

The Prosthetic Knee

Microprocessor and Non-Microprocessor Knee Joints



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For the above-knee amputee, the prosthetic knee joint is one of the most critical components of the prosthesis. Replacing the amazingly complex human knee has been an ongoing challenge since the beginning of modern prosthetics. A prosthetic knee has to mimic the function of the normal knee while providing stability and safety at a reasonable weight and cost. A prosthetic knee that produces the most functional outcomes is needed. Developing such a knee requires familiarity with normal gait, because that is the basis for understanding an above-knee amputee's gait.

The normal gait cycle is divided into two major phases: stance phase and swing phase. The stance phase describes the time when the foot is on the ground. It is not a period of inaction, but rather the time when weight is applied to the leg. The swing phase describes the time when that foot is in the air and swinging forward. The stance phase takes up approximately 62 percent of the gait cycle, the swing phase approximately 38 percent.

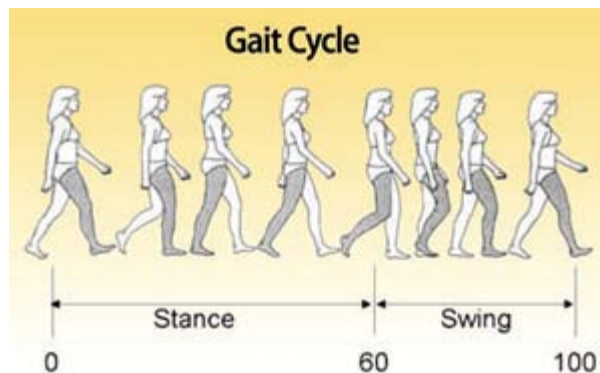
The quadriceps (muscles in the front of the thigh) and hamstrings (muscles in the back of the thigh) provide significant control of the knee joint in the stance and swing phases of The Prosthetic Knee Microprocessor and Non-Microprocessor Knee Joints by Erik Schaffer, CP, Chris Kort, CPO, and Phil Kreuter, PT gait. They both move the knee and lock it so that the knee doesn't bend when it shouldn't. In addition, the ligaments and bony anatomy of the knee joint provide a strong foundation for both static and dynamic function. The ankle joint assists gait by providing a second hinge during both gait phases. Hip and ankle joint muscles also provide control and stability of the leg during walking, but the knee is the most critical.

The above-knee amputee faces a considerable challenge since he/she has lost both the knee and ankle joints. The challenge for the prosthetist is to replace what has been lost and provide the best function for the patient based on his/her goals and lifestyle.

Prosthetic knees can be classified into two distinct types: those that use mechanical control of the knee joint (non-microprocessor) and those that use some form of computer chips (microprocessor) to control the swing and/or stance phases of gait.

The non-microprocessor knee

Hundreds of non-microprocessor knees are available worldwide. They all use a mechanical hinge; the speed and ease of the hinge's swing is controlled by one of the following mechanisms:



Free swing

- Manual lock
- Constant friction
- Weight-activated friction
- Geometrically locking
- Hydraulics.

The hinge swings, then locks manually when pressure is placed on the leg during stance phase. Mechanical-knee users must exert muscular and mechanical control to alter speed and step length and provide stability in the weight-bearing phase of gait. The prosthetist or the user can manually adjust some mechanical knee joints to set the controls in the swing and stance phases based on the patient's needs. These adjustments can only be made when the person is in a static (still) position.

The microprocessor knee

Since the early 1990s, microprocessor-controlled prosthetic knees have been available in the United States. The microprocessor controls the speed and ease with which the knee swings throughout the swing phase. It also controls the degree of stability the knee joint maintains during stance phase. Microprocessor-controlled prosthetic knees are equipped with sensors that continuously detect the position of the knee throughout the stance and swing phases of gait. These sensors provide input to the prosthetic knee so that the knee "knows" which gait phase it's in. This allows it to adapt to different walking speeds, terrain and environmental conditions as the user walks.

In addition to these features, a microprocessor knee has been shown to improve the stability in the stance phase of gait because it senses that the user is not walking and thus resists if the knee tries to collapse. This feature provides improved safety when standing and more confidence when walking. The knee's ability to control the swing phase during walking and to provide resistance in the stance phase reduces the amount of energy it takes to walk and provides additional safety for walking.

