality in addition to providing increased stability and safety.

Virginia Prosthetics is a certified provider for all current prosthetic devices. Call us and make and appointment for an evaluation to determine whether one of these advanced devices is right for you.

1-888-366-8287

Rheo Knee

Plié MPC knee

C-Leg

Prosthetic Knee Options Address Wide Range of Patient Needs, Capabilities

The knee component is a critical part of any above-knee prosthetic system intended to enable ambulation. Its essential role is to mimic the anatomical knee's function to the greatest extent possible, providing reliable support in stance phase; allowing smooth, controlled leg swing; and permitting unrestricted flexion for sitting, stooping and kneeling.

The spectrum of prosthetic knees includes many options spanning the needs and abilities of the limited household ambulator (Functional Level K1) to those of the high-activity adult, child or athlete (K4). Mechanical knees, vis-à-vis microprocessor-controlled systems, can be classified into five design categories based on their function (see table, page 3).

Courtesy Otto Bock Health Care

These basic designs involve tradeoffs between safety and quality of gait. More advanced (hybrid) units combine two or more design features to provide both safety in stance phase and enhanced gait performance in swing phase.

A key element in providing the proper knee system for any amputee is stability, keeping the joint fully extended and supportive during stance. For individuals lacking sufficient muscular strength to achieve that stability, a fixed or dynamic locking mechanism is indicated to guard against falls and possible injury. Increased stability frequently results in reduced gait quality, however.

Design Parameters

Selecting an appropriate knee mechanism for an above-knee prosthesis entails detailed assessment of the patient's health and ability to exercise voluntary control of the limb. Taking into account the amputee's abilities, activities and personal desires, the prosthetist evaluates a series of design and feature alternatives in recommending a particular knee unit:

Single-axis knee with weight-actuated brake and extension assist
Courtesy Otto Bock Health Care

GeoFlex™ polycentric knee
Courtesy Ohio Willow Wood

• **Single-axis vs. polycentric.** The *single-axis knee*, essentially a simple hinge mechanism, usually incorporates a mechanical friction control and frequently a manual lock. Its mechanical simplicity and ease of maintenance makes it a popular choice for geriatric or infirm patients. On the minus side, the single-axis knee provides minimal stability and generally limits the patient to a single, slow walking speed.

Polycentric designs, frequently incorporating a four-bar linkage system, provide a moving center of rotation keyed to the degree of knee flexion. This arrangement yields varying mechanical stability throughout the gait cycle: enhanced stability at heel-strike to reduced stability at toe-off, permitting easier commencement of leg swing. The polycentric design also effectively shortens the length of the shank during the swing phase, increasing ground clearance and reducing the potential of stumbling. Polycentric knee joints are uniquely applicable for patients with a knee disarticulation, a short above-knee amputation, and/or weak hip extensors.

• **Friction.** With all knee systems, some degree of swing dampening is necessary to keep prosthesis cadence under control. In many cases, this dampening is provided by mechanical friction applied about the axis of rotation and adjusted to match the normal cadence of the contralateral leg. Constant-friction knee units are simple, lightweight and dependable. Their main disadvantage is that the wearer is effectively limited to a single cadence.

Above-knee prosthetic limb incorporating Total Knee polycentric unit with hydraulic control and stance lock.
Courtesy Össur Americas

• **Locking systems.** Some amputees require or desire the added security of a knee that locks in extension to prevent buckling. The *manual locking knee* incorporates an automatic positive lock that can be unlocked voluntarily. Ambulation is possible with the lock either engaged or disengaged, though the former usually requires excessive energy and produces an awkward, vaulting gait. With the many advanced knee designs now available, the manual locking knee is generally considered appropriate only for weak or unstable patients.

Another locking approach is the *weight-actuated stance-control knee,* originally known as the "safety knee." This unit 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 and relatively inactive patients.

MightyMite® 4-bar knee for geriatric and pediatric patients
Courtesy Hosmer-Dorrance Corp.

• **Extension assist.** Typically provided by a spring, this enhancement releases energy stored during knee flexion to help the amputee propel the knee to full extension in late swing phase. Extension assist both prepares the prosthesis for heel-strike and weight-bearing and helps reduce energy expenditure and fatigue.

