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Review of the methodology of lower limb prosthesis

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Abstract:

Background: The replacement of inefficient or lost organs, especially in the case of lower ends, is associated with a huge experience for the patient, especially in emotional terms. However, with the development of medicine and technology, they allow patients, with properly conducted rehabilitation, to achieve satisfaction with the obtained effects of the

treatment. The variety of forms of lower limb prosthesis depends primarily on the location of the prosthesis.

Material and methods: Analysis of available literature, articles in the Google Scholar and PubMed database using keywords: Prosthesis, Lower limb, Amputation

Results: The lower limb prosthesis is built from a funnel that matches the stump, the mechanism of the knee joint, shin and the foot. Pours that are used at the lower extremities include: a quadrangular funnel, an ICS longitudinal oval or a CAD-CAM, a full-contact hip funnel, a residual femoral funnel or vacuum syphilis used in people with neoplastic amputations. In the case of knee joints, the distinction is made based on the number of axes around which the movement takes place. So we distinguish uniaxial and multi-axis joints. As important as the other parts is the construction of the prosthetic foot, because it is responsible for supporting the limb stabilizers through passive control of the ankle bending.

Conclusions: With the new generation of lower limbs prostheses, the patient can lead an active professional life, as well as practice various sports disciplines. However, this does not change the fact that there is still a great need for research, and holistic cooperation to increase the efficiency and satisfaction of life of amputees in the lower limbs.

Key words: Prosthesis, Lower limb, Amputation

Introduction

Amputations, or the removal of the limb, are surgical procedures that are performed to save human life. There are a lot of reasons for its implementation and can be divided due to the time of amputation and the nature of its cause.

The level of subtracting the limb depends on the extent to which the limb is infected. Surgeons perform the procedure in such a way to leave as much of the limb as possible. After performing the amputation, care should be taken to ensure the hygiene of the stump, as it is combined with many possible uncomfortable complications like any treatment. [1]

As a result of complications, the stump's healing time can be prolonged, in a more

difficult case re-operation is needed, and in the worst case it leads to death of the patient. After amputation, it is also necessary to ensure the rehabilitation of the stump so that there is no contracture of the muscles, distortion or poor stump adjustment. Adequate care of the stump is connected with the possibility of stenting the stump, thanks to which the patient will be able to regain mobility as much as possible. People who have been in this condition are able to lead an independent life, thanks to the progress in orthopedic supplies, which gives the patients better opportunities to return to work or interests.[2]

A more complex form of supply in relation to the shank stump is an orthopedic supply for the thigh stump. It should be adapted to two very important knee and ankle joints that perform a motor function. The prosthesis is made of a funnel fitted to the stump, knee joint, shin and foot [1].

Denture funnel

The funnel is an element connecting the prosthesis with the stump, which is why it is so important to fit it properly [2]. The thigh stump is made of more soft tissues that surround the thigh bone. Therefore, the appropriate shape of the inside of the funnel is important, which stabilizes and deposits the stump in it comfortably and allows the use of preserved muscles for movement functions. In order to enable such a shape, a rigid funnel should be used, which is made of resin laminate on a gypsum cast or from poplar wood matched and hollowed out only for a given person.[3]

Preservation of stability and convenience of the stump in the funnel is possible thanks to the appropriate internal dimension, both in the sagittal plane and the frontal plane of the funnel, located at the level of the ischial tuberosity. The first dimension, it is necessary to correspond to the distance of the ischial tuberosity from the front surface of the tendons of the adductors of the thigh. The second dimension, on the other hand, should be located on the outer surface of the femur near the subtrochanteric area. The location of the sciatic nerve should be located on the seat cushion, formed in the medial part of the posterior lip of the funnel. It is important that the shelf is leveled in the antero-posterior and transverse dimensions. In turn, the opposite shelf, part of the front wall, is tucked into the light of the funnel and topographically corresponds to the Scarpy triangle. The induced pressure on the anteromedial surface of the stump causes stabilization of the ischail tuberosity on the seat

cushion. In the upper corner, the anteromedial medulla, there is a channel for the tendon of the long adductor muscle, while on the middle section of the upper side wall of the funnel there is a depression corresponding to the great trochanter of femur. The recesses located in the posterior and frontal walls are created with the aim of free flexion of the middle gluteal muscle and thigh straight muscle. [4,5,6]

Body walls and the bottom of the funnel are also used to support the body mass. It is best to stick to the principle of full contact in order to choose a funnel. As a result, the load on the stump is distributed over a large area of the funnel, thus obtaining comfort, stabilization of the stump as well as preventing the formation of edema [2].

