Lower limb amputation for ischaemia with special reference to the diabetic patient

The ultimate goal after amputation is rehabilitation to the limit of what the patient can achieve.

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Amputations of the lower limb are frequently referred to in historical treatises, related especially to the surgery of trauma and war, particularly sea battles. One is only too familiar with the 'peg-leg and parrot' image. In modern times the approach has become more scientific, and the whole philosophy when amputation is considered is that rehabilitation to the limit of what the patient can achieve is the ultimate goal. The patient must be left with an amputation stump that can bear weight and, when necessary, to which a prosthesis can be fitted. The scope of what follows is not intended to be a detailed text on amputation, but to provide some insight for the clinician, based on general experience with amputation over a number of years.

Basic biomechanics

In order to adequately understand the principles involving amputation there must be some basic consideration given to the biomechanics. An important consideration is that of the axis of weight bearing, which is shown in Fig. 1. It will be seen that the axis passes vertically through the body and ends in the foot in an area which is just anterior to the tarsometatarsal joints. It can be appreciated what the significance of a flexion deformity would be in terms of retaining this axis when fitting a prosthetic limb, in terms of balance and weight bearing.

Movements of the foot and ankle

The movements around the ankle comprise plantar flexion, dorsiflexion, inversion and eversion. This is a dynamic co-ordinated process which enables one to walk over uneven terrain. Flexion and extension occurs at the ankle joint between the tibia, fibula and talus and acts as a simple hinge. Inversion and eversion occurs at the subtalar joint, which is between the talus and calcaneum. Plantar flexion is effected mainly by the tendo-Achilles apparatus, which inserts into the calcaneum and which involves the calf muscles, and the long toe flexors. Dorsiflexion is largely a function of the tibialis anterior muscle, which arises from the front of the tibia, and the long extensors of the toes.

The tibialis anterior inserts into the base of the first metatarsal, and inversion of the ankle also results from the action of this muscle. Eversion depends upon the action of the peroneal muscles which arise from the lateral aspect of the fibula. The peroneus longus tendon passes across the sole of the foot and is inserted into the base of the first metatarsal opposite to the tibialis anterior. The peroneus brevis is inserted into the base of the fifth metatarsal. In amputation of the foot careful consideration must be given to the actions of these various tendons and muscle groups. In Fig. 2 the joints of the ankle and various tendon insertions are shown.

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The knee joint essentially has two movements – flexion and extension – but there is also a process of rotation which locks the knee. The extensor of the knee is the quadriceps apparatus, which inserts into the patellar tendon while the flexors are the hamstrings, which insert into the upper tibia medially and laterally.

The hip joint has a full range of movement comprising flexion, extension, abduction and adduction. Flexion and medial rotation are largely the action of the psoas muscle. Abduction is by action of the gluteal muscles and extension by the hamstring muscles. Adduction results from action of the adductor group of muscles. Balanced muscle action is essential following any amputation and these principles must be considered.

In relation to the biomechanics the most important considerations will be the axis of weight-bearing of the body, the range of movement of the joints concerned, and the durability of the stump so that the patient can bear weight and can wear an appliance when required.

In specifically addressing the diabetic dysvascular amputee, and which essentially applies to all dysvascular patients, is the assurance that there is adequate perfusion of the tissue at the amputation site and that infection is prevented. Poor perfusion and the potential risk for infection is a vicious circle.

Fig. 1. Axis of weight bearing.

Assessment of perfusion

Most published work in relation to the prediction of healing potential, which is in turn related to perfusion, has been done on the below-knee amputation.

Clinical parameters that are used are the presence of a popliteal pulse, which is generally regarded as the most important, the extent of gangrene on the extremity, i.e. the number of toes involved or extension of the infection onto the dorsum of the foot, Doppler pressure, and the presence of collaterals on angiogram. An additional parameter is the assessment of bleeding of the skin edges when the initial incisions are made.

These clinical parameters are however extremely unreliable. The presence of a popliteal pulse will only give a 50% chance of stump healing. The other parameters have also been shown not to have much significance in terms of prediction of healing potential.[1]

The most significant predictor is measurement of transcutaneous oxygen pressure by means of an electrode placed over the reference point for the incision for amputation. This has been shown to accurately reflect skin and muscle perfusion. The absolute value is however unreliable due to variations with ambient temperature, which may cause vasoconstriction. Better discrimination is provided by using an index using the value at the reference point of the amputation site $TcPO_2$ to chest wall $TcPO_2$. Under normal circumstances this should be 1.0 as the pressures should be the same. If the index of reference point to chest wall is greater than 0.55 there is 90% accuracy in predicting healing. In the diabetic, however, this figure is 0.6.[2-4]

Unfortunately this has not been a good predictor of healing at the foot, as the test becomes unreliable if there is significant oedema or infection, which affects oxygen diffusion.