• **Fluid control systems.** Advanced swing control enhancements for various prosthetic knee designs utilize fluid dynamics to provide variable resistance to leg swing velocity and thus enable the amputee to vary walking speed.

Pneumatic control is achieved by a cylinder housed in the shank. With knee flexion, a piston rod attached to the thigh portion of the prosthesis is pushed into the cylinder, forcing air through an adjustable port. Because air is compressible, it provides extension assist as flexion begins to decrease. A spring coil assist can also be added. Pneumatic systems are generally considered to provide superior swing control to friction knees but to be less effective than hydraulic components.

Hydraulic control units, which use a liquid medium instead of air, provide nearly normal knee action over a wide cadence range. Most hydraulic systems provide swing phase control and incorporate a polycentric linkage or weight-actuated brake to provide stance phase control. However, hybrid units also provide stance stability through increased flexion resistance at heel-strike and foot-flat. This feature enables amputees to walk confidently down slopes or stairs in a step-over-step fashion.

Mechanical Knees Overview

Type	Function	Most suited for	Advantages	Limitations
Manual-locking knee	Eliminates knee flexion	Elderly, frail and infirm patients (K1/2)	Maximum knee stability	Abnormal gait, awkward sitting
Single-axis knee	Basic hinge action	Persons with good hip strength & reflexes, children (K1/2/3/4)	Simple, durable inexpensive	Inherently unstable; fixed slow cadence
Stance control "safety knee"	Weight-activated friction brake	Limited ambulators, short residual limbs, "training" prostheses (K1/2)	Enhanced weight-bearing stability	Slow cadence, abnormal gait
Polycentric knee	Moving center of rotation providing stability when needed	More active patients, bilateral amputees, long residual limbs (K2/3/4)	Variable stability, added toe clearance	Constant cadence, added weight, cost & upkeep
Fluid-control knee	Variable swing-phase resistance	Community ambulators, active amputees (K2/3/4)	Variable cadence, more natural gait	Higher cost, weight & upkeep
Hybrid designs	Combine benefits of different designs	Active amputees, patients with specific functional needs (K2/3/4)	Ability to provide user more versatile capabilities	Higher cost, weight & upkeep

Functional Levels: **K1** - Limited household ambulators **K2** - Unlimited household ambulators/ limited community ambulators **K3** - Community ambulators **K4** - Active adults and children; athletes

The Bottom Line

The selection and fitting of prosthetic knee joints involves evaluation skill, componentry knowledge, technical proficiency, and a fine sensitivity to the capabilities and desires of the amputee.

Our experienced prosthetic team is uniquely qualified to provide the most functional, comfortable and reliable knee system practical for above-knee amputee patients.

Who Shall Be Considered Qualified To Provide Custom O&P Devices?

Five national organizations representing the clinical, business and quality improvement aspects of the orthotic and prosthetic disciplines recently joined forces to promote a consensus set of minimum education and training requirements for providers and suppliers of custom orthopedic braces and prosthetic limbs.

The effort comes as CMS—the Centers for Medicare and Medicaid Services—drafts long-overdue proposed regulations to prohibit payment to any provider or supplier that is not qualified through specific education and training to demonstrate competency to treat patients requiring custom orthoses and prostheses. Currently, Medicare requires no specific education and training for O&P providers and the many suppliers who deliver O&P services.

The agreement establishes specific education requirements, mandating a bachelor's degree as well as specific formalized instruction from accredited O&P schools as the only standard in the United States for providers and suppliers of custom O&P care. Reference to accredited schools means a comprehensive set of O&P-specific courses will be required before a candidate is qualified to sit for an exam in orthotics or prosthetics administered by one of two O&P credentialing organizations. A training requirement stipulates that candidates must engage in supervised patient care for at least one year in each discipline (e.g., orthotics or prosthetics).

The organizations participating in the milestone agreement include:

- the American Academy of Orthotists and Prosthetists
- American Board for Certification in Orthotics and Prosthetics
- American Orthotic and Prosthetic Association
- Board for Certification/Accreditation, International, and
- the National Association for the Advancement of Orthotics and Prosthetics.

Walking 'Without Having to Think About It'

(Continued from page 1)

intelligent systems enable wearers to walk in one amputee's words, "without having to think about it" and thus concentrate on other things.