The quadrangle tray is a simple funnel and is currently used in temporary and geriatric prostheses. In this case, there is no blockage of the bone elements in the proximal part, thanks to which it allows its lateral displacement in the support phase and is the reason for the smaller pelvic stabilization [3].

When moving about the prosthesis, the soft tissue of the stump comes into contact with the existing funnel, during the support pressure occurs, and in turn during the phase of prosthesis healing occurs when the muscles tense and relax in the appropriate phases of gait.

The optimal funnel volume and shape influence the proper work of the stump muscles and the energy expenditure during the walk. To prevent edema and blood circulation disorders in the stump, a full-contact funnel should be appropriately selected, therefore for this purpose a lot of time is spent to create and adjust the hopper individually for the user.

Active people, usually are equipped with a longitudinal oval ICS or CAD-CAM or anatomical funnel, according to the principles of the MAS funnel. It is best suited for young people and active solution, because the muscles have a lot of space to work, and on the so-called bone castle and partially tissue the funnel is suspended. The best effects and allowing the practical control of all modern prosthetic solutions are achieved by stabilizing the funnel on the femur and the pubic symphysis. People who have long used a thigh prosthesis with a quadrangular funnel may have problems with accepting an MAS type anatomical funnel or an oval funnel. In these situations, a quadrangular funnel is made, made of flexible materials with a carbon fiber frame.[7]

The main application of a full-contact hip funnel is in the case of vascular amputation and is also built in the one- or two-layer version in addition to the shape that illustrates the form of the thigh stump. The external support frame acts as a transfer of control forces from the stump to the knee and the prosthesis foot. The inner hopper is made of flexible and soft materials such as thermoplastics or RTV or HTV silicone to increase comfort and comfort while walking and sitting. Better denture control provides the patient with a longer stump due to preserved muscles and a long bone lever.[2,8]

The best resistance was found in people after enucleation in the knee joint. It provides a greater functional effect and convenience. The load is transmitted through the top of the stump, almost completely to the prosthesis, and the edges of the prosthetic hopper do not limit the iliac rim. This type of amputation is rarely performed and sometimes impossible. The best example are athletes with thigh prostheses with a resistance funnel, because they are athletes in almost unbeatable runs and jumps, in thigh amputation teams. When we deal with enucleation in the knee joint, prostheses are made with a two-layer funnel with an open frame, to increase the comfort when fitting and putting on the prosthesis, as well as partly inflatable pipes for underpressure. Line liners or membranes are also used.[9]

For people with short thigh stumps reaching 8-15 centimeters, silicone liners are used, an internal hopper made of HTV silicone, a liner made from RTV or HTV silicone and a funnel made of thermoplastic with silicone. A positive and characteristic feature of these materials is adherence to the skin, ease of putting them on and maintaining the correct hygiene of the stump [2, 4].

Vacuum syphons are used in the case of traumatic and neoplastic amputations, where there are no circulatory disorders [4].

Liner

It provides protection in the form of a flexible insert during the transfer of loads in the prosthesis funnel for the skin and soft tissues. It is made of silicone, polyurethane or thermoplastic elastomer. In addition, it also plays a role as a connector of the stump with the prosthesis, i.e. the so-called suspension element. Having other traits by liners is caused by making them from other materials.[10]

One of the types is Silicone Liner, which has a high elasticity and compression, guarantees very good durability, as well as versatility and adhesion, in the gas form, sweat is released. This liner is resistant to both low and high temperature, and also allows chemical and thermal disinfection, provides comfort, easy hygiene and maintenance of the stump due to the impregnation with aloe and thanks to silver ions, it has antibacterial properties. It can reduce pain by combining it with compression fabrics and outer fabrics.[11]

The sweat-resistant Copolymer Liner, also known as thermoplastic elastomer, stands out with less compression due to its greater elasticity. Due to its stretchability it is reinforced by the knitwear from the outside. It is characterized by very good comfort due to the hygiene of the stump, it has thermoplastic properties, thanks to which it has the possibility of individual shaping of shapes, protects the skin and has antioxidant effect.[3,12]

Liner with the highest quality of comfort and convenience, as well as the softest, but requiring precise putting on and at the same time caring for the hygiene of the stump, made of a material that is similar in flexibility to soft tissues, is called Poliuretan Liner. Due to the large variety of products, depending on the type of funnel, connections, thickness and suspension, as well as the flexibility of the material and shape, appropriate. There are no clear indications as well as contraindications to the use of the right type of liner in patients [2].