Infection prevention and control

The time-honoured principle of excision of dead and infected tissue is paramount in controlling ascending infection, especially in the diabetic.

It has been well shown that a patient, particularly a diabetic with an infected lesion with associated cellulitic changes and oedema, is best served by a guillotine amputation of the limb below the site of election, with control of infection and oedema after amputation. Once this has been attended to the elective amputation can be planned. Fig. 3 summarises the results of a study comparing the rate of above-knee revision in two groups of patients. In one group the initial (primary) amputation was done at the site of election. In the second group a guillotine amputation was done below the site of election, as shown. Sepsis resulted in a significantly higher above-knee revision rate in the primary amputation group, compared with those who had a guillotine initially and then subsequent elective amputation at the appropriate level. Total mortality after all procedures was higher in the guillotine group, but not significantly so.[5]

Perioperative prophylactic antibiotics are essential and should provide broad-spectrum cover against *Staphylococcus aureus* and the Gram-negative aerobes particularly. Anaerobes only become problematic if tissue perfusion is poor. It is suggested that the prophylaxis should start just prior to amputation and continue arbitrarily for 48 hours after amputation.

Amputations confined to the foot ('minor amputations')

By inference this implies that no prosthesis is required, and the basic aim is that the patient should be able to bear weight on the plantar surface of the foot, and should be able to wear a shoe and walk comfortably.

Toe amputations

Toe amputations should be done using the 'ray' principle where the toe is divided just proximal to the metatarsal head so that when healing occurs there is no gap between the toes. This allows the toes to splint each other and prevent the development of deformities due to lateral deviation of the digits. This results from the pull of the long extensor and flexor tendons. This principle can be followed

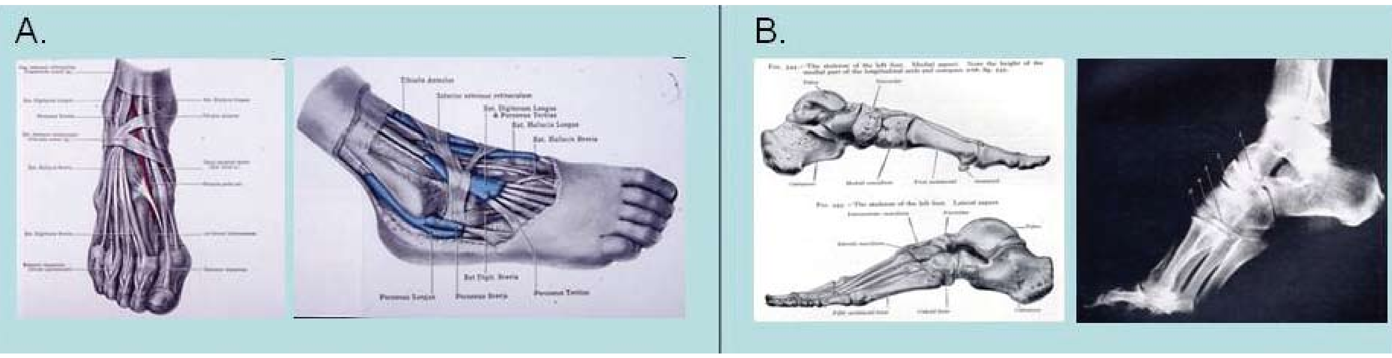
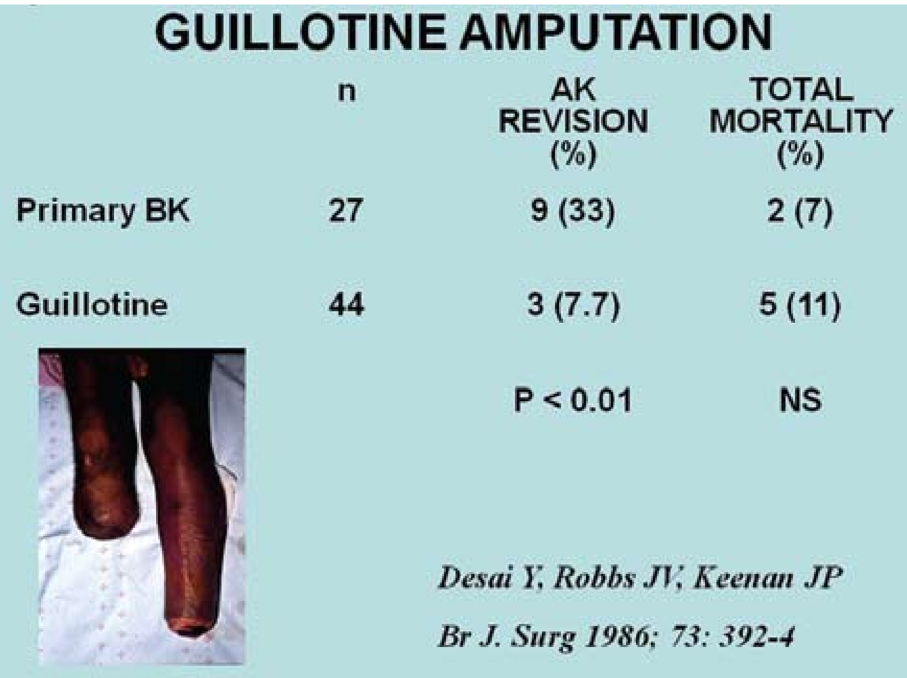


