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BRADDOM Fiziksel Tıp *ve* Rehabilitasyon

YEDİNCİ BASKI

ELSEVIER

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GÜNEŞ TIP KİTABEVLERİ

Bu kitap; beni bugün olduğum kişi yapan annem Rosa ve babam John'a; ayaklarımı her daim yere bastıran kardeşlerim ve eşleri John, Doug, Annemarie, Melissa, Pam ve Charlie'ye; ufka bakmayı hatırlatan çocuklarım Brie, Belle, Spencer ve Kayla'ya; sevgisi ve desteğiyle her şeyi anlamlı kılan eşim Hilary'ye ithaf edilmiştir.

Bu ders kitabının temelini atan ve süregelen desteğini esirgemeyen Randy Braddom, MD'ye özel teşekkürlerimi sunarım.

Virginia Commonwealth Üniversitesi'ndeki son derece destekleyici meslektaşlarıma, çalışma arkadaşlarıma ve asistanlarıma —Tıp Fakültesi ve Fiziksel Tıp ve Rehabilitasyon Anabilim Dalı dahil— mentorlukları, dostlukları ve bu projeyi tamamlamam için sağladıkları zaman için sonsuz şükranlarımı sunarım..

Amerika'nın gazileri ve askerlik hizmeti görenleri için gösterdikleri özveriyle ve bu projeyi tamamlamam için bana zaman tanıyan ABD Gazi İşleri Bakanlığı'nın değerli çalışanlarına teşekkür ederim.
Yıllar boyunca bakımlarına katılmama izin veren on binlerce hastaya ve ailelerine teşekkür ederim; sizler bana çok şey öğrettiniz.

Özetle, işimi ve kariyerimi sürdürmemi mümkün kılan süregelen destekleri için aileme, dostlarıma ve tüm sevdiklerime içten teşekkürlerimi sunarım.

Önsöz

Braddom'un Fiziksel Tıp ve Rehabilitasyon kitabının bu yedinci baskısı, fiziksel tıp ve rehabilitasyon (FTR) alanının sağlık hizmetlerinin geleceğine cesurca adım attığını, teknolojik ve entelektüel ilerlemelerin sunduğu tüm potansiyeli kucaklarken uzmanlık alanının 75 yıllık kurumsal temeli ve binlerce yıllık rehabilitasyon pratiği üzerine inşa ettiğini resmen tescil etmektedir. Rejeneratif tıp, sanal bakım, kök hücre tedavileri, genetik mühendislik, yapay zâkâ destekli tanı sistemleri, beyin-bilgisayar arayüzü, osseointegrasyon, robotik, giyilebilir tanı cihazları ve implante edilebilir stimülatör sistemleri artık yalnızca araştırmacıların ve mucitlerin dünyasında değil, FTR klinisyenlerinin günlük pratiğinin ayrılmaz bir parçasıdır. Bu teknolojik ilerlemeler bakımı zenginleştirirken, FTR alanı aynı zamanda popüler hale gelmeden önce her zaman en yüksek hasta memnuniyetini, klinisyen-hasta etkileşimini, klinik etkiyi ve en iyi sonuçları sağlamış olan bütüncül sağlık yaklaşımıyla kişi merkezli ve integratif tıp yaklaşımının daha fazla kabul görmesine —hatta yeniden canlanmasına— tanık olmaktadır.

Teknoloji ve bütüncül bakımın bu harmanına paralel olarak, yaşam boyu sağlık ve iyilik halinde daha fazla yenilik ve ilerlemelere yol açan fiziksel aktivite, beslenme, onarıcı uyku, duygusal sağlık, zihin-beden etkileşimi ve sağlığın diğer hayati unsurları üzerine son derece hoş karşılanan yenilenmiş bir odaklanma söz konusudur ve bu durum engelliliğin uzun vadeli bakımında ileri düzey yeniliklere öncülük etmektedir. Önemle belirtmek gerekir ki, FTR aynı zamanda belirli sağlığın sosyal belirleyicilerine sahip bireyler, askerlik hizmeti görenler, gaziler, ilk müdahale ekipleri, kadınlar, çocuklar, yaşlılar, sporcular ve yüksek riskli çalışanlar dahil olmak üzere engellilik riski taşıyan veya engelli olan benzersiz popülasyonlar için FTR pratiğini optimize etmek adına gereken bireysel yaklaşımı vurgulayan kişiselleştirilmiş bakım yaklaşımının değerini giderek daha fazla takdir etmektedir.

FTR'deki tüm bu iyileştirmeler, bireylerin daha uzun yaşamasına, vücutlarından ve zihinlerinden daha fazla talep etmesine, sağlık hizmet sunucularından daha fazla beklemesine, sağlık ve iyilik hallerinin tüm yönleriyle aktif olarak ilgilenmesine ve iyileşme ile işlevsellik beklentilerinin her zamankinden yüksek olmasına yanıt olarak ortaya çıkmıştır. Önceki FTR klinik başarıları hayat kurtaran veya ömrü uzatan keşifler, yaklaşımlar ve girişimler üzerinde odaklanırken, bugünün engelli bireyleri ve bakım verenler yalnızca akut olay veya yaralanmadan sağ kalmayı değil, aynı zamanda gelişmeyi ve daha yüksek bir yaşam, çalışma ve eğlenme düzeyine dönmeyi beklemektedir. Fizik tedavi ve rehabilitasyon uzmanından (fiziyatrist), bütüncül yaklaşımı ileri teknoloji ile dengelemesi, modern bilimi geleneksel inançlar ve uygulamalarla birleştirmesi ve bedeni, zihni ve ruhu iyileştirmesi istenmektedir.

Bu ders kitabı, FTR uygulamalarının ve sistemlerinin tüm yelpazesinden, uluslararası alanda tanınmış bir yazar ve yardımcı editör ekibini bir araya getirerek bu zorluklarla baş etmektedir. Akademik tıbbın en iyileri, özel muayenehane, gaziler ve askeri sağlık hizmetleri, rehabilitasyon hizmetlerinin tüm alanları, bütünleştirici klinisyenler ve geniş bir uzmanlık yelpazesi, alan için en güncel ve faydalı kaynağı sağlamak amacıyla bir araya getirilmiştir.

Braddom'un Fiziksel Tıp ve Rehabilitasyon kitabının güncellenen ve genişletilen bu yedinci baskısı, rehabilitasyon klinisyenleri ve asistanlar için paha biçilmez, pratik bir kaynak olan ve geleneksel temel yazılı materyallerin son teknoloji sanal eğitim ve öğretim materyalleriyle desteklendiği, rehabilitasyon disiplinleri genelinde temel bir referans olarak hizmet veren FTR'nin temel ders kitabı olmaya devam etmektedir. FTR alanında olduğu gibi, bu ders kitabı da asistanların ve klinisyenlerin engelli bireylerin iyileşmelerini, sonuçlarını ve uzun vadeli iyilik hallerini geliştirmeye çalışırken ihtiyaçlarını karşılamak üzere sürekli olarak yeniden tasarlanmakta ve iyileştirilmektedir.

David X. Cifu, MD
Baş Editör, Braddom'un Fiziksel Tıp ve Rehabilitasyon

Yenilik ve Sistem Entegrasyonu Dekan Yardımcısı ve Seçkin Bilim İnsanı
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Teşekkür

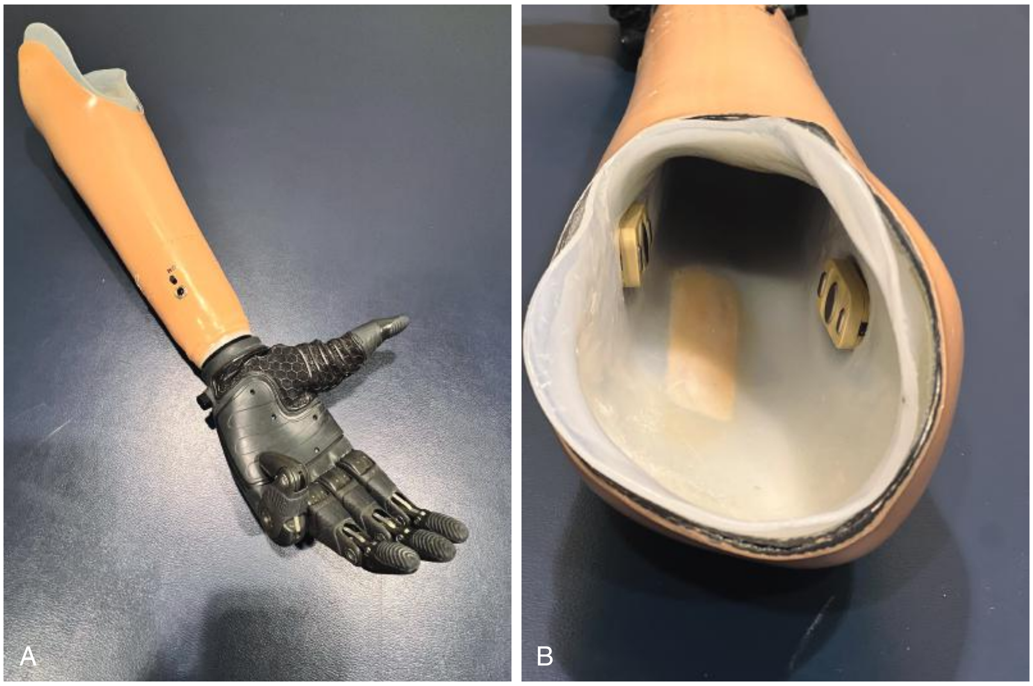
Braddom'un Fiziksel Tıp ve Rehabilitasyon kitabının bu yedinci baskısı, 100'den fazla yazarın —çok çeşitli uygulama ortamlarından, geçmişlerden ve uzmanlık alanlarından gelen fiziyatristler ve diğer rehabilitasyon profesyonelleri— alana olan bağlılıkları ve adanmışlıkları ile engelli bireylerin yaşamlarını iyileştirmek için iş birliği yapmaya olan kararlılıklarından ötürü zaman, emek ve bilgilerini ortaya koymasıyla mümkün olmuştur. Bu meslektaşlarım ve dostlarım, katkıları için en derin şükranlarımı ve saygımı hak etmektedirler.