Knee joints

They are a functional element that has a different construction, different number of axes and units. They are made of stainless steel, titanium or aluminum alloys and carbon composites. Due to the number of axes we distinguish uniaxial knee joints, so-called monocentric, which have one or two axes, where the movement takes place only around one axis.[13]

This division also includes multi-axis knee joints, called polycentric joints, made up of several members that combine several axes behind each other to create a spatial layout to provide movement in the joint that reflects the most natural movement, i.e. the reciprocating movement. This construction causes the bending motion to occur around several pivot points, the so-called momentary pivot point. Such a solution shortens the length of the lower leg during the stroke phase, thus eliminating the risk of infiltration with the fingers of the

prosthetic foot. The swing phase, movement dynamics and safety during the support phase can be set thanks to the geometrical change of the joint axis system. [14,15]

For a faster walking speed of 3-4 km / h. and mobility at the level 2-3, there are used joints with the possibility of blocking, brake and with the function of a spring-loaded launcher with having a pneumatic unit that controls the swing phase. A monocentric knee joint with a gravity block and a pneumatic unit that controls the swing phase is highlighted here. The speed of the leg extension and suppression of its last phase, which gives a quick and harmonious gait is possible thanks to the pneumatic unit. The control of three phases, i.e. the phase of erection, extension and flexion of the lower leg, is independent. A polycentric, pneumatic knee joint is also distinguished, in which the spring supports the piston of the pneumatic unit and with setting and adjustment similar to other joints. The impact on the efficiency and gait speed in the knee joint is the size of the pneumatic unit.[6,16,17]

If the efficiency of the pneumatic system, which is spring-assisted, does not yield results, then 3-4 people with monocentric or polycentric knee joints are used. This group of mobility includes pneumatic-hydraulic hybrid pneumatic joints. Advanced hydraulics often used with the help of a microprocessor, including a speed, position and pressure sensor, controls the knee joints used in people with mobility 3-4. These types of joints allow and ensure walking at a speed of 2-10 km / h, i.e. running, guarantee a safe and harmonious gait on varied terrain and the environment, including water at variable speed. However, they do not apply to practicing competitive sports. Considering the needs of people receiving the first prosthesis regardless of age and mobility, the knee joints can be set and used due to the high flexibility and precise measurements made. However, these types of joints are recommended for people with a higher level of mobility who are able to increase their mobility and control the fast control of the prosthesis function. C-Leg, Rheo, C-Leg 4 and Genium and Genium X3 joints have found the biggest application in this group. [4,18]

People with the highest mobility who use some of the electronic knee joints are used with polycentric hydraulic joints for mobility 3, moving in three planes with the help of the swing and extension phase.

In people after enucleation in the hip joint, with a short, ineffective thigh stump or after partial pelvis amputation, hip joints are used in prostheses with the hip basket [2].

Uniaxial joints

For persons with mobility 1-2, joints with a speed of up to 2 km / h are used, with lock, brake and spring release option. These include uniaxial joints, which are made of aluminum, titanium or stainless steel, with the function of blocking bending while walking. Automatic immobilization of the knee joint occurs as a result of a straightening, and when the seat is seated, it is unlocked by means of a cable. Such constructions are used by prescribing people who have low mobility and are learning to walk on a prosthesis.[7]

In temporary prostheses with an articulated joint, joints with a lock were used. In turn, a rigid blockade with a gravitational brake functioning under the influence of the prosthesis load, together with the knee launcher constitute a newer form of the solution, which includes the functions merged above. The gravity brake maintains the safety of the support when the block is released. Acting under load, it fulfills its function very well, also during a slight bending of the knee. Therefore, it is recommended for people walking at low speed on different, uneven terrain. In turn, the internal launcher and dynamic forefoot perform the phase of swing and extension.