Fig. 2. Tendon attachments of muscles responsible for flexion, extension, eversion and inversion of ankle and subtalar joints (A). Joints of the ankle and tarsus (B).



GUILLOTINE AMPUTATION

	n	AK REVISION (%)	TOTAL MORTALITY (%)
Primary BK	27	9 (33)	2 (7)
Guillotine	44	3 (7.7)	5 (11)
		P < 0.01	NS

Desai Y, Robbs JV, Keenan JP

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Fig. 3. A below-knee guillotine amputation compared with a below-knee amputation at the site of election. The above-knee revision rates as well as the total mortality comparing two-stage and primary elective amputation are also shown.

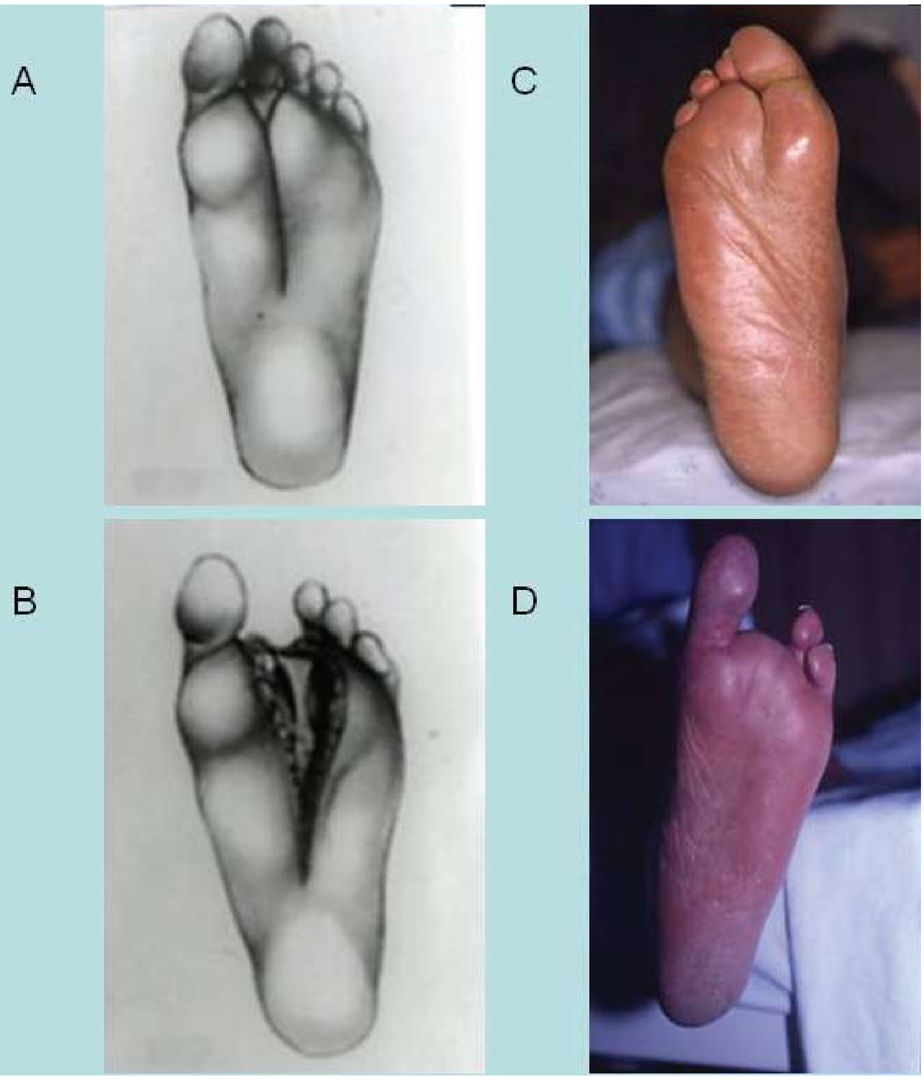

Fig. 4. Digital amputation. A - C: ray amputation. D: amputation through metatarsophalangeal joint.

for a single or two adjacent toes (Fig. 4 A - C). On occasion, however, when there is uninfected necrosis of a single digit, amputation can be performed through the metatarsophalangeal joint (Fig. 4D). It is then advisable to splint the toes by placing a sponge between them to prevent lateral deviation deformities. When amputating the hallux it is important to preserve the metatarsal head as this retains the transverse arch of the foot and provides better balance for walking (Fig. 5).

If the sepsis or gangrene extends beyond the hallux metatarsal head, or gangrene of the toes extends onto the dorsum of the foot, or non-adjacent toes are involved with the sepsis a transmetatarsal amputation should be considered.

Poor perfusion and the potential risk for infection is a vicious circle.

Transmetatarsal amputation

On performing this procedure one must ensure that all movements of the ankle are preserved. The landmark for the proximal extent would therefore be the tibialis anterior tendon (Fig. 6). If it is necessary to amputate proximal to this then it is better to perform a more proximal leg amputation such as at the below-knee level.

With the transmetatarsal amputation it is very important to ensure that the anterior aspect of the stump is covered so it is able to take pressure. Split-skin grafts are not durable enough under these circumstances (Fig. 7).

Amputations proximal to the foot ('major amputations')