Tüm bu parlak yazarları yönlendiren, teşvik eden, ikna eden ve zaman zaman "teşvik ve ısrar eden" kişiler, altı yardımcı editördür: Karen Kowalske, Michelle Miller, Blessen Eapen, Jeffery Johns, Amy Bowles ve Henry Lew. Bunlar gerçekten süreci ileri taşıyan ve her bölüm ile konu alanı için en iyiyi elde eden itici güç olmuşlardır. Titizlikleri, gözetimleri ve azimleri için minnettardım.

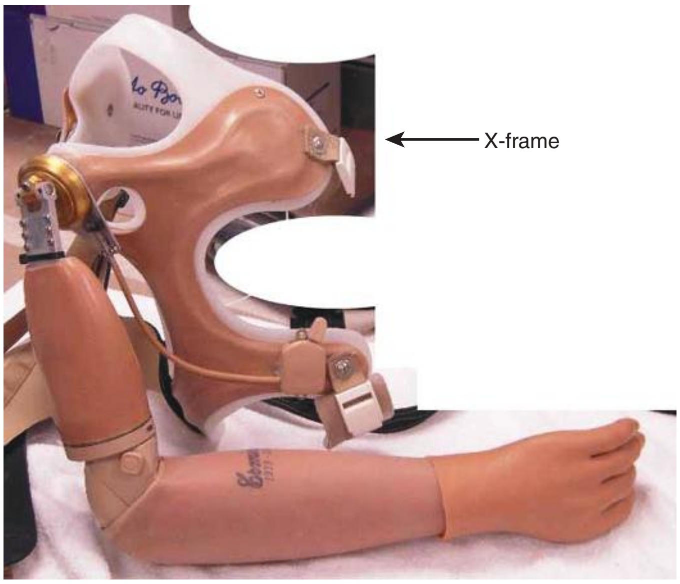
İçerik Stratejisti Mary Hegeler, Kıdemli İçerik Geliştirme Uzmanı Jennifer Shreiner ve Sağlık İçerik Kitap Uzmanı Kamatchi Madhavan liderliğindeki Elsevier editöryal ekibi, üstün profesyoneller olmuş ve bir kez daha en iyilerin en iyisi olduklarını kanıtlamışlardır. Son olarak, bu temel ders kitabına katkıda bulunan tüm bireylerin eğitim, şekillendirilmesi ve yetiştirilmesine yardımcı olan mentörlere, profesörlere, öğretmenlere ve uygulamacılara özel teşekkür ederiz; zira son birkaç on yıldaki çabalarıyla bu kitabı bir araya getirebilecek bu denli yetenekli ve adanmış profesyonellerin yetişmesini sağlayan onlardır. Tıpkı dünyanın dört bir yanındaki en iyi fiziksel tıp ve rehabilitasyon uygulamalarında olduğu gibi, en iyi sonuçları elde etmek için uyum içinde çalışan özverili bir profesyonel ekip gereklidir. Bu ders kitabı, bu kişiler alanın ilerlemesi için birlikte çalıştığında ortaya çıkan şeydir —harika bir sonuç. En sıcak teşekkürlerimi sunarım.

İçindekiler

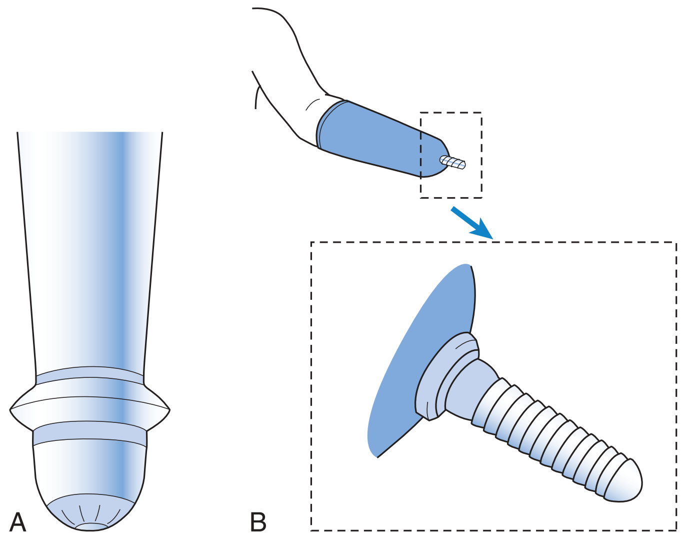
Kısım 4: Spesifik Tanılarda Güncel Yaklaşımlar



• **Fig. 10.5** Myoelectric prosthesis (A) with myoelectric control system (B) for a transradial amputee with socket electrodes visible.



• **Fig. 10.6** Shoulder disarticulation and forequarter prosthesis, body-powered elbow, and externally powered wrist and hand.



• **Fig. 10.7** Examples of prosthetic suspension systems. (A) Suction style with a seal-in ring. (B) Distal locking pin style, which inserts into a corresponding lock with quick-release button.

presence or absence of a residual limb shoulder joint. In transhumeral users with a fully body-powered prosthesis, it can be challenging to operate both the elbow and terminal device. Often the wrist joint is manually operated to reduce the amount of required input. Still, the prosthesis may require specific sequencing of the residual limb and torso to operate a specific joint in the desired way.

Components: Wrist

The wrist unit provides orientation of the terminal device in space. It can be positioned manually, by cable operation, or with external power (myoelectric or by switch). Once positioned, the wrist unit is usually held in place by a friction or mechanical lock.

Components: Terminal Devices

There are many terminal devices available for upper limb amputees, although the functionality of these terminal devices tends to be limited. Terminal devices are generally one of two categories: passive and active. Passive terminal devices fall into two classes: those designed primarily for function and those that provide cosmesis. Examples of the functional passive terminal devices include the child mitt frequently used as an infant's first prosthesis to

• **Fig. 10.10** Activity-specific terminal devices.

The Early Prosthetic Phase

Prosthetic Evaluation and Goals

When a patient with limb loss is being considered for a prosthesis, there are three initial areas of focus for the physiatrist.

First, has the residual limb fully healed from the surgery? Are there other new wounds or lesions since amputation? As in the lower extremity, adding a prosthesis adds pressure, heat, and weight to the underlying skin, thereby increasing the risk for damage and worsening existing skin issues. Has the patient already been prescribed a residual limb shrinker to help decrease tissue edema and shape the limb in preparation for a prosthesis? If not, the patient should be able to tolerate the shrinker for 23 of 24 hours a day, removing for personal hygiene and cleansing of the shrinker.

Second, is pain present, either residual limb or phantom limb pain, that will interfere with potential prosthetic use? Pain can be treated concurrently during the prosthetic fitting and fabrication stages, but if wearing the final prosthesis causes pain, then there is a high potential for device abandonment.

Third, and perhaps most importantly, what are the goals of the potential prosthetic user? Understanding a patient's current capabilities, goals, and intended use of the artificial limb is paramount to providing a prosthesis that is desirable and useful. No artificial limb will be a true replacement for what was lost. Prosthetic limbs are tools used to help accomplish specific goals and tasks. Especially with upper extremity loss, having a frank conversation with the patient helps to set expectations and ultimately influence the acceptance and use of any provided limb.