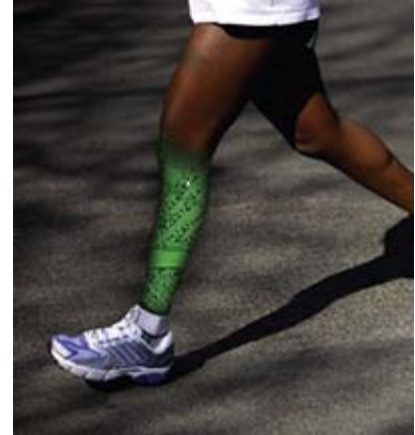
Microprocessor knees use a variety of systems within the knee mechanism to provide resistance, including pneumatics, hydraulics and magnetic systems. Each type of microprocessor knee uses software that controls and modifies the function of the knee. Microprocessor-knee manufacturers train and certify prosthetists in the setup and alignment of the knee as well as in the software used to adapt the knee to each patient's weight, functional status, and goals.

Comparing the two

There are many significant differences between a microprocessor and a nonmicroprocessor knee. The mechanical knee is generally more durable and requires less maintenance than a microprocessor knee. The cost of the non-microprocessor knee is significantly less than a microprocessor knee. It has no battery, so it does not require daily charging. Mechanical knees have fewer issues with water compared to microprocessor knees.

In general, an above-knee amputee who uses a non-microprocessor knee must give more thought to controlling the knee in both the stance and swing phases of walking. That is, walking is less natural and requires both more attention and energy. An amputee with an adjustable knee who wants to change the settings for running or for a different terrain must stop walking and adjust the settings before walking or running again. Most users who have tried both types of knee report the non-microprocessor knee shows significantly less stability in the stance phase of gait and on stairs, ramps and uneven terrain compared to a microprocessor knee.

Many, but not all, patients who have gone from a mechanical to a microprocessor knee report that they feel safer and stumble or fall much less; have a smoother and more natural gait; can descend stairs and ramps with greater ease and stability; expend less energy when walking; and don't have to think and focus on how to walk as much as they did with a non-microprocessor knee.





The microprocessor knee adjusts automatically for people who can walk with a variable cadence and walk in changing conditions.

Although a microprocessor knee can be used for many higher-level activities, a non-microprocessor knee would be the type of knee chosen for many recreational and competitive sports. When considering the addition of a custom cosmetic skin cover, a mechanical knee may offer simpler solutions due to the charging and maintenance needs of the microprocessor knee.

Compared to a non-microprocessor knee, the microprocessor knee's high-tech solutions come with a considerable increase in cost. Also, the knee's battery must be charged on a regular basis, and the knee must be kept from getting wet or immersed in water for long periods. In addition, with the current multiple forms of healthcare insurance for prosthetics in the United States, reimbursement for microprocessor knees varies widely, from full payment to complete denial. (Denial would be based on the insurance company determining that the knee is "not medically necessary" and/or "experimental" or "investigational.")

Who should get which kind of knee?

To determine which type of knee is appropriate for a given patient, a complete evaluation and profiling of that patient must be done. The type of prosthetic knee suitable for a person can only be determined through a complete understanding of that patient. The evaluation and profiling of the patient should include the following considerations: age, medical history, length of residual limb, muscle strength, activity level, home environment and occupational needs. The patient's functional goals and aesthetic concerns must be considered, too.

Major advances in the application of technology have improved the function of the lower-extremity amputee. Prosthetic knee joints with microprocessors have had a significant impact on the functional outcomes for the above-knee amputee. Indeed, they provide increased function and safety for many people. But not everyone can expect to benefit. Research needs to be conducted to objectively distinguish and measure the functional differences provided by the two major types of prosthetic knees. This would also help determine who benefits the most from this expensive option. Advances in design and technology in prosthetic knees will continue with exciting new possibilities for improved function with better microprocessor controls, advanced remote control systems, and neuro-bionics.

About the Authors

Erik Schaffer, CP, president of A Step Ahead Prosthetics, has been working in the prosthetics industry for over 21 years. Chris Kort, CPO, has more than 13 years' experience in the prosthetics industry. Phil Kreuter, PT, owner of Mobility Physical Therapy, has been working with amputee patients for over 25 years. With the assistance of his entire team, Erik Schaffer has contributed several articles to Amputee Coalition of America publications.



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