Major amputations imply that a prosthesis will be necessary. Possible levels of amputation are through-ankle (Symes), below-knee, through-knee, above-knee, and hip disarticulation. There are other procedures described through the tarsal joints but these have little place under these circumstances. The most frequently practised amputations are those at the below-knee and above-knee levels.

The Symes amputation is cited as being ideal in the Third World scenario. Reasons given are that a prosthesis is not required and all weight can be taken on the end of the stump. This is however not recommended in the dysvascular and in particular the diabetic patient in our practice. From general experience one finds that there are major healing problems and that the patients invariably develop a flexion and adduction deformity due to the unopposed pull of the tendo-Achilles on the heel pad. This results in a high revision rate to the

Fig. 5. Amputation of the hallux.

below-knee level, often at the patient's request (Fig. 8).

The ideal stump should have the following prerequisites:

- durable and pain-free weight-bearing areas
- sufficient length to provide leverage for moving the prosthesis
- good balanced muscle action to facilitate balance and walking
- free of flexion deformity so as to enable the axis of weight bearing to be preserved.

Below-knee amputation

In Fig. 9 the rehabilitation rate in terms of prosthetic fitting and ambulation is shown, comparing above-knee and below-knee amputations. It can be seen that at any one time the rehabilitation rate is considerably higher for the below-knee amputee and that at the end of 24 months approximately 80% of below-knee amputees are ambulant compared with approximately 50% of above-knee amputees. This relates to the weight of the prosthesis and energy expenditure in walking. Another important consideration is the degree of debility of the patient and their general state of health. This emphasises the importance of attempting to preserve the knee joint and to make an adequate assessment of the perfusion at the site at which the elective amputation is to occur, before committing to an above-knee amputation.

The major weight-bearing areas of the below-knee prosthesis are the patellar tendon and tibial flare. Pressure is also placed on the anterior tibial border when the prosthesis is fitted. It should be noted that there is no weight on the end of the

Fig. 6. Principles of transmetatarsal amputation.