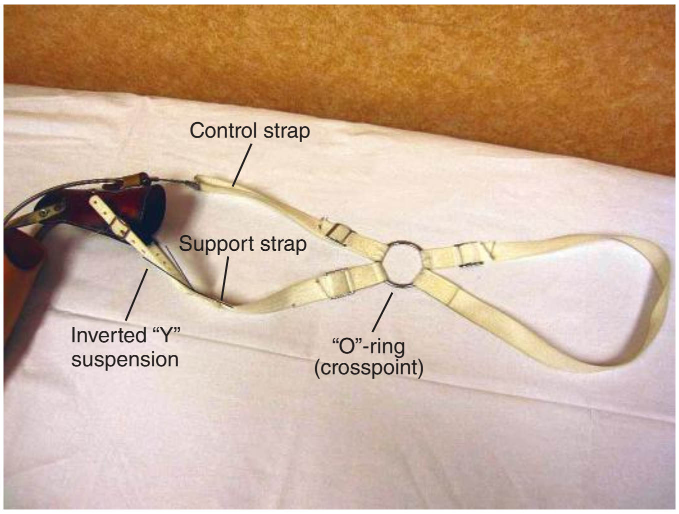
Once a patient's residual limb is ready for a prosthesis, pain is moderately to well controlled, and goals and expectations have been set in clinic, then a prosthetic prescription may be written. Like a medication prescription, there are certain required elements for the order. A specific diagnosis must be made (e.g., "Acquired absence of left upper limb above elbow Z89.222"), and the requested categories of components should be listed to include suspension type, socket type if needed, body powered or externally powered, and with or without myoelectric control if appropriate. Unlike lower extremities, upper limb prosthetics are not indicated based on a potential ambulation assessment or K level. The specific components and level of technology are normally determined based on the goals of the user and, ultimately, the insurance coverage and financial resources of the user. The cost of an upper extremity prosthesis can start at $3000 for a passive device, $10,000 for a body-powered hook, and $20,000 to $40,000 or more for an externally powered myoelectric arm. Insurance, if present, may cover all the cost, part of the cost, or in some cases decline any reimbursement at all. While a patient's health, capabilities, and goals should drive the primary decision making, it is important to understand and offer guidance on the financial realities of prosthetic costs. For veterans in the United States, note that the Veterans Affairs (VA) Hospital System operates a robust nationwide amputee rehabilitation network, and any veterans with limb loss should be encouraged to reach out to their local VA medical center to explore potential resources.

In most situations, it is beyond the physician's knowledge and experience to fully prescribe the exact componentry of the prosthesis. Maintaining a clear line of communication with the patient's prosthetist, or even better having them present in clinic, provides optimal quality and efficient care to the patient. Once prescribed, the patient will work with the prosthetist to develop a plan for the componentry, suspension system, and prosthetic socket. Often a clear plastic "check" socket will be produced to optimize the fit and function of the prosthesis. This allows monitoring of the skin and soft tissues of the residual limb during wear. Once the fit is finalized, a definitive socket, typically made of a plastic composite with carbon fiber and resin, will be produced and mounted to the prosthesis. After initial provision of the prosthesis, it is important for patients to follow up with their prosthetist regularly to ensure optimal fit and function.

Ideally, a patient should follow up with the physician within 1 to 2 months after receiving the definitive prosthesis so that a "checkout" visit may occur. This allows the patient to report any issues, such as pain or skin breakdown, and confirm that the device is meeting current needs. It also allows unforeseen problems with the prosthesis to be examined, and new prosthetic orders written if needed.

Early Prosthetic Training

Training for the upper limb amputee should ideally begin before the surgery and continue until advanced training is completed. The training is divided into three phases: preprosthetic training, early prosthetic training, and advanced prosthetic training. Each phase is focused on the end goal of maximal functional adaptation and proficiency with the prosthesis. The expectations of the



• **Fig. 10.8** Components of the figure-of-eight harness: axilla loop, anterior support strap, control attachment strap, and crosspoint.

facilitate crawling and the ball-handling terminal devices used by older children and adults for ball sports.

Active terminal devices are also one of two main categories: hooks (including prehensors, which are devices that have a thumblike component and a finger component producing a claw or bird's-beak type of function) and artificial hands (Fig. 10.9). Both device groups can be operated with a cable or by external power. No single device can reproduce the complex functional capability of the human hand.

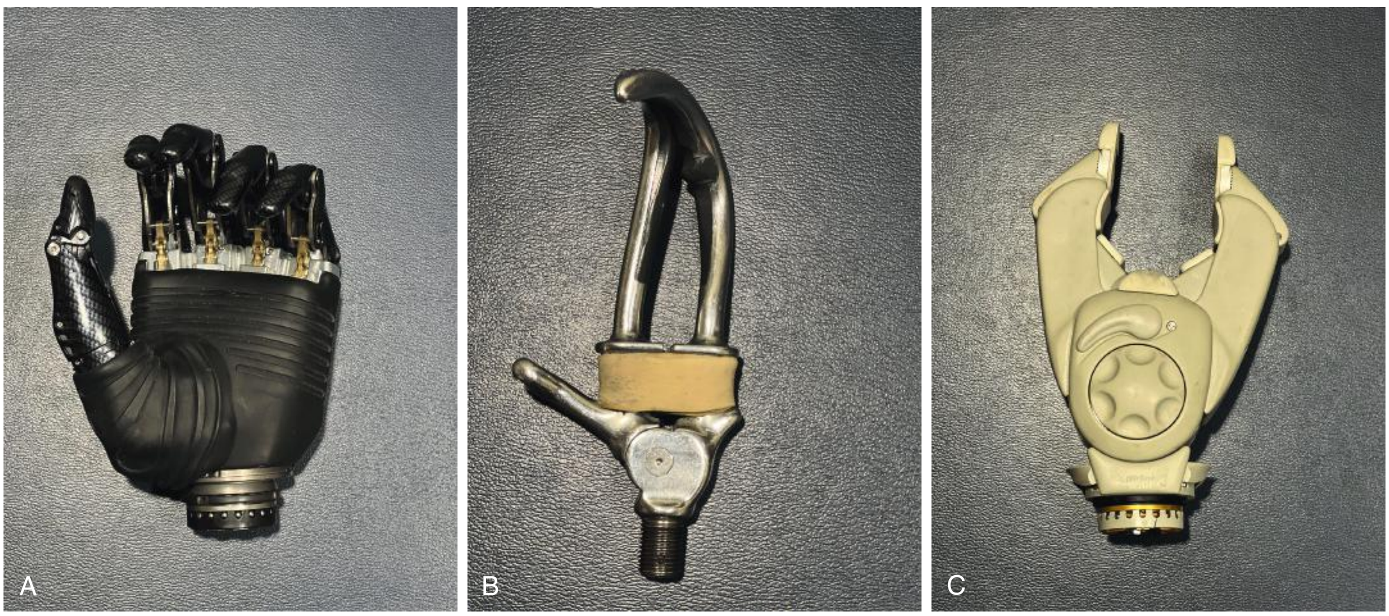
Cable-operated terminal devices (hooks or hands) can be of a voluntary opening design (most common) or a voluntary closing design. With a voluntary opening mechanism, the terminal device is closed at rest. The patient uses the control-cable motion to open the terminal device against the resistive force of rubber bands (hook) or internal springs or cables (hand). Relaxation of the proximal muscles allows the terminal device to close around the desired object. The number of rubber bands determines the amount of prehensile force that is generated. One rubber band requires 5 pounds of force to provide approximately 1 pound of pinch force (pinch force in a nonamputee is typically 15–20 pounds).

Hooks have many advantages: They are simple in design, lightweight, and durable; enable efficient grasp; have low maintenance; and permit visual feedback that is unavailable with a mechanical hand.

A prosthetic hand usually is bulkier and heavier than a hook. It can be powered by a cable or use external power. Some of the current hands on the market have unique grasping characteristics. These include a feature used to eliminate slipping of an item being grasped. Most hands are capable of several grips; however, switching between grip styles can be challenging, and most amputees tend to favor one or two programmed grips. Examples of the five major grip types can be found in Box 10.4. Not all electronic hands look like natural hands. Hands made for heavy-duty industrial purposes have other hooklike shapes. Task-specific terminal devices or systems also exist, such as a "basketball hand" or a bat/club attachment (Fig. 10.10) that may be used in conjunction with the abovementioned systems or deviate enough to earn its own category.

• BOX 10.4 Five Major Types of Grip

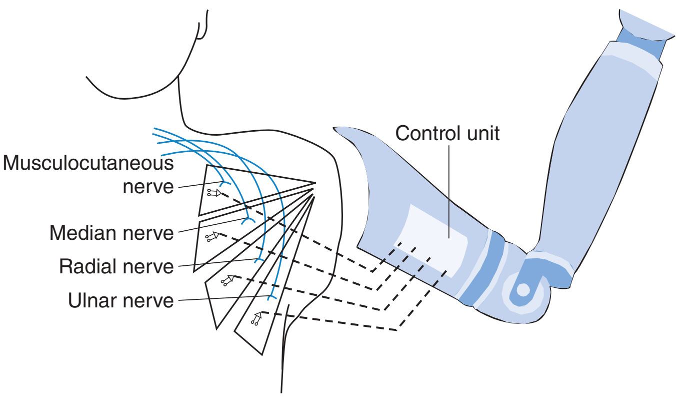
- *Precision grip* (i.e., pincher grip): The pad of the thumb and index finger are in opposition to pick up or pinch a small object (e.g., a small bead, pencil, grain of rice).
- *Tripod grip* (i.e., palmar grip, three-jaw chuck pinch): The pad of the thumb is against the pads of the index and middle finger.
- *Lateral grip* (i.e., key pinch): Tips of the fingers and thumb are flexed (e.g., when screwing in a light bulb or turning a doorknob).
- *Hook power grip:* The distal interphalangeal joint and proximal interphalangeal joint are flexed with the thumb extended (as when carrying a briefcase by the handle).
- *Spherical grip:* Tips of the fingers and thumb are flexed (e.g., when screwing in a light bulb or opening a doorknob).



