



Great Prosthetic Components Are Good, But a Good Socket Is Great

I intended our discussion of the transfemoral amputation level to be comprehensive, insightful and helpful. It certainly has turned into a marathon. There are so many elements and nuances to this common high level amputation that I thought it would be a disservice to readers to skip over any topics or touch on them too briefly.

Parts 1, 2 and 3 of this series covered topics ranging from pre-operative issues through recovery and rehabilitation. In this part, we'll focus on prosthetics, sockets and suspension. Technology is helpful and often marvelous, but it's still comfort that counts.

Finally, in Part 5 of this series, we will examine why walking is particularly challenging for individuals with transfemoral amputations. In addition, we will offer some thoughts on both the expected and the unforeseen consequences of technological advances.



The Prosthetic System

When discussing the transfemoral prosthesis, it is important to consider four major aspects of the system: the socket, the suspension, the components and the alignment.

- **The Socket:** This is the part of the prosthesis that attaches it to the body and largely determines whether the fit is good or not. It's what holds the prosthesis to the person and enables him or her

to make the foot and knee units work. Almost every transfemoral amputee I've met believes that it is the most important aspect of the prosthesis.

- **The Suspension:** This is the method used to attach the prosthesis to the body. Successful suspension keeps the prosthesis from falling off and prevents excessive motion of the residual limb, such as slipping, sliding, rotating, or

pistoning up and down, inside the socket. It also helps prevent bell-clapping, which is the phrase we use when the residual femur (thigh bone) moves around inside the socket like the clapper in a bell. Good suspension, together with a good socket, holds the femur in the right position.

- **The Components:** These are the parts that replace the various anatomic structures of the lower limb, such as the knee and foot, that were lost at birth or through amputation. These parts range from simple to very complex and are often what people focus on most. Improvements in the design of and materials for prosthetic foot, ankle and knee components over the last several decades have been truly amazing, but to really appreciate the advantages of technologically advanced components, the amputee must have a good socket and proper suspension.
- **The Alignment:** This is the unique way everything fits together – the way the socket, foot and knee are put together in three-dimensional space. Proper alignment ensures that the person isn't too bowlegged or knock-kneed and that the prosthetic knee doesn't buckle when the person stands. Proper alignment means getting the prosthetic knee under the socket in the right spot and the prosthetic foot uniquely positioned beneath the knee and the socket. Good alignment allows the components to accept and support body weight during the “stance phase” and to bend fluidly as the prosthesis moves through space during the “swing phase.” (The swing and stance phases will be more fully described in Part 5 of this series.)

Though all of these aspects are involved in a successful prosthetic system, in survey after survey, amputees identify a comfortable, well-fitting socket as the most important. That's why we say, “Great prosthetic components are good, but a good socket is great.” A comfortable socket is almost incalculably more important than the fanciest prosthetic parts (knees, feet, etc.) in the world.

Sockets: A Continuing Evolution of Design and Materials

As noted previously in this series, the transected femur can support very little weightbearing at its end. The socket is therefore designed to shift weight up onto the side of the thigh and the pelvis to take weight off the end of the limb. Though no one should underestimate the importance of a good socket fit, many people often do. In fact, there can be a tendency to focus so closely on prosthetic parts that the significance of socket comfort is overlooked. Some may think that a specific part – such as the prosthetic foot or the

prosthetic knee – is the major factor in overall function following a transfemoral amputation, but I believe that socket fit and quality are much more important. A great prosthesis doesn't work great if the socket doesn't fit and the alignment is not right.

Socket shapes have changed over the years. During the 1950s, there was an evolution to the quadrilateral socket. This design has two chief physical characteristics:

- The socket looks square when viewed from the top.
- It contains a contoured area for the ischium (part of the hip bone) to sit on called the ischial seat.

At first glance, you might think, “The thigh's not shaped like that. It's not square. What good is this socket?” But the socket is specifically designed to be narrower from front to back (anterior to posterior) to hold the residual limb back, keeping the ischium up on the ischial seat. The individual actually sits up on the back rim of the socket. To accomplish this, the socket must be higher in front than in back.

There's a downside, though. The high front wall of the socket often digs uncomfortably into the groin area, especially while the person is sitting. But if the front wall is lower, the leg slides forward and the ischium falls off the ischial seat. Sometimes, it's a no-win situation.

Transfemoral sockets began to change dramatically in the



1970s and '80s. Most sockets now are narrower from side to side (medial, the inside part of the thigh, to lateral, the outside part). The ischium, instead of sitting up on top of an ischial seat, is contained down in the socket. The femur, rather than sitting straight in the socket, is tipped inward to distribute some of the weight onto the lateral side. This is called adduction. Adducting the femur also helps stretch the hip abductors (butt muscles) a little, making them stronger and improving their mechanical advantage. If the femur is not secure and it drifts out, these muscles are mechanically weaker. Also, when the femur is tipped in, more weight can be put on the side of the thigh, and the hip muscles are positioned to provide better balance.

The quadrilateral socket is commonly called the quad socket, and all sockets that are narrower from side to side, medial to lateral, are called narrow ML sockets. While the majority of sockets today are ML designs, there are still many successful quad fittings and many good reasons for some people to continue using the quad design. While there's a tendency to think that a newer model must be better, it might be better or it might just be different. When the

ML socket came out, many people who used quad sockets wanted to change to the new model, assuming, "It must be better because it's new." But some people who were doing fine with the quad socket changed to the newer design and had trouble. "Best" is what works best for you.

