

TRANSTIBIAL SUSPENSION ALTERNATIVES

SUSPENSION – THE METHOD BY WHICH THE ARTIFICIAL LIMB IS ATTACHED TO THE BODY – IS ONE OF THE MOST CRITICAL ASPECTS OF PROSTHETIC DESIGN.

The better the human-machine connection, the more comfortable the prosthesis and the more effectively it can be controlled by the residual limb. Clinical experience has shown that even small improvements in suspension of the prosthesis are well received by amputees, which helps explain the variety of alternatives that have been developed.

The dozens of suspension alternatives can be conveniently classified into four functional groupings, which will be discussed in more detail later in this article:

- Atmospheric pressure
- Anatomical contour
- Straps
- Hinges.

Undesirable motion of the residual limb up and down within the socket is termed “pistoning,” and this movement has been shown to increase stresses on the skin. The best suspension is the one that minimizes pistoning without unduly complicating donning and doffing of (putting on and taking off) the artificial limb.

Atmospheric Pressure

In most cases, some form of attachment based on atmospheric pressure (usually called “suction suspension”) is the first choice, primarily because scientific studies have demonstrated that these suspensions minimize pistoning compared to alternatives. The primary limitation of suction suspensions is that the prosthesis must be donned consistently for good results. Sometimes complications such as upper-limb injuries make this problematic.

Knee Sleeves

All atmospheric pressure suspensions function by creating a seal between the patient’s skin



Figure 1

The use of elastomeric knee sleeves is one of the simplest methods for creating a vacuum seal against the thigh to use atmospheric pressure to suspend the socket. Reprinted with permission from Otto Bock HealthCare

and the prosthesis. For transtibial (below-knee) amputees, the simplest method is to apply a rubber-like external knee sleeve over the prosthesis that extends from the socket to midthigh and ends a couple of inches above the top of the limb socks, as shown in Figure 1. The knee sleeve prevents air infiltration into the prosthesis by serving as a gasket that seals against the skin. The textile limb socks wick perspiration away from the skin and permit the amputee to accommodate changes in residual

limb volume by adding or subtracting sock plies.

With this type of sleeve suspension, if the socket starts to displace distally on the leg, a partial vacuum is created inside the socket and atmospheric pressure holds the socket securely in contact with the skin. A one-way valve may be installed near the end of the socket so that air is automatically expelled as the amputee walks. This increases the partial vacuum significantly so that atmospheric pressure holds the prosthesis more securely against the residual limb.

The primary drawback of sleeve suspension is that even a pinhole leak will eliminate the suction effect, and sleeves wear out after a few months. For this reason, two or three sleeves are usually provided initially and then replaced as they abrade (wear away) or tear from normal use. Another common complaint is that the external sleeve limits maximum knee flexion, although this restriction can be minimized by careful attention to socket trim lines and selection of a sleeve made from one of the more elastic materials.

Some people complain of a "pulling sensation" or irritation at the top edge of the sleeve, but this can usually be eliminated by the application of a small amount of skin lubricant such as A&D Ointment. Sleeve suspensions are also difficult for people with a very tapered thigh since the cone-shaped musculature tends to force the sleeve to roll down the leg.

Roll-On Liners

Another common method of creating a vacuum seal against the skin is the use of a roll-on elastomeric liner that fits inside the socket. The original concept was to use a very thin silicone membrane that rolled on directly against the skin in place of textile limb socks, called a "Silicone Suction Socket," "3S," or "Iceross" (Icelandic Roll-On Suction Socket). The distal end of the roll-on liner is usually tethered to the bottom of the socket by a cord or strap (lanyard) or by a protruding pin that slides into a shuttle lock built into the prosthesis.

Figure 2

Roll-on liners of various thicknesses are worn directly against the skin and provide some protection against shear and peak pressure loads. "Locking liners" are attached to the inside of the socket by vacuum, straps, or by a pin and shuttle lock assembly, as shown here. The wearer can apply textile limb socks over the liner to accommodate volume reductions in the residual limb. Reprinted with permission from Otto Bock HealthCare



This method of suspension has proven to be very convenient and easy to use and is therefore quite commonly used. To remove the prosthesis, the amputee presses a small button to release the lock or unfastens the strap or cord.

One advantage of the roll-on liner is that knee flexion is less restricted than with an external sleeve. Another is that the liner material protects the skin against shear forces. If the residual limb loses volume due to weight loss or atrophy, the amputee can apply limb socks over the outside of the liner to compensate. It is also possible to use a somewhat thicker liner made from a gel material that adds cushioning (sometimes called a "gel locking liner"), as shown in Figure 2.

Another suspension variant combines the sleeve with the cushion liner and adds a small mechanical pump that increases the vacuum with every step. Preliminary data suggests that such augmented suction may reduce the normal fluctuations in the volume of the

Figure 3

A pilot study has suggested that augmented vacuum may help stabilize the volume of the mature residual limb. In this example, when the amputee is walking, the component just beneath the socket absorbs vertical shock and rotary stresses while drawing a vacuum inside the socket to enhance suspension. Reprinted with permission from Otto Bock HealthCare





Figure 4

A band of silicone rubber impregnated into the textile "hypobaric socks" seals between the skin of the residual limb and the inner socket wall. A one-way valve expels the air in the socket during weight bearing, and atmospheric pressure holds the prosthesis against the skin. Reprinted with permission from Sidney Fishman, PhD

mature residual limb, although why this may be so has not been established. If the residual limb volume is more constant, then the prosthesis should fit more precisely throughout the day, so this may prove to be an advantage of augmented vacuum systems. Figure 3 shows one example of this suspension system.