• **Fig. 10.9** (A) Myoelectric artificial hand. (B) Body-powered hook. (C) Myoelectric Greifer (Ottobock).

require more inputs from the user. TMR and RPNI allow this increase in input channels from the user and help enable complex motions (Fig. 10.11). Other options to improve user input bandwidth include implantable electrodes in patient muscles or around peripheral nerves, brain-computer interfaces, and the use of machine learning and artificial intelligence to provide some levels of autonomous function in the hands.

5. Osseointegration. Currently approved by the FDA for transfemoral level amputations, OI or bone-mounted attachment points for prostheses have been trialed with transhumeral (Fig. 10.12) and transradial levels, and even with thumb amputations. OI-mounted prostheses could be useful in upper extremities with short residual limbs or challenges with suspension systems.
6. Advances in residual limb and phantom limb pain. There are many groups studying the use of ketamine in acute and chronic amputation pain, peripheral nerve catheters to deliver continuous pain-blocking medication, cryoablation to denature peripheral nerves contributing to pain, and even high-concentration capsaicin patches. Severe phantom limb pain is notoriously difficult to treat, and it is important to explore all avenues of pain control to provide the highest quality of life possible.



• **Fig. 10.11** Target muscle reinnervation to improve myoelectric prosthetic control.

• **Fig. 10.12** Transhumeral osseointegration. Note the abutment, or prosthetic mount, extending percutaneously through the stoma, or hole, in the skin.

Pediatric Amputation and Congenital Limb Difference

There are special considerations for amputation care in the pediatric patient with upper extremity amputation and congenital limb loss or limb difference. About 4 of every 10,000 babies each year are born with at least partial limb loss. In approximately 58% of cases, this is due to congenital deficiencies in which the limb bud fails to fully form in utero, but usually it does not have genetic or hereditary implications for the patient and the family. Teratogens and amniotic band syndrome are two of the most common causes. The International Society for Prosthetics and Orthotics terminology for congenital limb reductions is described in Box 10.7, which divides limb malformations into transverse or longitudinal. By definition, a child who has a transverse deficiency has no distal remaining parts beyond the named bone. For example, a child with a transverse radial deficiency has a normal upper arm and a portion of the radius but is missing the hand and fingers. Longitudinal deficiencies have distal portions present with a partial or total absence of a specific bone. This naming convention is sometimes used alongside the older Greek-based nomenclature shown in Box 10.8, which is still used in some environments. The most common congenital limb deficiency in the upper limb is a longitudinal partial or complete lack of the radius. Longitudinal hand reductions represent half of all congenital upper limb reductions, and multiple limb reductions are found in less than 20% of live births. Acquired amputations in children have a wide variety of causes but are most commonly due to trauma.[3] Medical causes such as cancer, frostbite, vascular occlusion, or tumors also contribute.

Younger children with limb differences do not always experience the same sense of loss and psychological adjustment as an older amputee. In fact, it is quite common for children with

• BOX 10.7 ISPO Classification System for Congenital Upper Limb Reductions*

- *Transverse deficiency:* No remaining distal portions. Transverse level is named after the segment beyond which there is no skeletal portion.
- *Longitudinal deficiency:* Some remaining distal portions. Longitudinal deficiencies name the bones that are affected.

ISPO, International Society for Prosthetics and Orthotics.
*Any bone not named is present and of normal form.

• BOX 10.8 Original Classification Scheme for Congenital Upper Limb Reductions

- *Amelia:* Absence of a limb
- *Meromelia:* Partial absence of a limb
- *Phocomelia:* Flipper-like appendage attached to the trunk
- *Adactyly:* Absent metacarpal or metatarsal
- *Hemimelia:* Absence of half a limb
- *Acheiria:* Missing hand or foot
- *Aphalangia:* Absent finger or toe

• **Fig. 11.5** (A) LimbLogic Electric Vacuum Pump System with key fob. (B) WillowWood One system. (Courtesy WillowWood, Mt. Sterling, OH.)

Suction Suspension

By creating a proximal seal within an airtight socket environment, suction sockets create a slight negative pressure to hold the prosthesis on to the residual limb. However, because of this negative pressure, a prosthesis with a lack of distal contact can create skin problems, including verrucous hyperplasia, if the lack of distal contact is chronic in nature. Historically, this approach has utilized a direct skin fit (no socks or liners between the residual limb and socket). The advent of gel liners has enhanced traditional suction suspension methods.

Elevated Vacuum Suspension

Elevated vacuum suspension can be seen as a derivative of suction suspension facilitated in part by the advent of interface liners (Figs. 11.5 and 11.6). In contrast to traditional suction socket systems, in which air is passively expelled from the socket through a one-way air valve, elevated vacuum systems actively draw additional air from within the socket environment. These designs provide a secure fit and stabilize the prosthesis firmly to the patient's residual limb, which can provide additional proprioceptive feedback and improved function, such as climbing a ladder or walking on uneven surfaces. There are currently several mechanisms that are used to create an elevated vacuum suspension environment, all of which require a TSB socket. Elevated vacuum systems maintain an enhanced negative pressure between the gel liner and socket wall. This negative pressure provides suspension and may assist with maintaining stability of the patient's residual limb volume. Elevated vacuum requires a pump that draws air out of the prosthetic socket. These pumps can be either manual or powered devices, and this technique can be utilized for either transtibial or transfemoral levels. Notably, elevated vacuum requires the maintenance of an appropriate socket fit and the user's attention to that fit. As such, it is not universally indicated.[83]

• **Fig. 11.6** Ossur Unity mechanical vacuum pump incorporated into prosthetic foot. (Courtesy Össur, Reykjavik, Iceland.)

Pin Lock Suspension

Pin lock suspension requires a liner with a distal umbrella of an embedded mesh matrix and a threaded attachment site (Fig. 11.7). A locking pin can then be threaded into that liner, which will then engage into a locking mechanism attached to the

• **Fig. 11.7** WillowWood Alpha gel liner with pin, Pelite liner, and flexible inner socket.

prosthetic socket. The lock can be either a clutch mechanism or rotary style. Locks can be either push or pull to unlock. Pin lock suspension provides a secure mechanical link between the amputee and the prosthesis. The gel liner holds on to the patient, and the pin locks into the prosthesis. This system can be used for either transtibial or transfemoral amputation levels. Pin lock suspension can be very easy for the patient to use and offers an audible click to reenforce engagement of the lock. This is one of the simplest and safest designs. The biggest disadvantage is the consistent accurate donning of the liner and the potential for distal distraction and shearing forces on the tissues of the residual limb. The lanyard strap suspension is a version of pin lock suspension. Instead of a pin and locking mechanism, a Velcro strap is attached to the gel liner and fed through an opening in the distal portion of a prosthesis by the patient and fastened on the exterior portion of the socket. This system requires that the patient has some manual dexterity but may be simpler than the pin lock to manage. The lanyard strap is often favored in transfemoral applications because it reduces the build height distal to the prosthesis and facilitates a more proximal placement of the prosthetic knee joint. In addition, the lanyard allows the limb to be pulled, rather than pushed, into the socket, a favorable attribute for the additional soft tissues of the transfemoral limb.

Alternate Suspension Designs

There are many other methods of suspending a prosthesis. Boxes 11.3 and 11.4 list the most commonly used suspension methods for transtibial and transfemoral level amputations. Sleeves, straps, belts, and buckles have been used in the past and are still being used in some cases, either because of patient preference or because of anatomic considerations with the residual limb. These techniques can involve straps to proximal anatomic anchors. With transfemoral amputations, the suspension might involve a hip belt over the contralateral hip (Silesian belt) or a combination of a hip joint, pelvic band, and waist belt. The former may also be indicated for enhanced rotational control of the socket. In transtibial level amputations, this could include a cuff suspension strap that is just proximal to femoral condyles.