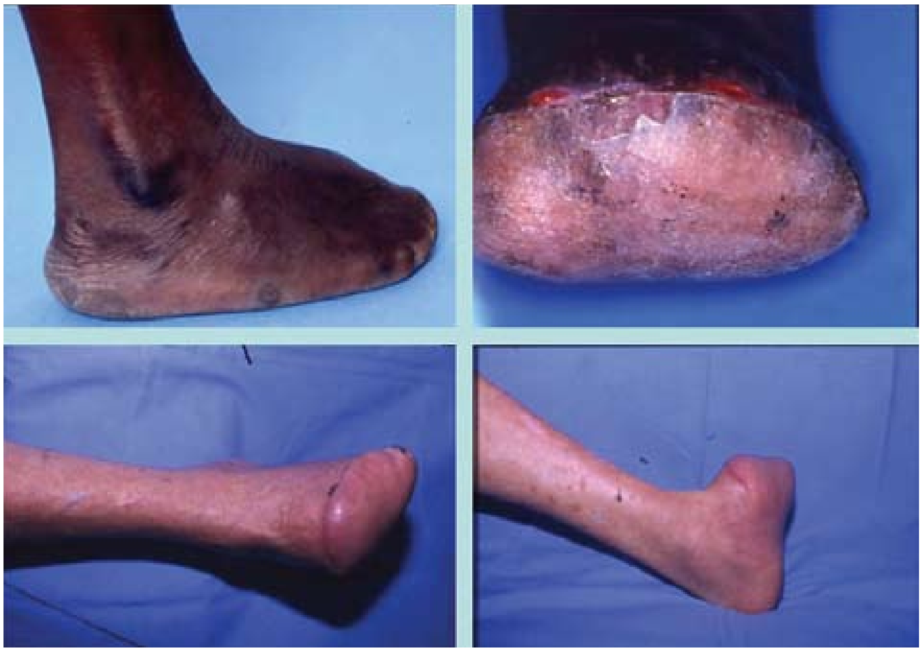

Fig. 7. Functional transmetatarsal amputation. Note the full-thickness skin flaps covering the pressure-bearing areas.

stump. Weight-bearing areas are shown in Fig. 10.

To provide adequate leverage the ideal length is approximately one-third of the length of the tibia and it is important to avoid any bony spicules or prominences. The tibia should be bevelled and filed smooth. It is also important to divide the fibula at least 3 cm shorter than the end of the tibia. While one should use a long posterior flap it is important to ensure that the scar is not placed over the anterior aspect of the tibia as this breaks down with pressure when the prosthesis is fitted.

Above-knee amputation

The weight bearing for an above knee prosthesis is on the ischium (Fig. 11).

It is important that balanced muscle action is preserved and that all the muscles are

Fig. 8. Through-ankle (Syme's) amputation. Adduction/equinus deformity involving the heel pad often occurs, causing walking and weight-bearing problems.

approximated in opposing groups over the end of the femur in order to give the full range of movement. The scar is best placed over the end of the stump, i.e. the flaps should be equal anterior and posterior. The optimum length to give maximum leverage is about 2/3 of the length of the femur, which is measured from the greater trochanter.

Other levels of amputation

Through-knee amputation

In general through-knee amputations are not favoured by prosthetists as the knee joint of the prosthesis requires 5 - 10 cm of space, which results in the patient having a very short leg. However, with more modern prostheses the knee does not require as much length and in many patients this may be a preferable option as some weight can also be taken over the end of the stump and there is good length for leverage. Often the through-knee level should be considered in elderly, bedridden, or chair-ridden patients as it does give them extra leverage to facilitate moving in bed or transferring to the wheelchair.

Hip disarticulation

High amputations such as disarticulation at the hip are reserved for desperate situations in terms of perfusion or control of infection. Under these circumstances, if at all possible one should attempt to preserve the greater trochanter, i.e. amputate at the level of the lesser trochanter as this provides a buttock contour and once the stump has healed the patient is able to sit comfortably.

Postoperative management and rehabilitation

In the immediate postoperative period one of the most important considerations is that dressings must be applied that do not cause any pressure on the skin. They must be well padded to avoid any pressure abrasions or ulceration. Elastic net dressings should be avoided (Fig. 12).

It is important to pay attention to the opposite heel and foot while the patient is in bed to prevent pressure sores there. It is best to rest the calf of the other leg on a pillow to keep the pressure points off the mattress.