This attribute is particularly valuable when walking on stairs, on a changing slope or in other circumstances requiring alternating stability and mobility. Mechanical knees cannot make that adjustment, requiring the wearer to look down and consciously adjust foot and body position.

Since the first microprocessor-controlled (MPC) knees appeared more than a decade ago, the technology has improved substantially, yet we're still only scratching the surface. New materials and manufacturing processes will provide lighter, more durable components, while software enhancements and research into direct neural control promise ever-more-responsive performance from existing and future designs.

With these exciting developments, will there still be a place for mechanical knee systems? Most assuredly, for these advanced systems are far from appropriate for all amputees. For one thing, though MPC systems have been shown to provide substantial quality of life improvement for patients as low as Functional (K) Level 2, a great number of older and less-vigorous amputees will be unable to appreciate the capabilities of these advanced systems. In addition, the high cost of this technology and third-party reimbursement resistance will likely be with us for some time, limiting access for many.

Nevertheless, smart prostheses are the future of limb rehabilitation, and that future is truly exciting.

The Rheo Knee® delivers near-natural ambulation on varying terrain.
Courtesy Össur Americas

1-09

Note to Our Readers

Mention of specific products in our newsletter neither constitutes endorsement nor implies that we will recommend selection of those particular products for use with any particular patient or application. We offer this information to enhance professional and individual understanding of the orthotic and prosthetic disciplines and the experience and capabilities of our practice.

We gratefully acknowledge the assistance of the following resources used in compiling this issue:
Freedom Innovations • Hosmer-Dorrance Corp.
Ohio Willow Wood • Össur Americas • Otto Bock Health Care

Plié Introduces Some Nice MPC Knee Enhancements

A great thing about new technology is that follow-on products often bring notable improvements over the initial concept. Barely 10 years ago, the prosthetics world plunged headlong into microprocessor control of knee components with the introduction of the C-Leg®. Subsequently, various competing systems appeared, incorporating enhancements that further improved the prosthetic performance of users and introduced a new buzzword, "MPC" (microprocessor-controlled), in the process.

What's New

The latest step forward in this progression is the Plié MPC knee from Freedom Innovations. This system augments the high-tech innovation of its predecessors with several nice features that improve prosthetic function, usability and reliability for the amputee:

The Plié MPC in action

Courtesy Freedom Innovations

• **Faster response—**The Plié (from the French word describing a ballet movement in which the knees are bent while the back is held straight) is said by its manufacturer to capture data 1000 times per second and react within ten milliseconds. In other words, the knee's response to changes in gait dynamics is all but instantaneous, so gait is smoother and more natural. Plié wearers can accelerate, slow down, change direction and take small steps with ease—at any speed, angle or incline.

• **Low profile—**Because this knee does not require an additional sensor pylon, transfemoral amputees with longer residual limbs, including knee disarticulations, may be Plié candidates.

• **Removable power source—**The Plié comes with two replaceable lithium ion batteries, an independent charger and even a car adapter, so one battery can be charging while the other is in use. A fully charged battery will power the system for 1-2 days depending on usage.

• **Water resistance—**Though not to be confused with a shower or swim leg, the Plié's electronics and mechanical parts are protected to withstand mild encounters with unexpected rain or spilled liquid, encounters than have proven fatal to some earlier systems. A quick rinse and air-dry, and it's good to go. Plié users are not precluded from boating or washing their car.

An internet video showing the Plié knee in action can be seen at **http://www.spsco.com/video/plie.asp**.

More Power to You!

Computerized decision-making was the first breakthrough in creating the superior above-knee prosthesis of the future. Adding electric power to flex and extend the knee under computer control is the second.

The Össur Power Knee™ incorporates compact battery powered motors powerful enough to lift the user step-over-step up stairs, walk confidently on uneven inclines and in soft surfaces such as dirt or sand, and facilitate sitting and standing. Users report that even on a level surface, walking with the Power Knee is faster with reduced effort and feels "natural" and "carefree."

The system utilizes advanced artificial intelligence for precise control of knee functions, using measurements of limb motion, load and position from sensors on both prosthetic and sound limbs.

Widespread availability of the Power Knee is still down the road, but its introduction provides ample cause for excitement for the future of lower-limb prosthetics.

Virginia Prosthetics, Inc.
4338 Williamson Rd.
Roanoke, VA 24012