• BOX 11.3 Transtibial Suspension Systems

- Supracondylar and suprapatellar cuff/strap
- Supracondylar Pelite liner with compressible or removable wall
- Auxiliary suspension with sleeve
- Liner with pin-locking mechanism
- Suction with or without liner
- Vacuum
- Thigh corset and side joints

• BOX 11.4 Transfemoral Suspension Options

- Pin-locking or lanyard system
- Total elastic suspension belt
- Silesian belt
- Hip joint and waist belt
- Suction or partial suction (dry or wet fit)
- Suction with seal-in liner
- Vacuum

• BOX 11.5 Prosthetic Interface Options

- Pelite liner
- Urethane liners
- Thermogel/gel liners
- Silicone liners
- Special feature liners
- Hard interface directly with socket

Prosthetic Interface Options

The contact of the residual limb against the socket can utilize either a hard or a soft interface (Box 11.5). An example of a hard interface is found in a transfemoral suction socket in which the skin of the residual limb is in direct contact with the hard socket. In contrast, modern prosthetic liners provide protection against

• BOX 11.7 Prosthetic Knee Design Options

- Manual locking
- Single axis with constant friction
- Weight-activated stance control (safety knee)
- Polycentric
- Hydraulic or pneumatic swing phase control
- Hydraulic swing and stance control
- Microprocessor control (stance or stance and swing phase control)
- Microprocessor with internal power
- Hybrid units with combined features

• **Fig. 11.15** Manual locking knee. (Courtesy Ottobock, Minneapolis, MN.)

Manual Locking Knee

Manually locking knees (Fig. 11.15) positively lock when fully extended and unlock by pulling a lever that is attached to the proximal portion of the socket (the lever is usually placed laterally or anteriorly). They cannot be flexed until unlocked. Manually locking knees provide the advantage of being the most stable knee designs, while the disadvantage of the knee is the compromised gait mechanics that occur because the patient must walk with a straight leg. This knee is utilized when stability is the primary issue for the patient, including during early bilateral fittings. This knee is relatively durable and inexpensive and is typically indicated for patients in the K1 functional classification category.

Single-Axis Knee

A single-axis, constant-friction knee is a basic knee joint similar to a hinge. It can have a spring-assisted extension so that the foot can advance more quickly during swing phase and achieve full knee extension sooner. The stability of the knee is based strictly on alignment and voluntary control, so patients need to have good proximal strength and control of the prosthesis to avoid knee instability. This knee is lightweight, durable, and inexpensive. It is typically indicated for patients in the K1 functional classification category.

Weight-Activated Stance: Control (Safety Knee)

A safety knee is a single-axis knee with a weight-activated locking mechanism. As the patient applies weight through the prosthesis during the stance phase, the knee locks automatically because of an internal braking system. For the braking mechanism to function appropriately, the knee cannot be flexed greater than approximately 20 degrees. When the patient's weight shifts off the prosthesis to initiate swing phase, the knee unlocks to allow flexion of the knee during swing phase. This knee can be used for new amputees and allows progressive adjustments from a very safe, locked status during stance phase to just a single-axis knee. This knee is generally indicated for amputees who fall into the functional classification K1 and K2 levels.

Polycentric Knees

A polycentric knee (Fig. 11.16) has inherent stability because of its construction and multiple points of rotation. These multiple joints create an instantaneous center of rotation that shifts as the knee flexes and extends. The instantaneous center of rotation is located more proximally and posteriorly with the knee in an extended position, which provides greater knee stability during the early part of stance phase. As the knee flexes, the instantaneous center of rotation shifts distally and anteriorly, which helps facilitate knee flexion in late stance phase. These knees are available with hydraulic or pneumatic swing phase control. Because of the relatively small distance between the knee axis of rotation and the attachment to the socket, this can also be an ideal knee for individuals with knee disarticulation level amputations. Such knees are often coupled with manual locking features to allow maximal stability in early gait training, maturing to enhanced mobility with gait training and experience.

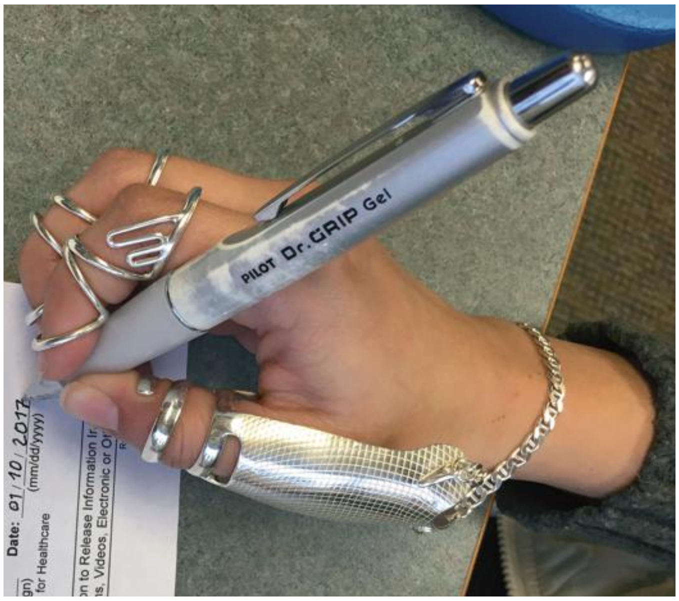
• **Fig. 11.16** Polycentric prosthetic knee with six-bar linkage. (Total Knee, Courtesy Össur, Reykjavik, Iceland.)

• **Fig. 11.24** (A–D) Specialty socket designs.

prosthesis. The REVO socket design is a technique that adds patient-adjustable panels to a custom socket. Some transfemoral socket designs, such as Martin Socket-less socket and Limb Innovation's Infinite socket, have very little socket other than struts and proximal brim. There is also the Bikini socket by Martin prosthetics for individuals with hip disarticulation–level amputations. All of these designs are a modern twist on older designs utilizing new materials and techniques (Fig. 11.25).

Although their introduction to the United States has been slowed by regulatory requirements, percutaneous osseointegration (OI) implants have been developed and utilized to achieve direct skeletal attachment of a prosthetic limb to the residual limb of a person with an amputation. Compared with socket suspension techniques, direct skeletal attachment of a prosthetic limb through OI offers many potential advantages, including improved mechanical transfer of motion, reduced skin irritation from a prosthetic socket, improved joint ROM, and enhanced comfort. However, OI also presents the possibility of serious risks, such as

• **Fig. 11.25** Historical evolution of prostheses. (Courtesy ABC Local, Clare Rawlinson, Australia.)



• **Fig. 12.30** The Silver Ring custom-fit orthosis resembles jewelry; compliance in its use may be higher than with thermoplastic alternatives.

hyperextension (see Figs. 12.11 and 12.12). The boutonnière orthosis holds the DIP or PIP joints in extension.

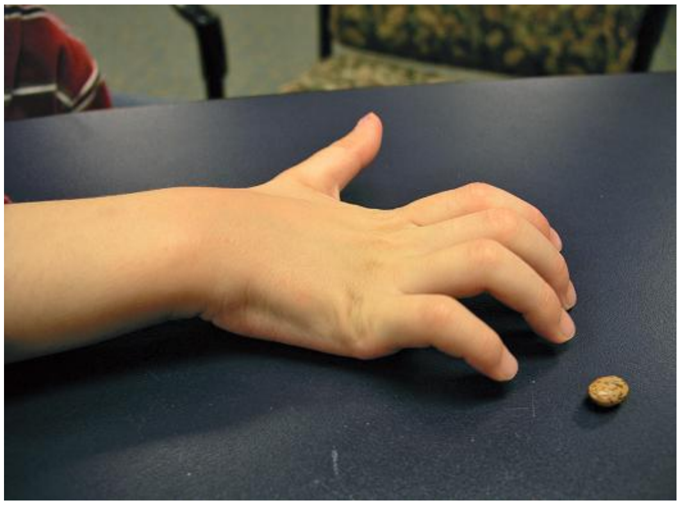
Osteoarthritis, the most common form of arthritis, is primarily a disease of cartilage. It most commonly involves the CMC joint of the thumb. A hand-based thumb spica orthosis (see Figs. 12.25 and 12.26), which offers more support to the CMC joint or forearm-based (see Fig. 12.16) thumb spica orthosis, can be prescribed for CMC joint osteoarthritis. By limiting motion at the base of the thumb, the orthosis decreases pain, especially with pinching-type activities. Previously, a long opponens orthosis was thought to have better efficacy. However, a double-blind randomized controlled trial demonstrated no difference in pain at rest, pinch grip strength, or hand function.[47] A short, comfortable orthosis is better tolerated and improves compliance.

Hypermobility syndromes, such as Ehlers-Danlos syndrome (EDS), are generally characterized by joint hypermobility, skin hyperextensibility, and tissue fragility. Patients with EDS may have loose, unstable joints that are prone to frequent dislocations, subluxations, and pain that lead to an early onset of osteoarthritis. The goal is to provide stability. Silver Ring (Fig. 12.30) offers several low-profile prefabricated and cosmetically attractive orthoses for such patients.