From day one psychological support is extremely important. There must be a positive attitude communicated to the patient in terms of rehabilitation. It is always advisable to ask the prosthetist to visit the patient in hospital to show what can be offered at this stage and to treat any depression, which is inevitable, with drug therapy if necessary.

Physiotherapy should start on day one. This aims at retaining a passive range of movement of the joints. Isometric exercises must be done so that muscle power is not lost and if possible under certain circumstances to start patients walking on crutches as early as possible.

The next phase starts once the wound has healed and one can start to shape the stump so that it will fit into the prosthesis. At this stage the ideal set-up is for the patient to attend an amputee rehabilitation clinic. The concept is that there is team activity comprising a physiotherapist, surgeon, occupational therapist, social worker and prosthetist who can then mutually decide when the patient is ready for fitting. It is also desirable to have the input of a psychologist.[11]

The patient should attend amputation classes and continue with physiotherapy aimed at muscle building, avoidance of flexion contracture, and learning balance by walking training using crutches and

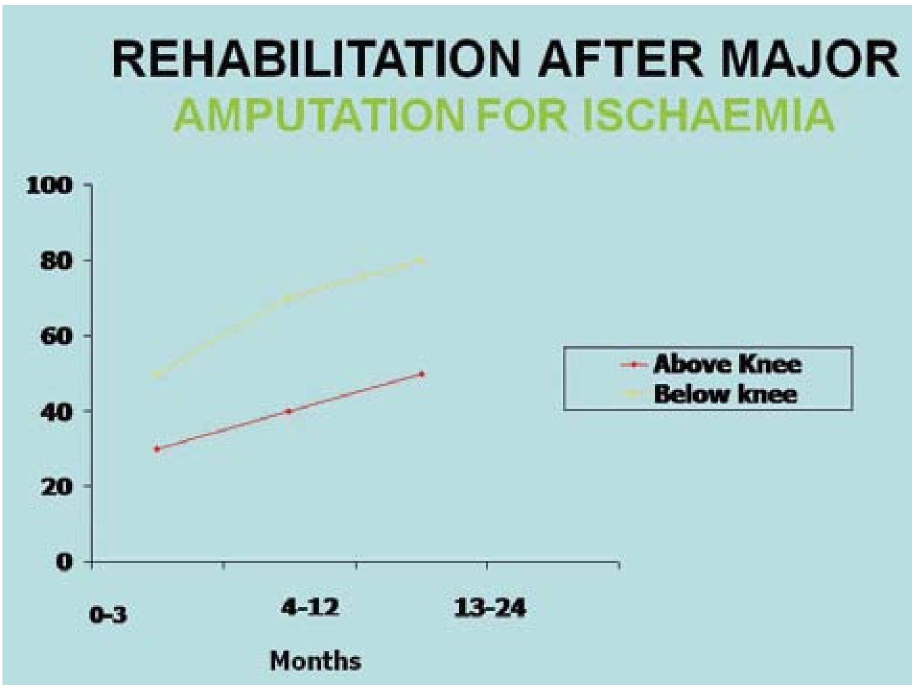

Fig. 9. Graph comparing rehabilitation after below- and above-knee amputation. (Courtesy Amputation Clinic, King Edward VIII Hospital, Durban.)

Fig. 10. Weight- and pressure-bearing areas on a below-knee stump.

Fig. 11. Patient walking on an above-knee prosthesis. Note major weight-bearing takes place on the ischium (arrowed).

temporary inflatable prostheses. This type of communal activity provides enormous encouragement. The clinic group will then decide when the patient is ready for the fitting of a prosthesis, which can

Fig. 12. Optimum method of bandaging stumps. Note cotton wool padding which protects the skin against abrasions from bandages.

be customised on an individual basis and ranges from a pylon ('peg leg') to a sophisticated articulated limb.

Those who will not be able to walk should go through the same system and be taught chair transfers, use of ablution facilities, etc. It must always be impressed upon the patient that an amputation does not mean the end of his or her active life and that rehabilitation to the utmost level of the individual's capabilities is the goal.

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In a nutshell

- A basic understanding of the biomechanics is important for planning procedures.
- Plan foot amputations so as to preserve function and the ability to use footwear.
- Preservation of the knee joint is important in terms of rehabilitation.
- Assessment of perfusion and prevention of infection are paramount in promotion of stump healing.
- A multidisciplinary approach is essential for early and rapid rehabilitation. This includes meticulous perioperative nursing, constant psychological support, directed physiotherapy and major input from the prosthetic team.