Uniaxial joints without bending blocking function are used by people with better mobility, while the blocking function is used in people with low mobility, as they reduce the risk of falling. Mobility 2-3 allows the use of uniaxial joints with a spring tube, which supports movement in the hip joint. The applications also found mobility in this group, uniaxial joints with positioning control in three possible planes and a spring-loaded rocker [2].

Multi-axis joints

People with mobility 1-2, who can move at most up to 2 km/h, use multi-axis joints with a blockade and a knee launcher. Just like monocentric wrists with a launcher and blockade, they are also called therapeutic joints and perform the above-mentioned functions, and the polycentric construction is the only difference. This type of joints is recommended for people who have greater efficiency and are able to use the stump to straighten the knee joint. The full extension of the articulation is the only source of safety during the support phase [2].

Structural elements

Other static elements, such as the foot or the knee, and the load transfer are used to connect the other elements of the prosthesis. In turn, the elements also having rotational, cushioning and also torsional functions are called dynamic structural elements. [19]

Fasteners, or adapters made of stainless steel and light alloys, such as aluminum, titanium and carbon composites, which provide a safer anchoring of the funnel, and also allow proper preservation of the prosthesis position, also appropriate alignment of dynamic and static prostheses in three dimensions. Currently, there are a lot of adapters which gives the opportunity to choose and allows to change and move the prosthesis in the temporary setting to the final setting. The final elements of the prosthesis naturally supersede temporary elements. The prosthesis user and the payer are more profitable and it is a cheaper solution for them [2].

Construction of the foot prosthesis

The passive control of the dorsiflexion in the ankle joint of the prosthesis is the prosthetic foot, which supports the activity of active limb stabilizers.

Patients in Poland after amputation most often walk on a prosthetic foot without a SACH type ankle which it is distinguished by low mass, simplicity, durability and low price. It is made of two basic elements, which is a rigid inner core, which functions as metatarsophalangeal joints and reaches from the point of contact of the heel with the ground to reflect the foot from the ground, which occurred after lifting the heel and transferring the weight of the body to the fingers, that is from the so-called reverberation feet.[20]

The second main element is the outer layer, which gives the foot an adequate shape and surrounds the core. It is made of elastic material, thanks to which it is possible to bend the front of the foot under the weight of the body and replace the natural flexion of the dorsal fingers.

The ankle joint's task is performed by squeezing the heel wedge during the percussion, when starting the support phase. Thanks to this, it is possible to smoothly transition from heel contact to substrate to the total footing of the sole. Mostly, orthopedic manufacturers have their own SACH model. However, they differ from each other by the type of material used, the external shape, the height of the indicated heel from 0 to 45 millimeters and the weight.

Therefore, it is necessary to tell the patient that the SACH type foot is created and individually selected for the worn footwear by the patient. It is important to remember to keep the same heel height when changing the foot, as this affects the setting of the entire prosthesis and its stability.[21]

In Poland, the dynamic prosthesis rate is more common, providing more efficient functionality. It is made of durable and light materials, and at the same time flexible mid-foot improves gait as well as running. Through the contact of the heel part with the ground, there is a deflection, as well as the accumulation of energy in it, where gradually released improves the transfer of weight to the forefoot, and in the final stage promotes propulsion. According to the individual needs of the patient, the construction of the prosthesis foot can be changed. Currently, three types of dynamic foot prostheses are used, including a core made of thermoplastics as well as carbon fiber and multi-axial plastics [4].

Summary

The dentures are individually matched to the patient, depending on his needs and use. Care should be taken to ensure the hygiene of the stump and prostheses in order to avoid bedsores, blisters, infection, blood circulation disorders in the stump, which also translates into a properly selected prosthesis.

In order to supplement the prosthetic missing limb at the thigh level, depending on the enucleation in the knee joint after the amputation of a very short thigh stump, prostheses are used.[5]

The implementation of the femoral prosthesis to a significantly short stump creates difficulties because the movement of the rest of the limb is impaired. In a too short stump we deal with a very small amount of muscles, a small lever and a lack of strength ensuring proper prosthesis control. In such cases, it is possible to use a safer prosthetic solution, using a silicone funnel, silicone liner or thermoplastic funnel, which will ensure better adhesion and improve the suspension of the prosthesis on the stump.

The use of dentures has made the lives of many people easier both in everyday life and in career. Prostheses have also found their place in sport, thanks to which amputees can continue their passion or just start it.[22]

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