Neuromuscular Conditions

Nerve Injuries

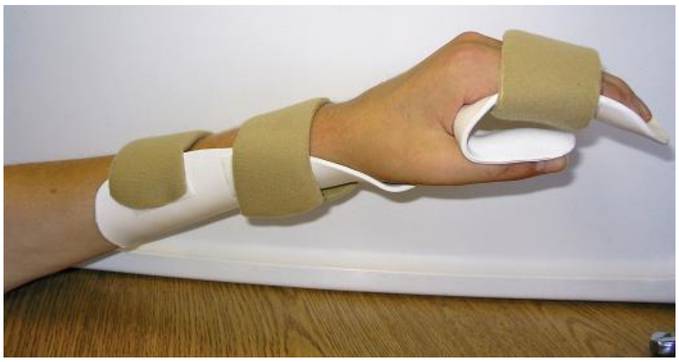
When a peripheral nerve is injured, the level and completeness of the injury determine the extent of the deficit incurred. For example, in a distal median nerve injury, a simian hand deformity may occur. The function most affected is thumb palmar abduction and opposition (Fig. 12.31). The thumb is held back in line with the fingers because of the pull of the extensor muscles. The goal of an orthotic device is to help restore lost function. The orthotic design holds the MCP joints in slight flexion but permits MCP extension. This orthosis also has a portion to position the thumb in palmar abduction. A median nerve lesion, proximal to the motor branches of the forearm flexors, is diagnosed if the patient is unable to make a fist. More specifically, the patient's index and middle fingers cannot flex at the MCP joint, and the thumb is usually unable to flex or oppose. This is referred to as the benediction sign. With a proximal ulnar nerve injury, the patient has wasting of the hypothenar muscles of the hand: the interossei muscles and the two medial lumbrical muscles. The patient will have difficulty with hyperextension of the fourth and fifth MCP joints and resultant flexion of the PIP joints caused by the loss of balance between the extrinsic and intrinsic hand muscles. This is referred to as ulnar claw hand. The goal is to prevent fixed deformity of the fourth and fifth MCP joints and improve function. An ulnar nerve palsy orthosis holds the MCP joints of the fourth and fifth fingers in slight flexion by using a figure-of-eight splint design. The figure-of-eight design assists MCP flexion and permits extension of the MCP joints but blocks hyperextension (Fig. 12.32). This can also



• **Fig. 12.31** Simian hand, as seen in low median and ulnar nerve injuries (also called the intrinsic minus hand).

• **Fig. 12.32** Ulnar palsy orthosis allows extension but blocks hyperextension of the metacarpophalangeal joints of the ring and small fingers.

• **Fig. 12.36** A prosthesis functions as a body-powered prosthesis and offers more functional movement than a flail arm as a result of a brachial plexopathy.



• **Fig. 12.37** Resting hand orthotic device.

decrease tone in the hand (Fig. 12.37). Botulinum toxin is commonly used to decrease the tone in patients with focal spasticity, followed by serial or dynamic splinting to regain normal posture or position.[12,23,29] The Ball antispasticity orthosis places the fingers and hand in a reflex-inhibiting position and serves to reduce tone (Fig. 12.38) (see Chapters 24, 44, and 45).[50]

Spasticity may be useful and might augment neuroplasticity for motor recovery.[40] The SaeboFlex[44] is a dynamic orthosis with functional electrical stimulation that is most appropriate for patients who have some shoulder and elbow movement but no hand function (i.e., lack of active finger extension). The SaeboFlex positions the wrist and fingers into extension in preparation

• **Fig. 12.38** Ball antispasticity orthosis to maintain hand and fingers in reflex-inhibiting position and wrist in neutral position to reduce spasticity. (Courtesy Linda Miner, OTR.)

• **Fig. 12.39** Rolyan figure-of-eight sling used for arm support and comfort of the shoulder joint in a patient with hemiplegia.

for functional activities. Users can grasp an object by voluntarily flexing their fingers after some motor recovery and may be aided by increased muscle tone. The extension spring system assists in reopening the hand to release the object. Individuals have demonstrated improvements in shoulder and elbow movements. Wrist extension also improved, but wrist flexion and finger movement did not.[16]

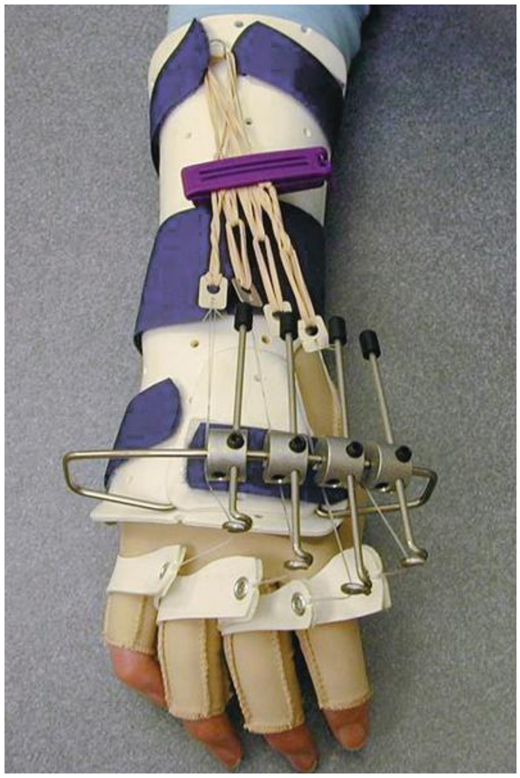
A proximal mobile arm support can be used to enhance function for patients with proximal upper limb weakness, especially when the weakness is profound and the outlook for recovery is guarded. A mobile arm support is particularly helpful when activities of daily living, such as eating and grooming, are performed. When it is attached to a wheelchair with a swivel joint, this is often called a balanced forearm orthosis.

Many types of slings are available for patients with decreased tone of the upper limb (Fig. 12.39). Decreased tone can result in shoulder subluxation, and a sling can moderate this deformity. These slings restrict active motion of the shoulder by keeping the humerus in adduction and internal rotation and placing the elbow in flexion.[46] They are designed to unload the weight of the arm on the shoulder but do not approximate the humeral head back into the glenoid fossa.[19] Slings or half arm trays have not been found to correct shoulder subluxation completely.[20] A sling

• **Fig. 12.47** Mallet finger orthosis. Zone 1 extensor tendon rupture.

• **Fig. 12.48** Extensor tendon orthosis used for postoperative care, allowing protected motion during the healing phase. (Courtesy Kelly Mikle, OTR/L, CHT.)

• **Fig. 12.49** Postoperative orthosis for a patient whose extensor tendon pollicis longus has been repaired. (Courtesy Kelly Mikle, OTR/L, CHT.)



• **Fig. 12.50** The metacarpophalangeal arthroplasty postoperative orthosis positions fingers in extension with slight radial pull. (Courtesy Jeanne Riggs, OTR/L, CHT.)

the range or when soft tissues underlying the skin are exposed. With tendon exposure, the orthosis plays a more protective role. It is important to monitor these patients frequently and reassess the needs for splinting.

After burn injuries, body parts should be positioned to prevent the development of expected deformities. For example, in burns of the dorsal surface of the hand, the wrist is placed in 15 to 20 degrees of extension, the MCP joints in 60 to 70 degrees of flexion, the PIP and DIP joints in full extension, and the thumb between radial abduction and palmar abduction (see Fig. 12.2). If tendons are exposed, the flexion of the MCP joints should be decreased to 30 to 40 degrees to keep some slack in the tendons until there is wound closure.[28] Palmar hand burns require maximal stretching to control the contracting forces of the healing burn.[28] The antideformity position of a palmar burn consists of 15 to 20 degrees of wrist extension, extension of the MCP and IP joints, digital abduction, and thumb abduction and extension. This has been referred to as an "open palm" or "pancake

• **Fig. 12.55** A 2-degrees of freedom robotic arm. The patient grips a handle at the end-effector and can push the handle in the horizontal plane, and two motors of the robot will drive the shoulder and elbow joints to follow. (InMotion2 courtesy Bionik Labs, Watertown, MA. https://bioniklabs.com/overview/.)

• **Fig. 12.56** Up to 7-degrees of freedom robotic arm. A highly sensitive hand grip and videogame-like exercises to simulate arm movements used in specific real-life tasks through a virtual environment with immediate feedback. Armeo®Power image courtesy Hocoma (Volketswil, Switzerland).

• **Fig. 12.57** Nonpowered antigravity assist exoskeletons are helpful in patients with severe shoulder girdle weakness. This will help accomplish self-feeding and tabletop activities, while increasing or maintaining range of motion and strengthening muscles. (Courtesy Michael Blackstock, MS, OTR/L.)

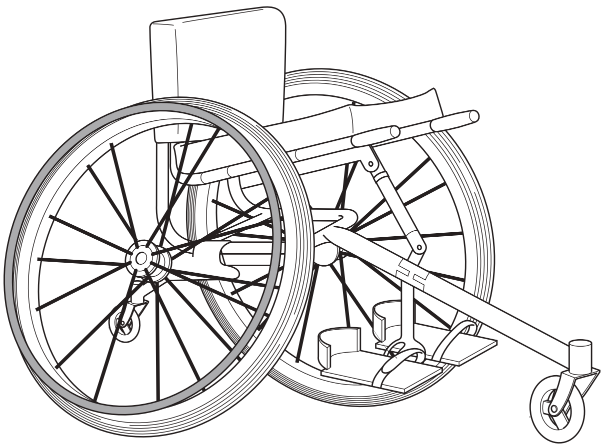
to recreate and reproduce intended motions according to the treatment plan while detecting deviations and provide corrective guidance or alerts.