Not only have the shapes of sockets evolved, so have the materials they're made of. Many of the initial sockets were made of carved wood. Then came leather and metal. Aluminum followed steel to reduce the device's weight. Rigid plastics and laminates followed. Most recently, plastics have advanced to become both flexible and durable. This enables sockets to rigidly support some areas and still allow for muscle motion and more flexible support in others. There are also combinations of an inner socket that's made of a flexible material and a rigid frame that has open spaces, which allow the brims to be a little more pliant (easily bent).

Traditionally, transfemoral sockets have been made with walking in mind, and all of the design changes have focused on holding the prosthesis securely while the person is standing up and in motion. However, the optimal shape for walking is not the best shape for sitting. A transfemoral socket molds up to or around the ischium – the part of the hip bone that we sit on – to transfer weight when the person is upright. But because of this construction, the socket can dig uncomfortably into the groin and buttocks when the person



of carbon fiber. Soft or rigid, all of these sockets need to be held on. The following are commonly used types of suspension:

- Suction valve
- Elastomeric roll-on liners with locking pins
- Soft straps or belts that go around the waist (the TES Velcro belt or the Silesian band)
- A rigid belt that securely grabs the pelvic area and uses a mechanical hip hinge to hold the limb on and support the pelvic area.

is seated. To this day, unfortunately, none of the sockets are really designed for sitting. If a socket were made to be comfortable while sitting, it might not provide the stability and support needed when standing. Technically, it's hard to design one socket that's optimal for both sitting and standing. The newer sockets that combine rigid and flexible materials are a start in the right direction. Socket design is an ongoing evolution, however, and most would acknowledge that we haven't solved all of the problems.

While sockets are better now than they were when they were carved out of wood, some transfemoral amputees still can't get a comfortable socket fit. Many of these amputees might agree with these words from Thomas Edison: "I have not failed. I've just found 10,000 ways that won't work."

Suspension: Keeping the Socket Attached

Regardless of design and materials, all sockets must have secure suspension to keep the prosthesis from falling off. Some sockets are made of softer plastics, some are composed of laminates, and still others are constructed

In the traditional suction valve suspension system, as the residual limb goes into the top of the socket, air is forced out through a one-way valve at the bottom. This creates a vacuum between the skin of the residual limb and the inside of the socket. When the limb is pushed all the way into the socket, the skin at the top of the thigh forms a seal with the plastic of the socket. Because air cannot get



back into the socket through the valve unless it's deliberately released, the vacuum that's created prevents the socket from falling off. This is called negative pressure, and it keeps the socket securely attached to the limb.

This suction valve suspension can fail, however, if there's not a good intimate fit between the top of the thigh and the socket where the skin and plastic seal is formed. If there's a dramatic weight change or a person's tissue has too many folds, air can slip in the top, eliminate the negative pressure, and cause the socket to fall off. While suction valve suspension is successful for many people, it doesn't work for everyone.

Roll-on locking liners were introduced more than 15 years ago and have really improved in recent years. The liner is still most typically connected to the socket by a distal pin lock. But like many things, the locking pin is not perfect. The pin concentrates many forces at the very end of the residual limb and causes a pistoning-suctioning effect that can be likened to a cow's udder during milking and may produce swelling and tenderness. Edema fluid, skin discoloration and ulceration can result. Up to one-third of the people using a distal locking pin for suspension simply cannot tolerate the stress on their tissues. People have put cloth, mesh and other types of reinforcement at the end of their liners to try to lessen the uncomfortable pistoning-suctioning forces, but the results have been mixed. Some people who have failed with distal pins feel bad because they think they did something wrong or that something is wrong with their residual limb. But there's no fault involved; it's actually a fairly common occurrence.

As noted in the section on sockets, when something new comes along there's a risk of forgetting about the benefits of previous designs. For example, a patient recently told me that he hadn't known it was possible to use a prosthesis without a roll-on liner. The roll-on liner was the only

form of suspension he'd been told about. After struggling for years with a roll-on liner and pin, however, when he tried the older suction valve system, he had great success. He had been introduced to what was perceived as the new and better technology, but when it failed, no one had attempted to help him return to the tried-and-true method. He didn't even know about it. When he did learn about it and try it, it worked. To avoid such situations, healthcare providers need to make their patients aware of advances in design, while at the same time reminding them of the benefits of the older, tried-and-true methods.

Other methods are being explored to attach roll-on liners to the socket for those who can't tolerate a pin. Alternatives include side-locking strips that work a bit like ski buckles and vacuum-assisted suspension in which a little pump is used to develop a vacuum between the liner and the socket. These new systems are helpful, but we're still growing in our understanding of which system is appropriate for which person. If only something like "Electronic Velcro" existed, we could just flip a switch and a small battery current would make the liner stick to the socket. To remove it, we could just flip the switch off and the socket would come right off. Someday, we may be able to secure gel liners to the entire surface of the socket, not just at one or two points.

For people who have difficulty with suspension, securing the prosthesis up around the waist is the next step. First attempts are always with softer materials, including neoprene, different types of cloth, and leather. One part of these soft suspension belts securely grasps the prosthesis, and the other part wraps around the waist, often above the belt line, where it is then cinched with Velcro or buckles.

Some people want something more solid than the softer suspension belts, and hip hinges and rigid belts may help these people feel more confident. A very rigid band that grasps the opposite iliac crest (hip) and a mechanical hip hinge may give them the feeling that the prosthesis will stay on and the hip will track properly. While this form of suspension adds weight to the prosthetic device and can be cumbersome, for some it provides a secure feeling of suspension that leads to success. ■

“When you're prepared,
you're more confident.
When you have a strategy,
you're more comfortable.”
– Fred Couples, PGA golfer

Next: Doc, Walking Is Not as Easy as It Looks