Hypobaric Seals

Another method to create a relative vacuum in the socket is the use of a hypobaric seal that is incorporated into the limb socks or into the cushion liner in combination with an expulsion valve. With these methods, only the lower portion of the socket forms the vacuum chamber. Figure 4 shows an example of a suspension based on a hypobaric seal.

Anatomic Contours

When atmospheric pressure suspensions are not feasible or not desired, suspension based on anatomic contours is the preferred mode.



Figure 5

Particularly when the residual limb is fairly short, the extended trim lines required for supracondylar suspension provide additional stability about the knee. In this example, a portion of the suspension wedge is built into the soft insert, which is donned before putting on the prosthesis. Reprinted with permission from Otto Bock HealthCare

For the transtibial amputee, this is typically accomplished by intimately molding the region just above the knee on the inner side of the leg. This supracondylar (above-the-condyle) suspension method usually requires a 'break-in' period for the amputee to get adjusted to the focused pressure, but most people find it comfortable once the skin is accustomed to this contour. It has the secondary benefit of adding additional side-to-side stability between the prosthesis and the leg and is therefore particularly advantageous for the individual with a fairly short transtibial amputation. For extremely short residual limbs, the socket is often extended above the kneecap so that the suprapatellar (above-the-kneecap) contour can help control knee extension.

It is usually most convenient to mold the supracondylar wedge directly into a soft insert that is applied over the residual limb before donning the socket. But the wedge can also be made as a removable piece or as part of a removable medial wall in the socket. Figure 5 shows one type of supracondylar socket.

Straps

The third type of suspension incorporates various straps, with or without a waist belt. The big advantage of straps is that they are patient-adjustable, which can be an important consideration when follow-up visits to the prosthetist will be difficult. Straps also accommodate gross volume changes better than any other alternative, making them the preferred suspension for people undergoing kidney dialysis or those who anticipate significant weight loss.

At one time, strap and belt suspensions were commonly prescribed for the initial prosthesis, as is shown in Figure 6. Advancements in sleeve and roll-on liner methods have made it possible to adjust for normal postoperative atrophy, however, so straps are no longer the only option for the preparatory limb.

One of the most common current applications for strap and belt suspensions is to provide auxiliary suspension for participation in activities such as sports, hunting or hiking. A removable fork strap and belt that can be applied to a prosthesis suspended by atmospheric pressure or anatomic suspension provide added security when jumping or walking through deep mud or snow.

Hinges

The least common method of suspension – often called “joints and corset” suspension – is the use of metal side hinges. In most instances, the bulk, weight, and inconvenience of this historic suspension are unnecessary. One example of such a prosthesis is shown in Figure 7.

There are two primary exceptions, however. The first is when the residual limb has been damaged and cannot tolerate the forces of full weight bearing. Studies have shown that a snugly laced thigh corset can shift approximately half the loading from the residual limb onto the upper leg. The second primary indication for the use of joints and corset suspension is when the ligaments have been damaged and the knee must be braced to prevent excessive motion. Side hinges are also sometimes helpful in providing stability when the residual limb is extremely short or the tissue consistency is very soft.

In rare instances, the corset includes a proximal weight-bearing structure intended to shift axial forces onto the pelvis and substantially unload the residual limb. This “bypass” prosthesis is seldom necessary today unless the skin of the residual limb has been so severely compromised that it cannot tolerate even moderate forces.

Conclusion

Suspension of prostheses is, in some respects, similar to wearing slacks: The best way to hold them on varies from person to person and is influenced by body contours, climate, activity level,

and personal preferences. People with ample midsections typically do not like belts on their slacks or on their artificial limbs.

Suction suspensions that require skin-tight contact are more readily tolerated in cooler northern regions than in humid southern climes where excess perspiration is a daily concern. Highly active people generally prefer the most secure suspension possible and commonly use more than one type of suspension to ensure that their prosthesis is always securely connected – like wearing a belt and suspenders to guarantee that one’s slacks will never fall down. Some people just don’t like the confining feeling of an intimate atmospheric pressure suspension and instead prefer straps that they can loosen.

The challenge for the prosthetist is to evaluate the relative advantages and limitations of each of these suspension methods and to recommend those that will prove most satisfactory for each individual in the long run. The more clearly the amputee’s personal goals and preferences are understood, the more likely it will be that the suspension method selected will be successful.

Ultimately, though, there is no substitute for firsthand experience with suspension alternatives. The time spent in fitting trials and dynamic alignment should be sufficient to rule out suspensions that are totally unacceptable to the amputee, and an alternative method can be chosen before completing the prosthesis. But, it is only after wearing the prosthesis day after day during a full range of activities that the subtle differences become clear to the wearer. Each time the prosthesis is replaced, the amputee and prosthetist should once again discuss the currently available suspension options and jointly determine the best course of action based on real-world experience to date.

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Figure 6

The amputee can easily adjust the suprapatellar cuff to accommodate volume changes in the residual limb. As shown with this preparatory prosthesis, the cuff strap is often used along with a waist belt. Reprinted with permission from CPO Services, Inc.



Figure 7

The “Thigh Lacer With Side Joints” unloads the residual limb and stabilizes the knee, but it is rarely necessary today. Reprinted with permission from CPO Services, Inc.