Rehabilitation robots are categorized into end-effector (EE) and exoskeleton (Exo) types according to their mechanical structures.[15] EE robots are connected to patients at one distal point, and their joints do not align with human joints. InMotion 2[26] is an example of one that is helpful in more impairment-based situations (Fig. 12.55). Exo robots resemble human limbs as they are connected to patients at multiple points, and their joint axes match with human joint axes.[30] Armeo Power[2] is an example (Fig. 12.56). Exo robots can be powered, such as Armeo Power,[2] or nonpowered, such as Armeo Spring[3] and Jaeco Orthopedic proximal elevating mobile arm support[27] (Fig. 12.57). Both allow the weight of the arm support to be counterbalanced, and the patient can use residual neuromuscular control to perform the exercises and gradually build strength in the arm. Exo robots are useful in helping coordinated movements in functional tasks.

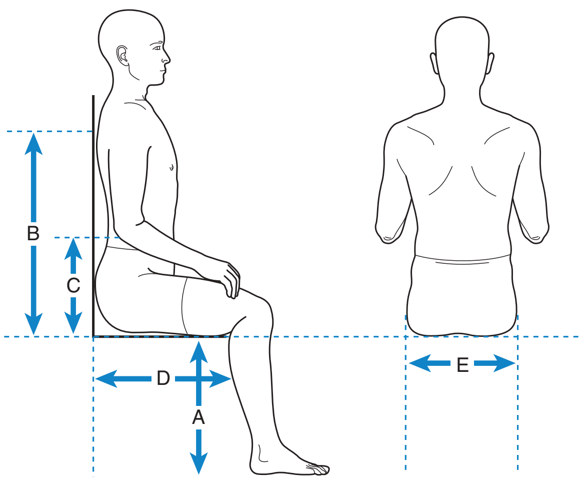
International Considerations

People with a disability are often caught in a vicious cycle of poverty and disability.[10] The World Health Organization estimates that only 5% to 15% of people with disabilities in Third World countries have access to assistive devices.[4] Low-income countries deliver assistive technology (including orthotic devices) differently because of cost, availability, materials, required skilled craftsmanship, health care access, and infrastructure issues. These factors represent the biggest and most difficult challenges to delivering orthotic devices to people in need. Training and retaining professionals in current orthotic principles, materials, and fabrication techniques is challenging. The goal is to fabricate a “universal”

• **Fig. 15.6** Pediatric adaptive stroller. (Courtesy Sunrise Medical, Longmont, CA.)



• **Fig. 15.7** Tennis sport wheelchair.



• **Fig. 15.8** Body measurements. *A,* Leg length: distance from bottom of heel to popliteal area. *B,* Back height: distance from buttocks to the inferior angle of the scapula. *C,* Arm rest height: distance from buttocks to forearm with elbow at 90 degrees. *D,* Seat depth: distance from back of buttocks to popliteal area. *E,* Seat width: distance between the widest parts of the buttocks.

recommended but might need to be more if the person propels with the feet.[13] A seat that is too shallow causes higher sitting pressures because less of the seat is in contact with the thighs. A seat that is too deep can cause excess pressure behind the knees and calves. There can also be a tendency for the pelvis to slide into a posterior tilt so that the back is no longer supported by the back rest.

Seat Width

The wheelchair seat width should be approximately 1 inch wider than the width of the widest part of the buttocks. When sitting on the seat, the individual's hips should be at or close to the edge of the cushion. If the seat is too narrow, the individual might develop pressure injury on the pelvic bony prominences. If the seat is too wide, the individual is forced to abduct the shoulders excessively, making it more difficult to propel the chair.

Back Height

The height of the back is determined by the amount of postural support the individual needs. The back rest should be positioned low enough to offer adequate support while maximizing the upper limbs' access to the push rims. Many practitioners use the inferior angle of the scapula as a basis for determining back rest height. The back rest height should be below the inferior angle so that it does not impede arm movements. There are various types of back supports (Table 15.2), and some have a tapered area that allows for greater freedom of scapular movement. Typically, the high-strength lightweight and ultralight wheelchairs permit the attachment of different types of back supports.[42,43,48]

Arm Rest Height

The arm rest height is determined by measuring the distance between the forearm and the seated surface. The forearm should be parallel to the ground when positioned on the arm rest. If the arm rests are too high, the person will continually elevate the shoulders, making it difficult to access the push rims. If it is too low, the arm rest will not properly support the upper limbs, including the shoulder complex.

Manual Wheelchair Setup

Ultralight wheelchairs provide the highest degree of adjustability and customization. This makes it possible to optimize the fit of the wheelchair to the user, which is likely to have a positive impact on propulsion biomechanics.[21,58] In addition to the basic adjustments on most other wheelchairs (e.g., foot rests, arm rests), ultralight wheelchairs have adjustable seat and back angles, rear wheel camber, and rear axle position.

Seat and Back Angle Adjustments

The seat angle, defined as the angle the seat makes relative to the horizontal plane, and the back angle, defined as the angle the back makes relative to the vertical plane, are both adjustable and configurable on ultralight manual wheelchairs. The adjustments, separately or together, optimize the postural support and comfort for the individual. Adjusting the seat to slope downward toward the wheelchair's rear (also called seat dump) can assist people with limited trunk control by stabilizing their pelvis and spine, making it easier to propel the wheelchair. It can decrease extensor tone and posturing. However, too much dump can cause the pelvis to rotate backward and the lumbar spine to flatten. This increases pressure on the sacrum, increases the risk of skin breakdown, and makes it more challenging to transfer into and out of the

• **Fig. 15.19** Indoor-outdoor power wheelchair shown with rehabilitation seating, a power tilt and recline seating system, head rest, and power-elevating leg rests.

• **Fig. 15.20** Front-wheel drive power wheelchair. (Courtesy Permobil, Lebanon, TN.)

• **Fig. 15.21** Heavy-duty indoor-outdoor power wheelchair. (Courtesy Quantum Rehab, Duryea, PA.)

• **Fig. 15.22** Rear-wheel drive power wheelchair. (Courtesy Quantum Rehab, Duryea, PA.)

the wheelchair difficult for some users to steer. However, this is no longer an issue because of improved control systems.

Mid-Wheel Drive

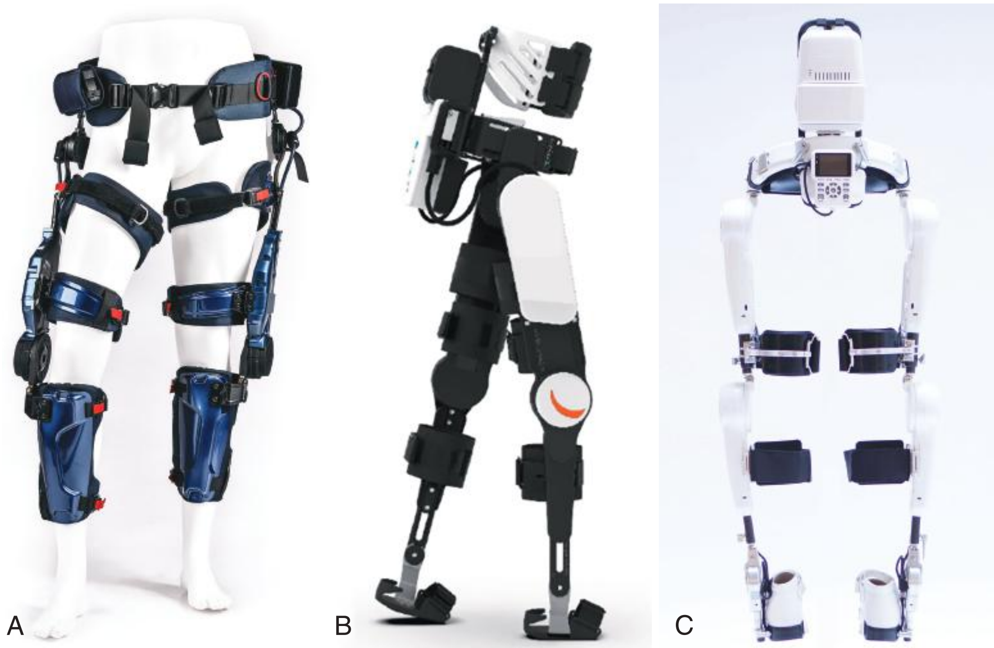
The mid-wheel drive power wheelchair (see Fig. 15.21) has been one of the fastest-growing power bases in the wheelchair industry. In this configuration, the drive wheels are located near the center of the power wheelchair, allowing the user to turn in place and dramatically increase indoor maneuverability. The mid-wheel drive is among the most effective at ascending and descending obstacles for skilled, practiced users. Most mid-wheel drive wheelchairs have front and rear antitip casters that actively raise or lower to stabilize the wheelchair when ascending or descending

• **Fig. 15.29** Vehicle lift systems. (A) Platform lift. (B) Overhead strap lift. (C) Automated height adjustable vehicle seat. (D) Automated height adjustable platform. (E) Side-door overhead wheelchair lift system. (B, Courtesy Braun Corp., Winamac, IN; C, courtesy St. Lambert, Quebec, Canada.)

next to the wheelchair and reduce the space separating the two surfaces, further assisting with transfers. For manual wheelchair users who are independent and drive, one potential solution would be to combine a transfer system with an overhead strap lift that attaches to the side door opening of a van. The lift stows the wheelchair behind the driver's seat (see Fig. 15.29E).

Ramps

Ramps are less expensive alternatives to vehicle lifts.[69] They can be portable, mounted inside the vehicle (nonpowered or powered), or integrated into its frame. Typically, they are installed in full-sized vans, minivans, and pickup trucks. They are usually installed on the side or at the rear of the vehicle and have either a single



• **Fig. 20.4** Exoskeletal robots for lower limbs. (A) Keeogo (B-Temia) (Wistron Medical Technology), triggered by movement sensors and algorithms, adapts to the user's movements in real time, providing the necessary support. (B) Free Walk (FREE Bionics Taiwan Inc.), robot assistance to stand, walk, and perform physical training, operated with a wireless control. (C) HAL (CYBERDYNE, Inc.), controlling the exoskeleton through the detected bio-electrical signals of users' intention, providing the necessary support to execute the movement. (A, Courtesy Wistron Medical Technology; B, courtesy FREE Bionics Taiwan Inc.; C, courtesy CYBERDYNE, Inc.)

• **Fig. 20.5** ACC How-Go-Tone is an iOS-based app that provides a customized user interface and allows patients to communicate by touching screens or using specialized triggers or pointing devices. (From Assistive Technology Engineering Lab, Inc.)

Daily Living Aids

Daily living aids are tools designed to help individuals perform everyday activities more efficiently and independently. Examples include the following:

Adaptive utensils: Modified eating utensils with ergonomic handles or specialized grips to assist individuals with limited hand function.

Dressing aids: Tools such as button hooks, zipper pulls, and dressing sticks that help individuals dress independently.

Bathing aids: Devices such as grab bars, toilet lift seats, shower chairs, shower stools, and bath lifts enhance safety and independence in the bathroom.

Environmental Control Systems and Home Automation

Home automation refers to installing technology that automates or remotely controls household functions via devices and programs linked with a wired or wireless connection. Integrating Internet of

Caregiver Aids

ATs, such as grab bars, sensor systems, and companion robots, are examined for their potential to alleviate some physical and psychological stresses on caregivers. For example, sensor and monitoring systems can enhance the safety and coordination of care in care homes by providing alerts and monitoring residents' activities, thus reducing constant physical supervision needs and allowing caregivers to manage their tasks more effectively.[14] The slide boards used by home care aides to assist client transfers highlight proper equipment that can significantly reduce biomechanical loading on caregivers, thereby potentially reducing injuries and physical strain.[14] Examples include the following:

Transfer assistive devices: These devices, such as sliding boards, lifters, raisers, and supporting belts, help caregivers transfer patients effectively and safely (Fig. 20.7).

Real-time locating systems: These systems automatically identify and track the location of objects or people in real time, typically within a building or other contained area. They can potentially improve residents' safety, quality of care, and efficiency of long-term care facilities.[33]

Assistive Technology Needs and Considerations for Specific Populations

Older Adults

Aging is a complicated, dynamic, and individualized process. Accelerating population aging is a global issue. How to achieve successful and healthy aging and the rising demand for aging-in-place technologies have drawn increasing attention.[55] Living independently can be challenging for seniors. Furthermore, the global challenge of an aging population outpacing the availability of caregivers necessitates technologies that enable older adults to live independently at home.[64] Cochrane reviews demonstrated that home fall-hazard interventions, including ATs, could reduce the overall rate of falls by 26%; however, these interventions were more effective in people with a higher risk of falling.[16] Among people who fall at home, seniors without using walking aids could sustain more severe injuries.[48] On the other hand, the prevalence of chronic diseases is significantly higher in the geriatric population compared to the general population. It is noteworthy that aging people with chronic diseases may also require technologies tailored to managing specific symptoms or conditions, adding to the complexity. For instance, those with diabetes might benefit from devices that monitor blood glucose levels and alert users to take insulin. Walking aids may reduce functional recline in sarcopenic patients.[61] Given that these chronic conditions can come with physical, sensory, or cognitive impairments, the user interface of ATs needs to be particularly intuitive and easy to use for those with specific disabilities (Fig. 20.8). Furthermore, there is often a higher need for ATs to integrate seamlessly with other health care systems to ensure continuous care. This includes the ability to share data with health care providers easily. Technologies for the general older population may focus more on enhancing daily living than integrating closely with medical care.[10]

Children

Pediatric populations using ATs have specific characteristics to consider when designing, prescribing, and managing ATs.[28] Children grow rapidly, so their assistive devices may need frequent adjustments, resizing, and updates to accommodate their physical growth and changes in their abilities and needs. ATs must support and not hinder the achievement of developmental milestones, such as motor skills, social skills, and language development. Furthermore, it has been noted that the widespread lack of ATs for children with disabilities leads to lower primary school completion rates. Education needs should be considered explicitly in children with disability.[53] Incorporating ATs promotes educational engagement and learning efficacy, which is paramount in care. Devices must be user friendly and suitable for children, often incorporating engaging and appealing elements to younger users. This can include using bright colors, interactive features, and designs that appeal to their imagination and interests. Family members and caregivers play a critical role in successfully utilizing ATs. They also need proper training and support to integrate these technologies into a child's daily routine. Emotional and practical support for families is essential because managing assistive devices can add to the caregiving burden.[54] The family-centered model could be helpful for AT provision for the pediatric population.[71]

• **Fig. 20.7** (A, B) Standing-and-raising aids. SARA Combilizer is an aid that helps patients perform sit-to-stand, transfer, and mobilize out of bed easily and safely. (Courtesy Arjo)

GAI enhances existing components of the brain-computer interface to enhance user interface and experience and to enable the development of new, more integrated applications that can convert brain signals directly into outputs such as speech, text, or images.[26]

Virtual Reality in Assistive Technologies

Virtual reality (VR) is a computer-generated simulation of an environment that allows users to interact with it in a seemingly natural or physical way through special electronic equipment, such as headsets with screens or gloves fitted with sensors. VR can be categorized into different types, from nonimmersive VR to augmented reality and mixed reality. VR becomes one of the valuable mediums for delivering therapy by creating an immersive environment that allows users to engage in scenarios that feel real, which is particularly beneficial for therapeutic and educational applications. VR environments are highly interactive, safe, and well controlled. VR systems can be extensively customized to meet the specific needs of individuals with different disabilities. This adaptability ensures that VR can assist a wide range of disabilities, from motor and cognitive impairments to sensory and communication disorders.[41,65] The users can practice and learn new skills without the real-world consequences of failure (Fig. 20.9). This is particularly important for users with severe impairments or those recovering from trauma or disease.

Barriers and Challenges in Using Assistive Technologies

The underadoption of ATs has been recognized in real-world circumstances. A survey of the adoption rates that included 22,666 care-dependent persons and caregivers reports that sophisticated types of ATs are still rather scarcely used for home care arrangements.[37] Although ATs offer significant benefits to individuals with disabilities, several barriers and challenges can hinder their practical use. These obstacles can stem from various sources, including economic, technical, social, and personal factors. There are multiple barriers across different domains, such as cost, complexity of interventions, and lack of evidence of effectiveness (Fig. 20.10). For instance, product-related factors such as comfort, durability, fit, and limited choices were significant barriers.[5] This discrepancy between users' needs and the system's provision can result in abandonment, especially when the users need to adapt to the technology (technology centered).[36] Understanding these challenges is crucial for developing strategies to overcome them and ensure that ATs can reach their full potential in improving users' lives.[49] Many patients face significant delays or outright denials when receiving these technologies. This lack of timely access can adversely impact their recovery. The study identified that only 55% of the assistive devices were delivered to children, with delivery times ranging from 12 to 250 days, showcasing considerable variability and potential for delayed rehabilitation.[28] Another example is a gap in the availability of modern braille technology, such as refreshable braille displays, especially in less affluent regions or schools with limited funding. This disparity limits students' exposure to braille, affecting their literacy and overall academic performance.

Economic Barriers

Over 2.5 billion people currently require one or more assistive products, which is expected to rise to 3.5 billion by 2050. Access

• **Fig. 20.9** (A, B) HappyGoGo (LongGood Inc, Taiwan) is a virtual reality/augmented reality (VR/AR) device with a depth camera that provides gamification of movement training. (C, D) A game-based VR/AR system for physical and mental health developed by Taipei Medical University.

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